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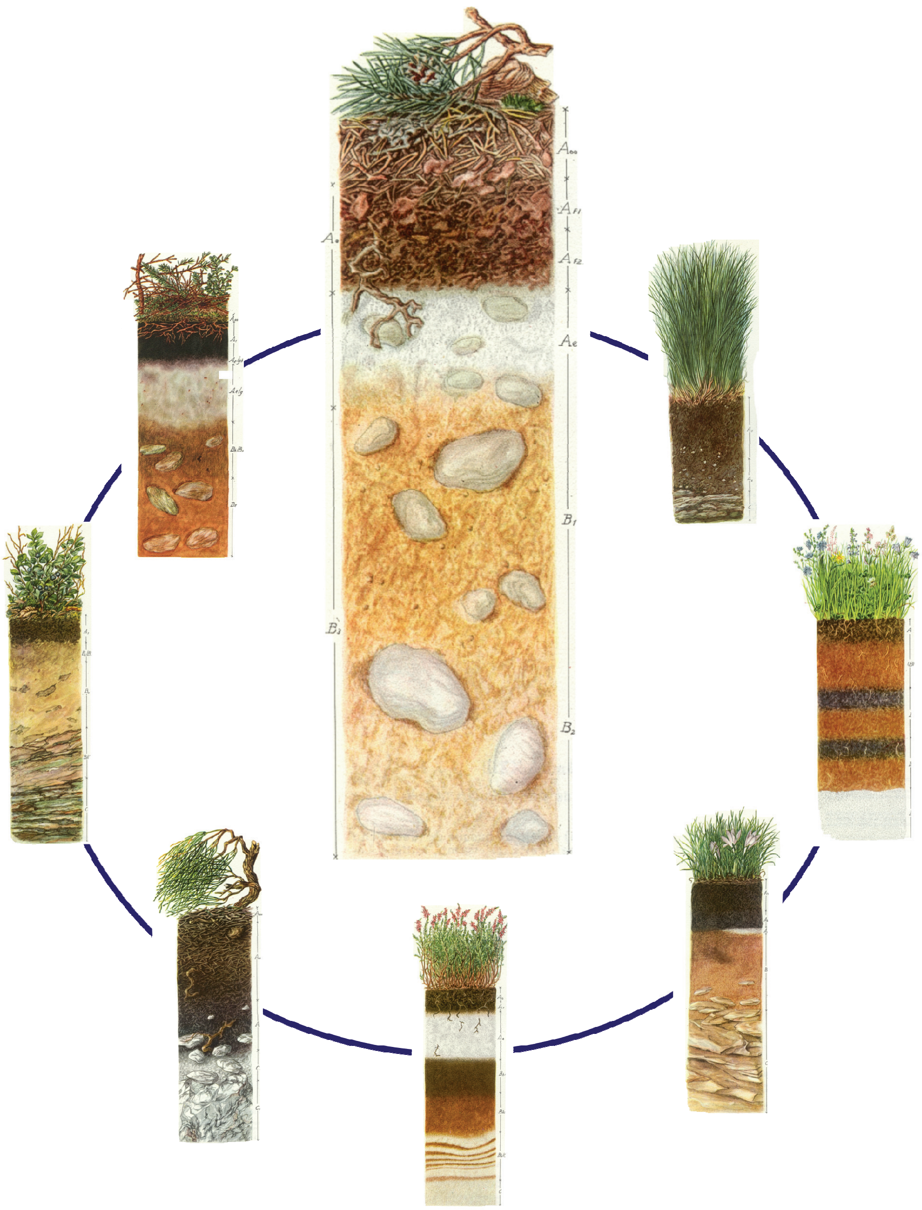
Environmental Assessment of Soil for Monitoring
Volume V: Procedures & Protocols

R.J.A Jones, F.G.A. Verheijen, H.I. Reuter, A.R. Jones (eds)



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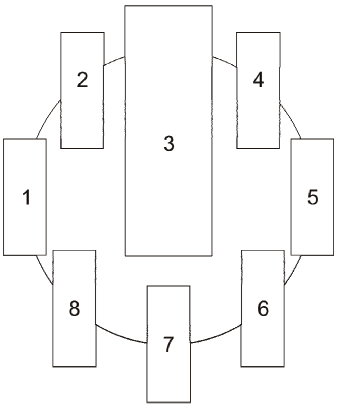

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Environmental Assessment of Soil for Monitoring
Volume V: Procedures & Protocols

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Preface

The ENVironmental ASsessment of Soil for mOnitoring – ENVASSO – Project (Contract 022713) was funded, 2006-8, as Scientific Support to Policy (SSP) under the European Commission 6^{th} Framework Programme of Research. The project's main objective was to define and document a soil monitoring system for implementation in support of a European Soil Framework Directive, aimed at protecting the continent's soils. The ENVASSO Consortium, comprising 37 partners drawn from 25 EU Member States, succeeded in reviewing soil indicators and criteria (Volume I) that are currently available upon which to base a soil monitoring system for Europe. Existing soil inventories and monitoring programmes in the Member States (Volume II) were also reviewed and a database system to capture, store and supply soil profile data was designed and programmed (Volume III). Procedures and protocols (Volume V), appropriate for inclusion in a European soil monitoring system have been defined and fully documented by ENVASSO, and several of these procedures have been evaluated by pilot studies in the Member States (Volume IV). In conclusion, a European Soil Monitoring System (Volume VI), comprising a network of sites that are geo-referenced and at which a qualified sampling process is or could be conducted, is outlined.

Volume V describes the procedures and protocols, needed for harmonised soil monitoring in Europe, which have been modified following the extensive testing of 22 indicators in 28 Pilot Areas of EU Member States reported in Volume IV. The results provide a foundation for implementing a soil monitoring programme in the near future but they are the scientific opinions of the ENVASSO Consortium, presented here without prejudice and in no way represent the official position of the European Commission on soil monitoring in Europe.

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29 June 2008

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TABLE OF CONTENTS

1 INTRODUCTION

This document details the procedures and protocols for deriving indicator values, at individual monitoring sites in Europe, which are harmonised in their measurement, calculation and expression. An initial indicator value may be part of an inventory, except where the site is already part of an inventory or monitoring system that conforms to the ENVASSO definition of a soil monitoring site.

The top three (TOP3) priority indicators were selected parsimoniously in Work Package (WP) 1 and the technical details described in indicator fact sheets compiled as an Annex to Report D2. Work Package 2 (WP2) has gathered metadata from all EU Member States (except Cyprus and Luxembourg) and Norway on existing soil inventory, and/or soil monitoring systems, and made recommendations for pan-European harmonisation of these systems. For the procedures and protocols, the WP1 and WP2 outputs have been combined and developed further by exploring the scientific literature and from discussions with technical experts from both within and outside the ENVASSO Project.

A procedure can be defined as a method of proceeding from a stated point or topic. A protocol is defined as an ‘accepted or established code of procedure in any situation’, a procedure for carrying out a scientific experiment or a formal record of scientific experimental observation. The procedures and protocols defined here (see also the ENVASSO Glossary of Key Terms; Chapter 4, p.161) are ‘the formal or official record of scientific experimental observations necessary to establish inventories of soil and monitor the TOP3 indicators defined by the ENVASSO Project’.

Some of these protocols are already established within the discipline of soil science, others have not been formally defined in such a way before but the definitions herewith have been agreed within the ENVASSO Project. They provide a step-by-step approach, together with all the ancillary information required, to arrive at robust indicator values for the threats to soil at each inventory/monitoring site. In addition, guidelines are given for the visualisation (presentation) of indicator values, where appropriate accompanied by some examples from the WP5 pilot studies in Annexes. In addition, procedures and protocols for monitoring, e.g. sampling strategy, are described.

2 INVENTORY AND MONITORING

For each indicator, the procedures and protocols are set up to provide both an overview and detailed technical information relevant to the indicator. The cover sheet is laid out as a stepwise guide that should be followed sequentially (Figure 1). Directly underneath the threat name is the indicator name (and code) followed by the ENVASSO definition. These definitions can also be found, together with many more ENVASSO definitions, in Chapter 4 (ENVASSO Glossary of Key Terms). Terms in the definitions that are underlined feature as separate entries in the glossary. The first table to the right side of the page lists the input parameters, and a second table lists the specific materials and equipment required. The actual procedure of deriving an indicator value at an inventory or monitoring site is listed on the left side of the page, as a series of steps that must be followed sequentially.

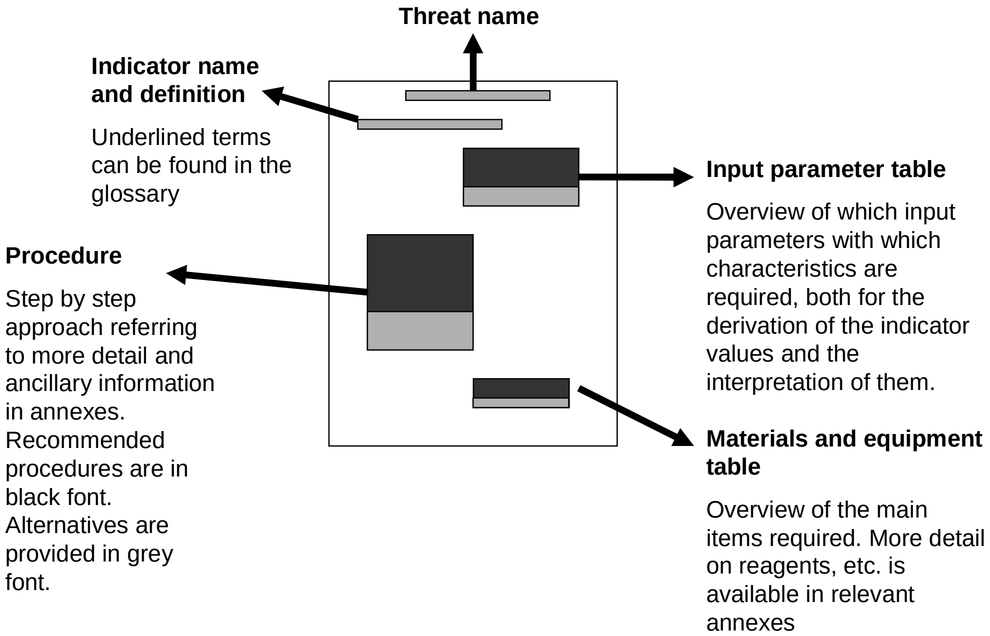


Figure 1 Template of the cover sheet of a procedure & protocol.

Both the tables and the step-by-step description refer to a number of annexes where the required detailed information is given. These annexes are attached to each relevant indicator cover sheet, thereby creating completely 'stand alone' procedures and protocols. Specific elements that are common in the procedures for several indicators are presented in appendix I, which are included in Chapter 3. Full reference is made to the relevant documents of the International Standards Organisation (ISO).

The ENVASSO system for monitoring threats to soil in Europe is harmonised to provide consistent information on the state and trends of soil for developing policy at the European scale. This means that the same indicators are used throughout Europe with the same units of measurement. However, data availability and the access to material and equipment is not the same throughout Europe, and therefore, differences in specific technical details in the methods employed for deriving indicator values may differ as well. In the procedures and protocols the preferred methods, parameters, materials, and equipment are clearly identified as such and presented in black font. Alternative options are identified and displayed in grey font.

The results of indicator testing have provided the basis for assessing the status of each indicator, expressed as green, amber, pink, red or yellow. The selection criteria adopted are as follows:

Green

1. Overall, indicator was applied successfully in the pilot areas
2. Monitoring could start tomorrow
3. Either no modifications of procedures & protocols required, or only some minor modifications/extensions

Amber

1. Indicator performance was partially successful in the pilot areas
2. Monitoring could not start tomorrow
3. With some structural modifications to the procedures & protocols monitoring could start within a year

Pink

1. Indicator performance showed major difficulties in one or more pilot areas
2. Monitoring could not start within a year

Red

1. Substantial technical/scientific progress is still required for this indicator to be monitored in a harmonised way throughout Europe, but is expected to be possible within 2-3 years, or
2. Indicator was found to be unsuitable for harmonised monitoring at European scale.

Yellow

1. Indicator already established and in use in some Member States; not selected for further testing by ENVASSO

2.1 Soil erosion

The threat 'soil erosion' is defined as 'the wearing away of the land surface by physical forces such as rainfall, flowing water, wind, ice, temperature change, gravity or other natural or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth's surface to be deposited elsewhere'. When the term 'soil erosion' is used as a threat to soil it refers to 'accelerated soil erosion' (see ENVASSO Glossary of Key Terms).

Water erosion is the wearing away of the land surface by rainfall, irrigation water, or snowmelt, that abrades, detaches and removes geologic parent material or soil from one point on the Earth's surface to be deposited elsewhere; soil or rock material is detached and moved by water, under the influence of gravity. In the case of this indicator, material is removed by surface runoff in rills, inter-rills and sheet wash. Water erosion, caused by surface runoff through rills, inter-rills, and sheet wash, is the most widespread form of soil erosion in Europe.

Wind erosion results mainly from the velocity of moving air. A wind speed of 30-40 km h^{-1} is sufficient to dislodge particles from the soil and transport them either by saltation, deflation or surface creep. Dry winds are more erosive than cold, humid winds. Wind erosion is not as widespread as water erosion in Europe, but it is a serious problem in certain regions – e.g. northern Germany, the eastern Netherlands, eastern England, parts of Eastern Europe and the Iberian Peninsula.

Tillage erosion has been the subject of a number of studies in the past decade (see Quine *et al.*, 2006). In this project, tillage erosion includes soil removed by crop harvesting and land-levelling, a process most common in the Mediterranean region. Although it is mainly restricted to agricultural areas and its extent is uncertain, it may be increasing. It is often confounded with both water and wind erosion which exacerbate soil losses. Although it is a local problem that can be monitored at field scale, estimation of the soil lost at European scale, by a harmonised methodology, is not possible at the present time.

References

Quine, T.A., Van Oost, K., Walling, D.E. and Owens, P.N. (2006). Development and application of GIS-based models to estimate national rates of soil erosion by tillage, wind and root crop harvest, University of Exeter, Exeter.

Soil erosion

ER01	Estimated soil loss by rill, inter-rill and sheet erosion

Definition: (indicator) the quantity of soil estimated to be lost by the processes of rill inter-rill and sheet erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). It is not possible to measure soil loss by water erosion at all soil monitoring sites; therefore, soil loss is estimated by a harmonised process model using the soil data combined with climatic, vegetation (cover), and topographic data. The soil loss estimated by the process model is validated by comparison with erosion measurements (ER02) from a representative subset of (benchmark) monitoring sites in a soil monitoring network.

The process model proposed for evaluation is the Pan-European Soil Erosion Risk Assessment (PESERA) model (Kirkby *et al.*, 2004). This has been selected because it incorporates a run-off module thought to be appropriate for European conditions, it provides estimated soil loss in t $ha^{-1}yr^{-1}$ instead of a risk class and its data requirements are such that it can be applied at coarse scale across the whole of Europe. The procedures described here for running the PESERA erosion model on a grid – PESERA_GRID model (Kirkby *et al.*, 2008) – for example at 1 km resolution could be applied at finer resolutions such as 250 m, given the necessary input data. At present, it is not clear that it would be valid to run the current version of PESERA_GRID at finer resolutions, such as 100 m.

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Climatic parameters	various	A & M	1 km
Vegetation parameters	various	A & M	1 km
Soil parameters	various	M	1 km
Topographic parameters	m	A & M	1 km

Step 1: Prepare climatic data sets
  i) See Annex I
Step 2: Prepare vegetation (includes land-use) data sets
  i) See Annex II
Step 3: Prepare soil data sets
  i) See Annex III
Step 4: Prepare topographic data set
  i) See Annex IV
Step 5: Run PESERA_GRID model
  i) See Annex V
  ii) See Annex VI (PESERA Users Manual by Irvine and Kosmas, 2003, 2007)
Step 6: Visualise results
  i) Input grid of estimated soil (sediment) loss data to a GIS to display a map of soil erosion by water
  ii) See Annex VII for legend and layout: 0-1 t ha^{-1} yr^{-1} as green and the areas with a cumulative estimated soil erosion value > 1 t ha^{-1} yr^{-1} in a range of colours from yellow through orange pink and red to dark purple, with dark purple being the most severe class >50t ha^{-1} yr^{-1}.

Or alternatively,
If there is a national methodology for estimating water erosion:
Step 1: Apply national methodology

i) Visualise results
ii) Use National legend
iii) Revisualise using European legend (see Annex VII)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
ARC GIS	ARC Workstation extension
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)
PESERA_GRID software	Latest version
Spatial data sets	In ARC_Grid format

Annex I Climatic parameters

[Source: PESERA Users Manual (Irvine and Kosmas, 2003)]

These parameters are described as input data for running the PESERA_GRID model at 1 km resolution for Europe. For smaller areas at more detailed scales, input data grids could be prepared using the same file nomenclature as below but with source and spatial resolution at for example 250 m instead of 1 km spacing. An important aspect of data preparation is that all input grids have the same spatial extent, i.e. they are prepared using the same 'mask'.

Table AI.1 Climatic Parameters (preferred parameters are in black, additional parameters are in grey); A=Actual (measured), M=Modelled, NA=not applicable.

Required	Description	Source	Units	Type	Spatial Resolution	Number of data sets
meanrf130_	Rainfall, mean monthly	MARS	mm	A	1 km	12
meanrf2_	Rainfall, mean monthly rain per rain day	MARS	mm	A	1 km	12
cvrf2_	CV of mean monthly rainfall per rain day	MARS	NA	A	1 km	12
mtmean_	Mean monthly temperature (Altitude corrected)	MARS	°C	A	1 km	12
mtrange_	Monthly temperature range (max-min)	MARS	°C	A	1 km	12
meanpet30_	Mean monthly Potential Evapotranspiration	MARS	mm	A	1 km	12
newtemp	Predicted future temperature (scenario lead)	Hadley	°C	M	1 km	12
newrf130_	Predicted future rainfall (scenario lead)	Hadley	mm	M	1 km	12

Annex II Vegetation parameters

[Source: PESERA Users Manual (Irvine and Kosmas, 2003)]

As for climate, the vegetation parameters are described as input data for running the PESERA_GRID model at 1 km resolution for Europe. For smaller areas at more detailed scales, for example 250 m, 100 m or less, input data grids could be prepared using the same file nomenclature as below but with source and spatial resolution at for example 250m instead of 1km spacing. An important aspect of data preparation is that all input grids have the same spatial extent, i.e. they are prepared using the same 'mask'.

Table AII.1 Vegetation Parameters (preferred parameters are in black, additional parameters are in grey); A=Actual (measured), M=Modelled

Required	Description	Units	Source	Type	Spatial Resolution	Number of data sets
Use	Corine land cover	code	CORINE Table AII.2	A	1 km	1
eu12crop1	Dominant arable crop	code	CORINE/FSS Table AII.3	A	1 km	1
maize_210c	Maize crop	code	CORINE	A	1 km	1
eu12crop2	2nd dominant arable crop	code	CORINE/FSS Table AII.4	A	1 km	1
itill_crop1	Planting month – dominant arable crop	code	FSS/PDD	M	1 km	1
itill_maize	Planting month maize	code	FSS/PDD	M	1 km	1
itill_crop2	Planting month, 2nd dominant arable crop	code	FSS/PDD	M	1 km	1
mtill_1	Planting marker: dominant arable crop	code	FSS/PDD	M	1 km	1
mtill_m	Planting marker: maize	code	FSS/PDD	M	1 km	1
mtill_1	Planting marker: 2nd dominant arable crop	code	FSS/PDD	M	1 km	1
cov_jan-cov_dec	Ground cover for each month	%	CORINE	A	1 km	12
rough0	Initial surface storage	mm	CORINE	M	1 km	1
rough_red	Surface roughness reduction per month	%	CORINE	M	1 km	1
Rootdepth	Rooting depth	mm	CORINE	M	1 km	1

FSS – Farm Structure Survey (EuroStat)
PDD – Planting Dates Database (expanded and modified from Orshoven *et al.*, 1999)

Table AII.2 Land use types used by the PESERA model with the corresponding codes (parameter Grid USE)

Code	Description
100	Artificial land
210	Arable land
221	Vineyards
222	Fruit trees and berry plantations
223	Olive groves
231	Pastures and grassland
240	Heterogeneous agricultural land
310	Forest
320	Scrub
330	Bare land
334	Degraded natural land
400	Water surfaces and wetland

Local land use codes should be translated into these codes for input to PESERA_GRID.

The table below lists, as an example, the description of local land use and vegetation types (identified in Greece) and CORINE codes to which these categories should be assigned in order to run the PESERA_Grid model

Categories	Type of vegetation	Description	PESERA USE
Land use/ Vegetation type	A	Annual natural vegetation	**231**
	C	Annual Cultivated vegetation	**210**
	K	Kastania	**222**
	O	Olives	**223**
	P	Pines	**310**
	Q	Oaks	**310**
	S	Shrubs	**240**
	W	Wetlands	**400**
	F	(Fagus Sylvatica)	**310**
	T	Trees	**310**
	G	Annual grass	**231**
	M	Macchia	**320**
	R	Reeds	**410**
	LO	Locust	**310**
	ME	Medic	**210**
	V	Vineyards	**221**
Non-vegetation	X	Towns and Villages	**100**
	AIR	Airports	**124**
	NTA (D)	Quarry	**100**
	B	Bare land	**330**

Table AII.3 Dominant arable crop (Grid EU12CROP1)

Code	Dominant arable crop
1	Cereal (spring sown)
2	Cereal (winter sown)
3	Cereal (spring sown)
4	Cereal (winter sown)
6	Maize
10	Root crop
13	Oilseed
18	Forage
21	Fallow

Table AII.4 Second Dominant arable crop (Grid EU12CROP2)

Code	Dominant arable crop
1	Cereal (spring sown)
2	Cereal (winter sown)
3	Cereal (winter sown)
4	Cereal (winter sown)
5	Cereal (Spring sown)
6	Maize
8	Cereal (Spring sown)
9	Pulses
10	Root crop
11	Root crop
13	Oilseed
14	Vegetables/flowers
18	Forage
21	Fallow

Annex III Soil parameters

[Source: PESERA Users Manual (Irvine and Kosmas, 2003)]

As for climate and vegetation, these parameters are described as input data for running the PESERA_GRID model at 1 km resolution for Europe. For smaller areas at more detailed scales, input data grids could be prepared using the same file nomenclature as below but with source and spatial resolution for example at 250 m instead of 1 km spacing. An important aspect of data preparation is that all input grids have the same spatial extent, i.e. they are prepared using the same 'mask'.

Table AIII.1 Soil Parameters (preferred parameters are in black, additional parameters are in grey); A=Actual (measured), M=Modelled

Required	Description	Units	Type	Spatial Resolution	Number of data sets
crust_0702	Crust storage	mm	M	1 km	1
erod_0702	sensitivity to erosion	mm	M	1 km	1
soil_stor	Effective soil water storage capacity (swsc_eff_2)	mm	M	1 km	1
p1xswap1	Soil water available to plants in topsoil (0-30 cm)	mm	M	1 km	1
p1xswap2	Soil water available to plants in subsoil (30-100 cm)	mm	M	1 km	1
zm	Scale depth (TOPMODEL: f (texture)	mm	M	1 km	1

Soil crusting and erodibility are estimated using pedotransfer rules (PTR) developed for interpretation of the European Soil Map and Database. The PTRs form part of the distribution software but Figure AIII.1 shows the relationship of those needed to estimate crusting and erodibility.

Soil crusting (crust_0702)

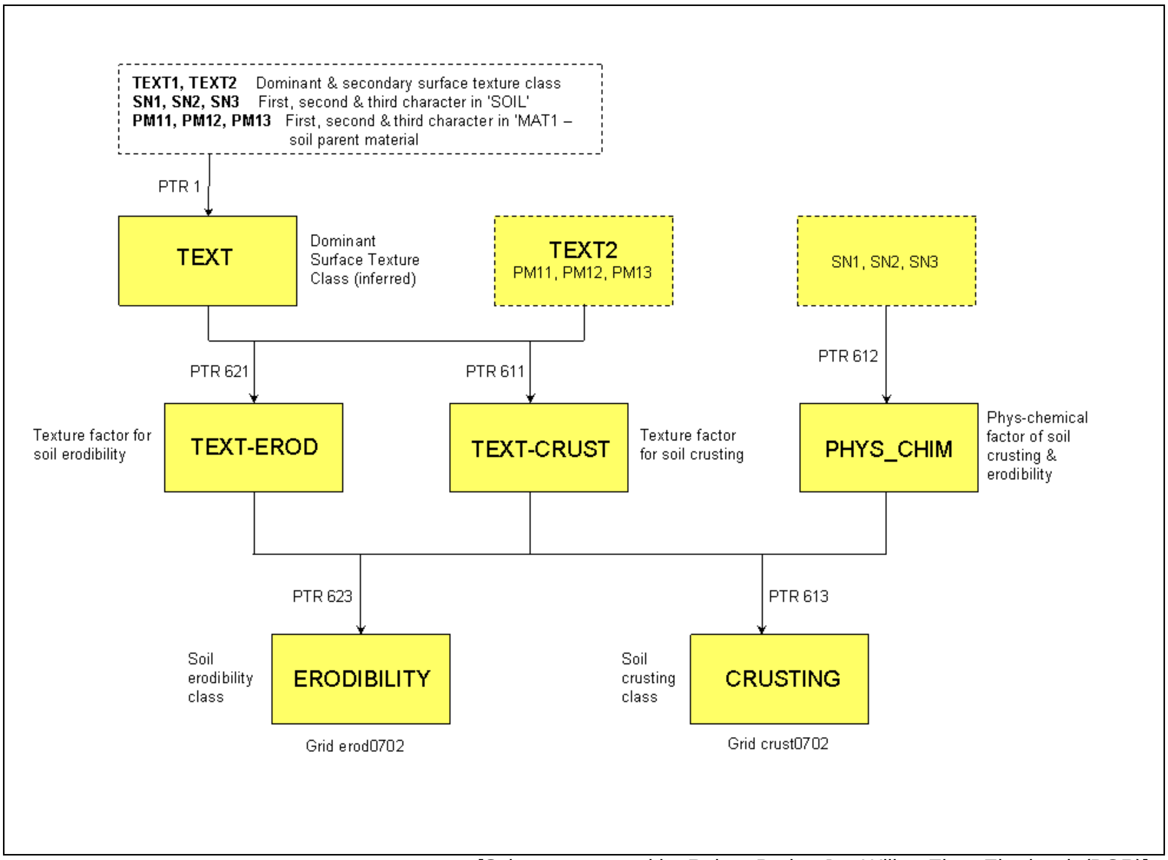
Sensitivity to soil crusting is assessed using the scheme pioneered by Le Bissonnais *et al.* (2000, 2002), applied to the European Soil Database. The pedotransfer rules required to directly estimate soil crusting are listed the the revised PESERA Manual (Irvine and Kosmas, 2007, p.59-72). However, the European Soil Database uses the simplified FAO (1974) coarse texture class scheme,classes 1-5, (Figure AIII.2), but national soil information systems usually use more detailed soil texture classes such as those defined in FAO (2006, Figure 4). The more complex soil texture classes have to be aggregated, in accordance with FAO (1974) 'broad texture classes' modified for the European Soil Map (CEC, 1985), before the soil crusting class can be assigned. This results in some loss of precision. Soil crusting classes are shown in Table AIII.2.

Table AIII.2 Soil Crusting Classes as defined for use with the European soil database

Code	Soil crusting class
1	very weak
2	weak
3	moderate
4	strong
5	very strong

Soil erodibility (Erod_0702)

Sensitivity to erosion is defined in accordance with the scheme outlined in Figure AIII.1. The broad soil texture classes (Figure AIII.2) defined by FAO (1974), and adopted for the European Soil Map (CEC, 1985), are also used to estimate erodibility. The erodibility classes in Table AIII.3 are estimated from pedotransfer rules applied to the European Soil Database. These PTRs are listed in the revised PESERA Manual (Irvine and Kosmas, 2007, p.73-78)



[Schema prepared by Rainer Baritz, Jan Willer, Einar Eberhardt (BGR)]

Figure AIII.1: Structure of the required soil property data for PESERA

Input data, coding and classes are developed on the basis of specifications and definitions coming from the European Soil Database, at 1:1,000,000 scale, in which:

'SOIL' comprises the code form Soil Name in the FAO (1974) – expanded for the 1:1,000,000 scale European soil map (CEC, 1985) .

'MAT1' is the code for parent material

Figure AIII.2 Broad texture classes of FA (1974)

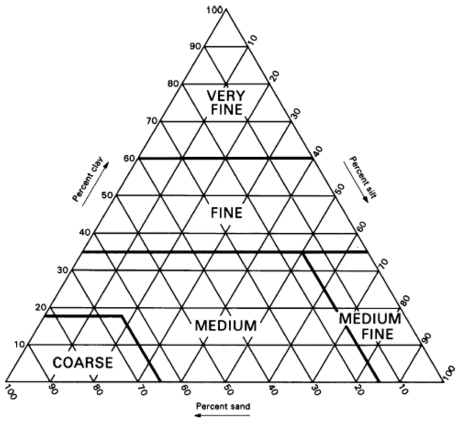


Table AIII.3 Soil Erodibility Classes as defined for use with the European Soil Database

Code	Soil erodibility class
1	very weak
2	weak
3	moderate
4	strong
5	very strong

In the medium term, the soil crusting and erodibility class systems could be expanded to accept more detailed soil texture classes (e,g FAO, 2006) directly, but the Fortran code of the PESERA_GRID model would need recoding to accommodate such changes. Recoding would only be worthwhile when those countries, for which the European Soil Database provides the only complete national coverage of soil types, can provide more detailed soil texture class data.

Soil Water Storage Capacity (swsc_eff-2)

The Soil Water Storage Capacity (swsc) is computed to include the Drainable Pore Space, and the Proportion of the Soil Water Available to Plants (SWAP) – see Jones *et al.* (2000) – which is available for storing precipitation, taking any restriction of soil depth by rock or hard pan into account.

The calculation is as follows:

Swsc_eff = (P1swap_top) * (Swap_top) + (P2swap_sub) * (Swap_sub_r) + k (Po_tot_mmr)

Where:

Swap_top – Soil Water Available to Plants in the topsoil (0–30 cm) in mm

Swap_top = 0.3 * (Awc_top2mm)

Awc_top – Topsoil Available Water Capacity in mm m^{-1}

Swap_sub_r – Soil Water Available to Plants in the subsoil (30–100 cm) in mm including any restriction of soil depth by rooting restriction within 100 cm depth to rock (Dr)

Swap_sub_r = Awc_sub2mm * (Dr_rest_10–30)/100

Awc_sub2mm – Subsoil Available Water Capacity in mm m^{-1}

P1swap_top – Proportion of SWAP available for storing precipitation in topsoil (0–30 cm)
P2swap_sub – Proportion of SWAP available for storing precipitation in subsoil (30–100 cm)

Table AIII.4 Proportion of SWAP available for storing precipitation

		P1swap_top				P2swap_sub		
Texture	**Textaw ctop**	**Pd_top**	**Pd_top**	**Pd_top**	**Textaw csub**	**Pd_sub**	**Pd_sub**	**Pd_sub**
Name	**CODE**	**LOW**	**MED**	**HIGH**	**CODE**	**LOW**	**MED**	**HIGH**
Coarse	1	1.0	1.0	0.8	1	1.0	0.8	0.6
Medium	2	1.0	0.8	0.6	2	1.0	0.8	0.6
Med-Fine	3	0.8	0.6	0.4	3	0.8	0.6	0.4
Fine	4	0.6	0.4	0.2	4	0.6	0.4	0.2
Very Fine	5	0.3	0.2	0.1	5	0.3	0.2	0.1
Organic	8	1.0	0.9	--	8	1.0	0.9	--
No texture	6	0	0	0	0	0	0	0

Po_top_% – Drainable Pore Space of topsoil (0–30 cm) (in % vol.)
Po_sub_% – Drainable Pore Space of subsoil (30–100 cm) (in % vol.)

Table AIII.5 Drainable pore space for storing precipitation

		Po_top_%				Po_sub_%		
Texture	**Textaw ctop**	**Pd_top**	**Pd_top**	**Pd_top**	**Textaw csub**	**Pd_sub**	**Pd_sub**	**Pd_sub**
Name	**CODE**	**LOW**	**MED**	**HIGH**	**CODE**	**LOW**	**MED**	**HIGH**
Coarse	1	30	25	20	1	25	20	18
Medium	2	20	15	10	2	18	15	10
Med-fine	3	15	12	8	3	15	12	8
Fine	4	10	8	5	4	10	8	5
V Fine	5	8	5	3	5	5	3	2
Organic	8	30	25	--	9	30	25	--
No text	6	0	0	0	0	0	0	0

For a full description of the computation of Awc, swap and swsc_eff_2, as shown in Figures AIII.3 and AIII.4, the user is referred to Irvine and Kosmas (2007), and http://eusoils.jrc.ec.europa.eu.

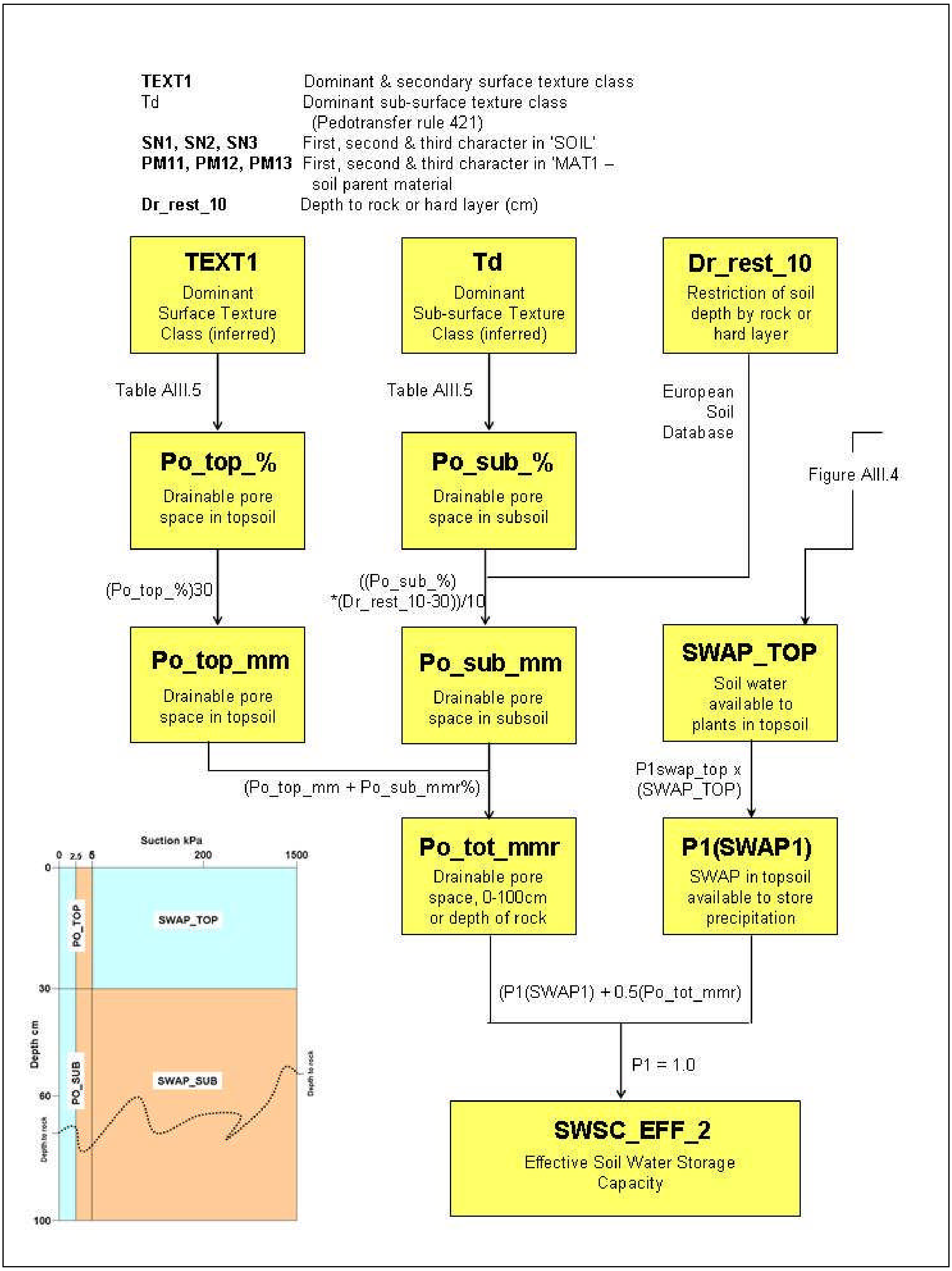


Figure AIII.3 Effective Soil Water Storage Capacity

[Original prepared by Rainer Baritz, Jan Willer, Einar Eberhardt (BGR) for ENVASSO Project]

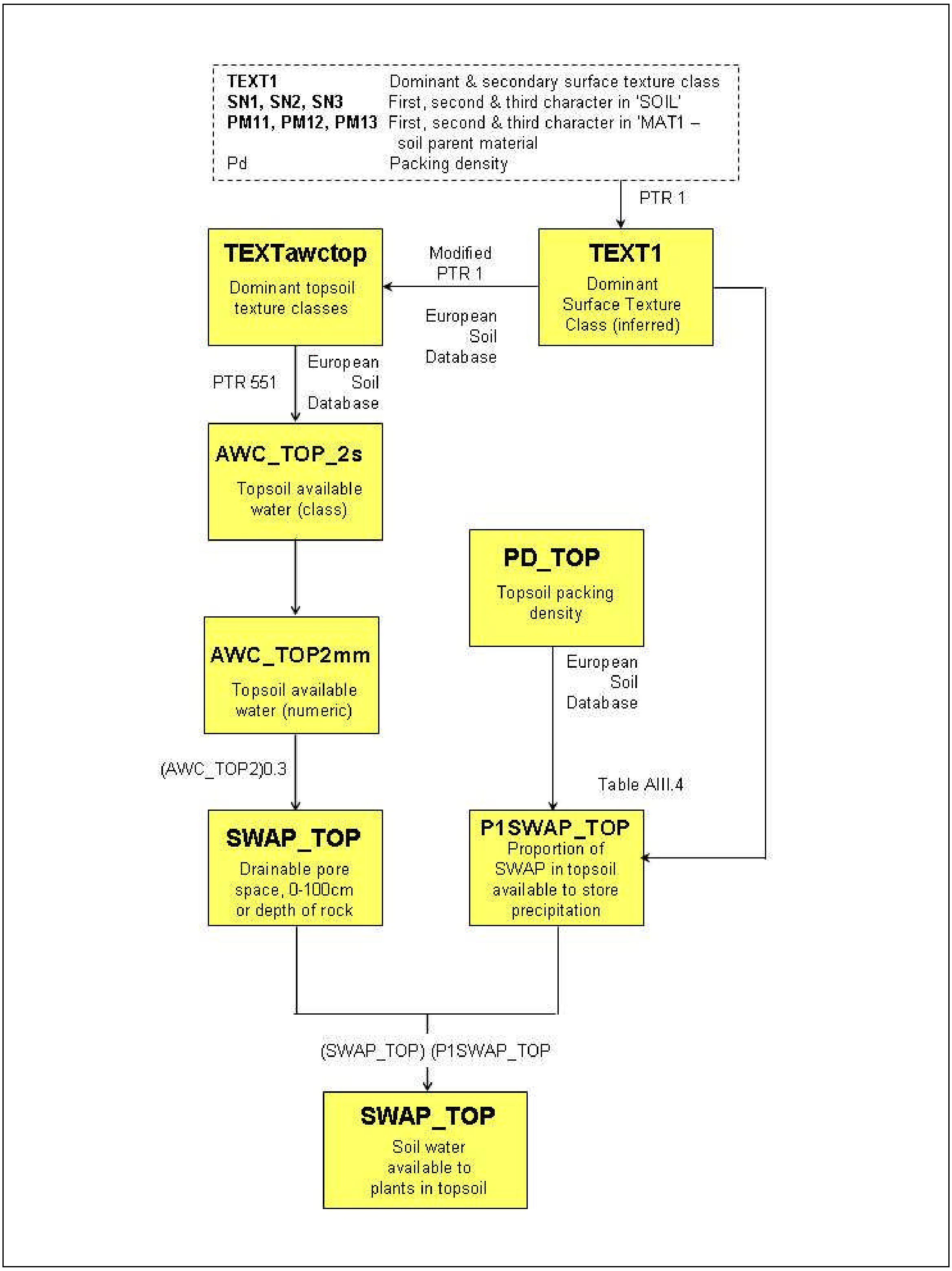


Figure AIII.4 Soil Water Available to Plants

[Original prepared by Rainer Baritz, Jan Willer, Einar Eberhardt (BGR) for ENVASSO Project]

Annex IV Topographic parameters

[Source: PESERA manual (Irvine and Kosmas, 2003)]

This parameter is described as the topographic input data for running the PESERA_GRID model at 1 km resolution for Europe. For smaller areas at more detailed scales, for example 250 m or 100 m, the input data grid should be prepared using the same file nomenclature as below but source and spatial resolution will be different. Thus the standard deviation (STD) of all points should be calculated using those that fall within a radius of 1.5 km irrespective of the grid resolution, i.e. the STD for 250 km will be based on many more points than the STD for a 1 km grid. An important aspect of data preparation is that all input grids have the same spatial extent, i.e. they are prepared using the same 'mask'.

Table AIV.1 Topographic Parameters (preferred parameters are in black, additional parameters are in grey); A=Actual (measured), M=Modelled

Required	Description	Units	Type	Spatial Resolution
std_eudem2	Standard deviation of all points within 1.5 km radius	m	M	1 km

Annex V Summary

Table AV.1 Summary of minimum data in Grid format needed to run the PESERA Grid model (total raster layers 93)

Data Source	Initial Grid name	Number of Layers	Description
Vegetation data	Rootdepth*	**1**	Root depth
	Rough0*	**1**	Initial surface storage
	Rough_red*	**1**	Roughness reduction
	Use	**1**	Land use characteristic
	Cov_jan – cov_dec*	**12**	Ground cover (%) (for each month)
Climatic data	Meanrf1301-meanrf13012	**12**	Monthly rainfall (mm) (for each month)
	Mtmean1- mtmean12	**12**	Mean temperature (deg C) (for each month)
	Mtrange1- mtrange12	**12**	Mean temperature range (for each month)
	Cvrf21 – cvrf212	**12**	Coefficient of variation of rain per rain day (for each month)
	Meanrf21-meanrf212	**12**	Mean rain per rain day (mm) (for each month)
	Meanpet301-meanpet3012	**12**	Mean potential Evapo-Transpiration (ET) (for each month)
Soil data (soil texture)	Soil_stor*	**1**	Soil storage
	Crust_0702*	**1**	Crusting
	Erod_0702*	**1**	Erodibility
	Zm *	**1**	Scale depth (range 5-30mm)
Topographic data (DEM)	Std_eudem2*	**1**	Standard deviation of elevation

** If these data are not available for Pilot Area testing, they can be extracted from a PESERA_GRID database for Europe, at 1000 m resolution for the PA. If these data are resampled to finer resolution the accuracy may be low.*

In order to extract the data for the PESERA_GRID model, it is necessary to transform the data into the Lambert-Azimuthal Equal Area projection system. For defining vegetation type for each grid, local land-use data must be transformed to the GRID_USE codes defined in Annex II (p 20). This will inevitably result in simplification of detailed land-use data that may exist for a Pilot Area.

Running the PESERA_GRID model using the minimum data sets listed above necessitates using the Europe data grids <newtemp> and <newrf130> as input, although these grids are not used to calculate soil loss unless a climate change scenario is selected. Using PESERA to model the effects of climate change necessitates the replacement of these two data grids by local scenario data.

Annex VI PESERA Users Manual

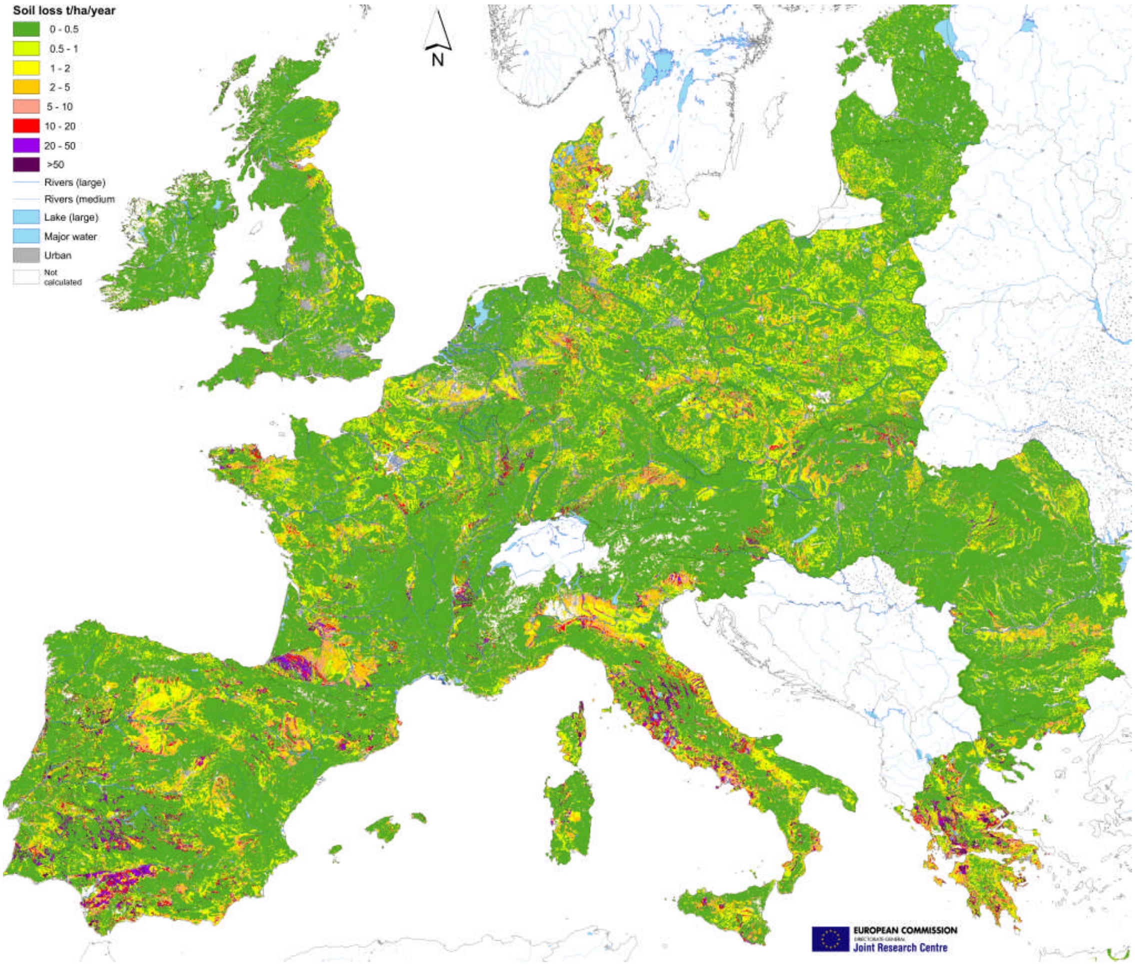
The original PESERA Users Manual was produced by Irvine and Kosmas (2003) as Deliverable 15 of the PESERA Project, Contract QLK5-CT-1999-01323, which is included on the CD 'Nature and extent of soil erosion in Europe' EUR 20972 EN, Office for the Official Publications of the European Communities. It describes the process adopted to run the PESERA_GRID model at 1 km resolution to produce a map of estimated soil loss by rill and inter-rill for Europe (S.P.I.04.73) as the final output from the PESERA Project. It was not intended to be a universal guide for operational use of PESERA by the research community at large and no resources have been made available since 2003 to fully revise the PESERA Users Manual.

In addition to its inclusion on the compact disk EUR 20792 EN, this manual can be downloaded from http://eusoils.jrc.ec.europa.eu . The ENVASSO Project decided to test PESERA in the context of soil erosion as a threat to soil and as a potential procedure for monitoring future soil conditions in Europe. The performance of the PESERA_GRID model was evaluated in 8 Pilot Areas in Europe and, to this end, the original manual was revised by R.J.A Jones in consultation with B. Irvine and M.J. Kirkby to provide more detailed guidance on the preparation of input data sets for the ENVASSO Pilot Areas.

The results of this evaluation are described in the ENVASSO Prototype Evaluation report (D8). The revised PESERA Users Manual ((Irvine and Kosmas, 2007) will be uploaded to the http://eusoils.jrc.ec.europa.eu website at the conclusion of the ENVASSO Project. However, the fact that the application of indicator ER01, using the PESERA_GRID model, retains an 'amber' status is because the model and users manual require further revision before full implementation at European scale is possible.

Annex VII Visualisation of Results

The results shown below derive from running the PESERA_GRID Model at 1 km resolution for Europe. It is proposed that this format, i.e. classification and colour scheme (Table AVII.1), should be adopted for reporting the results from application of the model in other areas. Thus the resulting maps of sediment loss for different parts of Europe will be directly comparable.



(reproduced from S.P.I.04.73, 2004)

Figure AVII.1 Soil erosion estimates for Europe

Table AVII.1 Colour codes for soil erosion classes for visualisation using a GIS

Legend Colour code			Estimated Soil loss
R	G	B	t/ha/yr
84	173	36	0-0.5
220	255	0	0.5-1
255	255	0	1-2
255	201	0	2-5
255	161	138	5-10
255	0	0	10-20
152	0	235	20-50
97	0	87	>50

References

CEC (1985) Soil Map of the European Communities, 1:1,000,000. Office for Official Publications of the European Communities, Luxembourg.

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Irvine, B. and Kosmas, C. (2007). PESERA User's Manual. PESERA Technical Report Deliverable 15, contract QLK5-CT- 1999-01323. Revised for the ENVASSO Project (Contract 022713) by R.J.A. Jones. European Commission FP5 &6 research projects, 133pp.

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Kirkby, M.J., Jones, R.J.A., Irvine, B., Gobin, A, Govers, G., Cerdan, O., Van Rompaey, A.J.J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., Van Lynden, G.J. and Huting, J. (2004). Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.73 (S.P.I.04.73). European Soil Bureau Research Report No.16, EUR 21176, 18pp. and 1 map in ISO B1 format. Office for Official Publications of the European Communities, Luxembourg.

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S.P.I.04.73. (2004). Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Special Publication Ispra 2004 No.73, map in ISO B1 format. R.J.A. Jones, R. Hiederer and L. Montanarella. Joint Research Centre, Ispra, European Communities.

ER02	Measured soil loss by rill, inter-rill and sheet erosion

Definition: (indicator) the quantity of soil measured as lost by the processes of rill inter-rill and sheet erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). It is not possible to measure soil loss by water erosion at all soil monitoring sites; but carefully located 'benchmark' measuring sites could provided measured soil loss, from representative soil-landscapes in Europe, from a representative subset of (benchmark) monitoring sites in a soil monitoring network. These measured soil losses would enable calibration and validation of model estimates.

Soil erosion by surface runoff (water) is most commonly measured by experimental field plots of different types and sizes, and the methods adopted as regards spatial and temporal scale of measurements are reviewed in depth by Boix-Fayos *et al.*, (2006). Results from experimental erosion plots in many countries of Europe have been compiled by Boardman and Poesen (2006).

Such measurements have been on-going for the past 50 years and thus monitoring at benchmark sites could be organised immediately given sufficient resources, hence the 'green' status accorded to this indicator (ER02). However, further resources are needed for researching, defining and specifying the devices which would be appropriate for installation at the 'benchmark' monitoring sites that are needed to measure erosion across Europe.

In this respect, the recent Pan-European project SOWAP (Soil and Water Protection) is of interest because it has recently established a number of benchmark sites in Europe where soil loss by water erosion is being measured on field plots that have standard devices and instrumentation. Further details can be found at http://www.sowap.org and http://eusoils.jrc.ec.europa.eu.

References

Boardman, J. and Poesen, J. (2006). Soil Erosion in Europe. Wiley, England, 855pp.

Boix-Fayos, C., Martinez-Mena, M., Arnau-Rosalen, E., Calvo-Cases, A., Castillo, V. and Albaladejo, J. (2006). Measuring soil erosion by field plots: Understanding the sources of variation. Earth-Science Reviews 78, 267-285.

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Soil erosion

ER05 Estimated soil loss by wind erosion

Definition: (indicator) the quantity of soil estimated to be lost by the process of wind erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). Soil loss could be estimated by a harmonised process model using the soil data combined with climatic, vegetation (cover), and topographic data. The model estimates of soil loss would need to be validated by comparison with erosion measurements (ER06) from a representative subset of monitoring sites in a soil monitoring network

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Climatic parameters: Wind direction frequency and Annual mean wind speed in 10 m above surface in open areas Moisture parameters	various: Compass bearing m s^{-1} % (humidity)	A & M	1 km
Vegetation parameters: Cultivated crops	various	A & M	Attribute for vector data
Soil parameters: Soil texture' Soil organic matter content	class (FAO) %, w w^{-1}	M	Attribute for vector data
Topographic parameters: Height & extent of wind-breaks	m	M (Vector data)	

Step 1: Prepare climatic data sets of
- i) Wind velocity, frequency and direction
- ii) Air and soil temperature
- iii) Relative humidity
- iv) Rainfall intensity and amount

Step 2: Prepare vegetation (includes land-use) data sets
- i) Vegetation cover (density), form and height
- ii) Cultivation practices and grazing intensity
- iii) Land-use system (field crops)

Step 3: Prepare soil data sets
- i) Soil texture, structure
- ii) Soil surface condition
- iii) Soil moisture status

Step 4: Prepare topographic data set
- i) Surface form (micro-relief)
- ii) Surface roughness (wind breaks)

Step 5: Run wind erosion assessment model of FAO
- i) Determine wind erodibility class of the soil according to Table AI.3
- ii) Assess the site-dependent susceptibility to wind erosion according to Table AI.4
- iii) Assess the protective effect of cultivated crops against wind erosion according to Table AI.5a (for crop rotations, Table AI.5b)
- iv) Determine distance to wind break perpendicular to the dominant wind direction

v) Assess the zones of sheltering effect of wind breaks perpendicular to the dominant wind direction according to Figure A.1 by combining distance to and height of wind breaks
vi) Assess the current susceptibility to wind erosion according to Table 5

Step 6: Visualise results using GIS (e.g. ArcMap™)
i) See ER01_Annex VII (p.29)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
ARC GIS	ARC_Workstation extension
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)
Model software	Latest version
Spatial data sets	In ARC_Grid format

Conclusion

This method determines the present susceptibility of the soil to wind erosion, with regard to soil properties (texture class, organic matter content), field crop, and sheltering effect of wind breaks perpendicular to the dominant wind direction (note that the sheltering effect of wind breaks not perpendicular to the wind direction cannot be classified properly with this approach). The tables are adapted from the German "Methodendokumentation Bodenkunde" (Hennings 2000) to the FAO soil texture classes (FAO 2006) (see Figures 2 and 3). Half-steps rather express fuzziness than enhanced accuracy (the original methods only deal with full classes). This indicator (ER05) retains its red status because substantial technical/scientific progress is still required before it can be included in a European Soil Monitoring programme. However, this progress is expected to be possible within the next 2-3 years.

The extent of erosion can be expressed in the form of the following dependence (Bondarov, 1984), consisting of four major characteristics:

$$E = f\,(W,S,M,A)$$

Where:

W is the characteristics of the wind regime
S is the nature of the surface soil layer
M is the characteristics of the meteorological elements
A is the degree of human interference on the soil surface and other factors resulting from agricultural practices.

Wind erosion is the result of wind interacting with the soil, in inhabited regions as well as natural areas. The wind regime is characterised by the instantaneous, mean diurnal, mean annual, maximum (gust) velocity and the frequency distribution, the direction and the turbulence of the wind current. The soil is characterised by the mechanical composition (texture), dampness/wetness, lumpiness or composition of non-erodible fractions, soil surface crustiness, water repellency and wind resistance of soil crumbs. A detailed analysis of the processes of wind erosion is given by Funk and Reuter (2006).

The meteorological conditions are characterised by the air temperature, soil temperature (degree of soil freezing), rainfall (quantity and intensity) and relative air humidity. Agricultural activities cause changes in many natural features that are responsible for the occurrence and spread of wind erosion of soil. These include:

> Field relief, previous erosion (was the soil blown away or deposited nearby), field width (along the direction of the wind), degree of erosion in adjacent fields, surrounding structures (height and girth of trees and bushes and distance between wind breaks), ridge formation on the surface (height, shape and distances between crests), surface roughness, soil cover (vegetation height and density of plants, presence of post-harvest debris, cultivation practice, grazing intensity and surface crustiness.

Wind velocity has a direct effect of on the extent of wind erosion, and without wind no soil will be displaced by these forces. Cultivation can result in conditions favourable for erosion, for example, ploughing loosens soil, changes the roughness of the surface, breaks up crusts and buries plant residues.

Future Prospects

Future prospects will include approaches based on physical models with higher temporal resolution than merely annual time-steps. The USGS Wind Erosion Prediction System (WEPS) allows modelling wind erosion on sub-hourly time-steps whereas the Wind Erosion of European Light Soils (WEELS) model (Böhner *et al.*, 2003) quantifies single events. However, these models have significant data requirements and are currently not suitable for monitoring wind erosion at European scale. However new data, for example high resolution climate data (e.g PRUDENCE from Danish Meteorological Service, soil and crop data (e.g. FSC from Meteosat), uncertainty estimates from digital soil mapping, offer the prospect of improved monitoring of wind erosion across Europe. It is important to emphasise that for reliable monitoring, model estimates must be validated against field measurements, which are difficult to collect because of variation in time and space and the event-nature of wind erosion. Methods of measuring soil losses by wind erosion exist (Bocharov, 1984; Funk, 1995) but there are insufficient sites operating at European scale and those that exist are not connectec in any measningful way.

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Annex I FAO Methodology

Eberhardt, Einar; Hennings,Volker (BGR 2007)

Table AI.3 Wind erodibility class

Wind erodibility class (name)			
Soil texture class	**Organic matter content of the dry soil**		
	< 1 %	**1 to <15 %**	**15 to <30 %**
Heavy clay (HC), Sandy Clay (SC), Clay (C)	1 (very low)	0 (none)	1
Silty clay (SiC), Silty clay loam (SiCL), Sandy clay loam (SCL)	1.5	0.5	1.5
Clay Loam (CL), Silt (Si)	2.0 (low)	1.0	2.0
Loam (L), Silt Loam (SiL)	2.5	1.5	2.5
Sandy loam (SL)	3.0 (medium)	2.0	3.0
Loamy sand (LS)	3.5	2.5	3.5
Sand (S): Coarse sand	5.0 (very high)	4.0	5.0
Sand (S): Medium sand	5.0	4.5	5.0
Sand (S): Fine sand, Unsorted sand	5.0	5.0	5.0

Table AI.4 Site-dependent susceptibility to wind erosion

Wind erodibility class (Table AI.3)	Annual mean wind speed in 10 m above surface in open areas [$m \cdot s^{-1}$]					
	< 2.0	**2.0 - 2.9**	**3.0 - 3.9**	**4.0 - 4.9**	**5.0 - 5.9**	**> 5.9**
0	0.0	0.0	0.0	0.0	1.0	1.0
0.5	0.0	0.0	0.5	0.5	1.5	1.5
1	0.0	0.0	1.0	1.0	2.0	2.0
1.5	0.0	0.5	1.5	1.5	2.5	2.5
2	0.0	1.0	2.0	2.0	3.0	3.0
2.5	0.5	1.5	2.5	2.5	3.5	4.0
3	1.0	2.0	3.0	3.0	4.0	5.0
3.5	1.5	2.5	3.5	3.5	4.5	5.0
4	2.0	3.0	4.0	4.0	5.0	5.0
4.5	2.5	3.5	4.5	4.5	5.0	5.0
5	3.0	4.0	5.0	5.0	5.0	5.0

Table AI.5a Assessment of the protective effect of cultivated crops against wind erosion – Crops

Protective effect				
1 (very low)	**2 (low)**	**3 (moderate)**	**4 (high)**	**5 (very high)**
Vegetation cover closed from summer on	**Vegetation cover closed from early summer on**	**Vegetation cover closed from spring time on**	**Vegetation cover closed from late autumn on**	**Vegetation cover closed all year round**
Legumes - peas - Field bean Maize - Grain maize - Corn-Cob-Mix - Forage maize - Root crops - Potatoes - Sugar beet - Field mangel - Cabbage - Carrots Horticulture: - Vegetables - Flowers - Strawberries	Spring cereals - Spring wheat - Spring barley - Oats - mixed spring cereals Spring rape Flax Oleiferous fruits Sunflower	Winter cereals - Winter wheat - Winter rye (Sowings after 1.10.) - Mixed winter cereals	Winter cereals - Winter barley - Winter rye (Sowings before 1.10.) Green fallow Winter rape	Grassland and pastures (permanent) Forage plants - Clover - Lucerne - Grass

Table AI.5b Assessment of the protective effect of cultivated crops against wind erosion - Crop rotations

Crop rotation	Share	Protective level
Cereal crop rotations:		
Winter cereals (Sowings before 1.10.)	80 - 100 % winter cereals	4
Winter cereals (Sowings after 1.10.)	80 - 100 % winter cereals	3
Winter / Spring cereals	> 20 % spring cereals	3
Cereals – Rape	> 20 % rape	4
Cereals/Root crops/Maize rotations:		
Winter cereals – Root crops or Maize	10 to < 25 % root crops/maize	3
Winter or spring cereals – Root crops or Maize	10 to < 25 % root crops/maize and > 20 % spring cereals	2
25 to < 50 % Root crops/Maize		2
< 50 % Root crops/Maize		1
Forage plants – cereal crop rotations with perennial forage plants	20 to 50 % clover, rape, lucerne	4

Table AI.6 Assess the site and crop dependent susceptibility to wind erosion

Site-dependent susceptibility to wind erosion according to Table AI.4	Assessment of the protective effect of cultivated crops against wind erosion according to Table AI.5				
	1	2	3	4	5
0 (none)	0	0	0	0	0
0.5	0.5	0	0	0	0
1 (very low)	1	0	0	0	0
1.5	1.5	0.5	0	0	0
2 (low)	2	1	0	0	0
2.5	2.5	1.5	0.5	0	0
3 (medium)	3	2	1	0	0
3.5	3.5	2.5	1.5	0.5	0
4 (high)	4	3	2	1	0
4.5	4.5	3.5	2.5	1.5	0
5 (very high)	5	4	3	2	0

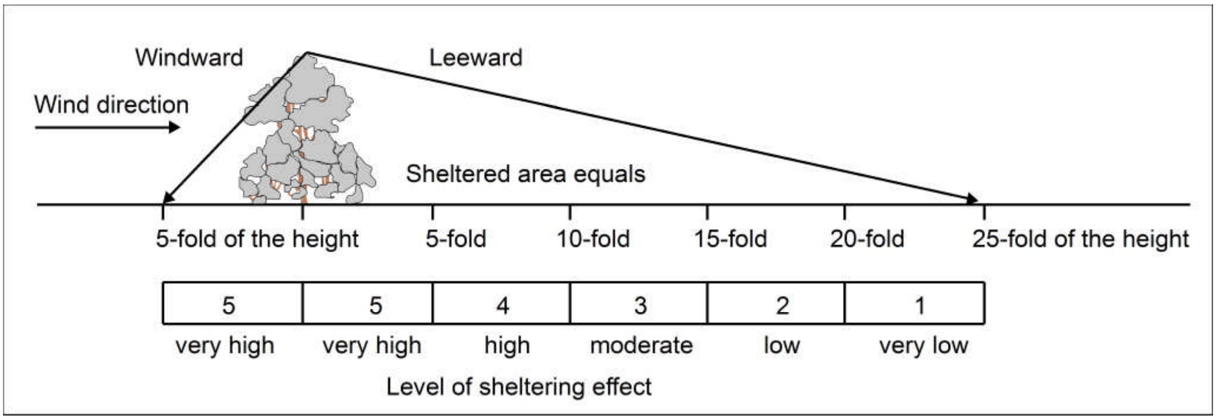

Figure AI.1 Assess the maximum length and sheltering effect from wind break height

[See also: DIN 19706 (2004). Soil quality – Determination of the soil exposure risk from wind erosion. Deutsches Institut fur Normung (DIN), Berlin, 15pp.

Soil erosion

ER06	Measured soil loss by wind erosion

Definition: (indicator) the quantity of soil measured as lost by the processes of wind erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). It is not possible to measure soil loss by wind erosion at all soil monitoring sites; but carefully located 'benchmark' measuring sites could provide measured soil loss, from representative soil-landscapes in Europe, from a representative subset of (benchmark) monitoring sites in a soil monitoring network. These measured soil losses enable calibration and validation of model estimates.

One of the problems with measuring soil loss by wind erosion is that a soil loss up to 40 t ha year can occur with no distinct effects of soil movement (Chepil, 1960) as the airborne material is distributed widely. As a result, wind erosion attracts less attention than water erosion, and thus investigation sites and subsequent measurements are not as widely distributed as for water erosion. Measurements in Europe have been performed with several devices at different heights above the ground, depending on the experimental conditions. The devices range from saltiphones over passive samplers like BOSTRA (BOttle Sediment TRAp or modified Wilson and Cooke trap), the Marble dust collectors or Big Spring Number Eight (BSNE) up to automatic samplers like the SUSTRA (Suspension Sediment Trap) or other high volume samplers (Sierra, GRIMM). Intercalibration exercises have ben already been performed.

Field measurements have been made in a few locations often spanning several years. However, consistent time series and spatially distributed measurements of soil loss by wind do not exist currently. The only harmonised, standardised and European wide data currently available in is PM10, which is a subset of the soil loss by wind, provided by the different Member States for background stations setup for Air Quality Control.

Only two research projects in Europe, WEELS and WELSON, have investigated the extent and amount of wind erosion (Gross, 2002; Goosens and Gross, 2002). Despite the progress made by these projects, further resources are needed to research, document and test standard procedures that would be suitable for measuring and monitoring soil loss by wind erosion in Europe.

References

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Goossens D, Gross J. (2002). Similarities and dissimilarities between the dynamics of sand and dust during wind erosion of loamy sandy soil. Catena 47: 269–289.

Gross, J. (2002). Wind erosion in Europe: Where and when? In Wind erosion on agricultural land in Europe. A Warren (ed.), EUR 20370 EN, 13-28, Office for the Official Publications of the European Communities, Luxembourg.

Soil erosion

ER07	Estimated soil loss by tillage erosion

Definition: (indicator) the quantity of soil estimated to be lost by the processes of tillage erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). It is not possible to measure soil loss by tillage erosion at all soil monitoring sites; but carefully located 'benchmark' measuring sites could provide measured soil loss, from representative soil-landscapes in Europe. Soil loss must be estimated by a harmonised process model using the soil data combined with climatic, crop type, and harvest data. The estimated soil loss by the process model should be validated by comparison with erosion measurements (ER08) from a representative subset of monitoring sites in a soil monitoring network. These measured soil losses enable calibration and validation of model estimates.

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Climatic parameters	various	A & M	1 km
Vegetation parameters	various	A & M	1 km
Soil parameters	various	M	1 km
Topographic parameters	m	M	1 km

Step 1: Prepare climatic data sets
 i) See Annex (TBD)
Step 2: Prepare vegetation (includes land-use) data sets
 i) See Annex (TBD)
Step 3: Prepare soil data sets
 i) See Annex (TBD)
Step 4: Prepare topographic data set
 i) See Annex (TBD)
Step 5: Run model
 i) See Annex (TBD)
Step 6: Visualise results
 i) See Annex (TBD) - using standardised legend for spatial representation

NB TBD = To Be Decided

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Climatic database	In ARC Grid format
Vegetation database	In ARC Grid format
Soil database	In ARC Grid format
Topographic database	In ARC Grid format

Conclusion

Modelling of tillage erosion, proposed by Govers *et al.* (1996), has evolved to the stage exhibited by for example WATEM (Van Oost *et al.*, 2000). Though spatially variable, tillage erosion is regarded as highly predictable on the basis of current processes and estimated rates are considered to be a robust assessment of the magnitude of tillage erosion (Quine *et al.*, 2006).

Tillage erosion (key issue)was defined as: The wearing away of the land surface by tillage operations, including the quantities of soil removed by harvesting root crops such as potatoes and sugar beet. Data requirements for estimating soil removed by harvesting of root crops, e.g. exact time of harvesting and soil moisture content at harvesting, cannot be satisfied at present. Therefore, in first instance this indicator should focus on estimating soil loss by tillage operations.

The TERON Project (http://www.people.ex.ac.uk/yszhang/teron/#par last accessed 12/12/2008) has defined equations for calculating soil movement by tillage practices but currently these equations are only applicable at local (field) level. For the foreseeable future, detailed data on cultivation implements and methods are unlikely to be available to apply either the WATEM or TERON approaches at meaningful European scale.

At the present time, substantial technical/scientific progress is still required for this indicator to be monitored in a harmonised way throughout Europe, but it could be possible within 2-5 years. Therefore, this indicator (ER07) retains its 'red' status and requires further technical/scientific progress before it could be included in a soil monitoring programme for Europe.

ER08 Measured soil loss by tillage erosion
Erosion by tillage is most commonly measured by experimental field plots with a hole drilling method or a trench method, using a diverse set starting from measuring the displacement of coloured gravels up to CS137 measurments of soil redistribution. Influencing factors for tillage erosion after Loob et al (1991) are the erodibility of the slope, based on slope morphology, and physical properties of the soil at time of tillage (soil type, soil moisture, bulk density) as well as the erosivity of the tillage management in terms of placement and form of the device and the actual application (depth and speed as well as operator behavour). Rates of tillage erosion can be expected to be in the range 400–800 kg $m^{-1}yr^{-1}$ and 70–260 kg $m^{-1}yr^{-1}$ for mechanized and non-mechanized agriculture, according to Van Oost *et al.* (2006).

Soil loss by tillage erosion has been measured in the 20th Century (Mech & Free, 1942), but was largely abandoned in favour of measuring soil loss by water erosion. However sInce the 1990s, interest has increased and several investigations we were launched (Heckrat *et al.* 2005, Van Oost *et al.*, 2006). Further resources are needed now for researching, defining and specifying the devices which would be appropriate for installation at the 'benchmark' monitoring sites that are needed to measure erosion across Europe.

References

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Govers, G.; Vandaele , K.; Desmet, P. J. J.; Poesen, J.; Bunte, K. (1994): The role of tillage in soil redistribution on hillslopes. European Journal of Soil Science 45, 469-478.

Heckrath, G., J. Djurhuus, *et al.* (2005). Tillage Erosion and Its Effect on Soil Properties and Crop Yield in Denmark. JEQ, 34: 312-324.

Van Oost, K., G. Govers, *et al.* (2006). Tillage erosion: a review of controlling factors and implications for soil quality. Progress in Physical Geography 30: 443-466.

2.2 Decline in soil organic matter

The threat 'Decline in Soil Organic Matter' is defined as: a negative imbalance between the build-up of soil organic matter and rates of decomposition leading to an overall decline in soil organic matter contents and/or quality, causing a deterioration or loss of one or more soil functions (see ENVASSO Glossary of Key Terms Appendix).

Organic carbon is the primary constituent of soil organic matter and affects, directly and indirectly, many components of agro-ecosystems and their environmental functions. Soil organic matter contents and stocks can, and will, both increase and decrease under influence of environmental and land use and land management factors. However, the threat to soil is identified as 'decline in soil organic matter'. Topsoil organic carbon content is the simplest indicator that can be measured, and provides an indication of the evolution in organic matter. Topsoil organic carbon content is also relevant to soil erosion and decline in soil biodiversity.

The organic matter contained in the Earth's soils is a large reservoir of carbon, containing about 1500 Pg C (Post *et al.* 1982; Eswaran *et al.* 1993; Batjes 1996), that can act as a sink or source of atmospheric CO_2. About half of this carbon stock is contained in topsoil. Moreover, changes in organic carbon stocks have been shown to be faster in topsoil than in subsoil (Arrouays and Pelissier, 1994). Topsoil organic carbon stock determination requires measurements of organic carbon content in fine earth (particles < 2 mm), of coarse elements (stone content), and of soil bulk density. Numerous data are available on topsoil organic carbon content in parts of Europe. However, soil bulk density data are often lacking.

Peat is soil that is characterised by sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material. The rate of peat accumulation depends upon water regime and temperature. Estimates of the mass of carbon stored globally in peatlands of the world range from 120 to 400 Pg (Franzén, 2006), with 20% just in northern peatlands (Gorham, 1991). Because this large peat store is sensitive to changes in temperature and precipitation, peat soils are crucially important as a potential sink or source for atmospheric carbon dioxide (e.g. Davidson and Janssens, 2006).

All the TOP3 indicators for this threat are currently at inventory level, i.e. sufficient knowledge and understanding of sampling procedures and schemes (measurement uncertainties) needs to be developed before recommendations can be made regarding statistical significance of calculating changes in indicator values.

References

Arrouays, D. and Pelissier, P. (1994). Changes in carbon storage in temperate loamy humic soils after forest clearing and continuous corn cropping in France. Plant and Soil 160, 215-223.

Batjes, N.H. (1996). Total carbon and nitrogen in the soils of the world. European Journal of Soil Science 47, 151-164.

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Eswaran, H; Vandenberg, E; and Reich, P. (1993). Organic Carbon in Soils of the World. Soil Science Society Of America Journal 57 (1), 192-194.

Franzén L.G. (2006). Increased decomposition of surface peat in Swedish raised bogs: are temperate peatlands still net sinks of carbon? Mires and Peat 1 (3), 1-16, http://www.mires-and-peat.net.

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Post, W. M., Peng, T. H., Emanuel, W. R., King, A. W., Dale, V. H., and Deangelis, D. L. (1990). The Global Carbon-Cycle. American Scientist 78, 310-326.

Decline in soil organic matter

OM01	Topsoil organic carbon content

Definition: (indicator) the gravimetric proportion of carbon, as part of soil organic matter, in dry topsoil (%, w w^{-1}).
This indicator is used for mineral soils only.

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Land use	FAO 2006	M & A	NA
Soil group	WRB 2006	M & A	NA

If the soil monitoring site consists of peat soil, then go to OM03

Otherwise:
Step 1: Take topsoil samples at two depths (0 to 15-30 cm depth and 15-30 to ca. 50 cm depth)
 i) Appendix I
Step 2a: Perform sample pretreatment
 i) ISO 11464:2006
Step 2b: Subsample and archive sample material not used in step 3
 i) ISO 11464:2006
Step 3: Perform SOC content analysis by the dry combustion method
 i) ISO 10694:1995
If the site is part of an existing soil monitoring or soil inventory system and SOC has been measured by methods other than dry combustion, then
Step 4: Establish conversion factor
If samples from the existing soil inventory have been stored, then:
 i) Analyse a representative subset (soil group, land use, etc.) of existing soil samples by dry combustion (n>=30 and at least 10% of the initial dataset)
 ii) Establish conversion factor
If samples from the existing soil inventory have not been stored, then:
 i) Analyse a representative subset (soil group, land use, etc.) of the new samples by the SOC determination method used in the existing soil inventory (n>=30 and at least 10% of the initial dataset)
Step 5: Present indicator values
 i) In tabular and/or map format: if presenting SOC distribution in map form a standardized legend should be adopted that shows relative differences clearly, for example see S.P.I.04.72. (2004).
 ii) Differentiated for land use and soil group

Or alternatively,
If the soil is hydromorphic and/or has an estimated SOC content of > 8%, then use the loss on ignition method:
Step 1: Take topsoil samples
 i) ISO 10381-2:2002
Step 2: Perform sample pre-treatment
 i) ISO 11464:2006
Step 3: Perform the loss on ignition method (Annex I)
Step 4: Visualise indicator values
 i) In map format
 ii) Differentiated for land use and soil group

If the soil is not hydromorphic and/or has an estimated SOC content of < 8%, then use a wet oxidation method:
Step 1: Take topsoil samples

i) ISO 10381-2:2002

Step 2: Perform sample pre-treatment

i) ISO 11464:2006

Step 3: Perform SOC analysis by wet oxidation

i) Walkley Black method
ii) Modified Walkley Black method
iii) Tyurin method

Step 4: Make results compatible with preferred method

i) Use established conversion factors to adjust the SOC values.

Step 5: Visualise indicator values

i) In map format
ii) Differentiated for land use and soil group

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	**Description**
Land use database	In ARC Grid format
Soil group database	In ARC Grid format
Other	See relevant ISO methods

References

S.P.I.04.72. (2004). Topsoil Organic Carbon Content in Europe. Special Publication Ispra 2004 No.72, map in ISO B1 format. Hiederer, R., Jones, R.J.A., and Montanarella, L. European Communities.

Annex I Loss on ignition

Weight-loss-on-ignition (LOI) is a common, widely-used method of measuring the organic carbon content of soils with high organic matter. LOI is rapid, inexpensive and straightforward to perform. There is wide variation among the LOI methods used and comparisons of results from different laboratories can be misleading unless practices have been harmonised including via inter-laboratory comparison exercises. It is recommended to carefully record the parameters of ignition temperatures, ignition exposure times, and sample sizes in the LOI methodology.

Summary: This method quantifies the amount of organic matter that is lost when sample is ignited at 350-600°C in a controlled muffle furnace overnight. This method is used on samples such as soil, compost and manure samples with organic matter content greater than approximately 17%. The method has a detection limit of 0.1 % and is generally reproducible within 10%. (Nelson and Sommers, 1996).

Sample preparation and pre-treatment

- Removal of water
    - air drying
- Removal of visible plant and animal residues
- Sieving: air-dried soil ground to < 0.4 mm
- Removal of interfering substances (e.g. inorganic carbonates) can be achieved by pretreating the sample with a mixture of HCl an HF to remove hydrated mineral matter and carbonates prior to ignition. This pretreatment dissolves part of the organic matter so that a correction for this solubilised material is necessary.

Procedure

Heat beakers or crucibles in muffle furnace at 400 ^{o}C for 2h, cool and determine tare weight to 0.1 mg. Add 1 to 3 g of air-dried soil ground to <0.4 mm to a tared beaker and heat at 105^{o}C for 24 h. Cool the beaker in a desiccator over desiccation agent, e.g.$CaCl_2$, and determine weight of beaker plus sample to 0.1 mg. Obtain weight of oven-dried sample by subtraction. Ignite samples in a muffle furnace at 400^{o}C for 16h. Cool beakers in a desiccator over $CaCl_2$ and determine weight of beaker plus ignited sample to 0.1 mg. Calculate weight of ignited sample by subtraction. The LOI content of the sample is calculated as

$$LOI\% = [(Weight_{105} - Weight_{400}) / Weight_{105}] * 100$$

Where
$Weight_{105}$ is a weight of soil sample after heating at 105 ^{o}C
$Weight_{400}$ is a weight of soil sample after ignition at 400 ^{o}C

The organic matter contents assume to equal the LOI in most surface soils (Nelson and Sommers, 1996).

References

Nelson, D.W. and L.E. Sommers. (1996). Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., A.L. Page *et al.*, Ed. Agronomy. 9:961-1010. Am. Soc. of Agron., Inc. Madison, WI.

Decline in soil organic matter

OM02	Topsoil organic carbon stock

Definition: (indicator) the mass of carbon, as part of soil organic matter, in dry topsoil (t ha^{-1})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Depth of topsoil	m	A	Appendix I
Topsoil OC content	%	A	Appendix I
Topsoil bulk density	t m^{-3}	A (or M)	Appendix I
Topsoil stone content	t m^{-3}	A (or M)	Appendix I
Carbonate content of soil (ISO 10693)	g kg^{-1}	A	Appendix I

If the soil monitoring site consists of organic soil, then go to OM03

Otherwise:
Step 1: Take bulk density samples
- i) ISO 11272:1998

Step 2: Determine bulk density value
- i) ISO 11272:1998

Step 3: Determine volumetric stone content
- i) Perform a volume determination on the > 2 mm stones in the bulk density sample

Step 4: Retrieve value for OM01 for this site
Step 5: Determine topsoil OC stock
- i) Perform equation 1

Step 6: Express indicator value
- i) SOC_{stock} of 0-30 cm soil depth (t ha^{-1})
- ii) SOC_{stock} of topsoil (t ha^{-1})
- iii) if presenting SOC_{stock} distribution in map form, a standardized legend should be adopted that shows relative differences clearly, for example see S.P.I.04.72. (2004)

$$SOC_{stock} = D_b * SOC_{content} * 0.1 * D * SV \qquad \text{Equation 1}$$

Where:
- Db (bulk density) in t m^{-3}
- $SOC_{content}$ in g kg^{-1}
- SOC_{stock} in t ha^{-1}
- D (depth of topsoil) in m
- SV (stone volume) in ratio (0-1.0)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Physico-chemical sampling equipment	Appendix I
Bulk density sampling equipment	ISO 11272:1998

References

S.P.I.04.72. (2004). Topsoil Organic Carbon Content in Europe. Special Publication Ispra 2004 No.72, map in ISO B1 format. Hiederer, R., Jones, R.J.A., and Montanarella, L. European Communities.

Decline in soil organic matter

OM03	Peat stock

Definition: (indicator) the mass of peat estimated for a specified area (Mt)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled, NA=Not Applicable

Required	Units	Type	Spatial Resolution
Depth of peat	m	A	NA
Area of peat	m^{-2}	A	>= 2 km
Bulk density of peat	$t\ m^{-3}$	A	NA
Bulk density of peat	$t\ m^{-3}$	M	NA

Step 1: Determine area of peat
- i) Acquire a peat area map with at least a spatial resolution of 2 km

Step 2: Determine depth of peat (m)

Step 3: Determine the bulk density
- i) Use an empirical pedo-transfer function to estimate the bulk density.

Step 4: Determine peat stock
- i) Perform equation 1

$$P_S = P_A * P_D * 10^{-4} * D_b \qquad \text{Equation 1}$$

Where
- P_{Stock} is Peat Stock in Mt;
- P_{area} is Peat Area in km^2;
- P_{depth} is Peat Depth in m;
- D_b is bulk density in $t\ m^{-3}$ ($Mg\ m^{-3}$)

Step 5: visualise results, differentiated for land use

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Field equipment	NA
Land use data	FAO, 2006
Peat area database	CORINE or soil maps
Bulk density data	ISO 11272:1998

Conclusion

The performance of this Indicator showed major difficulties in one or more pilot areas and it is clear that monitoring could not start within a year.

2.3 Soil contamination

The threat 'soil contamination' is defined as: The accumulation of a pollutant in soil above a certain level, causing a deterioration or loss of one or more soil functions (see ENVASSO Glossary of Key Terms).

Diffuse soil contamination by heavy metals is a well recognised phenomenon in Europe (e.g. Peris *et al.*, 2008). The reasons for heavy metal contamination in upper soil horizons can be, e.g. anthropogenic influence due to industry, traffic, use of fertilizers and sewage sludge or natural pedo-geochemical enrichment due to weathering processes, so that the origin of the contamination cannot be derived directly from this indicator. Heavy metal contents of soil identifies where contents of heavy metals exceed national thresholds in Europe.

Soil acidification is known to be a widespread problem, especially in many countries in northern Europe. Critical load exceedance by sulphur and nitrogen targets the question of whether environmental protection measures are effective against acidification and the extent of progress being made towards national and international targets for reducing the exposure of soils to acidification.

Local soil contamination is a characteristic of regions where intensive industrial activities, inadequate waste disposal, mining, military activities or accidents have contaminated soil. If the natural capacity of soil to buffer, filter and transform pollutants is exceeded, a variety of negative environmental impacts may arise, the more serious of which are water pollution, uptake of toxic contaminants by humans, damage to ecological systems and increased explosion hazard from gases generated by landfill waste disposal. Progress in the management of contaminated sites is an indicator that shows the progress in dealing with contaminated land (local soil contamination) according to completion of defined management steps in the EU Member States. The indicator is also a defined EEA core set indicator.

Management of contaminated sites should follow a tiered process starting with a preliminary survey (searching for sites that are likely to be contaminated), followed by site investigations to determine the actual extent of contamination and its environmental impacts are defined, and finally implementation of remedial risk management and after care measures.

References

Peris, M.; Recatala, L.; Mico, C., Sanchez, R, and Sanchez, J. (2008). Increasing the knowledge of heavy metal contents and sources in agricultural soils of the European Mediterranean region. Water Air and Soil Pollution 192 (1-4): 25-37.

Soil contamination

CO01	Heavy metal contents of soil

Definition: (indicator) the measured, gravimetric proportion of a heavy metal in dry soil at a monitoring site at a specific point in time (mg kg^{-1})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required parameters	Units	Type	Spatial Resolution
See ISOs: 10381-2:2002; 11464:1994; 11465:1993; 11466: 1995; 11047:1998; 16772: 2004			

Step 1. Collect samples
- i) ISO 10381-2:2002 Soil quality - Sampling - Part 2: Guidance on sampling techniques

Step 2. Prepare samples
- i) ISO 11464:1994 Soil quality - Pretreatment of samples for physico-chemical analyses

Step 3. Determine moisture content
- i) ISO 11465:1993 Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method

Step 4. Extract samples
- i) Aqua Regia extraction: ISO 11466: 1995 Soil quality - Extraction of trace elements soluble in aqua regia

Step 5. Test samples
- i) Pb and Cd in soil: ISO 11047:1998 Soil quality - Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc - Flame and electrothermal atomic absorption spectrometric methods
- ii) Hg in soil: ISO 16772: 2004 Soil quality - Determination of mercury in aqua regia soil extracts with cold-vapour atomic spectrometry or cold-vapour atomic fluorescence spectrometry

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Sampling equipment	See Appendix I
Sample pre-treatment equipment	See ISO 11464:2006
Moisture content	See relevant ISO
Extraction	See relevant ISO
Chemical analysis	See relevant ISO

Soil contamination

CO07	Critical loads exceedance by sulphur and nitrogen

Definition: (indicator) the quantity of atmospheric deposition of sulphur and nitrogen to soil above the critical load for a specified period of time (kg ha^{-1} yr^{-1})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required parameters	Code	Units
Maximum critical load of sulphur	CLmaxS	ha^{-1} yr^{-1}
Minimum critical load of nitrogen	CLminN	ha^{-1} yr^{-1}
Maximum critical load of nitrogen	CLmaxN	ha^{-1} yr^{-1}
The quantity –ANCle(crit)	nANCcrit	ha^{-1} yr^{-1}
Chemical criterion used	crittype	na
Critical value for the chemical criterion	critvalue	na
Equilibrium constant for the Al-H relationship (log10)	lgKAlox	na
Exponent for the Al-H relationship	expel	na
Partial CO2-pressure in soil solution as multiple of the atmospheric CO2 pressure	pCO2fac	na
Total concentration of organic acids (m*DOC)	cOrgacids	m^{-3}
Amount of water percolating through the root zone	Qle	mm yr^{-1}
Total deposition of calcium	Cadep	ha^{-1} yr^{-1}
Total deposition of magnesium	Mgdep	ha^{-1} yr^{-1}
Total deposition of potassium	Kdep	ha^{-1} yr^{-1}
Total deposition of sodium	Nadep	ha^{-1} yr^{-1}
Total deposition of chloride	Cldep	ha^{-1} yr^{-1}
Net growth uptake of base cations	Bcupt	ha^{-1} yr^{-1}
Weathering of base cations	Bcwe	ha^{-1} yr^{-1}
Thickness of the soil	thick	m
Acceptable amount of nitrogen immobilised in the soil	Nimacc	ha^{-1} yr^{-1}
Net growth uptake of nitrogen	Nupt	ha^{-1} yr^{-1}
Denitrification fraction (0<=fde<1) (-)	fde	na
EUNIScode of ecosystem	EUNIScode	na
Area of the ecosystem within the EMEP grid cell	EcoArea	km^2
Sulphur depositions	Sdep	na
Nitrogen depositions	Ndep	na

A detailed description of the procedure of calculating critical loads and their exceedances is given in the 'Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads & Levels and Air Pollution Effects, Risks and Trends' (ICP M&M, 2004) available at www.icpmapping.org.

National Focal Centres (NFCs) of the International Cooperative Programme on Modelling and Mapping (ICP M&M) of the UNECE Convention on Long-range Transboundary Air Pollution (UNECE/CLRTAP) are requested to submit data in accordance with this manual to ensure comparability.

Methods for the calculation of Critical Loads, their exceedances as well as the calculation or estimation of auxiliary variables are discussed in detail. The CCE offers free software (VSD) and additional information to calculate Critical Loads based on the above named input parameters, available at www.rivm.nl/cce. Furthermore periodical Status Reports about the situation in the UNECE area as well as Critical Loads- and Exceedance-maps are provided at this site.

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Literature	- ICP Modelling and Mapping (2004): Manual on Methodologies and Criteria for Mapping Critical Levels/Loads and geographical areas where they are exceeded. UBA-Texte 52/04. www.icpmapping.org - CCE Status Reports. www.mnp.nl/cce - EMEP – European Monitoring and Evaluation Program (2007): The EMEP Grid. Detailed description. www.emep.int/grid/index.html
Data	- Critical loads- and exceedance-maps: national datasets, CCE (www.mnp.nl/cce) - Sulphur- and Nitrogen depositions: national datasets, European datasets provided by the CCE (in colaboration with IIASA and EMEP/MSC-W) - Base cation depositions: national datasets, EMEP/MSC-W (Van Loon, M.; Tarrason, L. & Posch, M. (2005): Modelling Base Cations in Europe. Norwegian Meteorological Institute, EMEP/MSC-W & CCE Note 2/2005. www.emep.int/basecations) - Soil data: national soil inventories or soil maps - Precipitation, mean temperature, geological information: national datasets - Biomass uptake information: national maps or inventories
Software	- VSD: free available at www.mnp.nl/cce (contact Max Posch) - SMART (contact Wim de Vries at ALTERRA) - SAFE (contact Harald Sverdrup at Lund University, Institute of Technology/Chemical Engineering) - MAGIC (contact RF Wright at the Norwegian Institute for Water Research)

Soil contamination

CO08	Progress in the management of contaminated sites

Definition: (indicator) the proportion of contaminated sites where a specified tier has been completed in a specified period of time (%)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey)

Required parameters	Description
Tier 1 (actual)	Number of sites identified for the management step 'Site Identification / Preliminary Study' (=Tier 1) for a defined region
Tier 1 (total)	Total number of sites estimated for the management step 'Site Identification / Preliminary Study' (=Tier 1) for a defined region
Tier 2 (actual)	Number of sites identified for the management step 'Preliminary Investigation' (=Tier 2) for a defined region
Tier 2 (total)	Total number of sites estimated for the management step 'Preliminary Investigation' (=Tier 2) for a defined region
Tier 3 (actual)	Number of sites identified for the management step 'Main Site Investigation' (=Tier 3) for a defined region
Tier 3 (total)	Total number of sites estimated for the management step 'Main Site Investigation' (=Tier 3) for a defined region
Tier 4 (actual)	Number of sites identified for the management step 'Implementation of Remediation Measures' (=Tier 4) for a defined region
Tier 4 (total)	Total number of sites estimated for the management step 'Implementation of Remediation Measures' (=Tier 4) for a defined region
Tier 5 (actual)	Number of sites identified for the management step 'Measures completed' (=Tier 5) for a defined region
Tier 5 (total)	Total number of sites estimated for the management step 'Measures completed' (=Tier 5) for a defined region

Step 1[*]

$$\text{Progress Tier 1} = \frac{\text{Tier 1 (actual)}}{\text{Tier 1 (total)}}$$

Interpretation: Completion of site identification in a defined region

Step 2.

$$\text{Progress Tier 2} = \frac{\text{Tier 2 (actual)}}{\text{Tier 2 (total)}}$$

Interpretation: Completion of preliminary investigations in a defined region

Step 3.

$$\text{Progress Tier 3} = \frac{\text{Tier 3 (actual)}}{\text{Tier 3 (total)}}$$

Interpretation: Completion of main site investigations in a defined region

Step 4.

$$\text{Progress Tier 4} = \frac{\text{Tier 4 (actual)}}{\text{Tier 4 (total)}}$$

Interpretation: Completion of implementing remediation measures in a defined region

Step 5.

$$\text{Progress Tier 5} = \frac{\text{Tier 5 (actual)}}{\text{Tier 5 (total)}}$$

Interpretation: Completion of remediation measures in a defined region

Step 6. Visualise results (see Annex I)

[*] In the first tier the original number of sites needs to include as many contaminated sites, or sites believed to be contaminated, in order that the precautionary principle can be applied.

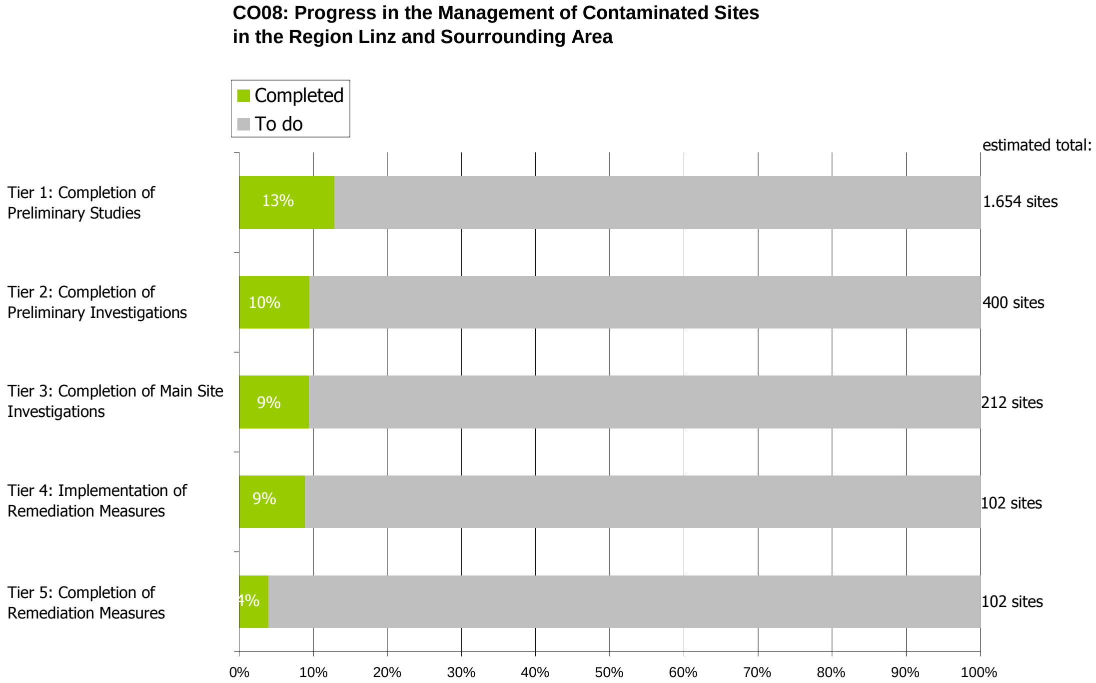
Reference

CSI 015 Specification - Progress in management of **contaminated ...** Management of **contaminated sites** aims at assessing the adverse effects caused **...** The indicator tracks progress in the management of **contaminated sites** and **...** themes.eea.europa.eu
themes.eea.europa.eu/IMS/ISpecs/ISpecification20041007131746/guide_summary_plus_public

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Literature	The indicator corresponds to the EEA corset indicator CSI015, further information can be found on the EEA website: http://themes.eea.europa.eu/IMS/ISpecs/ISpecification20041007131746/IAssessment1152619898983/view_content [last accessed 12/12/2008]
Data	Data at the country level are available at the EEA data service: http://glossary.eea.europa.eu/terminology/sitesearch?term=contaminated+sites [last accessed 12/12/2008] http://themes.eea.europa.eu/IMS/ISpecs/ISpecification20041007131746/guide_summary_plus_public [last accessed 12/12/2008] Annual updates have been made since 2001

Annex I Visualisation of results



2.4 Soil sealing

The threat 'soil sealing' is defined as: The destruction or covering of soil by buildings, other constructed object and layers, or other bodies of artificial material which may be very slowly permeable to water (e.g. asphalt, concrete, etc.), causing a deterioration or loss of one or more soil functions (see ENVASSO Glossary of Key Terms).

Sealed area is the most direct and a largely self-explanatory indicator for the process of soil sealing. Whilst the absolute size of the sealed surface area provides information on the state of soil sealing, its growth rate indicates the change or trend of sealing. In particular when compared to the extent and growth rate of corresponding land consumption, the proportion of sealed area provides an indication of the intensity of land use and soil consumption in built-up areas. Sealed area is relatively easy to calculate, interpret, comprehend and report. As databases based on national cadastral maps (land use registers) generally exist in most Member States, additional costs for data gathering should be limited

Sealed area requires careful interpretation because urban areas that in broad terms are 'sealed' often contain 'green' vegetated land – gardens, wooded land, parks, community greens spaces and sports fields – which is not sealed with impermeable materials such as concrete, tarmac and buildings.

Land take by the expansion of urban and other artificial land developments is the main cause of the increasing soil loss as a result of human activities. The indicator quantifies how much, in what proportions and at what growth rate soil is lost to agricultural, forest, semi-natural and natural land to urban and other artificial land covers. Cross-country comparison of assessment results shows to what extent individual Member States contribute to land take in Europe. It also provides information on the drivers for land take, via analysis of land cover changes.

'New settlement area established on previously developed land' is an indicator that measures the area and proportionate extent of new construction (housing, commercial and industrial sites, infrastructure, etc.) established on previously developed land (brownfields) in relation to the total area of newly developed land. The indicator quantifies changes in the rate of brownfield re-development, and the extent to which this is reducing demand for undeveloped agricultural and other 'green field' land and soil..

Soil sealing

SE01	Sealed area

Definition: (indicator) the degree to which soil in a specified area or region is destroyed or covered by buildings, constructions and layers or other bodies of artificial material in a specified period of time (ha, %, ha yr^{-1}, ha d^{-1})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution	
			Observation	Assessment
National cadastral map (land use registers)	Land use sub-classes	A	Field (sub) parcel	NUTS-5 to NUTS-1
Remote sensed data (GMES 2008)	Land use classes	A	1 ha (from 2008)	

If a national cadastral database exists, then use the cadastral method. If a national cadastral database does not exist, then use the remote sensing method.

Cadastral method[†]

Step 1: Determine sealed areas
i) Access statistical data on land use in the national cadastral database[1].
ii) Identify those categories and sub-categories of land use that represent the land that is actually sealed (buildings, car parks, roads, and other sealed land).
iii) Calculate the total sealed area

If your national cadastral map does not provide exact or reliable information on the proportion of sealed area in certain categories of built-up land (e.g. transport infrastructure), then:
i) Use mean values based on literature and/or aerial photograph interpretation and/or field surveys to estimate the sealing degree of those land use categories.
ii) Use this best available mean estimate of the sealing percentage to calculate the sealed area of the respective land use (sub)categories by approximation.

Step 2: Express inventory indicator value
i) Total sealed area in number of hectares (ha)
ii) Proportion of reference area :
  a) Divide sealed area (ha) by reference area (ha), e.g. municipality area, NUTS-5, LAU-2
  b) Multiply result value of ‘a’ by 100 and express as %
iii) Sealed areas as a proportion of consumed land
  a) Calculate the cumulative area (ha) of land consumed by housing, industry, transport and other physical infrastructure, incl. utilities and military installations, by aggregating the area values of the respective cadastral land use categories
  b) Divide sealed area (ha) by consumed land area (ha)
  c) Multiply result value of ‘b’ by 100 and express as %
iv) Proportion of sealed land in the area potentially suitable for permanent human living space
  a) Define the ‘area suitable for permanent human habitation’ (see Annex I)

[†] Cadastral data can only be used for determining sealed areas when it discriminates land use (sub)categories that adequately represent the land that is actually sealed (e.g. it must discriminate buildings from unsealed portions of a field parcel). If this is not the case, you must use other suitable geodata sources (e.g. remote sensing as described for the GMES method)

b) Calculate the cumulative surface area (ha) of all land that is not suitable for permanent human habitation by aggregating the areas of all respective land use categories according to your national definition, or according to the guidelines in Annex I
c) Calculate the area (ha) that is potentially suitable for permanent human habitation by subtracting the area not suitable for permanent settlement (ha) from the total area (ha) of the assessment unit
d) Divide the sealed area (ha) by the 'area that is potentially suitable for permanent human habitation' (ha)
e) Multiply result value of 'd' by 100 and express as %

Step 3: Express monitoring indicator value
i) Absolute increase
a) Use the methodology described under step 1 to calculate indicator values (ha) for two points in time not longer than 5 years and not closer than 3 years apart
b) Calculate the absolute change in the area of sealed land (ha) by subtracting the indicator value at t_1 from indicator value at t_{1+n} (n = number of years)
c) Express as %

ii) Proportional increase
a) Calculate the absolute change in the area of sealed land (ha) according to the procedure described under step 3 (i)
b) Divide absolute change in area of sealed land (ha) by initial value at t_1 (ha) and multiply by 100 and express as %

iii) Growth rate
a) Calculate the absolute change in the area of sealed land (ha) according to the procedure described under step 3 (i)
b) Divide the absolute change in area of sealed land (ha) by the number of years (n)
c) Express as ha yr^{-1}
d) Divide the absolute change in area of sealed land (ha) by the number of days (365 n)
e) Express as ha d^{-1}

Remote sensing method[‡]

Step 1: Determine sealed area (Global Monitoring for Environment and Security – GMES - www.gmes.info)
i) Access GMES database
ii) Retrieve assessment results of new sealing product for desired assessment unit (reference area)
iii) Determine the sealing percentages of built-up land (sealing degrees) as indicated by the new sealing layer

Step 2: Express inventory indicator value
i) Calculate the area (ha) of sealed land for your assessment unit (reference area) by converting the sealing percentage per area unit (grid cell) into absolute area values and aggregating them
ii) Express indicator value in number of hectares (ha)
iii) Calculate other expressions of indicator value as described under the cadastral map-based method, step 2, items ii) – iv)

Step 3: Express monitoring indicator value
i) Use the methodology described under step 2 to calculate indicator values for two points in time that are 5 years apart (expected monitoring interval of future GMES database)
ii) Use the same procedure as described under the cadastral map-based method to calculate the absolute change in the area of sealed land in numbers of hectares (ha)
iii) Calculate other expressions of indicator value using the procedures as described under cadastral map-based method, step 2, items ii) – iii)

[‡] The GMES Land Monitoring fast track service is expected to be available from 2009-10. High resolution maps can be used directly for this method.

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)
GIS software	Geographical Information System
Cadastral data	Discriminating buildings from unsealed portions of a field parcel
Remotely-sensed imagery	GMES 2008

2

Annex I Soil sealing terms

The ‘area suitable for permanent human living space’ may also be referred to as the ‘potential permanent settlement area’. In general, this is the area that can potentially be used as building land for housing, industry, transport and other physical infrastructure. However, since no common European definition exists, national definitions that do exist should be applied. If there is no national definition, ideally the ‘potential permanent settlement area’ should be defined as the entire area of the assessment unit (e.g. national territory) minus at least the following categories of land use/land cover: water surface area, alpine area, protected areas, protected forests, risk zones exposed to floods and other natural hazards, other areas that are not available for development purposes because of other legal constraints (e.g. water protection zones, areas that exceed critical thresholds of noise emissions, etc.).

Soil sealing

SE04	Land take

Definition: (indicator) the area of land that enters the land use of infrastructure (from another land use) and other facilities that accompany it, such as service stations on roads and railway stations, during one year (ha yr^{-1}, % yr^{-1})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled; MOU=minimum observation unit, MMU=minimum mapping unit

Required	Units	Type	Spatial Resolution
Corine Land Cover Change database (CLC1990 – CLC2000); 5 year time steps (from 2008)	Land cover classes	A	MOU=5 ha, MMU=25 ha; MOU=1 ha (from 2008), MMU=5 ha (from 2008)

Step 1: Determine built-up areas

i) Access Corine Land Cover (CLC) change database via the website of the European Environment Agency (EEA; http://www.eea.europa.eu). Assessment results for 'land take' (CLC1990 - CLC2000) are available under indicator 'CSI014 Land take' of the EEA Core Set of Indicators (CSI)

ii) Retrieve published assessment results for the area of interest e.g. Member State or for EU 23/27[1]

Step 2: Express indicator value[2]

i) Mean annual land take in number of hectares (ha yr^{-1})

ii) Mean annual land take as percentage of urban and artificial land of reference year[3] (% yr^{-1})

iii) Land take of individual Member States as percentage of the total area of those countries (% yr^{-1})

iv) Land take of individual countries as percentage of total European land take (% yr^{-1})

v) Land take as percentage of the total initial area of all land cover classes taken by urban and artificial land (sum of Corine Land Covers: CLC2 – CLC5)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)

[1] Area of changes in land cover classes in ha or %: from agricultural, forest, natural and semi-natural land (CLC2, CLC3, CLC4, CLC5) to urban and artificial land (CLC1)

[2] Indicator values can be expressed for Member States or for the EU23/27

[3] The 'reference year' is defined as the baseline year of one CLC assessment period (e.g. 1990 for the available assessment period 1990-2000)

Soil sealing

SE05	New settlement area established on previously developed land

Definition: (indicator) the proportion of settlement areas that have been built on previously developed land (i.e. brownfields) in a specified time period (%)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Information on area of redeveloped brownfield sites[1]	Area (ha) of redeveloped brownfield land as % of entire newly developed land	A	Parcel size

Step 1: Determine area of redeveloped brownfield land[2]

i) Acquire data on the area of brownfield land that has been redeveloped during the last monitoring period (1 year)[3]

Step 2: Determine area of newly developed land

i) Access national cadastral map-based statistical database on land use.

ii) Identify those categories and sub-categories of land use applied by your national cadastral system that represent the land developed for (consumed by) housing, industry, transport and other physical infrastructure, incl. utilities and military installations

iii) Calculate the cumulative area (ha) of the entire land that has been developed for settlement purposes (according to the definition given under footnote (2) for the current year (t_2) and the previous year (t_1) by aggregating the area values of the respective cadastral land use categories.

iv) Calculate the area (ha) that has been newly developed during that one year period by subtracting the value at t_1 from the value at t_2 (absolute change in ha).

Step 3: Calculate and express indicator value (%)

i) Perform equation 1:

$$\left| \frac{\textit{Area of new settlements built on previously developed land (ha)}}{\textit{New settlement area (ha)}} \right| * 100 = \textit{New settlement area on previously developed land (\%)}$$

Equation 1

---

[1] Provided by a brownfield reporting and registration system, a brownfield cadastre, or similar information tools

[2] 'Brownfields' are defined as previously developed land that has been used for settlement, transport, industrial or commercial purposes, but is not in current active use. This includes sites that have been used for mining, quarries, waste dumpsites, military installations, and similar uses. 'Settlement area' is defined as land that is developed for housing, industry, trade, transport, and other physical infrastructure, including utilities (e.g. waste disposal, water distribution, electricity supply) and military installations

[3] Regular monitoring requires the existence of a reporting and registration system that records the area and previous development status (undeveloped greenfield land or previously developed brownfield land) of sites where development activities occur, or of a brownfield cadastral database. If such information tools do not exist, the required information must be investigated directly at local spatial planning or building authorities. If neither approach is feasible at the present time, the indicator cannot be monitored yet

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)
Land use data	cadastral map-based statistical database on land use

.

2.5 Soil compaction

The threat 'soil compaction' is defined as: the densification and distortion of soil by which total and air-filled porosity are reduced, causing a deterioration or loss of one or more soil functions (see ENVASSO Glossary of Key Terms).

Soil compaction may reduce soil functions by: decreasing soil permeability; increasing soil strength; partly destroying soil structure; altering soil fabric and affecting soil behaviour characteristics. Anthropological soil compaction can be initiated by e.g. wheels, tracks or rollers, the passage of cultivation machinery, and the passage of draft or grazing animals.

Dense, compact soils restrict rooting and hinder or obstruct the movement of air, water and nutrients in the rooting zone. Changes in compaction can be detected by repeated measurements that show bulk density to be increasing or decreasing. Soil compaction can result from natural causes (e.g. compression by glacier ice from the Last Glaciation), as well as from anthropogenic activities, such as the passage of agricultural or forestry machinery, construction traffic and grazing animals). A simple measurement or estimate of soil bulk- or packing density is proposed as a proxy for bearing strength. Soil density is inversely proportional to porosity, thus as density increases porosity decreases.

A small proportion of air-filled pores (<10%) obstructs the supply of air and movement of water in the rooting zone. Compaction can be detected by repeated measurements that show air capacity to be decreasing. A simple measurement or estimate of air capacity (air-filled pore volume) at a specified suction (e.g. generally 5, sometimes 3 or 6 kPa), is proposed as a measure of the degree of densification. Air capacity is the volume of pores > 0.06 mm ESD (equivalent spherical diameter). It is generally inversely proportional to soil bulk density, thus as density increases the volume of air-filled pores decreases. Air capacity should not be confused with total porosity which is the volume of all pores which are not occupied by solid (mineral or organic) material.

A highly susceptibility soil is one that has properties that make it likely to compact, given the appropriate compactive forces and the moisture contents above field capacity (5 kPa). An indicator is proposed, based on a simple classification system for subsoil vulnerability to compaction.This system is based for field use on local soil and wetness data at the time of critical trafficking, and, for Europe as a whole, on related soil and climatic information. A two-stage methodology is proposed: i) assessing the inherent susceptibility on the basis of the relatively stable soil properties of texture and packing density, and ii) combining this soil susceptibility with an index of climatic dryness/subsoil wetness, or actual subsoil moisture status, to determine the vulnerability class.

References

Hall, D.G.M., Reeve, M.J., Thomasson, A.J., Wright, V.F. (1977). Water retention, porosity and density of field soils. Soil Survey Technical Monograph No. 9, Harpenden, UK, 75pp.

Smith, P.D. and Thomasson A.J. (1982). Density and water release characteristics. In: Soil survey laboratory methods. B.W. Avery and CL Bascomb (ed.). Soil Survey Technical Monograph No.6, Harpenden, p42-56.

Soil compaction

CP01	Density (bulk density; packing density; total pore volume)

Definition: (indicator) the mass of dry soil per unit bulk volume, using the clay content (t m^{-3}).

Bulk density can be measured directly in the field as described by Hodgson (1997, p.112-113) or in the laboratory on undisturbed cores (Hall *et al.*, 1977; Smith and Thomasson, 1982).

However, in the absence of bulk density measurements, packing density can be estimated in the field from soil structure – ped size and shape, and degree of ped development – see Hodgson (1997, p.37-49).

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required parameters	Units	Type	Spatial Resolution
texture	%	A	Appendix I
	Classes (field test)		
Bulk density	t m^{-3}	A	ISO 11272:1998
Soil or ped strength	classes	M	Appendix I
Degree of ped development	classes	M	Appendix I
Size and shape of peds	classes	M	Appendix I
Soil moisture (water) content	% v v^{-1}.	A	Appendix I
Soil moisture potential	kPa	A	Appendix I

Step 1: Take bulk density samples
  i) ISO 11272:1998
Step 2: Determine bulk density value
  i) ISO 11272:1998
Step 3: Perform particle size distribution analysis on bulk density samples
  i) ISO 11277:1998
Step 4: Calculate packing density
  i) Calculate the packing density by using equation 1

$$PD = Db + 0.009\ C \qquad \text{Equation 1}$$

(Benecke, 1966; Renger, 1970; Hodgson, 1997,p.46)

where C = clay content (% w w^{-1})
Db = bulk density, t m^{-3} (g cm^{-3})
PD = packing density, t m^{-3} (g cm^{-3}).

Or alternatively,
Step 1: Perform field soil structure analysis
  i) Test soil or ped strength (Annex I)
  ii) Test degree of ped development (Annex I)
  iii) Test size and shape of peds (Annex I)
Step 2: Determine packing density class
  i) Assign a packing density class by inserting the soil structure data (step 1) in the conversion table (Annex II).

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Excavation and sampling tools	ISO 11272:1998
Laboratory analysis equipment	ISO 11272:1998

References

Benecke, P. (1966). Die Geländeansprache des Bodengefüges in Verbindung mit Entnahme von Stechzylinderproben für Durchlässigkeitsmessungen. Zeitschrift für Kulturtechnik und Flurbereinigung 7, 91-104.

Hodgson, J.M. (Ed.), (1997). Soil Survey Field Handbook. Soil Survey Technical Monograph No. 5, Harpenden, UK, 116pp.

Renger, M., 1970. Uber den Einflus der Dränung auf das Gefüge und die Wasserdurchlässigkeit bindiger Böden. Mitteilungen Deutschen Bodenkundlich Gesellschaft 11, 23-28.

Annex I Soil Structure

Structure: shape, size and degree of development of peds; Soil strength

Soil structure refers to the natural arrangement of soil particles into discrete soil units (aggregates or peds) that result from pedogenetic processes. The aggregates are separated from each other by pores or voids. The description of soil structure in the field is precisely described in the Guidelines for Soil Description (FAO, 2006, p.44-48), which are similar to those in use in the UK (Hodgson, 1997, p.37-46).

Having determined the shape, size and degree of development of peds, and the strength of the soil, the charts in Annex II (Figures AII.1-3) can be used to estimate packing density from these soil parameters.

References

Hodgson, J.M. (Ed.), (1997). Soil Survey Field Handbook. Soil Survey Technical Monograph No. 5, Harpenden, UK, 116pp.

FAO (2006). Guidelines for Soil Description, Fourth edition. Food and Agriculture of the United Nations, Rome, 97pp.

Annex II packing density conversion tables

[Source: Hodgson, 1997, p.47-9]

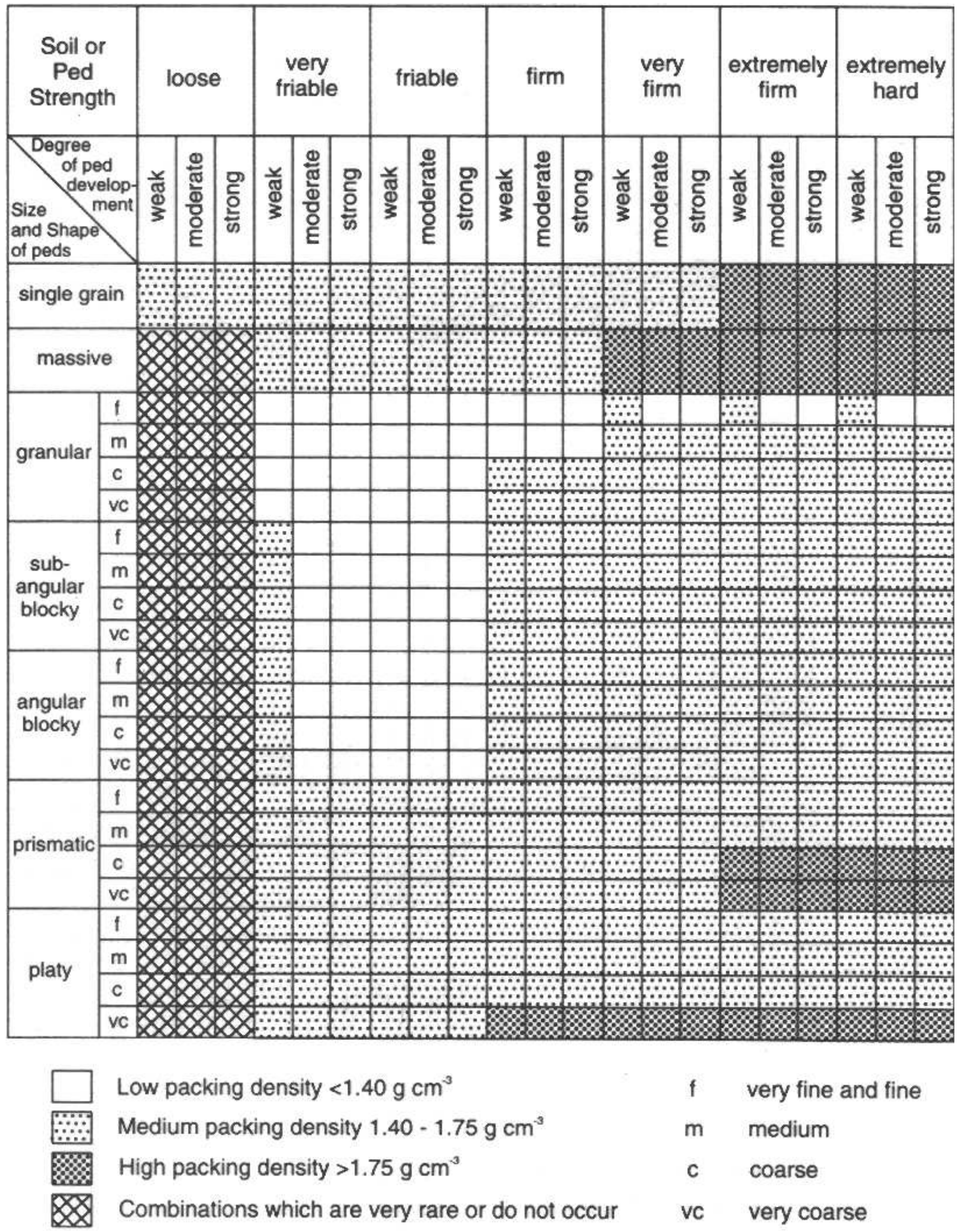


Figure AII.1 Assessment of packing density from soil structure and strength of subsoil horizons with sand or loamy sand texture. [After Hodgson, 1997, p.47]

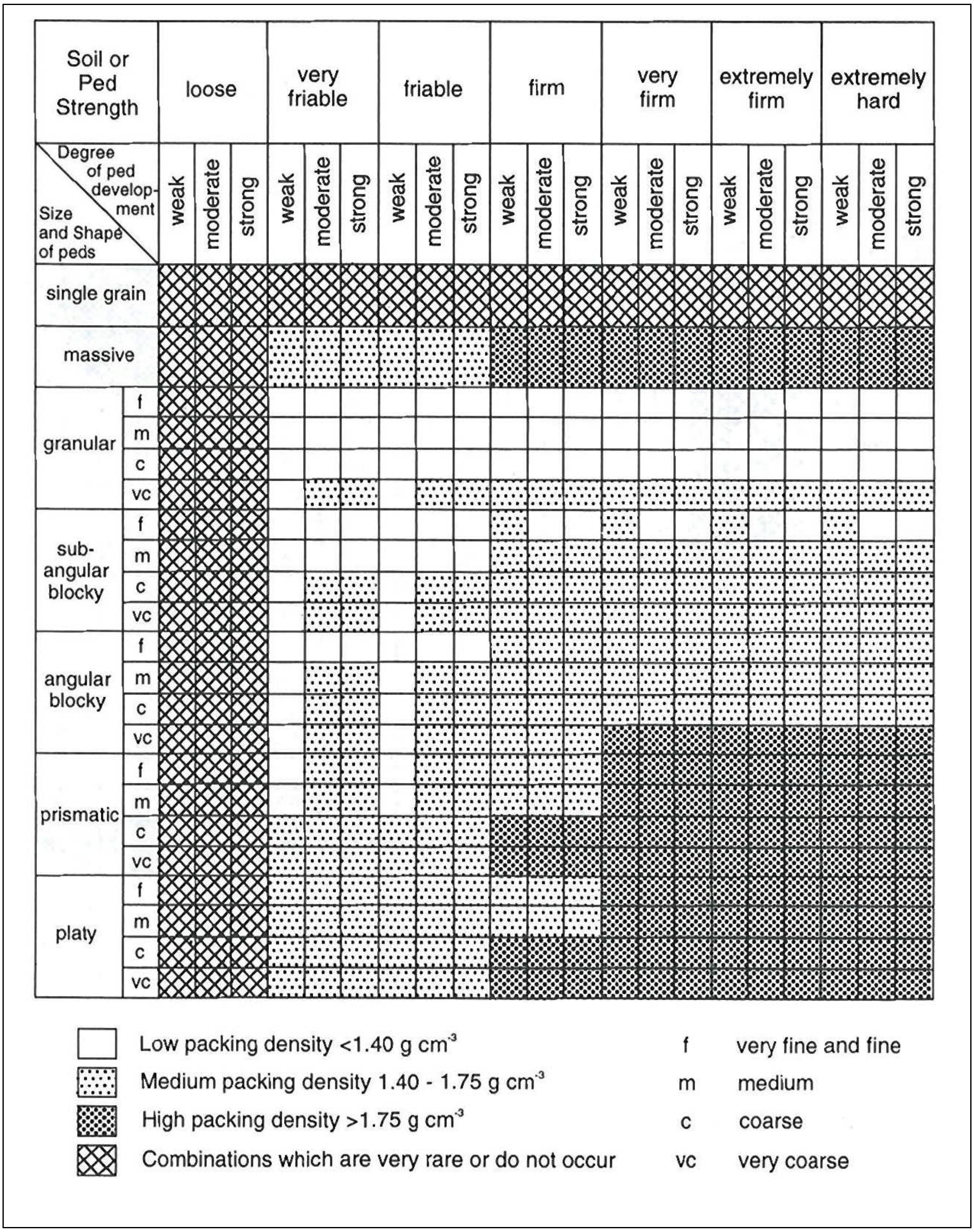


Figure AII.2 Assessment of packing density from soil structure and strength of subsoil, horizons having sandy loam, sandy silt loam or silt loam texture.
[After Hodgson, 1997, p.48]

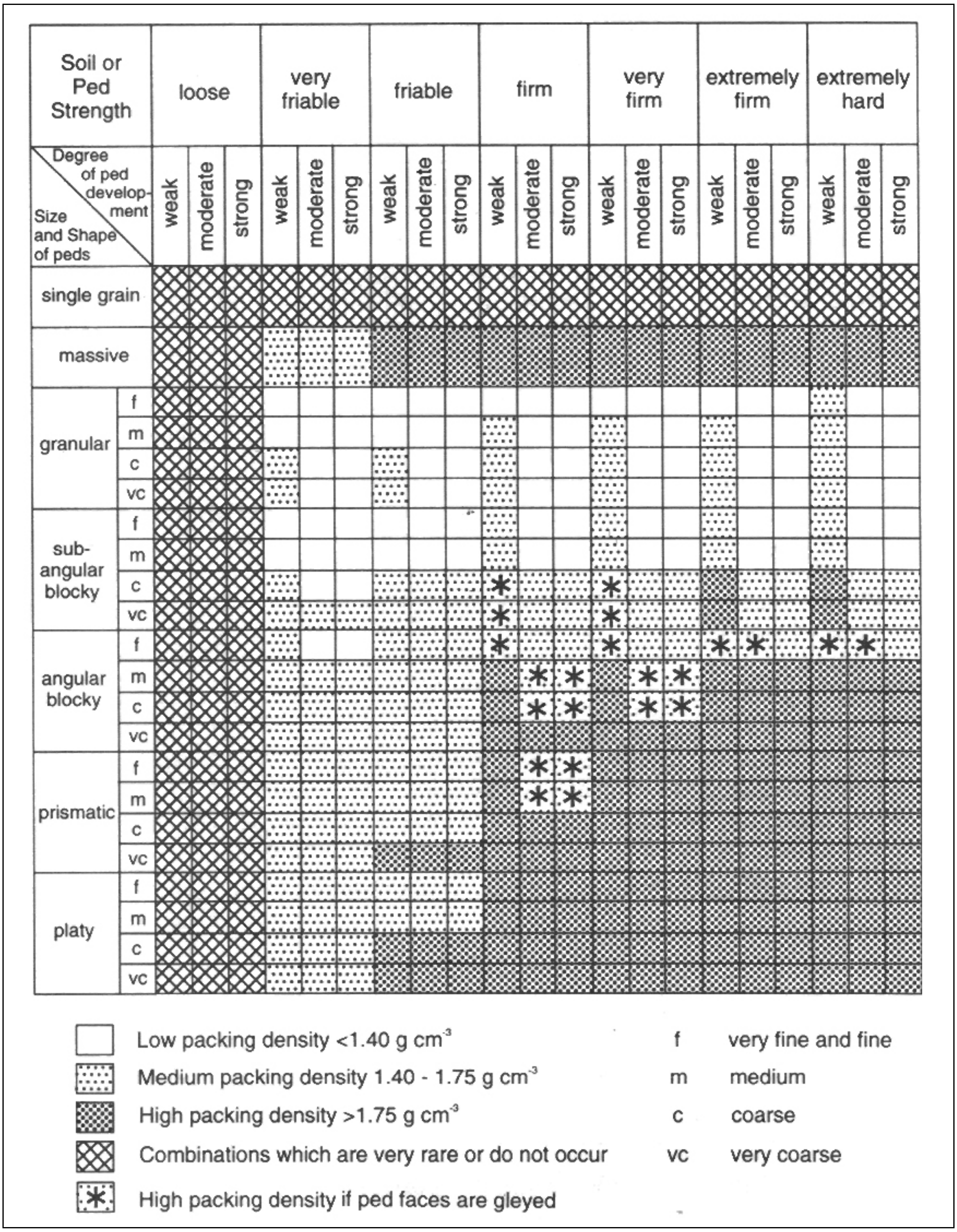


Figure AII.3 Assessment of packing density from soil structure and strength of subsoil horizons with sandy clay loam, clay loam, silty clay loam, sandy clay, clay or silty clay loam texture. [After Hodgson, 1997, p.49]

Soil compaction

CP02	Air capacity (air-filled pore volume at specified suction)

Definition: (indicator) the proportion of the total pore space which can be occupied by gases (usually air) but maybe occupied by liquids (water) when the soil is saturated (%, w w^{-1})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Retained water content at 5kPa (θ_v (5))	% v v^{-1}	A	Appendix I
Bulk density	t m^{-3}	A	ISO 11272:1998
Particle density	t m^{-3}		Appendix I
Particle-size distribution (PSD) (Sand, silt, clay)	%	A	Appendix I
Broad PSD	classes	M	Appendix I

Step 1: Take bulk density samples
- i) ISO 11272:1998

Step 2: Determine bulk density value
- i) ISO 11272:1998

Step 3: Take particle density samples
- i) ISO 11272:1998

Step 4: Determine particle density value
- i) ISO 11272:1998

Step 5: Calculate Total Pore Space (v v^{-1})
- i) Equation (2)

Step 6: Determine soil water content at 5kPa suction
- i) ISO 11274:1998

Step 7: Calculate Air Capacity from equation (1)

Step 8: Visualise indicator value
- i) Use Table AI.2 for threshold values

Or alternatively,
If soil water retention properties are not measured, then:

Step 1: Determine particle size distribution for bulk density samples
- i) ISO 11277:1998

Step 2: Estimate θ_v (5)
- i) Identify broad particle-size class (FAO) from Figure 1
- ii) Determine moisture contents at pF 1.7 (5kPa) from Table 1 (after Wösten *et al.*, 1998, p.59)

Step 3: Calculate Air Capacity from equation (1)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Excavation and sampling tools	ISO 11272:1998
Laboratory analysis equipment	Appendix I & relevant ISOs

Annex I Equations

Air filled pore volume at specified suction or *air capacity* is an important measure of the degree of soil compaction, but estimation of the air-filled pore volume requires sampling undisturbed cores (e.g. 222 cm^3) of soil to be equilibrated on a sand-suction bath as described by Smith and Thomasson (1982) and Hall *et al.* (1977, p.6-18).

Air capacity (C_a) is calculated from equation 1:

$$C_a = T - \theta_v (5) \qquad \text{Equation 1}$$

where T = total pore space (% w w^{-1})
θ_v (5) = Volumetric water content at 5kPa (v v^{-1})

Total pore space (T) is detemined from equation 2

$$T = (1 - D_b/D_p).100 \qquad \text{Equation 2}$$

where D_b = bulk density
D_p = particle density

Thus by measuring bulk density from undisturbed soil cores, and then equilibrating these cores on a sand-suction bath at 5kPa suction to measure the volumetric water content (at 5kPa), the air capacity can be determined using a known value for D_p, usually in range 2.55 – 2.65 t m^{-3} for mineral soils.

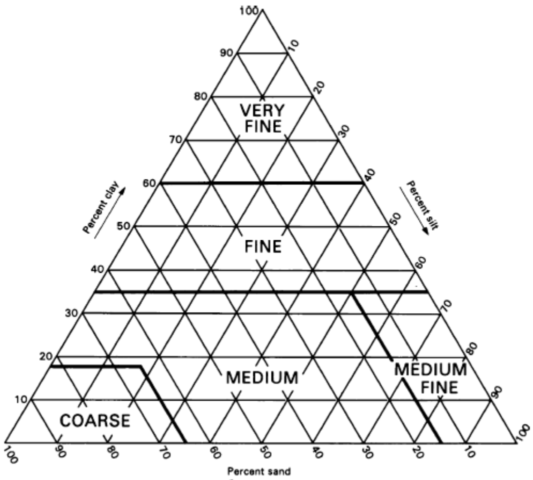


Figure AI.1 Broad particle-size classes of FAO (1974)

Table AI.1 Moisture content at different suctions (after Wösten *et al.* (1998)

TOPSOILS	texture class	h (cm)	0	10	20	50	100	200	250	500	1000	2000	5000	10000	15000	16000
		pF	0	1	1.3	1.7	2	2.3	2.4	2.7	3	3.3	3.7	4	4.17	4.2
	coarse	K	60.00	6.68	2.37	0.31	4.7E-2	5.8E-3	2.8E-3	3.2E-4	3.5E-5	3.8E-6	1.9E-7	2.1E-8	5.9E-9	4.7E-9
		θ	0.403	0.379	0.352	0.294	0.243	0.197	0.184	0.148	0.12	0.098	0.077	0.065	0.06	0.059
	medium	K	12.10	0.61	0.29	0.08	2.5E-2	7.4E-3	4.8E-3	1.3E-3	3.5E-4	9.2E-5	1.6E-5	4.1E-6	1.9E-6	1.7E-6
		θ	0.439	0.425	0.41	0.379	0.347	0.313	0.302	0.27	0.24	0.213	0.182	0.162	0.152	0.15
	medium-fine	K	24.80	0.38	0.16	0.04	1.3E-2	3.5E-3	2.3E-3	5.9E-4	1.5E-4	3.8E-5	6.1E-6	1.5E-6	7.0E-7	6.1E-7
		θ	0.52	0.507	0.495	0.472	0.448	0.423	0.414	0.388	0.364	0.34	0.311	0.291	0.28	0.278
	fine	K	2.27	0.51	0.33	0.14	5.7E-2	1.8E-2	1.1E-2	2.7E-3	5.9E-4	1.2E-4	1.4E-5	2.8E-6	1.1E-6	9.3E-7
		θ	0.43	0.426	0.421	0.406	0.383	0.349	0.336	0.293	0.252	0.215	0.173	0.147	0.134	0.132
	very fine	K	15.00	0.30	0.13	0.03	8.0E-3	1.8E-3	1.1E-3	2.1E-4	3.9E-5	7.3E-6	7.6E-7	1.4E-7	5.3E-8	4.5E-8
		θ	0.614	0.602	0.592	0.567	0.541	0.511	0.501	0.47	0.439	0.41	0.374	0.349	0.336	0.334
SUBSOILS	texture class	h (cm)	0	10	20	50	100	200	250	500	1000	2000	5000	10000	15000	16000
		pF	0	1	1.3	1.7	2	2.3	2.4	2.7	3	3.3	3.7	4	4.17	4.2
	coarse	K	70.00	10.50	3.24	0.30	3.1E-2	2.7E-3	1.2E-3	9.6E-5	7.6E-6	6.0E-7	2.0E-8	1.6E-9	3.7E-10	2.9E-10
		θ	0.366	0.338	0.304	0.233	0.179	0.135	0.123	0.094	0.073	0.059	0.046	0.039	0.037	0.036
	medium	K	10.80	0.58	0.28	0.07	2.2E-2	5.6E-3	3.5E-3	8.0E-4	1.8E-4	3.9E-5	5.2E-6	1.1E-6	4.7E-7	4.1E-7
		θ	0.392	0.382	0.372	0.349	0.324	0.296	0.286	0.258	0.231	0.207	0.179	0.16	0.151	0.149
	medium-fine	K	8.47	0.13	0.09	0.03	1.1E-2	3.6E-3	2.4E-3	7.1E-4	2.1E-4	5.8E-5	1.1E-5	3.0E-6	1.4E-6	1.3E-6
		θ	0.481	0.475	0.47	0.456	0.441	0.422	0.415	0.394	0.373	0.353	0.327	0.309	0.299	0.297
	fine	K	4.00	0.72	0.45	0.19	7.1E-2	2.1E-2	1.3E-2	2.8E-3	5.5E-4	1.0E-4	9.9E-6	1.7E-6	6.4E-7	5.3E-7
		θ	0.412	0.409	0.405	0.392	0.373	0.344	0.333	0.297	0.261	0.227	0.189	0.164	0.151	0.149
	very fine	K	8.16	0.14	0.07	0.02	7.6E-3	2.2E-3	1.4E-3	3.5E-4	8.5E-5	2.0E-5	2.8E-6	6.4E-7	2.8E-7	2.4E-7
		θ	0.538	0.533	0.529	0.517	0.503	0.486	0.479	0.459	0.438	0.418	0.392	0.373	0.363	0.361
	organic*	K	8.00	0.97	0.55	0.18	5.9E-2	1.5E-2	9.2E-3	1.9E-3	3.7E-4	6.8E-5	6.9E-6	1.3E-6	4.7E-7	4.0E-7
		θ	0.766	0.756	0.743	0.708	0.663	0.604	0.5[illegible]	0.517	0.455	0.398	0.332	0.29	0.269	0.265

Table AI.2 Determined minimum and preferred air-filled pore volumes to avoid (severe) anaerobic conditions for plant root growth

Soil structure	Air-filled pore volume (ng) should be:	
	At least	Preferably
Excellent	> 2 %	> 14%
Good	> 5 %	> 15%
Moderate	> 8 %	> 17%
Poor or structureless	> 12 %	> 21%

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Soil compaction

CP06	Vulnerability to compaction (estimated)

Definition: (indicator) the likelihood of a specific soil to be subjected to the process of soil compaction during a year (classes)

A two-stage methodology is described (Jones *et al.*, 2003). In stage A, the inherent susceptibility is assessed. In stage B, the inherent susceptibility is combined with an index of climatic dryness/subsoil wetness, or actual moisture status, to determine the vulnerability class. An alternative approach, based on measuring pre-compression stress, is offered by Horn *et al.* (2005). This may offer improved estimates of subsoil compaction risk in future when more pre-compression measurements have been made.

Stage A Assess inherent susceptibility

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Subsoil texture	FAO classes	A	Same as for topsoil, see Appendix I
	Field test		
Bulk density	t m^{-3}	A	ISO 11272:1998
Pedological data	various	M	Various

Step 1: Determine texture codes
- i) Perform particle size distribution analysis on subsoil samples (ISO 11277:1998)
  - Alternatively, use field soil texture test by surveyor.
- ii) Assign a texture code to each sample by using the conversion system in Table 3 and Figure 1

Step 2: Determine packing density class
- i) Perform actual bulk density measurement on subsoil samples (ISO 11272:1998)
- ii) Calculate the packing density (PD) by using equation 1 (use the gravimetric clay content from step 1)
- iii) Assign a packing density class to each sample by using the conversion system in Table 4.
  - Alternatively, use PTR to estimate subsoil density from pedological inputs (Van Ranst *et al.*, 1995).

Step 3: Determine inherent susceptibility classes
- i) Assign an inherent susceptibility class to each sample by using the conversion system in Table 5.

Stage B Determine susceptibility class

Step 1: assess the excess of evapotranspiration over rainfall during the growing season.
- i) Obtain precipitation data for each site
- ii) Obtain the calculated potential evapotranspiration for each site
- iii) Calculate the maximum potential soil moisture deficit (PSMD) for each site using equation 2

Step 2: determine the vulnerability class
- i) Assign a vulnerability class for each site by using the inherent susceptibility class (stage A) and the PSMD in the conversion system in Table 5.

Table 2 Texture and particle size grades used by the FAO soil classification system

Code	Class	Particle size grades
1	Coarse	Less than 18% Clay and more than 65% sand
2	Medium	Less than 35% clay and more than 15% sand; more than 18% clay if the sand content exceeds 65%
3	Medium Fine	Less than 35% clay and less than 15% sand
4	Fine	between 35% and 60% clay
5	Very Fine	More than 60% clay
9	Organic	
0	No texture	

Table 3 Packing density (PD)classes

PD class	PD (t m^{-3})
Low	<1.40
Medium	1.40–1.75
High	>1.75

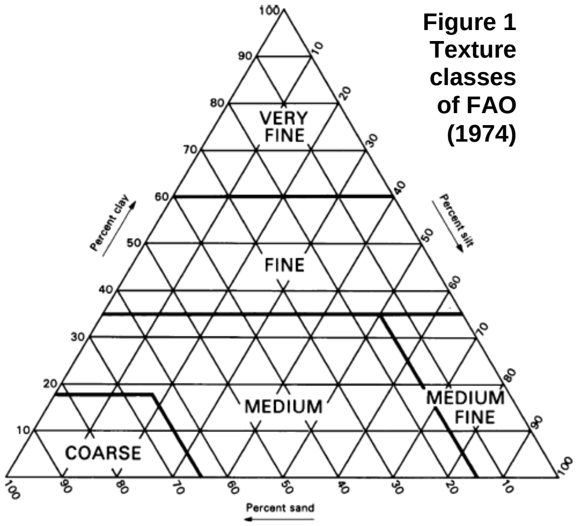

Figure 1 Texture classes of FAO (1974)

Packing density is calculated from bulk density and clay content:

$$PD = Db + 0.009C$$ Equation 1

(Benecke, 1966; Renger, 1970; Hodgson, 1997, p.46)

where C = clay content (% w w^{-1})
Db = bulk density, t m^{-3} (g cm^{-3})
PD = packing density, t m^{-3} (g cm^{-3}).

A subsoil packing density PTR is defined by Van Ranst *et al.* (1995) for use in the absence of bulk density and clay content, although the uncertainty attached to the resulting packing density data is much greater than using directly measure data.

Potential evapotranspiration (PET) is calculated by the Penman (1948) equation, incorporating refinements of Penman (1962), Monteith (1965) and Tom & Oliver (1977)

$$PSMD = \Sigma (R - PET)$$ Equation 2

when PET exceeds R),
where PSMD is the maximum potential soil moisture deficit,
R the rainfall (mm)
PET the potential evapotranspiration (mm).

Table 4 Inherent susceptibility to compaction according to texture and packing density

		Packing density t m^{-3}		
		Low	**Medium**	**High**
Texture		< 1.40	1.40 – 1.75	> 1.75
Code	**Texture Class**			
1	Coarse	VH	H	M[1]
2	Medium	H	M	M
3	Medium fine	M(H)	M	L[3]
4	Fine	M[2]	L[4]	L[3]
5	Very fine	M[2]	L[4]	L[3]
9	Organic	VH	H	

Susceptibility classes: L low; M moderate, H high, VH very high

[1] except for naturally compacted or cemented coarse (sandy) materials that have very low (L) susceptibility.

[2] these packing densities are usually found only in recent alluvial soils with bulk densities of 0.8 to 1.0 t m^{-3} or in topsoils with >5% organic carbon.

[3] these soils are already compact.

[4] Fluvisols in these categories have moderate susceptibility

Table 5 Vulnerability to compaction according to soil susceptibility and climate

Class	**Climate Zone**	**Perhumid**	**Humid A**	**Humid B**	**Sub-humid**	**Dry**
	Subsoil Moisture state	**Usually wet, always moist**	**Often wet, usually moist, rarely dry**	**Usually moist, seasonally dry**	**Seasonally moist and dry**	**Mostly dry**
Soil Susceptibility	**PSMD mm**	**≤ 50**	**51 – 125**	**126 – 200**	**201 – 300**	**> 300**
	FC Days	**> 250**	**150 – 250**	**100 – 149**	**< 100**	**≤ 40**
VH		E[1] (E)[2]	E (E)	V (E)	V (V)	M
H		V (E)	V (E)	M (V)	M (M)	N
M		V (E)	M (V)	N (M)	N (N)	N
L		M (V)	N (M)	N (N)	N (N)	N

Classes of vulnerability to compaction:
N not particularly vulnerable; M moderately vulnerable; V very vulnerable, E extremely vulnerable

Moisture states are defined in Hodgson (1997) as: Wet <1 kPa, moist 1-1500 kPa, dry >1500kPa

[1] Classes outside brackets refer to situations with firm topsoil conditions.

[2] Classes within brackets refer to situations with loose/weak topsoil conditions.

PSMD potential soil moisture deficit (Jones and Thomasson, 1985).

FC Days Duration of field capacity, measured in days (Jones 1985, Jones and Thomasson, 1985).

Table 6 Parameters (preferred parameters are in black, alternative parameters are in grey)

Required	**Units**	**Actual/ modelled**	**Spatial Resolution**
Precipitation data	mm	M	
Potential Evapotranspiration	mm	M	
Soil texture data		A	

References

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2.6 Decline in soil biodiversity

The threat 'decline is soil biodiversity' is defined as: a reduction of forms of life living in soils (both in terms of quantity and variety) and of related functions, causing a deterioration or loss of one or more soil functions (see ENVASSO Glossary of Key Terms).

Species diversity of earthworms (*Oligochaeta,* class *Clitellata*, phylum *Annelida*), also known as megadriles (or 'big' worms), together with other biodiversity indicators and complementary information (e.g. land use, soil type, climate), will provide information on the decline of biodiversity. Species diversity of enchytraeids (microdriles, or 'small' worms), is to be measured if megadriles are not available in the soil.

Species diversity of collembola (springtails), together with other biodiversity indicators and complementary information (e.g. land use, soil type, climate), will provide complementary information on the decline of biodiversity.

By measuring the soil microbial respiration, an integrated measure of microbial biomass and activity and soil organic matter quantity and quality is obtained. Hence, this indicator will give a measure of the soil biological functioning. This soil functioning is based on the diversity and activity of all individual players in the soil.

Decline in soil biodiversity

BI01	**Earthworms diversity**

Definition: (indicator) the abundance, biomass and species richness of (epigeic, endogeic, anecic) earthworms at a monitoring site at a specific point in time (No. m^{-3}, kg m^{-3}, No. m^{-3})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=model

Required	**Units**	**Type**	**Spatial resolution**
Soil description			
Soil depth	m (below surface)	A	2 replicates within $100m^2$
Heavy metal content	mg kg^{-1}	A	
Nutrient content	cmol kg^{-1}	A	
pH	pH units	A	
Ground water level	m (below surface)	A	
Soil moisture	% vol.	A	
Texture	% clay, silt, sand	A	
Bulk density	t m^{-3}	A/M	
Organic carbon & total carbon	% w w^{-1}	A	
Site description			
Climatic conditions (monthly average)	mm, °C	M	Local station
Land management	FAO 2006	A	Field
Land uses	FAO 2006	A	
Vegetation type and cover	FAO 2006	A	
Soil group	WRB 2006	A	

Step 1: Site description and soil characterisation

i) ISO 23611-1: 2006; section1.1 Scope

ii) Land management, land use and vegetation type should follow FAO 2006 classification (ftp://ftp.fao.org/agl/agll/docs/guidel_soil_descr.pdf).

iii) Soil type should follow WRB 2006 (ftp://ftp.fao.org/agl/agll/docs/wsrr103e.pdf), or a referred international soil classification as FAO 2006. Moreover, in order to prevent mistakes in soil type attribution, soil description has to be definite (FAO 2006). Especially, soil depth should be clearly identified (WRB). Depth is critical and, therefore, it is essential to do this measurement (auger depth to 1 m or soil profile pit). However, soil profile horizon(s) depth would be preferable.

Step 2: Installation of the sampling area (surface definition, localization, replicates)

i) Sampling area has to be about 100 m².

ii) If there is an existing monitoring network which assess the site and soil characteristics ('conventional' monitoring area), in order to use the collected data (e.g. climatic, land use, physicochemical analysis) the earthworm sampling area should be located:

- Inside the 'conventional' monitoring area, if possible
- Or, nearby the 'conventional' monitoring area (5 m from the conventional area at the most)
- Location of the future sampling campaigns: N, E, W, S around the 'conventional' monitoring area, 5 m then 10 m.

iii) If there is no monitoring network, complementary analyses have to be performed on a composite sample from the investigated area to explain biodiversity data (required parameters)

iv) Localization of the sampling area in a homogeneous[4] area (based on pedological characteristics and soil cover).

v) Record the location of the sampling area position with a differential GPS device.

vi) Sampling strategy: minimum of 3 replicates, with equal distance between subplot/replicates.

Step 3: Soil sampling area preparation

i) Cut the vegetation or take off the soil cover as mulch without damaging the soil surface

ii) In case of forest: take the litter and put it in a plastic sample bag in order to assess the fauna in the laboratory.

Step 4: Soil analysis

i) pH: ISO 10390 (Soil quality- determination of pH)

ii) Soil moisture content: ISO 11465:1993

iii) Organic carbon, total carbon: ISO 10694, *Soil quality — Determination of organic carbon and total carbon after dry combustion (elementary analysis)*

iv) Heavy metal analysis:

- ISO 14869-1:2001 *Soil quality -- Dissolution for the determination of total element content -- Part 1: Dissolution with hydrofluoric and perchloric acids*
- ISO 11466:1995 *Soil quality -- Extraction of trace elements soluble in aqua regia*

v) Texture*:* ISO 11277, *Soil quality — Determination of particle size distribution in mineral method*

Step 5: Perform earthworm sampling according to

i) ISO standard ISO 23611-1: 2006 with some advances (annex I)

Step 6: Perform earthworm diversity analysis

i) Species determination. ISO standard ISO 23611-1: 2006; section annex B.

ii) Determination of earthworm biomass.

- ISO 23611-1:2006; section 6.3 Determination

iii) Data assessment.

- ISO standard ISO 23611-1: 2006; (section 7. Data assessment) with some advances (annex II)

Step 7: Visualise results (Annex III)

i) Express data depending on: i) soil characteristics, soil type (WRB or FAO), total soil depth (WRB), or topsoil texture; and ii) land use (FAO 2006), using box and whisker plots to show the degree of variability.

ii) Present spatial distribution of soil biodiversity with a map

[4] Homogeneous area should be determined according to:

- pedological characteristics based on vegetation distribution (often linked to pH, soil moisture) or assessed by a drill survey (e.g. depth)
- soil cover (e.g. vegetation, OM applied)

If no earthworms are found in natural conditions (e.g. acidic forest soils, acidic wetland soils), then:

Step 5: Perform Enchytraeid diversity analysis

i) ISO standard 23611-3. with a minimum of 3 replicates. The end parameters will be:
- Mandatory: Total abundance and Species richness
- Optional: Species abundance and Ecological groups

Step 6: Visualise results (see Annex III)

i) Express data depending on soil characteristics: i) soil type (WRB or FAO), total soil depth (WRB), or topsoil texture; and ii) land use (FAO 2006) using box and whisker plots to show degree of variability

ii) Present spatial distribution of soil biodiversity with a map (Annex III)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	**Description**
Field material	See relevant ISOs and annexes
Laboratory material	See relevant ISOs and annexes
Reference material	WRB 2006, FAO 2006

Annex I Earthworm sampling

[Source: ISO 23611-1: 2006 advances]

AI.1 General

In temperate regions, favourable sampling times are spring or autumn (soil moisture should be at field capacity), times of the year where the animals are not forced by the environmental conditions (i.e. low soil moisture and/or high temperatures) into lethargy (i.e. are not reacting to formalin).

AI.2 Earthworm sampling

Two methods are possible:

i) Hand-sorting followed by formalin extraction. Minimum sampled area according to ISO 23611-1:2006 (0.5m x 0.5m) but with a minimum of 10 replicates

ii) Formalin extraction followed by hand-sorting. For the formalin extraction, increase sampling area to 1m² to take into account heterogeneity[5]. Then, hand sorting can be done on a volume of 0.25 by 0.25 by 0.20 m. Make 3 replicates at least (for formalin and for hand-sorting)

a. Reagents

a1. Formalin [formaldehyde solution 4% (volume fraction)].

a2. Formalin [formaldehyde solution 37% (volume fraction)].

[Note: Allyl isocyanate may be used instead of Formalin}

b. Apparatus

Use standard laboratory equipment and the following.

b.1 Ruler (1m) or 1 m² grid

b.2 Marking plastic stakes (4)

b.3 Water-can, preferably 30 l, with water (30 l per sampling plot)

b.4 Test-tubes (50 ml)

b.5 Wash bottle

b.6 Funnel

b.7 Plastic gloves

b.8 Mask

b.9 Watering cans (3)

b.10 Irrigation line

b.11 Pillboxes (125 ml to 500 ml) half-filled with formaldehyde solution 4% to store the worms

b.12 Forceps

b.13 Spade

b.14 Plastic vat (40 cm by 60 cm)

b.15 Pencil, notebook, water resistant marker

c. Procedure

c1. Formalin sampling

A sufficient amount of water shall be transported (30l per sampling plot) beforehand to the plots using large water-cans (b.3). Three formalin applications will be realised: i) for the first application, formalin solution is prepared in a watering-can (b.9) by diluting 25 ml of 37 % formalin (a.2) in 10l water using a test tube (b.4). Diluting 25 ml of 37 % formalin in 10 l water produces a solution of 0.25 %. The diluted formalin solution is carefully and evenly applied on the 1m² [1m² can be identified using a grid or a ruler (b.1) and 4 marking plastic stakes put on each corner (b.2)]. During 15 minutes, the plot is observed in order to collect all earthworms appearing on the soil surface of the sampling plot. After 15 minutes, this step is repeated applying the same formalin concentration (0.25%), earthworms are collected during 15 minutes. The last application is realised using a higher formalin concentration (0.4%): this formalin solution is prepared in an identified watering-can, in order to identify this different concentration, by diluting 40ml of 37 % formalin in 10l water using a test tube. The sampling is finished 45 minutes after the application of the last watering can. Earthworms should be

[5] This is already covered by the ISO Standard *"However, at places with a low density of earthworms [e.g. soils with low pH (< 4,5) or which are anthropogenically used like crop sites], larger plots (i.e. 1 m²) are recommended"*.

collected by forceps (b.12). The collected earthworms should immediately be fixed in pillboxes (b.11) half-filled with 4% formalin solution (a.1).

c2. Hand-sorting sampling

Choice a sub-square (25 cm by 25 cm) inside the m², by a random approach, and identify it with 4 marking plastic stakes (b.2). Remove a single soil block (25 by 25 by 20 cm) by means of spade (b.13), and put the excavated soil in a plastic vat (b.14). Then, cautiously search the soil for earthworms.

The collected earthworms should immediately be fixed in pillboxes (b.11) half-filled with 4% formalin solution (a.1).

Annex II Data assessment

[source: ISO 23611-1: 2006 advances]

AII.1 Data assessment

AII.1.1 The end parameter will be:

i) Mandatory:
   a. total abundance (number of individuals per area or volume)
   b. total biomass (fresh or dry mass of the earthworms per area or volume)
   c. Species richness (number of species)

ii) Optional:
   a. Abundance/biomass of ecological groups[6] (epigeic, endogeic, anecic)[7]
   b. Abundance/biomass of species
   c. Age structure of the population (e.g. the adult/juvenile ration)
   d. Morphological alteration in individuals.

AII.1.2 Assessment of earthworm number (abundance/biomass).

Three methods are possible:

i) According to ISO 23611-1: 2006; [section 7 data assessment]: firstly, the number of worms is counted and expressed as individuals per sample (separately for hand-sorting and formalin samples). Secondly, both values are added in order to determine the total abundance of earthworms. This number is then multiplied by a factor in order to achieve the number of worms per square meter [the factor is 4 in the case 0.25m² is used (usually 50 cm by 50 cm samples)].

ii) When using a larger area (1m² for formalin extraction, and 0. 25 by 0.25 m² for hand-sorting extraction), firstly the number of worms is counted and expressed as individuals per sample (separately for hand-sorting and formalin samples). Secondly, the number for hand-sorting samples is multiplied by a factor in order to achieve the number of worms per square meter [the factor is 16 (in the case) when 1/16 m² is used (usually 25 cm by 25 cm samples)]. Both values are added in order to determine the total abundance of earthworms.

iii) Two images of the results are presented separately: one resulting from the hand-sorting extraction, the other one resulting from the formalin extraction. In both case, the earthworm number for samples (hand-sorting or formalin) is multiplied by a factor in order to achieve the number of worms per square meter [the factor is 16 in the case 1/16 m² is used (usually 0.25 cm by 0.25 cm samples), or is 4 in the case 0.25 m² is used (usually 50 cm by 50 cm samples)].

---

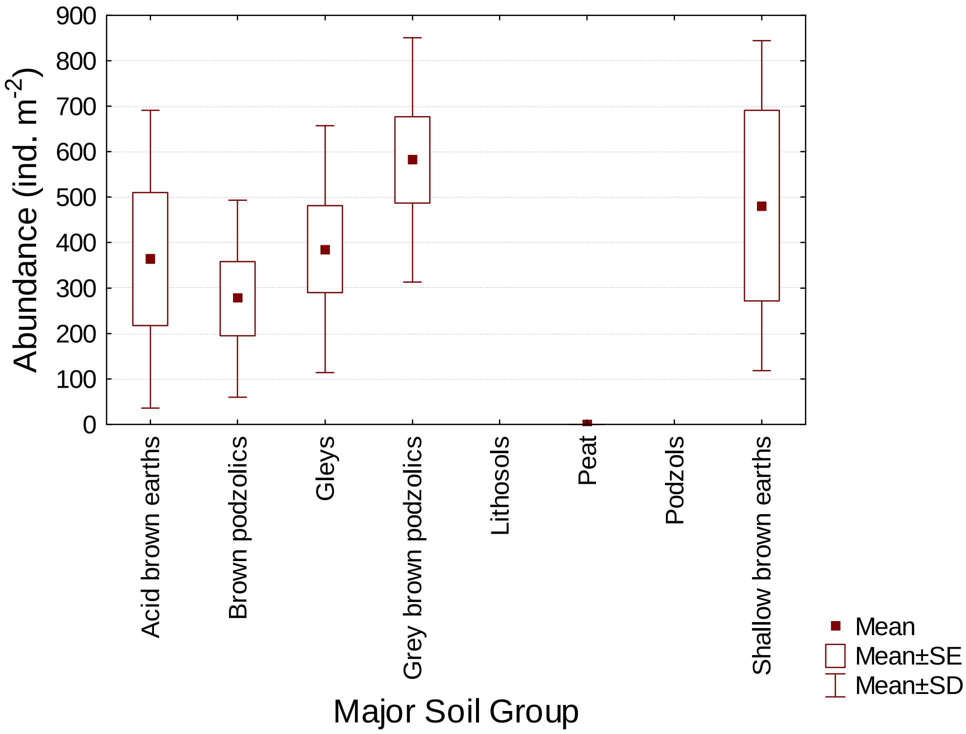
[6] The classification in ecological groups is based on earthworm morphology, physiology and ecology (localisation in soil profile, feeding behaviour, predator pressure, mobility on soil surface, resistance to dryness). Applied to *lumbricidae* the three main life history strategies are termed epigeic, anecic, and endogeic (Bouché1977; Lavelle, 1981; Lee, 1985).

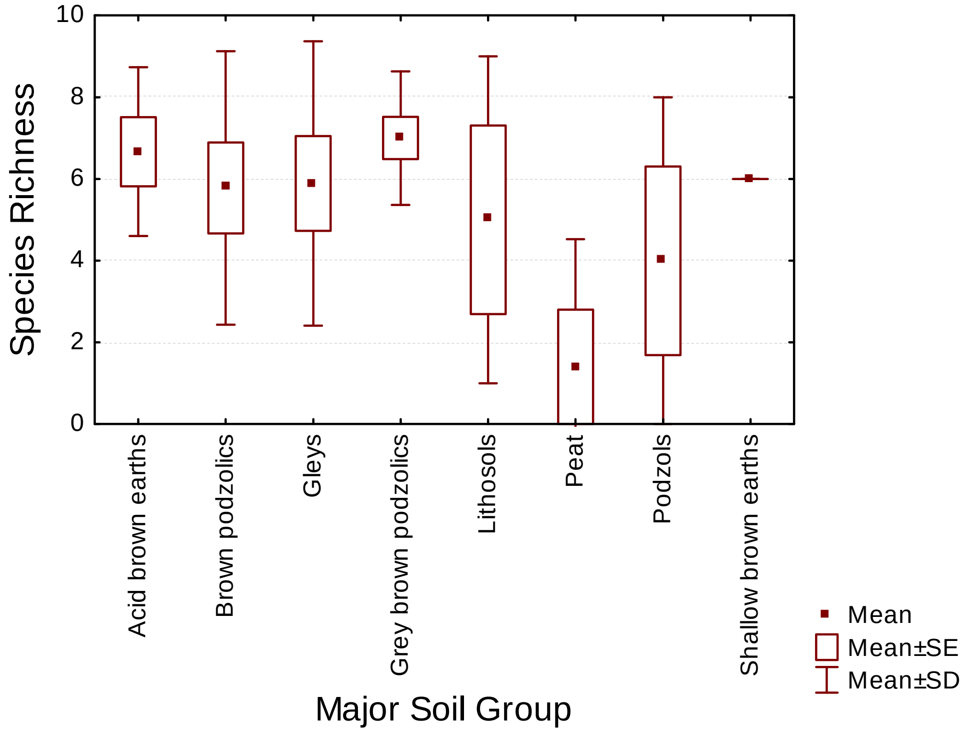
BOUCHE M.B., 1977. Stratégies lombriciennes. Bull. Ecol., Paris, 25: 122-132.
LAVELLE P., 1981. Stratégie de reproduction chez les vers de terre. *Acta Oecol. Gener*., 2: 117-133.
Lee, K. 1985. Earthworms: Their Ecology and Relationships with Soils and Land Use; Academic Press: New. York,

[7] The anecics' ecological group should be subdivided in two: anecic and epianecic that could distinguish between: *Aporrectodea* genus and *Lumbricus* genus

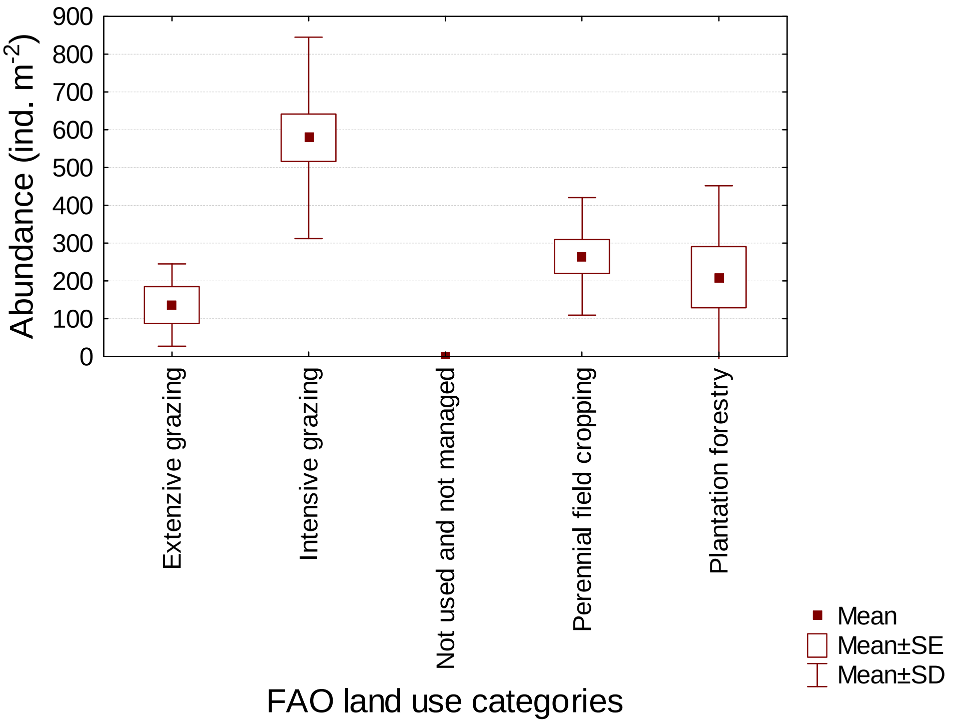
Annex III Visualisation of results

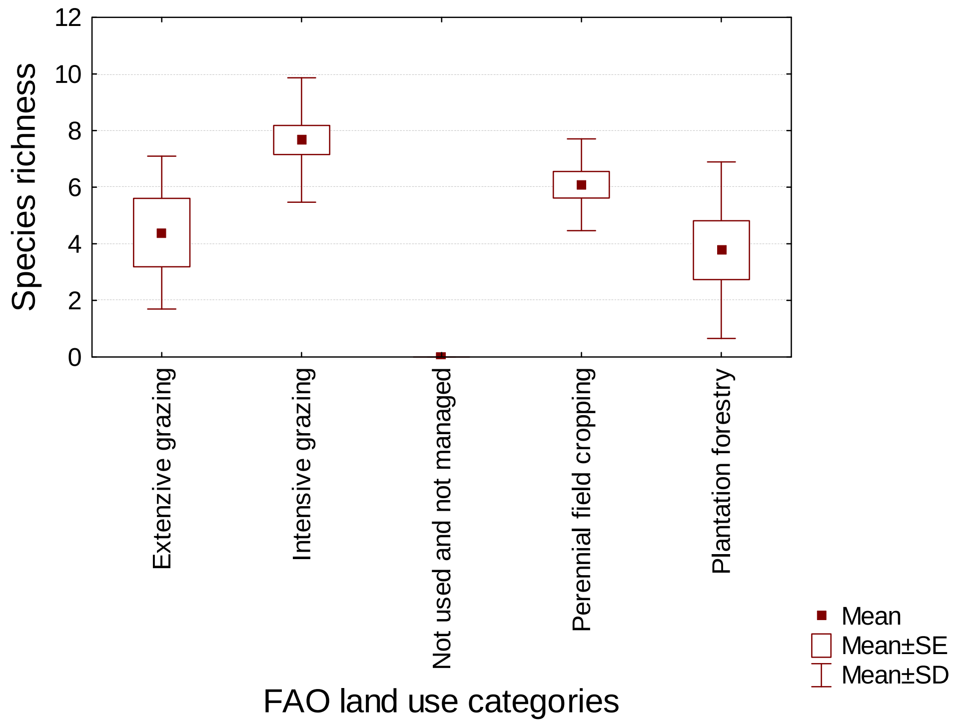
Soil type vs. Indicator BI01 (Results from Republic of Ireland)



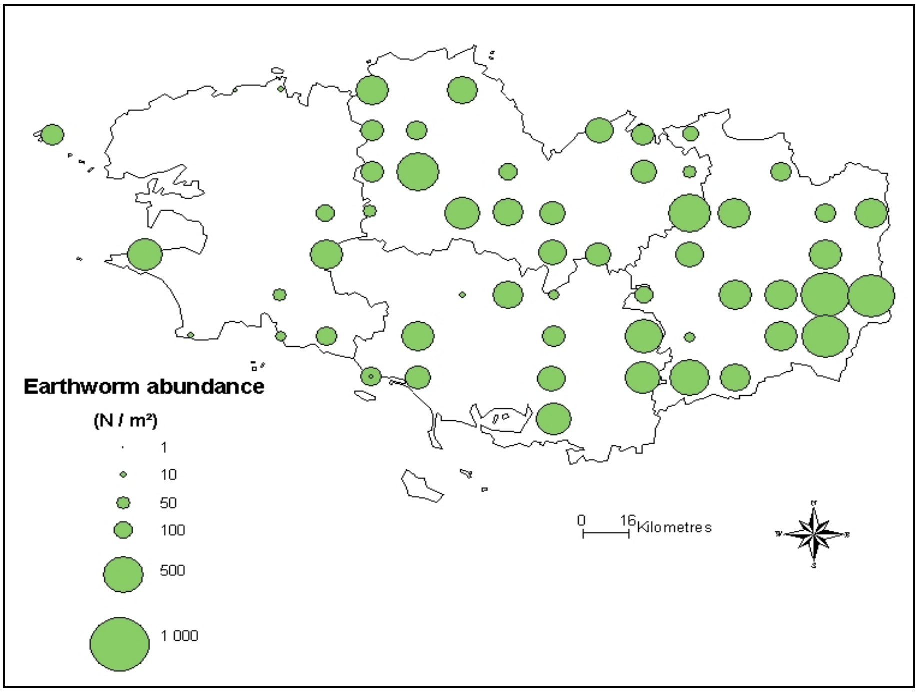


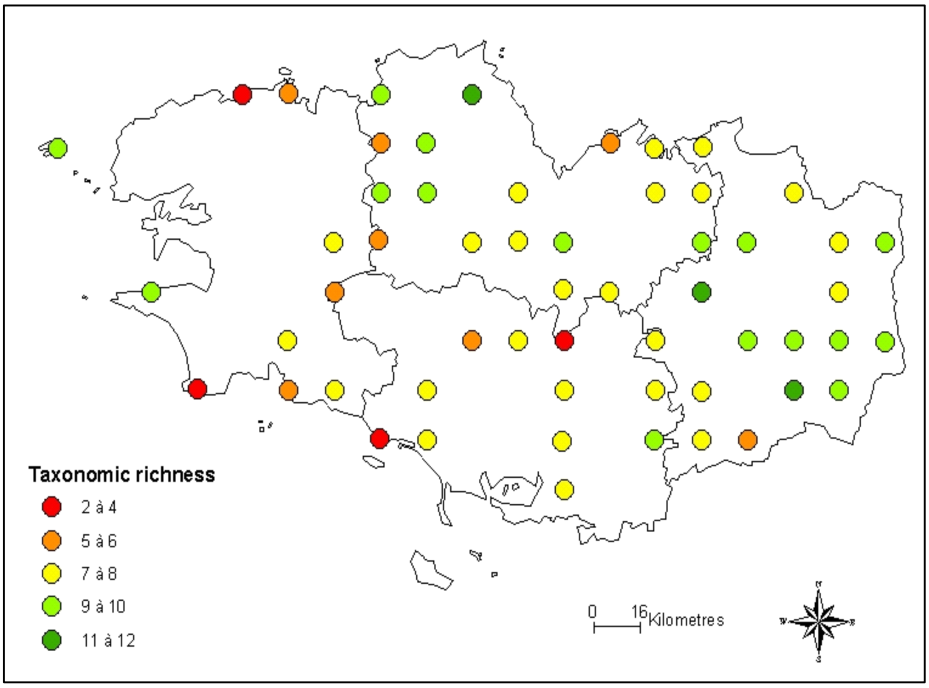
FAO land use vs. Indicator 1 (Results from Republic of Ireland)





Mapping indicator 1 results (Results from RMQS BIODIV, France)





Decline in soil biodiversity

BI02	Collembola diversity

Definition: the abundance and species richness of collembola in the soil at a monitoring site at a specific point in time (No. m^{-3}, g m^{-3})

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial resolution
Soil description			
Soil depth	m (below surface)	A	3 replicates within 100m²
Heavy metal content	mg kg^{-1}	A	
Nutrient content	cmol kg^{-1}	A	
pH	pH units	A	
Ground water level	M (below surface)	A	
Soil moisture	% vol.	A	
Texture	% clay, silt, sand	A	
Bulk density	t m^{-3}	A/M	
Organic carbon & total carbon	% w w^{-1}	A	
Site description			
Climatic conditions (monthly average)	mm, °C	M	Local station
Land management	FAO 2006	A	Field
Land uses	FAO 2006	A	
Vegetation type and cover	FAO 2006	A	
Organic horizon thickness	m	A	

Step 1: Site description and soil characterization
- i) ISO standard ISO 23611-1: 2006

Step 2: Installation of the sampling area (surface definition, localization, replicates)
- i) Sampling area has to be about 100 m².
- ii) If there is an existing monitoring network which assess the site and soil characteristics ('conventional' monitoring area), in order to use the collected data (e.g. climatic, land use, physicochemical analysis) the collembolan sampling area should be located:
  - Inside the 'conventional' monitoring area, if possible
  - Or, nearby the 'conventional' monitoring area (5 m from the conventional area at the most)
  - Location of the future sampling campaigns: N, E, W, S around the 'conventional' monitoring area, 5 m then 10 m.
- iii) If there is no monitoring network, complementary analyses have to be performed on a composite sample from the investigated area to explain biodiversity data (required parameters)

iv) Localization of the sampling area in a homogeneous[8] area (based on pedological characteristics and soil cover).
v) Record the location of the sampling area position with a differential GPS device.
vi) Sampling strategy: minimum of 3 replicates, with equal distance between subplot/replicates.

Step 3: Soil sampling area preparation
i) In case of forest: take the litter and put it in a plastic bag in order to assess fauna in the laboratory.

Step 4**:** Soil analysis
i) pH: ISO 10390 (Soil quality- determination of pH)
ii) Soil moisture content: ISO 11465:1993
iii) Organic carbon, total carbon: ISO 10694, *Soil quality — Determination of organic carbon and total carbon after dry combustion (elementary analysis)*
iv) Analyse heavy metal contents:
- ISO 14869-1:2001 *Soil quality - Dissolution for the determination of total element content -- Part 1: Dissolution with hydrofluoric and perchloric acids*
- ISO 11466:1995 *Soil quality - Extraction of trace elements soluble in aqua regia*

v) Texture*:* ISO 11277, *Soil quality — Determination of particle size distribution in mineral method*

Step 5: Perform Collembola sampling according to
i) ISO standard ISO 23611-2: 2006
ii) A minimum of 3 individual replicates should be taken. Four replicates can also be taken in order to make a composite sample (the composite sample has to be carefully realised in order to preserve the animals)[9]

Step 6: Perform Collembola conservation according to
i) ISO standard ISO 23611-2: 2006

Step 7: Perform Collembola extraction according to
i) ISO standard ISO 23611-2: 2006
ii) Note that to extract animals, the Tullgreen extraction can be substituted to the Mac Fayden technique; however any technique is acceptable if it provides adequate extraction efficiency.

Step 8: Perform Collembola diversity analysis
i) If possible, Collembola species should be identified according to the keys proposed in the ISO standard. If not, individuals extracted should be preserved according to the ISO standard to be sent to an expert for determination.
ii) The end parameter will be:
- Mandatory: Total abundance and Species richness
- Optional: Ecological groups (ecological morphotypes). The definition of morpho-ecological groups can be done on several parameters such as the adaptation to the soil habitat (Gisin, 1943; Parisi *et.al*., 2005).

Step 9: Visualise results (see Annex I)
i) Express data in relationship to soil type and land use using box and whisker plots to infer degree of variability
ii) Present spatial distribution of soil biodiversity with a map

[8] Homogeneous area should be determined according to :
- pedological characteristics based on vegetation distribution (often linked to pH, soil moisture) or assessed by a drill survey (e.g. depth)
- soil cover (e.g. vegetation, OM applied)

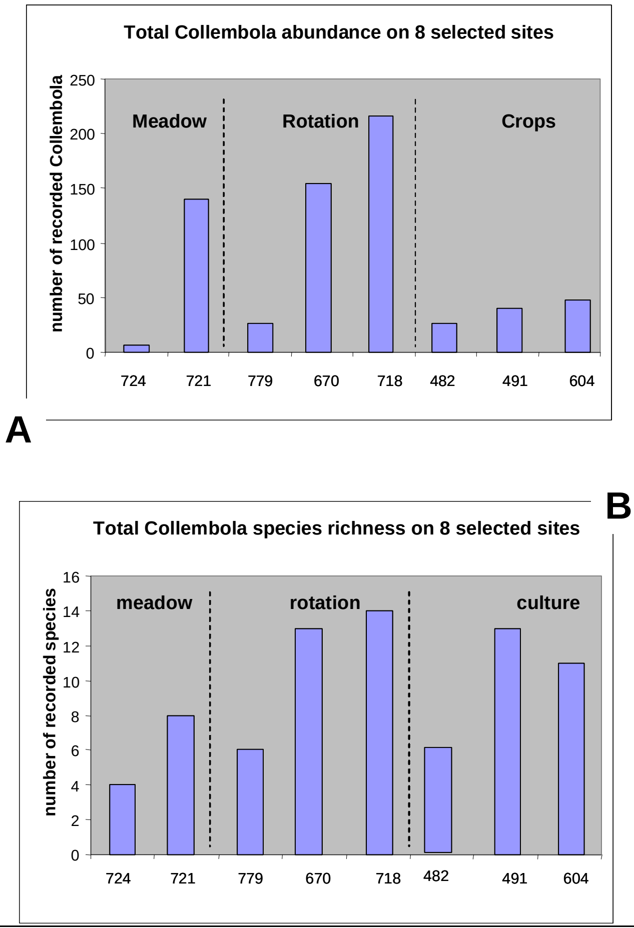
[9] Small-scale spatial heterogeneity and the highly aggregated spatial distribution of springtail populations lead to a high variance of abundance and species richness data. By using composite sampling strategy the precision of the measurements can be increased. A composite sample comes from a 20 cm x 20 cm area, where a small soil core sampler is used to collect five sub-samples. The composite sample can be standardised by its weight. To compensate for heterogeneity of higher scales due to vegetation patchiness, etc., up to 4 replicates of composites can be used.

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Field material	See relevant ISOs and annexes
Laboratory material	See relevant ISOs and annexes
Reference material	WRB 2006, FAO 2006

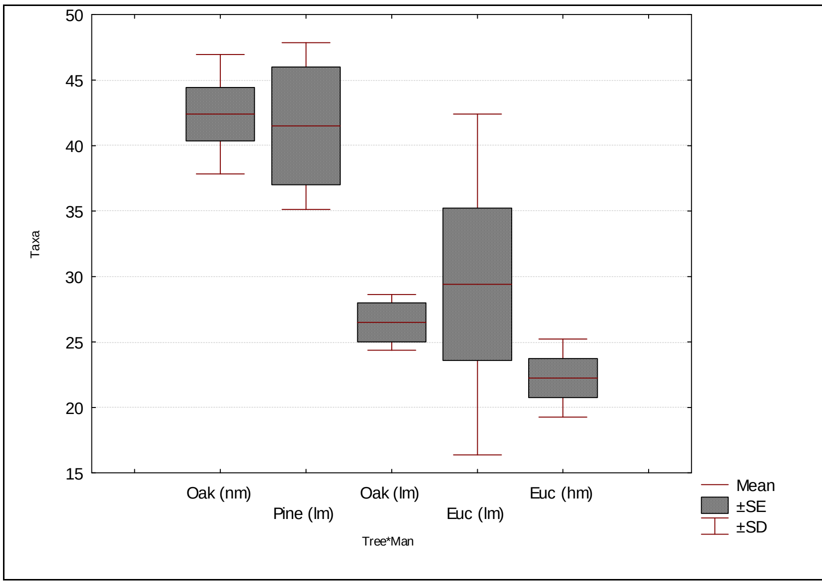
Annex I How to visualise results of BI02

Land use vs. Indicator 2 (Results from RMQS BIODIV, France)



Collembola abundance (A) and species diversity in 8 sites (B)

Species richness (average + SE + SD) of Collembola according to tree and management intensity (Portugal) vs management intensity and tree plantation (Portuguese Pilot Areas)



Legend:

- Oak (several oak forests)
- Pine (Pinus pinaster plantations)
- Euc (Eucalyptus globulus plantations)

- nm: not managed
- lm: low management intensity
- hm: high management intensity.

Decline in soil biodiversity

BI03	Soil microbial respiration

Definition: (indicator) the quantity of carbon dioxide that is produced by the microbial decomposition processes in a sample of topsoil during one hour (mg CO_2 (kg dry soil)$^{-1}$ h^{-1})

Table 1. Parameters (preferred parameters are in black,alternative parameters are in grey); A=Actual (measured), M=modelled

Required	Units	Type	Spatial resolution
Soil description			
Heavy metal content	mg kg^{-1}	A	3 replicates within 100 m²
Nutrient content	cmol 100 g^{-1}	A	
pH	pH units	A	
Ground water level	m (below surface)	A	
Soil moisture	% vol.	A	
Texture	% clay, silt, sand	A	
Bulk density	g cm^{-3}	A/M	
Organic carbon & total carbon	% w w^{-1}	A	
Site description			
Climatic conditions (monthly average)	mm, °C	M	Local station
Land management	FAO 2006	A	Field
Land uses	FAO 2006	A	
Vegetation type and cover	FAO 2006, %	A	
Organic horizon thickness	m	A	

Step 1: Site description and Soil characterization

i) ISO 23611-1: 2006; Section 1.1 Scope

Step 2: Installation of the sampling area (surface definition, localization, replicates)

i) Sampling area has to be about 100 m².

ii) If there is an existing monitoring network which assess the site and soil characteristics ('conventional' monitoring area), in order to use the collected data (e.g. climatic, land use, physicochemical analysis) the microbial sampling area should be located:
- Inside the 'conventional' monitoring area, if possible
- Or, nearby the 'conventional' monitoring area (5 m from the conventional area at the most)
- Location of the future sampling campaigns: N, E, W, S around the 'conventional' monitoring area, 5 m then 10 m.

iii) If there is no monitoring network, complementary analyses have to be performed on a composite sample from the investigated area to explain biodiversity data (required parameters)

iv) Localization of the sampling area in a homogeneous[10] area (based on pedological characteristics and soil cover).

v) Record the location of the sampling area position with a differential GPS device.

[10] Homogeneous area should be determined according to :
- pedological characteristics based on vegetation distribution (often linked to pH, soil moisture) or assessed by a drill survey (e.g. depth)
- soil cover (e.g. vegetation, OM applied)

vi) Sampling strategy: minimum of 3 replicates, with equal distance between subplot/replicates.

Step 3: Soil sampling area preparation

Step 4: Soil analysis

i) pH: ISO 10390 (Soil quality- determination of pH)

ii) Soil moisture content: ISO 11465:1993

iii) Organic carbon, total carbon: ISO 10694, *Soil quality — Determination of organic carbon and total carbon after dry combustion (elementary analysis)*

iv) Analyse heavy metal content:

- ISO 14869-1:2001 *Soil quality -- Dissolution for the determination of total element content -- Part 1: Dissolution with hydrofluoric and perchloric acids*
- ISO 11466:1995 *Soil quality -- Extraction of trace elements soluble in aqua regia*

v) Texture*:* ISO 11277, *Soil quality — Determination of particle size distribution in mineral soil material*

Step 5: Perform soil sampling and preserving samples for microflora analysis,

i) ISO 10381-6: 1993

ii) A minimum of 10 elementary samples should be collected and mixed to composite sample

Step 6: Perform soil microbial respiration of topsoil samples

i) ISO 16072:2002 with some advances (see Annex I)[11]

ii) The end parameter will be: (mg CO_2.(kg dry soil)$^{-1}$ h^{-1}).

Step 7: Visualise results (see annex II)

i) Express data depending on soil groups [soil type (WRB or FAO) or total soil depth (WRB), or topsoil texture] and land use (FAO 2006) using box and whisker plots to infer degree of variability

ii) Present spatial distribution of soil biodiversity with a map (see Annex II)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	**Description**
Field material	See relevant ISOs and annexes
Laboratory material	See relevant ISOs and annexes
Reference material	WRB 2006, FAO 2006

[11] Depending on the laboratory equipment, some modifications can be accepted:

- flask volume can reach to 600 mL,
- the determination of CO_2 release can be realised by titration in a static system (CO_2, absorption by NaOH) or by an infrared gas analyser in a dynamic system (the rate of formation of CO_2 (e.g. milligrams CO_2 per gram per hour) is calculated by the evaluation software taking into account the actually measured gas flowrate (millitres air per minute) and the mass of the soil sample (grams dry mass).

Annex I Soil respiration
ISO 16072:2002 advances

AI.1 General
Soil respiration is a pivotal aspect of the living soil, addressing major flows of carbon and energy conversions associated with active organisms in soil, predominantly the microbial life. In a practical sense, respiration can be defined as the uptake of oxygen and the release of carbon dioxide. Although these processes are coupled within organisms, in soil also other mechanisms of oxygen consumption and carbon dioxide consumption and release are present, which are not necessarily linked to each other. Further reading on respiration methods can be found in the literature (e.g. Winding *et al.*, 2005; Pell *et al.*, 2005).

Basal respiration (BAS) is the steady rate of soil respiration originating form the turnover of organic matter in the soil. The measurement of BAS in a monitoring system should be designed for indication of some representative part of the soil microbial life and should be relatively independent from local and temporal variations in time and climatic conditions. It is the objective to standardise the method in a way that a reasonable comparison between measurements is possible, independent from sampling date and the laboratory for analysis.

AI.2 Sample storage, preparation and equilibration
For virtually all microbiological indicators invasive sampling and time for laboratory analysis are necessary. Consequently, disturbances due to the sampling, the transport, and the storage are almost inevitable (Stenberg *et al.*, 1998). In general, a limited boost of microbial activity can be recorded during a couple of days immediately after sampling.

In order to prepare homogenized and representative samples it is recommended to sieve the sub-samples through 2-6 mm mesh. If not immediately processed, the representative sample is to be stored at 4°C.

In addition, season and climatic conditions influence the soil ecosystem significantly in shallow soil horizons (Grayston *et al.*, 2001; Mulder *et al.*, 2003). To a certain extent, this can be circumvented by sampling in a specific and limited time period and by including an equilibration period in the laboratory under standard climatic conditions:

i) in the Dutch Soil Monitoring Program, soil samples are taken in spring (April and May) and incubated for about 4 weeks at 50% water holding capacity (WHC) at 10°C in the dark (Mulder *et al.*, 2003)
ii) in the ICP-IM network soil is sampled during autumn (from August to October) and pre-incubated for 12 days at 60% WHC at 20°C

An equilibration stage of at least one week, with a standardized temperature and humidity of the samples, is needed to reduce the effect of soil sampling periods. It is reasonable to suggest a range of temperatures since ambient soil temperatures differ significantly in Europe. The yearly average soil temperature does not provide sufficient guidance for selecting an appropriate temperature for respiration measurements, since activity is also dependent on organic matter and humidity. Furthermore, this may lead to many different incubation temperatures. For these reasons, the average soil temperature at 10-15 cm depth during the active period in spring or autumn, at reasonable humidity conditions (e.g. 60 ± 10% water holding capacity), is a good approximation of the optimal measurement temperature for soil respiration.

For monitoring purposes we suggest to realise the equilibration stage by using temperatures of 15, 20 and 25-28°C and by setting the humidity of the soil samples at 60 ± 10% of the water holding capacity. The duration of the equilibration stage will depend on the chosen temperature:

i) 2 to 4 weeks equilibration for 15°C
ii) 1 week equilibration for 20°C
iii) 2 to 3 days equilibration for 25 to 28°C

Such equilibration should be performed in the dark under contained conditions allowing free exchange of gases, but preventing too much loss of humidity. Usually, loosely knotted plastic bags or containers with a small hole in the lid will provide these conditions.

AI.3 Measurement

After the equilibration period measurements of carbon dioxide production and/or oxygen consumption can be started. The temperature of incubation should be set according to the range of temperatures chosen for the equilibration period. Soil samples should be incubated in air-tight containers. Repeated measurements (at least 2) are recommended to obtain multiple data points on the carbon dioxide production or oxygen consumption. A period of one to five weeks is recommended for this. Different methods to measure carbon dioxide and oxygen concentration in the headspace are available (ISO 16072, Pell *et al.*, 2005; Winding *et al.*, 2005).

As soil respiration is influenced by water content, temperature and incubation duration, these parameters should be recorded in the final report as well as the equilibration parameters.

AI.4 Summary of the proposed protocol for the ENVASSO indicator 'Soil Respiration':

i) sample during favourable periods (e.g. spring or autumn). A delay of at least 15 days should be respected after a dry or frost episode.
ii) at least 10 sub-samples have to be collected and homogenized by sieving through 2-6 mm mesh
iii) store the collected sample at 4°C if not processed immediately,
iv) measure the humidity of the soil and the WHC,
v) adjust the WHC to 60 % ± 10 % and start an equilibration period (see text for delay and temperature). Equilibration should performed in the dark under contained conditions allowing free exchange of gases.
vi) start the incubation period for measuring CO2 release or O2 according to ISO 16072
vii) report all parameter regarding the used protocol (e.g. temperature and duration of equilibration and incubation, % WHC).

AI.5 References

Grayston, S.J., Griffith, G.S., Mawdsley, J.L., Campbell, C.D., Bardget, R.D., 2001. Accounting for variability in soil microbial communities of temperate upland grassland ecosystems. Soil Biol. Biochem. 33, 533-551.

Mulder, C., De Zwart, D., Van Wijnen, H.J., Schouten, A.J., Breure, A.M., 2003. Observational and simulated evidence of ecological shifts within the soil nematode community of agroecosystems under conventional and organic farming. Funct. Ecol. 17, 516-525.

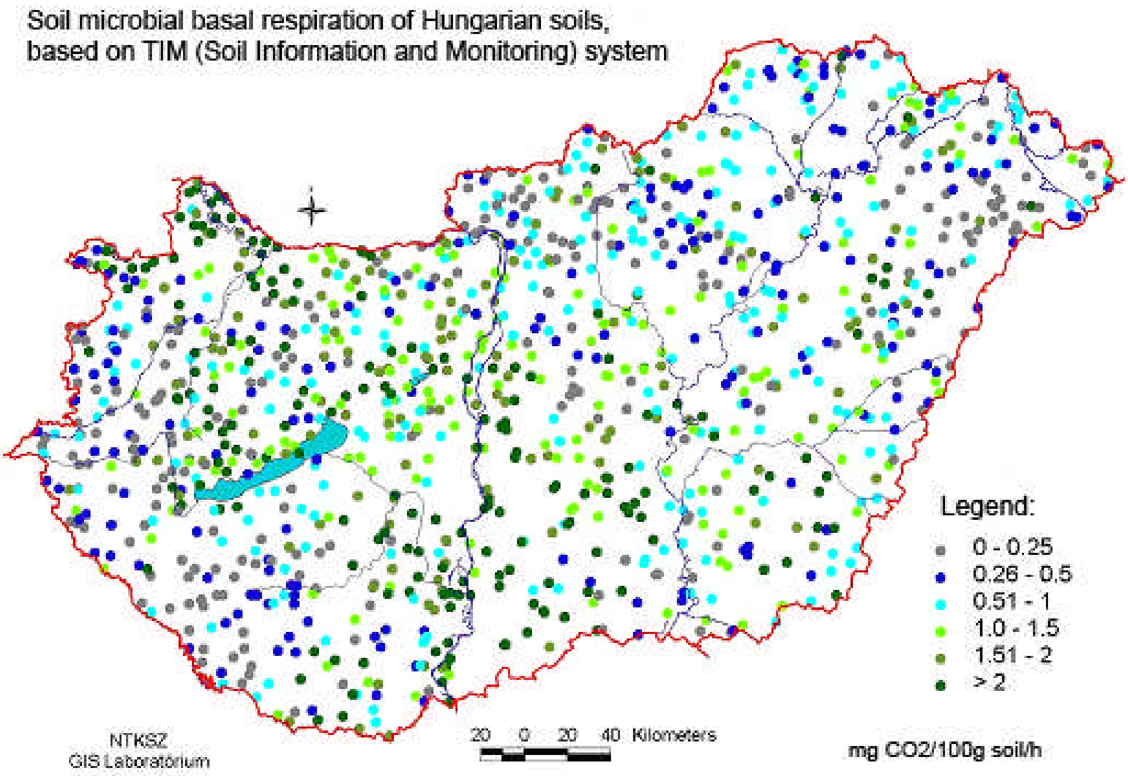
Pell, M., Stenström, J., Granhall, U., 2006. 7.2 Soil Respiration. In: Microbiological Methods for Assessing Soil Quality (J. Bloem, A. Benedetti and D.W. Hopkins, editors). CABI, Wallingford, Oxfordshire, UK. pp. 117-126.

Stenberg, B., Johansson, M., Pell, M., Sjödahl-Svensson, K., Stenström, J., Torstensson, L., 1998a. Microbial biomass and activities in soil as affected by frozen and cold storage. Soil Biol. Biochem. 30, 393-402.

Winding, A., Hund-Rinke, K., Rutgers, M., 2005. The use of microorganisms in ecological soil classification and assessment concepts. Ecotoxicol. Environ. Saf. 62: 230-248.

Annex II Visualisation of results

Mapping the results at national scale of Indicator 3 (TIM points, Hungary)



2.7 Soil salinisation

The threat 'soil salinisation' is defined as: the accumulation of water soluble salts in the soil, causing a deterioration or loss of one or more soil functions (see Glossary).

The accumulated salts include sodium-, potassium-, magnesium- and calcium- chlorides, sulphates, carbonates and bicarbonates. A distinction can be made between primary and secondary salinisation processes. Primary salinisation involves accumulation of salts through natural processes as physical or chemical weathering and transport processes from salty geological deposits or groundwater. Secondary salinisation is caused by human interventions such as inappropriate irrigation practices, use of salt-rich irrigation water and/or poor drainage conditions. The salt profile gives a complete picture of the salinity/sodicity state of the soil, or more exactly the salt-affected area. The salt profile gives the vertical and horizontal distribution as well as the chemical composition of the salts, which are extremely important data regarding the unfavourable impacts of salinisation/alkalisation/sodification

Exchangeable sodium percentage (ESP), together with Sodium Adsorption Ratio (SAR), quantifies the main processes in sodification of soils. Sodification results in unfavourable changes in the physical/hydrophysical soil properties and moisture regime of the affected areas, increasing the hazard (frequency, duration and ecological consequences) of extreme moisture situations.

Potential salinisation/sodification is the risk of saline or brackish irrigation water combined with inappropriate irrigation practices; salt accumulation from the rising water table with high salt content and unfavourable ion composition; the salt movement from the deeper horizons to upper layers or to the active root zone by capillary action; salt water inundation or subsurface intrusion from the sea.

Soil salinisation

SL01	Salt profile

Definition: (indicator) the horizontal and vertical distribution in soil of salts and their chemical composition ($dS \cdot m^{-1}$)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
pH	pH units	A	Appendix I
Ion composition	cmol+ kg^{-1}	A	Appendix I
EC or % salts	$dS \cdot m^{-1}$ %	A	Appendix I

Field *in situ* method

If the soil at the monitoring site is known to be saline, then go to step 2:

If the soil is known to not be saline or if no prior knowledge of the salinity exists or is available, then:

Step 1: Perform field assessment of salinity ($EC_{1/5}$ + pH)

i) Test the EC in the 1:5 extract by a hand-held device, at 4-100 (see Appendix I) randomly positioned points in the soil monitoring site.

If one or more subsampling points show EC values above the threshold value, then:

Step 2: Sample soil

i) At 5 randomly positioned points in the monitoring site: collect soil samples (using an auger) from every 10 cm depth increment from the soil surface down to 1 m depth, or to the salt accumulation layer, or to the ground water level.

ii) Store each individual sample in labelled, double plastic bags.

Step 3: Perform sample pre-treatment

i) ISO 11464:2006

Step 4: Perform EC analysis

i) ISO 11265:1994

Step 5: Perform pH analysis

i) ISO 10390:2005

Step 6: Perform ion composition analysis

i) ISO 13536:1996

ii) Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} cations, and CO_3^{2-}, HCO_3^{-}, Cl^{-} and SO_4^{2-} anions

Step 7: Visualise results in tabular form

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Field equipment	See relevant ISOs
Laboratory equipment	See relevant ISOs

Soil salinisation

SL02	Exchangeable sodium percentage

Definition: (indicator) exchangeable sodium (Na^+) fraction expressed as a percentage total cation concentration (%)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
pH	pH units	A	Appendix I
Cation concentration	cmol+ kg^{-1}	M	Appendix I
Exchangeable Sodium Percentage (ESP)	%	M	Appendix I
Sodium absorption ratio (SAR)	none	M	

Step 1: Sample soil
i) Appendix I
Step 2: Perform sample pre-treatment
i) ISO 11464:2006
Step 3: Perform cation concentration analyses
i) Na concentration (ISO 13536:1995)
ii) Mg concentration (ISO 13536:1995)
iii) Ca concentration (ISO 13536:1995)
iv) K concentration (ISO 13536:1995)
Step 4: Calculate ESP using equation 1

$$ESP = \frac{Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \cdot 100 \qquad \text{Equation 1}$$

If K^+ concentration data is not available, then:
Step 4a: Calculate SAR using equation 2
Step 4b: Calculate ESP using equation 3

$$SAR = \frac{Na^{+}}{\sqrt{0.5\,(Ca^{2+} + Mg^{2+})}} \qquad \text{Equation 2}$$

$$ESP = \frac{(1.475(SAR) - 1.26)}{(1 + (0.01475(SAR) - 0.0126))} \qquad \text{Equation 3}$$

Step 5: Perform pH analysis
i) ISO 10390:2005
Step 6: Express indicator value
i) If pH (in accumulation horizon) > 8.5; and SAR >10; and ESP > 15, then soil is classified as ‘salinised/sodificated’.
ii) Accompany results with tables in Annex I

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Field equipment	See relevant ISOs
Laboratory equipment	See relevant ISOs

Annex I Thresholds

Exchangeable Sodium Percentage (ESP)

ESP < 5	no sodification symptom
ESP 5–15	slightly sodic (solonetzic) soil
ESP 15–25	strongly sodic (solonetzic) soil
ESP > 25	sodic (solonetz) soil

Depth of ESP accumulation:

< 7 cm	shallow sodic soil (solonetz)
7–15	medium sodic soil (solonetz)
> 15 cm	deep sodic soil (solonetz).

Soil salinisation

SL03	Potential salt sources

Definition: (indicator) the identification of secondary salinisation caused by either salty groundwater or salty irrigation water (%)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
pH	pH units	A	Appendix I
Cation concentration	cmol+ kg^{-1}	M	Appendix I

Step 1: Sample ground water and irrigation water
  i) ISO 5667-11:1993 (groundwater); ISO 5667-4 (irrigation water)
Step 2: Perform cation concentration analyses
  i) Na concentration (ISO 13536:1995)
  ii) Mg concentration (ISO 13536:1995)
  iii) Ca concentration (ISO 13536:1995)
  iv) K concentration (ISO 13536:1995)
Step 4: Calculate ESP using equation 1
Step 5: Calculate SAR using equation 2

$$ESP = \frac{Na^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \cdot 100$$ Equation 1

$$SAR = \frac{Na^{+}}{\sqrt{0.5\,(Ca^{2+} + Mg^{2+})}}$$ Equation 2

Step 6: Visualise results

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
Field material	See relevant ISOs
Laboratory material	See relevant ISOs

2.8 Landslides

A landslide as a 'threat to soil' can be defined as: 'the movement of a mass of rock, debris, artificial fill or earth down a slope, under the force of gravity, causing a deterioration or loss of one or more soil functions' (see the ENVASSO Glossary of Key Terms). Clearly, landslides sometimes form more dramatic hazards in populated areas, threatening human lives and properties, but in the context of ENVASSO we focus on the threat to the soil itself. Landslides threaten soil functioning in two ways: i) removal of soil from its *in situ* position, and ii) deposition of colluvium on *in situ* soil downslope from the area where the soil mass 'failed'.

Where a landslide removes all soil material, all soil functions will be lost and weathering processes of the hard rock, or sediment, now exposed at the surface, need to operate for hundreds if not thousands of years to produce enough soil material for soil functioning to resume. When only a part of the soil profile (e.g. the A horizon) is removed by a landslide, no soil function may be lost entirely, although most functions are likely to be impaired. The 'engineering' soil function (see ENVASSO Glossary of Key Terms) may not suffer to any great extent, and in some cases may even benefit, from topsoil removal by landsliding. A similar rationale can be used for the deposition area. When the soil is covered by a thick layer of colluvium (e.g. > 30-50 cm) the 'production', 'habitat' and 'engineering' soil functions (see ENVASSO Glossary of Key Terms) are lost. However, when the colluvium layer is thin (e.g. < 10 cm), mixing of the colluvium into the A horizon may be beneficial to those same functions.

The first step in any landslide risk management programme should be to develop an inventory map of previous landslide activity. All types of landslides leave a topographical signature when they occur, and are driven largely by topographical effects. Thus mapping the spatial distribution of landslides is relatively straightforward, although uncommon in the EU. Improved sources of high-resolution topographic information have the potential to increase greatly the accuracy of landslide hazard maps. Geomorphological mapping can be used to identify active, relict, dormant and stabilised areas. Areas prone to landsliding in the past have a high risk of further failure taking place, unless substrate material has been removed completely. Topographical maps and remote sensing can be used to recognize different kinds of active or recently active landslides by detailed examination of the land form, micro-relief and surface composition of predefined sets of geomorphological units for both 'stable parts surrounding the slide' and 'parts that have moved'. In addition, automatic recording systems connected to different sensors can be installed to closely monitor a specific area under threat of landsliding

The first indicator LS01, the occurrence of landslide activity, addresses the first stage in monitoring landslide activity under a soil protection strategy. The second indicator LS02, volume or mass of displaced material will require refinement of remote sensing techniques before it could be implemented.

Landslide hazard assessment or vulnerability to landsliding is addressed by the third indicator LS03. This is the most important for any future monitoring system. The simplest approach to predicting the occurrence of landslides is to identify where, and how frequently, failure has taken place in the past. More complex approaches consider slope stability models that can be used to predict the short and long term occurrence of mass slope failure. The development of a predictive model applicable at European level will require more technical and scientific progress and thus LS03 is a future prospect rather than an indicator that could soon be implemented.

References

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Wood, M. and Jelinek.R. (2007). Risk Mapping in New Member States: a summary of general practices for mapping hazards, vulnerability and risk. European Commission JRC-IPSC, EUR 22899 EN, 26pp. Office for the Official Publications of the European Communities, Luxembourg.

Landslides

LS01	Occurrence of landslide activity

Definition: (indicator) the number and extent of landslides that have occurred in a specified area over a specified time period (Number km^{-2}, ha km^{-2}).

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
Area active landsliding	ha, km^2	A	
Area dormant landslides	ha, km^2	A, M	
Estimated area of landslides	ha, km^2	M	

Step 1: Construct landslides distribution map
  i) Aerial photograph interpretation
Step 2: High-resolution survey to identify types of landslide
  i) Graphic and spatial analysis
Step 3: Visualise results in map format using GIS

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
High resolution field survey maps	Large scale maps at 1:5,000 or 1:10,000 scale
Aerial photography	!:10,000 scale aerial photographs
GIS	
GPS device	handheld for field use
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)

Landslides

LS02	Volume/mass of displaced material

Definition: (indicator) the volume or mass of soil that has been displaced by landslides in a specified area over a specified time period (m^3 ha^{-1} yr^{-1}, t ha^{-1} yr^{-1}).

Procedures and protocols for this indicator are not defined here because substantial technical/scientific progress is still required for this indicator to be monitored in a harmonised way throughout Europe and, even if progress is made, LS02 retains its red status as currently it is not suitable for harmonised monitoring at the European scale.

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution

Step 1: TBD*
i)
Step 2: TBD*
i)
ii)
Step 3: TBD*
Step 4: TBD*
* TBD = To Be Decided

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description

Landslides

LS03 Landslide hazard assessment

Definition: (indicator) the likelihood of a specified area to be subjected to the process of landsliding (classes)

A Landslide hazard map indicates the probability of landslides occurring in a given area at a given time or with a given frequency. A hazard map may be based simply on occurrence of previous landslides to indicate potential instability or may incorporate probabilities based on variables such as rainfall thresholds, slope angle, soil type and severity of earthquake vibrations (Jeliinek *et al.*, 2007). Landlside hazard maps usually delineate zones of differing likelihood of slope movement and can also be called *landslide hazard zonation maps* (Varnes *et al.*, 1984).

From a detailed survey of mapping practices adopted in eleven New Member States – Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia – for eight major natural and technological hazards including landslides, it is clear that currently there is no standard methodology for assessing likelihood of landsliding (Jelinek *et al.*, 2007). Recommendations emanating from this survey include the need to examine in more detail the different landslide hazard mapping practices adopted by adopted by Member States, with a view to identifying a common approach to classifying vulnerability to landsliding (Wood and Jelinek, 2007). In general, the Member States that collaborated in the survey demonstrated a willingness to test different methods of classification and it is accepted that common approaches to mapping landslide risks should meet the needs of the INSPIRE Directive (http://www.ec-gis.org/inspire/).

Therefore, it must be concluded that procedures and protocols for this indicator cannot defined at this time because, although the initiatives to date offer hope for the development of a common EU appraoch to classifying and mapping landslide hazard in the future, substantial technical/scientific progress is still required before this indicator could be monitored in a harmonised way throughout Europe.

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description

References

Jelinek, R., Hervas, J. and Wood, M. (2007). Risk Mapping of Landslides in New Member States. European Commission JRC-IPSC, EUR 22950 EN, 34pp. Office for the Official Publications of the European Communities, Luxembourg.

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Wood, M. and Jelinek.R. (2007). Risk Mapping in New Member States: a summary of general practices for mapping hazards, vulnerability and risk. European Commission JRC-IPSC, EUR 22899 EN, 26pp. Office for the Official Publications of the European Communities, Luxembourg.

2.9 Desertification

The threat 'desertification' is defined as: land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities, causing a deterioration or loss of one or more soil functions

In the broadest terms, desertification includes the degradation of land, water, vegetation and other resources (Martínez-Fernández and Esteve, 2005). Because of its importance worldwide, the United Nations has formulated the Convention to Combat Desertification (UNCCD), to which the European Union is a signatory.

Desertification is identified in the thematic strategy for soil protection as an important process of land degradation in the arid, semi-arid and sub-humid zones of Europe. In the context of the ENVASSO project, it is a cross-cutting issue that is closely associated with soil erosion, decline in soil organic matter, soil salinisation and decline in soil biodiversity. To address this cross-cutting issue, two specific indicators have been identified in ENVASSO, namely: vulnerability to desertification (DE01) and wildfires (DE02, burnt land area).

At the European scale it is not possible to identify specific fields or communes where the risk of desertification is highest, but it should be possible to identify regions where more detailed work is needed. It is practicable to express the impact of socio-economic drivers through patterns of land use (Kirkby and Kosmas, 1999). The MEDALUS (Kosmas *et al.,* 1999a) system is the most applicable approach to assess the vulnerability to desertification in Europe at the present time because it is based on existing concepts and available data. Thus, land area at risk of desertification (DE01) is included as an indicator.

Wildfires strongly degrade soil in arid, semi-arid and dry sub-humid regions and their frequency is increasing, partly as a result of climate change (Westerling *et al.*, 2006) and probably as a result of a decline in the collection of combustible debris for firewood. Abandonment of land is an additional fire hazard. Wildfires destroy vegetation which binds soil together protecting it from erosion. In intense fires, above ground organic matter and roots and other organic matter within the soil itself, are lost, increasing the decline of SOM. At the same time, the loss of vegetation cover and soil structure, and enhanced soil water repellency, greatly affects the hydrology and increases the potential soil erosion (Shakesby and Doerr, 2006; Doerr *et al.*, 2000). The area where vegetation has been destroyed by wild fires can be measured (and subsequently monitored) by remote sensing (Land Management Unit, JRC, Ispra; Eva and Lambin, 2000; Fox *et al.,* 2006). Therefore, wildfires (DE02, burnt land area per year) was selected as the second indicator.

References

Doerr, S.H., Shakesby, R.A. and Walsh, R.P.D. (2000). Soil water repellency: its causes, characteristics and hydro-geomorphological significance. Earth-Science Reviews, 51(1-4): 33-65.

Eva, H. and Lambin, E.F. (2000). Fires and land-cover changes in the tropics: a remote sensing analysis at the landscape scale. Journal of Biogeography 27, 765-776.Fox, D., Berolo, W., Carrega, P. and Darboux, F. (2006). Mapping erosion risk and selecting sites for simple erosion control measures after a forest fire in Mediterranean France. Earth Surf. Process. Landforms 31, 606-621.

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Shakesby, R.A. and Doerr, S.H. (2006). Wildfire as a hydrological and geomorphological agent. Earth-Science Reviews, 74(3-4): 269-307.
Westerling, A. L., Hidalgo, H. G., Cayan, D. R. & Swetnam, T. W. (2006). Warming and earlier spring increase western US forest wildfire activity. Science, 313, 940-943.

DE01	Land area at risk of desertification

Definition: (indicator) the total land area that is estimated to be at risk of desertification at a specific point in time (classes)

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured) (measured), M=Modelled; Complete list in Annex I

Required	Units	Type	Spatial Resolution
Soil quality indices	various	A & M	1 km
Climate quality indices	various	A & M	1 km
Vegetation quality indices	various	M	1 km
Management quality indices	m	M	1 km

Step 1: Prepare data to compute Soil Quality Indices (SQI)
i) See Annex II
Step 2: Prepare data to compute Climatic Quality Indices (CQI)
i) See Annex III
Step 3: Prepare data to compute Vegetation Quality Indices (VQI)
i) See Annex IV
Step 4: Prepare data to compute Management Quality Indices (MQI)
i) See Annex V
Step 6: Compute quality indices for Soil (S), Climate (C), Vegetation (V), & Management (M)
i) See Annexes II-V
Step 7: Assign Environmentally Sensitive Area (ESA) classes
i) See Annex VI
Step 8: Visualise results
i) Map ESA classes

Or alternatively,
If there is a National methodology for assessing the risk of desertification or an alternative European method to Medalus:
Step 1: Apply national/alternative methodology
i) Visualise results

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
ARC GIS	ARC Workstation extension
PC	> 60Gb free disk space Win2000 or XP Processor >2.8 GHz (1.7 GHz dual-core)
Spatial data sets	In ARC_Grid format

Annex I MEDALUS Methodology

[source: Medalus Manual (Kosmas *et al.*, 1999)]

Table 1 Parameters needed to compute quality indices (preferred parameters are in black, additional parameters are in grey)

Required	Description	Units	Type	Spatial Resolution
Soil_texture	texture class	class	A	1 km
Soil_depth	depth range	cm	A	1 km
Soil_PM	Soil parent material	class	A	1 km
Slope	Gradient range	class	A	1 km
Rock_fragments	Proportion of stones	class	A	1 km
Soil-drainage	Drainage class	class	M	1 km
meanrf_Ann	Rainfall, mean annual	mm	A	1 km
meanPET_Ann	Rainfall, mean annual	mm	A	1 km
mtmean_Ann_	Mean annual temperature (Altitude corrected)	°C	A	1 km
Aridity	Aridity index	ratio	A	1 km
newrf_Ann	Predicted future Average Annual rainfall (scenario)	mm	M	1 km
newt_Ann	Predicted future Annual temperature (scenario lead)	°C	M	1 km
Fire_risk	Vegetation Type	land class (e.g. CLC	A	1 km
Erosion_protection	Vegetation type	Land class group	A	1 km
Drought_resistance	Vegetation type	Land class group	A	1 km
Plant cover	Ground cover	%	M	1 km
Management_ cropland	Land use intensity	class	M	1 km
Management_ Pasture	Stocking rate	class	M	1 km
Management_ Natural_Areas	Management characteristics	class	M	1 km
Management_ Mining_Areas	Erosion control measurements	class	M	1 km
Management_ Recreation_Areas	A/P visitor ratio	ratio	M	1 km
Management_ Policy_Enforcement	Proportion of land under protection	%	A/M	1 km

Annex II Soil quality indices

[source: Medalus Manual (Kosmas *et al.*, 1999, p.37-8)]

These indicators are determined for according to soil properties, climatic parameters and vegetation characteristics.

Soil quality indices for mapping Environmentally Sensitive Areas (ESA) are related to: (a) water availability, and (b) erosion resistance. These qualities can be evaluated by using simple soil properties or characteristics given in regular soil survey reports such as soil texture, parent material, soil depth, slope angle, drainage, and stoniness. The use of these properties for defining and mapping ESAs requires the definition of distinct classes as presented in Table 1.

Table 1. Classes, and assigned weighting indices for assessment of soil quality

(A) Texture and Soil depth

TEXTURE

Class	Description	Texture	Index
1	Good	L, SCL, SL, LS, CL	1.0
2	Moderate	SC, SiL SiCL	1.2
3	Poor	Si, C, SiC	1.6
4	Very poor	S	2.0

S – sand, Si – silt, C – clay, L - loam

SOIL DEPTH

Class	Description	Depth (cm)	Index

(B) Parent material and Slope gradient

PARENT MATERIAL

Class	Description	Parent material	Index
1	Good	Shale, schist, basic, ultra basic, Conglomerates, unconsolidated	1.0
2	Moderate	Limestone, marble, granite, Rhyolite, ignimbrite, gneiss, siltstone, sandstone	1.7
3	Poor	Marl*, Pyroclastics	2.0

*For perennial vegetation, marls are moved to class 1.

SLOPE GRADIENT

Class	Description	slope (%)	Index
1	Very gentle to flat	<6	1.0
2	Gentle	6-18	1.2
3	Steep	18-35	1.5
4	Very steep	>35	2.0

(C) Drainage and Rock fragments

DRAINAGE

Class	Description	index
1	well drained	1.0
2	Imperfectly drained	1.2
3	Poorly drained	2.0

ROCK FRAGMENTS (Stoniness)

Class	Description	RF cover (%)	Index
1	Very stony	>60	1
2	Stony	20-60	1.3
3	Bare to slightly stor	<20	2

Soil quality index (SQI) is calculated as the product of the above attributes, according to the equation:

$$\text{SQI} = (\text{texture} * \text{parent material} * \text{rock fragment} * \text{depth} * \text{slope} * \text{drainage})^{1/6}$$

Table 2 Soil Quality Index (SQI)

SOIL QUALITY

Class	Description	Index
1	high quality	<1.13
2	Moderate quality	1.13 to 1.45
3	low quality	>1.46

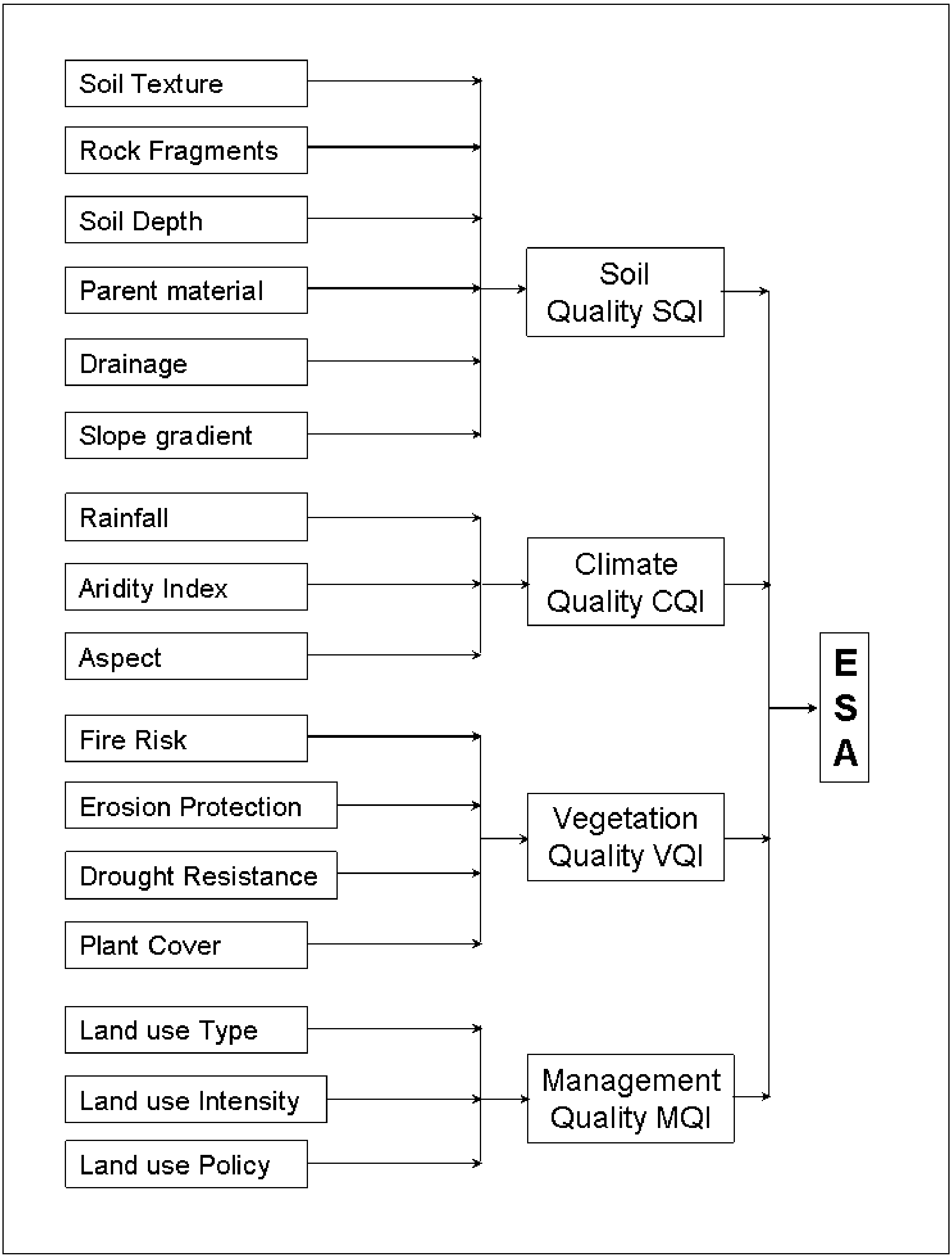

Figure 1. Indicators and qualities used for the definition of areas (environmentally) sensitive (ESA) to desertification

Annex III Climatic quality indices

[source: Medalus Manual (Kosmas *et al.*, 1999, p.39, 43)]

Climatic quality is assessed by using parameters that influence water availability to the plants such as amount of rainfall, air temperature and aridity, as well as any climate hazards as frost which might inhibit or even prohibit plant growth. Annual precipitation is classified in three classes, considering the annual precipitation of 280 mm as a crucial value for soil erosion and plant growth (Table 2).

Table 2. Classes and weighting indices for climate quality assessment

RAINFALL

Class	Rainfall (mm)	Index
1	>650	1
2	280-650	2
3	<280	4

CLIMATE QUALITY INDEX (CQI)

Class	Quality	Index range
1	High	<1.15
2	Moderate	1.15 to 1.81
3	Low	>1.81

ARIDITY

Class	BGI range	Index
1	<50	1
2	50-75	1.1
3	75-100	1.2
4	100-125	1.4
5	125-150	1.8
6	>150	2

Aspect is divided here into two classes: (a) NW and NE, and (b) SW and SE, assigned to indices 1 and 2, respectively.

The aridity index is estimated by the Bagnouls-Gaussen index (BGI) using the following equation:

$$BGI = \sum_{i=1}^{n} (2Ti - Pi)*k$$

Where: Ti is the mean air temperature for month i in 0°C,
Pi is the total precipitation for month i in mm;
k represents the proportion of month during which 2ti - Pi >0.

The three attributes above are then combined to provide the climate quality index (CQI) using the following algorithm, three classes being defined in Table 2.

$$CQI = (rainfall * aridity * aspect)^{1/3}$$

Annex IV Vegetation quality indices

[source: Medalus Manual (Kosmas *et al.*, 1999, p.38, 44)]

Vegetation quality is assessed in terms of: (a) fire risk and ability to recover, (b) erosion protection to the soils, (c) drought resistance, and (d) plant cover. The existing dominant types of vegetation in the Mediterranean region are grouped into four categories according to fire risk (Table 3). Also four categories are used for classifying the vegetation according to the protection for the soil from erosion (Table 3). Five categories are used for classification of vegetation with respect to drought resistance. Finally, three classes of plant cover are distinguished.

Table 3. Classes and weighting indices of parameters used for vegetation quality assessment

FIRE RISK

Class	Description	Type of vegetation	index
1	Low	bare land, perennial agricultural crops, annual agricultural crops (maize, tobacco, sunflower)	1
2	Moderate	annual agricultural crops (cereals, grasslands), deciduous oak, (mixed), mixed Mediterranean, *macchia*/evergreen forests	1.3
3	High	Mediterranean *macchia*	1.6
4	very high	pine forests	2

EROSION PROTECTION

Class	Description	Vegetation types	Index
1	Very high	Mixed Mediterranean *macchia*/evergreen forests	1
2	High	Mediterranean *macchia,* pine forests, Permanent grasslands, evergreen perennial crops	1.3
3	Moderate	Deciduous forests	1.6
	Low	Deciduous perennial agricultural crops (almonds, orchards)	1.8
4	very low	Annual agricultural crops (cereals), annual grasslands, vines	2

DROUGHT RESISTANCE

Class	Description	Types of vegetation	Index
1	Very high	Mixed Mediterranean *macchia*/evergreen forests, Mediterranean *macchia*	1
2	High	Conifers, deciduous, olives	1.2
3	Moderate	Perennial agricultural trees (vines, almonds, orchards	1.4
4	Low	Perennial grasslands	1.7
5	Very low	Annual agricultural crops, annual grasslands	2

PLANT COVER

Class	Description	plant cover (%)	index
1	High	>40	1
2	Low	10-40	1.8
3	very low	<10	2

VEGETATION QUALITY INDEX (VQI)

Class	Description	Index range
1	High quality	1 to 1.6
2	Moderate quality	1.7 to 3.7
3	Low quality	3.8 to 16

The vegetation quality index (VQI) is considered to be the product of the above vegetation characteristics, related to sensitivity to desertification using the following algorithm. Then the vegetation quality index is classified into three classes defining the quality of vegetation with respect to desertification. (Table 3).

$$\mathbf{VQI = (fire\ risk * erosion\ protection * drought\ resistance * vegetation\ cover\ )^{1/4}}$$

Annex V Management quality or degree of human-induced stress

[source: Medalus Manual (Kosmas *et al.*, 1999,p.39-41, 45-6)]

Land is classified into the following categories according to major land use for assessing the management quality or the degree of human induced stress:

a. Agricultural land – cropland, pasture
b. Natural areas – forest, shrubland, bare land
c. Mining areas (quarries, mines, etc.)
d. Recreation areas (parks, compact tourism development, tourist areas, etc.)
e. Infrastructure facilities (roads, dams, etc.)

After defining the type of land use, then the intensity of land use and the enforcement policy for environmental protection is assessed for the particular type of land use.

A. Land use intensity

Agricultural land-cropland: The intensity of land use of a cropland is classified into three classes (Table 4) based on the frequency of irrigation, degree of mechanisation of cultivation, application of fertilisers and agrochemicals, types of plant varieties used, etc. Land use intensity for plain areas is graded with 1 since there is no erosion.

Pasture land: The intensity of land use of pasture land is defining by estimating the sustainable stocking rate (SSR) and the actual stocking rate (ASR) for the various of land under grazing. The sustainable stocking rate (SSR) expressed in animals per hectares can be calculated from the following equation:

$$\mathbf{SSR = (X * P * F)/R}$$

where: R is the required annual biomass intake per animal (sheep or goat 187.5 kg animal^{-1} year^{-1}, FAO 1991),
X is the fraction including grazing efficiency and correction for biomass not produced during the latest growing season (grazed: 0.5, non-grazed 0.25 year^{-1}),
P is the average palatable biomass after the dry season (kg ha^{-1}),
F is the average fraction of the soil surface covered with annual plant species.

Then, the intensity of land use is assessed by using the ratio of ASR/SSR and classified into three classes (Table 4).

Natural areas: In natural areas such as forests, shrubland etc., the intensity of land use is defined by assessing the actual (A) and sustainable (S) yield. Then, the intensity of land use is classified into three classes based on the ratio A/S (Table 4).

Mining areas: The intensity of land use for areas with mining activities is defining by evaluating the measurements undertaken for soil erosion control such as terracing, vegetation cover, etc. Then, the intensity of land use is classified into three classes based on the evaluated degree of land protection from erosion (Table 4).

Recreation areas: In areas undergoing active recreational use such as skiing, rallies etc., the intensity of land use is evaluated by defined the actual and the permitted number of visitors per year (A/P). Then the land use intensity is classified into three classes based on the ratio A/P (Table 4).

B. Policy enforcement

Policies related to environmental protection are classified according to the degree to which they are enforced for each case of land use. The information on the existing policies is collected and then the degree of implementation/enforcement is evaluated. Three classes related to the policy on environmental protection are defined (Table 4).

The management quality index (MQI) is assessed as the product of land use intensity and the enforcement of policy for environmental protection using the following algorithm. Then the management quality is defined using Table 4.

MQI = (land use intensity * policy enforcement)$^{0.5}$

Table 4. Classes and weighing indices of parameters for land management quality assessment

CROPLAND

Class	Description	Index
1	low land use intensity (LLUI)*	1.0
2	Medium land use intensity (MLUI)	1.5
3	high land use intensity (HLUI)	2.0

* Land use intensity for plain areas is graded with index **1**

PASTURE

Class	Description	Stocking rate	Index
1	Low	ASR< SSR	1.0
2	Moderate	ASR=SSR to 1.5*SSR	1.5
3	High	ASR>1.5*SSR	2.0

NATURAL AREAS

Class	Description	Management characteristics	Index
1	Low	A/S = 0	1.0
2	Moderate	A/S < 1	1.2
3	High	A/S = 1 or greater	2.0

MINING AREAS

Class	Description	Erosion control measurements	Index
1	Low	Adequate	1.0
2	Moderate	Moderate	1.5
3	High	Low	2.0

RECREATION AREAS

Class	Description	A/P visitors ratio	Index
1	Low	>1	1.0
2	Moderate	1 to 2.5	1.5
3	High	>2.5	2.0

POLICY ENFORCEMENT

Class	Description	Degree of enforcement	Index
1	High	Complete: >75% of the area under protection	1.0
2	Moderate	Partial: 25-75% of the area under protection	1.5
3	Low	Incomplete: <25% of the area under protection	2.0

MANAGEMENT QUALITY INDEX (MQI)

Class	Description	Index range
1	High	1 to 1.25
2	Moderate	1.26 to 1.50
3	Low	>1.51

Annex VI Combining the results

[source: Medalus Manual (Kosmas *et al.*, 1999, p.47)]

The final step comprises the matching of the physical environment qualities (soil quality, climate quality, and vegetation quality) and the management quality for the definition of the various types of ESAs to desertification. The four derived indices are multiplied together for the assessment of the ESA index (ESAI) as following:

$$\mathbf{ESAI = (SQI * CQI * VQI * MQI)^{0.25}}$$

The ranges of ESAI for each of type of ESA (as defined above), including three subclasses in each type, appear in Table 5. Each type of ESA is defined on a three-point scale, ranging from 3 (high sensitivity) to 1 (lower sensitivity), in order that the boundaries of the successive classes of ESAs may be better integrated. It must be pointed out that the range for each type of ESA has been adjusted in such a way that it can include the various types of ESAs resulting from the various studies conducted in the target area of the island of Lesvos. This methodology has then been validated in two areas (a) the Agri basin (Italy) and (b) the Alentejo region (Portugal), which have been assigned as target areas for desertification studies in the frame of the EC research project MEDALUS.

Table 5. Types of ESA and corresponding ranges of indices

Type	Subtype	ESAI
Critical	C3	>1.53
«	C2	1.42-1.53
«	C1	1.38-1.41
Fragile	F3	1.33-1.37
«	F2	1.27-1.32
«	F1	1.23-1.26
Potential	P	1.17-1.22
Non affected	N	<1.17

The mapping symbol for each type of ESA includes the class and subclass, four suffixes corresponding to land use qualities ('s' for soil, 'c' for climate, 'v' for vegetation and 'm' for management) and four numbers indicating the degree of limitation for each quality (Figure 2).

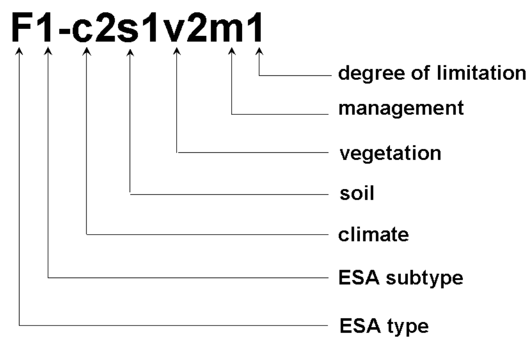

Figure 2. Mapping symbol used for characterisation of the ESAs to desertification

References

Kosmas, C., Kirkby, M. and Geeson, N. (eds) (1999). The MEDALUS Project: Mediterranean desertification and land use. Manual of Key indicators and mapping environmentally sensitive areas to desertification. EUR 18882 EN, 88pp. Office for Official Publications of the European Communities, Luxembourg.

Annex VII Additional information

[source: Medalus Manual (Kosmas *et al.*, 1999)]

Medalus Project:
Mediterranean desertification and land use Manual
Climate quality – additional information (p19, 20)

Precipitation

The atmospheric conditions that characterise a desert climate are those that create large water deficits, that is, potential evapotranspiration (ETo) much greater than precipitation (P). These conditions are evaluated by a variety of indices. One of these is the FAO-UNESCO (1977) bioclimatic index: P/ETo. Areas which are sensitive to desertification can be divided into the following categories:

i) The arid zone : $0.03<P/ETo<0.20$
ii) The semi-arid zone : $0.20<P/ETo<0.50$
iii) The sub-humid zone: $0.50<P/ETo<0.75$.

An area becomes naturally desertified when the ratio: P/ETo acquires values below a certain threshold, regardless of the other components. In contrast, when the ratio exceeds an upper threshold, desertification does not advance (FAO-UNESCO, 1977). The following scheme is proposed for the threat of desertification induced by the climate:

(DESERTIFICATION) 0.03 > P/ETo > 0.75 (NO DESERTIFICATION)

Erosion data collected in various sites along the Mediterranean region shows that the amount of annual rainfall of 280-300 mm is very crucial (Fig. 6). There is a tendency of increasing runoff and sediment loss with decreasing rainfall in hilly Mediterranean shrublands, especially in the region where rainfall is greater than 300 mm/year. Below to that limit, runoff and sediment loss decrease with decreasing rainfall.

Climate

The following data on climate are required for the assessment of climate quality:
i) Temperature-mean monthly air temperature (deg C)
ii) Precipitation-mean monthly precipitation amount (mm)
iii) Frost-mean monthly number of days with minimum temperature < 0 deg C
iv) Potential evapotranspiration-mean monthly potential evapotranspiration (mm).

A regionalization of the climate data is required for deriving climate maps. The regionalization can be achieved by creating Thiessen polygons around each climate station. Corrections of Thiessen network can be made, where appropriate, in order to take into account topographic factors.

References

Kosmas, C., Kirkby, M. and Geeson, N. (eds) (1999). The MEDALUS Project: Mediterranean desertification and land use. Manual of Key indicators and mapping environmentally sensitive areas to desertification. EUR 18882 EN, 88pp. Office for Official Publications of the European Communities, Luxembourg.

DE02	Land area burnt by wildfire

Definition: (indicator) the extent of land that has been subjected to the process of wildfire over one year (km^2 yr^{-1}).

Table 1 Parameters (preferred parameters are in black, alternative parameters are in grey); A=Actual (measured), M=Modelled

Required	Units	Type	Spatial Resolution
EFFIS data	Various	M & A	50 ha

Step 1:

i) Apply the EFFIS[12] 'rapid damage assessment' tool for forest fires (http://effis.jrc.ec.europa.eu/wmi/viewer.html)
ii) Contact EFFIS for bespoke damage assessments (effis@jrc.it)

Table 2 Materials and equipment (preferred parameters are in black, alternative parameters are in grey)

Required	Description
EFFIS database	The European Forest Fire Information System (EFFIS) has been established by the Joint Research Centre (JRC) and the Directorate General for Environment (DG ENV) of the European Commission (EC)

[12] European Forest Fire Information System

3. APPENDIX I

Topsoil sampling for physico-chemical analyses

ENVASSO refers to ISO 10381-2:2002 for guidelines regarding the procedures for topsoil sampling for the purpose of physico-chemical analyses. The following additions, preferences and changes are suggested by ENVASSO:

1. Sampling area and scheme

The sampling area should not be smaller than 100 m², as repeated sampling in time may induce changes linked to the effect of the sampling itself. The sampling area should not be greater than 1 ha, as many subsamples would be required.
We recommend avoiding the extreme situations (i.e. very dense sampling in a small area or very few subsamples in a large one). In all cases, a unique sample should be avoided if the aim is to monitor changes on a given site. We recommend to take at least 4 subsamples for every 100 m^2 of sampling area. It is recommended that the exact location of subsamples is known in order to avoid these locations in a further re-sampling procedure, e.g. by recording differential GPS coordinates for each subsample location (WGS84 in decimal degrees).

Organic layers at the soil surface should be sampled separately from the underlying organo-mineral soil. For organo-mineral layers, we recommend to adopt systematic depths in order to:

- Avoid subjectivity in sampling
- Harmonise sampling protocols
- Facilitate comparisons between SMNs

The best practice would be to sample both by depth increments in the site and by pedogenetic horizons in soil pits, near, but outside the monitoring area

We recommend that sampling is done so as at least concentrations or stocks of elements could be calculated for depths ranging 0-15 cm to 0-30 cm, as well as at a second depth of 15-30 cm to ca. 50 cm. If the parent material occurs within 15 cm to 50 cm then the second depth sampling should be until the start of the parent material. The exact sampling depths should be measured at each soil monitoring site and recorded.

2. Sample storage

We recommend to sample and store higher quantities (from 3 to 10 kg) as we do not know which quantities future determinations will require.

3. Hand-operated auger techniques

In Annex A of ISO 10381-2:2002, only A.1.1 (hand-operated auger techniques) is relevant to ENVASSO

4. ENVASSO GLOSSARY OF KEY TERMS

"*For science it is essential that there be a diversity of opinion.*
[…]
The policy maker, on the contrary, expects the scientist to remove all doubt."

Kuenen, 1987

4.1 INTRODUCTION

The aim of this glossary was to create common understanding and consistent terminology between ENVASSO work packages and consortium members. Existing definitions have been used where appropriate and fully referenced. New definitions have been formulated for existing terms for which no referenced definition exist *or* when the term is used in a specific context in ENVASSO. Figures have been introduced to illustrate definitions or to identify differences between terms.

4.2 TABLE OF TERMS

Reference = the source of the definition (if the term is unique to ENVASSO, or specifically defined in the ENVASSO context this is specified as 'ENVASSO').
Input author = initials of the person responsible for entering the definition and/or term
Org. = the relevant organisation (project partner) of the input author
WP = the work package for which the term is most relevant, or where the term was first used

Term	**Definition** (incl. 'usage sections' and underlining cross references where appropriate)	**Reference**
Distributed system	communication of (harmonized) data between infrastructures (different web mapping services) based on 'GetCapabilities' (→*interoperability)*; functions and services of different information systems can be accessed and exchanged in real time without download	
Accelerated soil erosion	Soil erosion, as a result of anthropogenic activity, in excess of natural soil formation rates causing a deterioration or loss of one or more soil functions	ENVASSO; Based on SSSA (2001)
Acceptance of methodology	(selection criterion) The degree to which a methodology is regarded, by the scientific community, to be based on sound science	ENVASSO
Actual landslide potential	(indicator) an analysis of landslides that have occurred in the past and often expressed as a map delineating areas that are at risk of future landslides	ENVASSO
Agricultural land	i) land used for farming, agricultural, horticultural, viticulture, vegetable-growing, market gardening, pastoral, grazing, poultry farming, silvicultural, floricultural or piscicultural purposes, and (ii) any other land declared to be farm lands for the purpose of soil legislation	Hannam & Boer (2004)
Air capacity	(indicator) the proportion of the total pore space which can be occupied by gases (usually air) but may be occupied by liquids (water) when the soil is saturated **(%,** w w^{-1}) Usage: The air-filled pore volume is also called the air capacity (C_a) which is usually measured at a specific suction, e.g. 3, 5, 6 kPa or sometimes at a slightly higher suction. Air capacity is the total pores space minus the volumetric water content (θ) at the chosen suction. Hall *et al.* (1977) define air capacity as: $C_a = T - \theta_{v(5kPa)}$. Air capacity is used as a measure of the volume of coarse pores, if at 5kPa this is the volume of pores > 0.06mm	
Air-filled pore volume	See 'air capacity'	ENVASSO; based on Hall *et al.* (1977)
Anecic earthworms	species of earthworm that are capable of burrowing and normally have burrows that are open at the surface. They feed on leaf litter that they find at the surface and mix it	Lee (1985) Lavelle *et al.* (1987)

	within the soil horizons. This type of earthworm is responsible for the formation of surface casts, and they have a slow growth rate and a low fecundity	
Application schemas	INSPIRE data specification: application schemas independent of the data model of the base data	
Area suitable for permanent human living space	(Synonym of: potential permanent settlement area) The entire area of the assessment unit (e.g. national territory) minus at least the following categories of land use/land cover: water surface area, alpine area, protected areas, protected forests, risk zones exposed to floods and other natural hazards, other areas that are not available for development purposes because of other legal constraints (e.g. water protection zones, areas that exceed critical thresholds of noise emissions, etc.).	ENVASSO
Availability of baselines and thresholds	(selection criterion) The degree to which scientific thresholds and baselines have been established for the evaluated indicator.	ENVASSO
Background content	concentration of a substance characteristic of a soil type in an area or region arising from both natural sources and non-natural diffuse sources, such as atmospheric deposition Usage: Commonly expressed in terms of average, typical, median, a range of values or a background value.	ISO 11074:2005
Background value	Statistical characteristic of the background content	ISO 11074:2005
Baseline	minimum or starting point of indicator values (e.g. measurement which serves as a basis to which all following measurements are compared; a characteristic value - such as the background value - for an element content in soil)	ENVASSO
Benchmark site/reference site	(ISO: permanent monitoring areas) Representative areas according to specific criteria where soils are investigated over long periods to obtain reliable information on the effects of environmental influences Usage: Benchmark sites may be nested into a soil monitoring network. Their purpose is to monitor soil profile change and to monitor threats requiring representative sites and more intensive 'early warning' general monitoring (by measuring all indicators, i.e. not just the top3).	ISO 11074:2005
Biogeographic region	Area throughout which animal and plant distributions have similar or shared characteristics	Based on Encylopaedia Britannica
Biological diversity	The variability among all sources, including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems	UNEP (1992)
Biological functions	(key issue) maintenance and functioning of specific ecosystems or habitats; driving processes such as soil formation, nutrient cycling and nitrogen fixation; assist in the maintenance of soil structure and provide a source of symbiotic soil fungi on which many plants depend; and to counteract the effects of environmental stresses through the breakdown of chemical contaminants and pathogens	
Biowaste	All exogenous organic materials (usually by-products or residues from farming and industry) that can be used as safe soil amendments	ENVASSO

Brownfield	Land that has been used previously for settlement and industrial or commercial purposes, but is currently not used for these purposes, and may be derelict Usage: This includes sites that have been used for mining, quarries, waste dump sites, military installations, and similar uses.	ENVASSO
Bulk density	(indicator) The apparent density of field soil calculated from the oven-dry (105°C) mass divided by the volume occupied in the field. The value is expressed as Mg per cubic metre, Mg m^{-3} , or t m^{-3} (abbreviated as D_b)	Hall *et al.* (1977)
Carrying capacity	See 'critical load'	
Causes of soil organic matter changes	(key issue) The factors controlling soil organic matter dynamics Usage: Some are inherent soil properties (e.g. clay or clay+silt contents), others are external or human induced factors (e.g. climate, land cover, land use, agricultural practices, etc.).	ENVASSO
Coastal erosion	(key issue) The wearing away of the land surface by the actions of marine waves, through their fourfold process of hydraulic action, corrosion, attrition and solution. Usage: In excess to the loss of soil, coastal erosion causes severe damage in many areas and high costs for society. Commonly, there is no serious problem until structures are built within the impact zone of storm surges or close to soft rock cliffs. Probably the most important consequence of coastal erosion is flooding (Jones *et al.*, 2004)	Based on Whittow (1984)
Collembola	The largest order of modern hexapods that are no longer considered to be insects. Usage: Commonly known as 'springtails'. Normally less than 6 mm in size. Feed on dead organic matter.	Wikipedia
Contaminated land	A geographical area with confirmed presence of 'dangerous substances' caused by man in such a level that they may pose a significant risk to a receptor in such a way that action is needed to manage the risks. The risk is evaluated on a site-specific base taking into account current and expected use of the site.	Van Camp et al (2004g)
Combinable crops	Any arable crop that can be harvested with a combine (e.g. cereals, oil seeds, beans etc.)	ENVASSO
Composite sample	Sample resulting from the planned aggregation or the combination of sample units (ISO 11074:2005; bulk sample)	ISO 11074:2005
Comprehensibility	(selection criterion) The degree of expert knowledge needed to interpret the information on the status of a soil threat provided by an indicator Usage: The less expert knowledge required, the better the comprehensibility. Indicators should be relatively easy to interpret to facilitate communication of results provided by indicators to the public and decision makers. Particularly the final information should be logical and easy to interpret, behind that, complex functions/models can be used, but have to be combined in a logical and clear structure.	ENVASSO
Cone	An instrument in the form of a cylindrical rod with a cone-	SSSA

penetrometer	shaped tip designed for penetrating soil and for measuring the end-bearing component of penetration resistance. Usage: The resistance to penetration developed by the cone equals the vertical force applied to the cone divided by its horizontally projected area. It is used to detect compacted layers (horizons) in the soil.	
Contaminant	a substance or agent present in the soil as a result of human activity	(ISO11074)
Contaminated site	A location where a substance or agent has been introduced into the soil as a result of human activity.	ENVASSO
Criterion	A standard of judging, or rule or test by which something may be judged	Oxford Dictionary of English (2003)
Critical load	The maximum load that a given system can tolerate before failing Usage: Carrying capacity is the ability of eco-systems/the Earth to bear environmental load without significant damage. The threshold is the critical load	EEA
Critical load exceedance	The quantity of atmospheric deposition of a pollutant to soil above the critical load (kg ha^{-1} yr^{-1})	
Critical load exceedance of sulphur and nitrogen	(indicator) the quantity of atmospheric deposition of sulphur and nitrogen to soil above the critical load for a specified period of time (kg ha^{-1} yr^{-1})	
Cumulative estimated soil erosion value	The sum of the individual estimated soil erosion values for water, tillage and wind erosion	
data bases management system (DBMS)	the coordination of data entry, storage and retrieval of data from a data base. Usage: By realizing this, it must consider specific criteria such as those related to data integrity (accuracy, correctness, validity in a relational DBMS)	
Data requirement	Property that the data, generated by an indicator, that is required for application at the European scale, based on expert knowledge. Usage: Main requirements are the input parameters, the spatial resolution and the frequency of monitoring in order to provide scientifically sound and representative assessments.	ENVASSO
Decline in soil biodiversity	(soil threat) Reduction of forms of life living in the soil (both in terms of quantity and variety) and of related functions, causing a deterioration or loss of one or more soil functions	ENVASSO; based on Jones *et al.* (2005)
Decline in soil organic matter	(soil threat) A negative imbalance between the build-up of soil organic matter and rates of decomposition leading to an overall decline in soil organic matter contents and/or quality, causing a deterioration or loss of one or more soil functions	ENVASSO
De-sealing	(indicator) The process of regaining land area with its original soil by removing, completely or partially, its impermeable cover of settlement structures, concrete, tarmac etc.	ENVASSO

Desertification	(key issue and soil threat) land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities, causing a deterioration or loss of one or more soil functions	Based on UNCCD, Article 1, 1994
Detection limit	Minimum unit of a measurement that can be analysed Minimum concentration of a substance to be determined by laboratory analyses	ENVASSO
Diffuse soil contamination	Soil contamination caused by different sources, where emission, transformation and dilution of the pollutants in other media have occurred, so that the relationship between the pollution source and the soil contamination is indistinct. Usage: It is generally associated with atmospheric deposition, certain farming practices and inadequate waste and wastewater recycling and treatment. Atmospheric deposition (including N-deposition) and acidification is due to emissions from industry, transport, households and agriculture.	(EEA-UNEP, 2000).
Diffuse source input	the input of a substance emitted from moving sources, from sources with a large area, or from many sources	(ISO 11074).
Directed nested sampling	(see also figure 1)	
Dissolution erosion	(key issue) The wearing away of the land surface by water flowing underground dissolving soil and rock material. Also known as 'chemical denudation'.	ENVASSO
Dutch auger	A soil sampling implement that takes internal cores of soil. Usage: Sometimes referred to as 'Edelman auger' after its original manufacturer. 	
Earthworm	Burrowing soil organism that belong to the order *Oligochaeta* (class *Clitellata*, phylum *Annelida*) and feed of undecayed, dead organic matter. Usage: Adult individuals range from a few cm to 1 m in length. Also referred to as 'megadrile'. Earthworms can be classed as anecic, endogeic, or epigeic	Based on ISO23611-1:2005
EC	(acronym,) electrical conductivity	
Ecosystem functions	The capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly Usage: Gas regulation is one of the 'ecosystem regulation functions'. Associated ecosystem processes and components are 'bio-geochemical cycles' (e.g. CO_2/O_2 balance, ozone layer, etc.). Associated goods and services are UVb-protection by O_3 (preventing disease), maintenance of (good) air quality, influence on climate, etc.	
Effective mesh	the degree and intensity of landscape fragmentation by	ENVASSO

size	the high-ranking road network Usage: It represents an intensive and area-proportionate, additive measure and has proven to be well-suited for comparing the fragmentation of regions with differing total size.	
Electrical conductivity	Conductivity of electricity through water or an extract of soil. Usage: Commonly used to estimate the soluble salt content in solution	SSSA
Endogeic earthworms	Endogeic: species of earthworm that form burrows that are not open to the surface and that feed mainly on soil organic matter and plant roots. They live in the upper soil horizons (normally the top 15 to 20 cm	Lee (1985); Lavelle *et al.* (1987)
ENVASSO	(acronym) ENVironmental ASsessment of Soil for mOnitoring Usage: The project acronym is used to refer to the project (FP6; contract No. 022713) as well as its outputs. The objective of ENVASSO is to design and test a single, integrated, EU-wide operational set of measurable criteria and indicators as a basis for a harmonised and comprehensive European soil and land information system	
Environment Information System	Overarching information system which links sectoral and disciplinary information (e.g. climate, soil water, geology, etc.)	
Epigeic earthworms	species of earthworm that feed on, and live in, the leaf litter. They are unable to burrow into the soil and are most commonly found in woodland environments. These species normally have a high fecundity and short life expectancy	Lee (1985); Lavelle *et al.* (1987)
Erosion control	(key issue) the implementation of techniques that reduce or minimise erosion by water and/or wind Usage: Commonly these are contour ploughing, minimum or no-tillage, terracing, planting ground cover crops, re-afforestation, reduction in stocking densities, laying of geo-textiles, wind-breaks etc	ENVASSO
ESA	(acronym) Environmentally Sensitive Area	
esd	(acronym) Equivalent spherical diameter	
ESDI	(acronym) European Spatial Data Infrastructure	
ESP	(acronym) Exchangeable Sodium Percentage	
Estimated soil loss by rill, inter-rill and sheet erosion	(indicator) the quantity of soil estimated to be lost by the processes of rill inter-rill and sheet erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). Soil loss is by a harmonised process model using the soil data combined with climatic, vegetation (cover), and topographic data. The estimated soil loss by the process model is validated by comparison with erosion measurements (ER02) from a representative subset of monitoring sites in a soil monitoring network.	ENVASSO
Estimated soil loss by tillage erosion	(indicator) the quantity of soil estimated to be lost by the processes of tillage erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). Soil loss is by a harmonised process model using the soil data combined with climatic, crop type, and harvest data. The estimated	ENVASSO

	soil loss by the process model is validated by comparison with erosion measurements (ER08) from a representative subset of monitoring sites in a soil monitoring network	
Estimated soil loss by wind erosion	(indicator) the quantity of soil estimated to be lost by the processes of wind erosion from a hectare of land during a period of one year (t ha^{-1} yr^{-1}). Soil loss is by a harmonised process model using the soil data combined with climatic, vegetation (cover), and topographic data. The estimated soil loss by the process model is validated by comparison with erosion measurements (ER06) from a representative subset of monitoring sites in a soil monitoring network	ENVASSO
Exchangeable sodium percentage	(indicator) Exchangeable sodium (Na^+) fraction expressed as a percentage. Acronym = ESP.	SSSA
Exploratory investigation (phase 2)	Collection of samples for analysis to confirm the hypothesis concerning soil quality from phase 1 investigation and to provide information to enable the design of the main investigation (phase 3)	ISO 11074
eXtensible Mark up Language (XML)	Standard for generating documents readable to machines and humans in the form of a document tree defined by the World Wide Web Consortium (W3C). XML defines the rules for the structure of such documents. XML application: defines structural elements and their arrangement within the document tree	
Fact sheet	Description of an indicator, for a key issue of a soil threat, which provides sufficient information for the application of the indicator in a soil monitoring system	ENVASSO
Farmyard manure	The excreta of animals mixed with bedding (usually straw) or litter, fresh or at various stages of further decomposition or composting (acronym: FYM).	Based on SSSA
Fragmentation	The process of spatial segregation among entities that need to be together in order to function optimally	Carsjens, 2000
FYM	(acronym) FarmYard Manure	
Genetic diversity within species	The variety of genes within a particular species, variety or breed	EEA
Geographic Mark up Language (GML)	An XML standard for encoding of spatial data, developed by the Open Geospatial Consortium (OGC). Usage: In GML the positions of map data annotations are expressed in geographic or pixel coordinates; GML handles the spatial elements of thematic objects	
Geographical coverage	(selection criterion) The area where an indicator, or input parameters needed to calculate the indicator, have already been measured or monitored. Usage: For the selection of indicators special attention is given to indicators that are already implemented, especially if the coverage across Europe is large. The advantage is a wide applicability and most likely a high acceptance. But this should not hinder innovation, if another indicator is more suitable to illustrate the key issue.	ENVASSO
GeoScience Markup Language (GeoSciML)	A discipline- or theme-specific XML that interchanges digital geoscientific data Usage: GeoSciML is the focus of an ongoing project of the IUGS Commission for the Management and Application of	

	Geoscience Information (CGI). GeoSciML is expected to develop as the XML implementation (interchange format) for geosciences. Another example of a theme-specific XML is XMML: eXploration and Mining Markup Language; it contains elements, such as those for boreholes.	
Gouge auger	A hand-held soil sampling implement consisting of a halved (lengthwise) cylinder used for organic soils 	
GPS	(acronym) Global Positioning System	
Greenfield	Land on which no urban development has previously taken place; usually defined as 'greenfield' where located on the periphery of an existing built-up (urban) area	EEA
Gross nutrient balance	(i) The difference between the total quantity of nutrient inputs entering the soil and the quantity of nutrient outputs leaving the soil annually. (ii) Condition in which there is equilibrium between intake and excretion of nutrients.	Based on EEA
Ground	synonym of 'land'	
Harmonised sampling	Sampling that has been conducted according to agreed procedures compatible with the requirements of the sampling campaign	ENVASSO
Harmonization (INSPIRE)	The process of providing access to data through network services in a representation that allows for combining it with other spatial data in a coherent way, i.e. known coordinate reference system and geometry type. Usage: This can be achieve by developing and applying a common data model and data level harmonization (e.g. edge matching in border areas); to be pragmatic: 'harmonisation' can be achieved through interoperability in service-based architectures (e.g. raster maps in a web mapping service using common georeferencing) rather than (full) harmonisation of the underlying data models. Data harmonisation within the European spatial data infrastructure (ESDI) means that all countries use a common set of coordinate reference systems, data model, classification system, etc.	
Heavy metal contents of soil	(indicator) The measured gravimetric proportion of a heavy metal in dry soil at a monitoring site (mg kg^{-1})	ENVASSO
Human activity	Something that people do or cause to happen	http://wordnet.princeton.edu/man/wnglo ss.7WN
Indicator	Measure, generally quantitative, that can be used to illustrate and communicate complex phenomena simply, including trends and progress over time. Usage: It provides relevant and meaningful information on key issues about soil threats. An indicator provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. An indicator is a sign or symptom that makes something known with a reasonable degree of certainty. An indicator	EEA (2005)

	reveals, gives evidence, and its significance extends beyond what is actually measured to a larger phenomenon of interest.	
INSPIRE	(acronym) INfrastructure for SPatial InfoRmation in Europe Usage: A proposed Directive of the European Parliament and the Council	http://www.ec-gis.org/inspire/:
INSPIRE compliant	In accordance with the principles of INSPIRE Usage: Data should be collected once and maintained at the level where this can be done most effectively • It should be possible to combine seamlessly spatial data from different sources and share it between many users and applications • Spatial data should be collected at one level of government and shared between all levels • Spatial data needed for good governance should be available on conditions that are not restricting its extensive use • It should be easy to discover which spatial data is available, to evaluate its fitness for purpose and to know which conditions apply for its use.	EC (2004)
Interoperability (INSPIRE)	(within the ESDI) a data infrastructure option where each country maintains their own infrastructure, but adopts a framework that enables existing datasets to be linked up from one country to another, e.g. via transformation or translation	
ISO	(acronym) International Organisation for Standardisation (original from French: Organisation Internationale de Normalisation)	
Judgmental sampling	(see also figure 1)	
Key issue	Specific process, or group of processes, that form a single unit suitable for addressing in soil monitoring. Usage: A key issue is a subdivision of a soil threat, and may be represented by one or a number of indicators	ENVASSO
Land	The entire complex of surface and near surface attributes of the solid portions of the surface of the Earth that are not permanently covered by liquid water	Based on SSSA
Land consumption	(key issue) Land development for settlement-related human activities by which previously undeveloped land is urbanised, i.e. agricultural, forest or natural land are turned into built-up areas. Usage: Consumed land comprises both sealed & unsealed areas	ENVASSO
Land information system	Computerised system storing information about the land and soil, comprising both spatial and attribute data. Most land information systems are structured on a relational model and have data management and modelling capabilities.	
Land take	(indicator) the area of land that enters the land use of infrastructure (from another land use) and other facilities that accompany it, such as service stations on roads and	ENVASSO

	railway stations, during one year (ha yr^{-1}, % yr^{-1})	
Land use	Type of activity for which the land is used, e.g. agriculture, forestry, viticulture, recreation, urban etc.	
Land cover	Plants, vegetation, infrastructure actually covering the ground surface	
Land degradation	Damage to and destruction of land (and soil) and the functions normally performed as a result of erosion by water and wind, salinisation, acidification, contamination (both diffuse and local), damage to life in soils, compaction, surface sealing and excavation.	Tutzing Project
Landslide	The movement of a mass of rock, debris, artificial fill or earth down a slope, under the force of gravity. Usage: This '*en masse*' movement (or slope failure) may be induced by physical processes such as excess rainfall, snow melt or seismic activity, or it may be a consequence of human interference with slope morphology (e.g. constructing artificially over-steepened slopes), which affects slope stability.	Based on Cruden & Varnes (1996)
Landslide hazard assessment	(indicator) the likelihood of a specified area to be subjected to the process of landsliding (classes)	ENVASSO
Local soil contamination	(key issue) Soil contamination affecting areas with a high density of urban agglomeration, or with a long tradition of heavy industry or occurring in the vicinity of former military installations. Usage: The seriousness of the problem is linked to its consequences on human health and ecosystems, and its irreversibility. The major impact is often a limited access to resources such as clean drinking water	Based on (EEA-UNEP, 2000).
Main investigation (phase 3)	Accurate evaluation of the soil quality for contaminants and all other information necessary for identification and assessment of risks and to enable decisions to be made about the need for remedial actions and for preliminary decisions about the nature of the works required	ISO 11074
Measures completed	Land use restrictions or remediation and/or safety measures to reach different quality targets are realised.	EEA (2006)
Mineral soil	A soil consisting predominantly of, and having its properties determined predominantly by, mineral matter. Usually contains <200 g kg^{-1}organic carbon (< 120-180 g kg^{-1} if saturated with water), but may contain an organic surface layer up to 30 cm thick.	SSSA
Microbial decomposition	See 'soil microbial respiration'	
Microbial respiration	See 'soil microbial respiration'	
Monitoring site	See 'soil monitoring site'	
Minimum indicator set	The smallest number of indicators required to monitor soil in the EU, for all identified soil threats, to a level which is regarded appropriate (by experts) for the present and the medium to long term future, i.e. 10 to 100 years	ENVASSO
NASIS	(acronym) NAtional Soil Information System Usage: NASIS is the core component of a vision which shifts the focus of the National Cooperative Soil Survey from the production of static printed soil survey reports to providing a dynamic resource of soils information for a wide range of	

	needs and is designed to manage and maintain soil data from collection to dissemination. (http://www.ia.nrcs.usda.gov/about/iowaglossary.html)	
National sampling strategy	Spatial pattern of monitoring sites in a country	ENVASSO
Natural soil formation rates	The rate at which soil material is added to a soil via the processes of parent material weathering and dust deposition, expressed in t ha^{-1} yr^{-1}. Usage: In Europe, the natural soil formation rates range from about 0.3 – 1.0 t ha^{-1} yr^{-1}	
Nested random sampling	(see also figure 1)	
Occurrence of landslide activity	(indicator) the number and extent of landslides that have occurred in a specified area over a specified time period (No. km^{-2}, ha km^{-2}).	ENVASSO
OGC	(acronym) Open Geospatial Consortium	
Organic farming	(indicator) Crop production system that reduces, avoids or largely excludes the use of synthetic compound fertilizers, pesticides, growth regulators, and livestock feed additives.	SSSA
Organic soil	A soil in which the sum of the thicknesses of layers containing organic soil materials is generally greater than the sum of the thicknesses of mineral layers	SSSA
Packing density	(indicator) The mass of dry soil per unit bulk volume, using the clay content. Usage: The term 'Lagerungsdichte (L_d)' is defined as D_b + 0.009 C, where C is the clay content (%, gravimetric) and the units Mg (or tonne) per cubic meter, Mg m^{-3} or t m^{-3} (abbreviated as PD)	Renger (1971); Hodgson, (1997 p.46-51)
Organic soil materials	Soil materials that are saturated with water and have 174 g kg^{-1} or more organic carbon if the mineral fraction has 500 g kg^{-1} or more clay, or 116 g kg^{-1} organic carbon if the mineral fraction has no clay, or has proportional intermediate contents, or if never saturated with water, have 203 g kg^{-1} or more organic carbon.	SSSA
Parent material	Unweathered inorganic solid or unconsolidated rock, from which soil is developing or originated (C-horizon)	ISO 11074
Parser	software that reads, interprets and – if needed – validates XML data	
Particulate organic matter	Particulate organic matter (POM) is a labile fraction of soil organic matter, mainly constituted of incompletely decomposed plant residues. Usage: POM is usually separated by physical separation by size (i.e. OM particles > 50 µm or by density (light fractions)). POM is very sensitive to changes in soil management and is rapidly depleted on cultivation of virgin soils	ENVASSO
Peat	Sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material Usage: "Sedentary" (cf. Von Post 1922) is used in this document to mean formed on the spot and not transported after its formation and death. Peat differs in this respect from organic sediments like gyttjas and folisols (Blattmudde, "Waldtorf"), which originate from organic matter "falling" from above (planktonic material, resp. leaves and	Joosten & Clarke (2002)

	branches) (cf. Pakarinen 1984). Peat may have a sedimentary component (e.g. derived from algae in hollows, seeds and leaves, or in case of spring and flood mires consisting of mineral material), but a strict sedentary component derived from non-aquatic plants should always be present (cf. Succow & Stegmann 2001a). 10 Varying with country and scientific discipline, peat has been defined as requiring a minimal content of 5, 15, 30, 50, 65% or more (dry mass) of organic material (cf. Andrejko *et al.* 1983, Agriculture Canada 1987, Driessen & Dudal 1991, Succow & Stegmann 2001b). The organic matter content is of importance for the use of peats. The different approaches, however, probably do not lead to strongly different global volumes of “peat” (Joosten 1999). The definition used here is proposed so as to provide this document with a consistent term. The 30% is a value often encountered in definitions of peats and organic soils in international literature. 11 Peat may contain living organisms and (living and dead) biomass, even in deep layers, including micro -organisms, spores, and living roots (Cf. Belanger et al 1988, Küster 1990), but these do not dominate (Joosten & Couwenberg12 By “organic” is meant that the material results from carbon chemical biosynthesis. Organic materials belong to the larger group “organogenic” materials, which include all substances that have originated from organisms. For example, corals are organogenic, but not organic, sedentates (Joosten & Couwenberg 1998).	
Peat soil	An organic soil in which the plant residues are recognizable. The sum of the thicknesses of the organic layers are usually greater than the sum of the thicknesses of the mineral layers.	SSSA
Peat stock	(indicator) the mass of peat estimated for a specified area (Mt)	ENVASSO
Peatland	An area, with or without vegetation, where a natural peat layer has accumulated at the surface Usage: Varying with country and scientific discipline, peatlands have been defined as having a minimum thickness of 20, 30, 45, 50 or 70 cm of peat. This question is discussed in detail in work on soil classification – for example in Agriculture Canada 1987. See also Joosten & Couwenberg 1998. The definition used here is proposed so as to provide this document with a consistent definition. It should be noted that – to provide a uniform standard – the inventories in section 2.4 use a minimum peat depth of 30 cm to which all available data were recalculated.	Joosten & Clarke (2002)
Penetrometer resistance	(indicator) A transient localized soil property which is a combined measure of a given pedon's, horizon's, or other soil subunit's solid phase adhesive and cohesive status. Usage: This property is most easily affected by changes in soil water content and bulk density, although other factors including texture, mineralogy, cementation, cation composition and organic matter content also affect it. *In situ* characterization with soil penetrometer is the most common agricultural measure of soil strength, although measurements of other engineering components of	SSSA

	strength on disturbed samples are also regarded as valid characterizations.	
Persistence	(indicator) Resistance of a substance to chemical changes Usage: Note 1 Persistence is always related to environmental conditions. Thus, a substance may be persistent in one soil, but not in another. Note 2 Persistence may be expressed as the half-life of a substance under clearly defined environmental conditions.	ISO 11074
Persistent organic pollutant (POP)	A class of chemicals that persist in the environment, are capable of long-range transport, bioaccumulate in human and animal tissue, and have significant impacts on human health and the environment. Usage: They include such substances as dioxin, PCBs, DDT, brominated flame-retardants or tributyltin (TBT). POPs released to the environment can travel through air and water to regions far distant from their original source.	Wikipedia
Piston Sampler	A hand-held soil implement for sampling saturated and/or non-cohesive soil 	
Pitchfork	A two to four pronged fork used for (Figure x) 	
Policy relevance	(selection criterion) The thematic coincidence of an indicator with key topics of the current agenda of soil policies. Usage: In order to be of value for decision-making, key issues and indicators should be related to the objectives of the EU Thematic Strategy for Soil Protection and other initiatives for environmental protection already in place	ENVASSO
Pollutant	Substance or agent present in the soil (or groundwater) which due to its properties, amount or concentration causes adverse impacts on soil functions	ISO 11074
Polluted site	A location where, as a result of human or natural activity, an unacceptable risk to human health, animal health and ecosystem functioning exists. Usage: Local pollution (polluted sites) is a problem in restricted areas (or sites) around the source, where there is a direct link to the source of pollution.	ENVASSO
Pore volume	The portion of soil bulk volume occupied by soil pores. The value is expressed as %. In Europe pore volume is also called 'total pore space' or 'total porosity' (T). T = (1-Db/Dp)100, where Dp is the particle density.	Based on SSSA
potential permanent settlement area	(Synonym of: area suitable for permanent human habitation:) The entire area of the assessment unit (e.g. national territory) minus at least the following categories of land use/land cover: water surface area, alpine area, protected areas, protected forests, risk zones exposed to	ENVASSO

	floods and other natural hazards, other areas that are not available for development purposes because of other legal constraints (e.g. water protection zones, areas that exceed critical thresholds of noise emissions, etc.).	
Potential salt sources	(indicator) the identification of secondary salinisation caused by either salty groundwater (e.g. by natural groundwater fluctuations, seepage from reservoirs) or salty irrigation water (by high salt content water sources, or by irrigation water dissolving salts during its flow from the pumping station to the irrigation field in unlined earth canals	ENVASSO
Potentially contaminated site	Any site where soil contamination is suspected but not verified and investigations need to be carried out to verify whether relevant impacts exist.	CSI015 fact sheet, EEA 2006)
Practicability	(selection criterion) The degree to which efforts are needed for monitoring, data gathering and for indicator calculation. Usage: A low degree means high practicability. High practicability would trigger acceptance of application from decision makers. This criterion is strongly linked with data availability. In order to be operational, indicators should be easily measurable and quantifiable	ENVASSO
Preliminary investigation (phase 1)	Desk study and site reconnaissance	ISO 11074
Primary soil salinisation	See 'soil salinisation'	
Procedure	A method of proceeding from a stated point or topic	ENVASSO
Procedures and protocols	The formal or official record of scientific experimental observations' necessary to establish inventories of soil and monitor the TOP3 indicators defined by the ENVASSO Consortium Usage: Some of these protocols are already established within the discipline of soil science, others have not been formally defined in such a way before but the definitions herewith are accepted with the ENVASSO Project. They provide a step-by-step approach, together with all the ancillary information required, to arrive at robust indicator values for the threats to soil at each inventory/monitoring site.	ENVASSO
Progress in the management of contaminated sites	(indicator) the proportion of contaminated sites where a specified tier has been completed (%)	ENVASSO
Protocol	i) Accepted or established code of procedure in any situation ii) A procedure for carrying out a scientific experiment or observation, i.e. a formal record of scientific experiment or observation	ENVASSO
Proxy-indicator	A measurement that can be made, and for which data exist, on a widespread basis that can be used as a surrogate of the optimal indicator (of a key issue) that is not generally available (or for which there are not enough data) Usage: Compelling scientific evidence on the correlation between the optimal indicator and the proxy-indicator is required for a proxy-indicator to be meaningful	ENVASSO
Random	(see also figure 1)	

sampling		
Recalcitrant SOM	(indicator) a fraction of SOM which is thought to be protected from biodegradation, either because of its chemical composition (Derenne and largeau, 2001), or because of its physical localisation in soil (Balesdent *et al.* 2000), or physico-chemical interactions with other soil components (Rumpel *et al.* 2002).	ENVASSO
Reference year	A year selected to be the baseline year for the values of an indicator, i.e. the state of an indicator against which monitoring results will be compared or referenced. Usage: There are no scientific preferences for specific years to be selected as reference years. It is often the first availability of robust data for an indicator that will determine the selection of a reference year.	ENVASSO
Risk	The chance of a bad consequence or loss	Oxford Dictionary of English (2003)
Risk area	A spatial unit of land where evidence exists of the probability or occurrence of a soil threat	ENVASSO
Salinisation	(soil threat)	
Salt profile	(indicator) The horizontal and vertical distribution in soil of salts and their chemical composition	ENVASSO
Sample archiving	The storage of soil samples after pre-treatment and under controlled conditions for the purpose of future analyses	ENVASSO
Sample pre-treatment	The procedures applied to field-fresh soil samples before chemical, physical, or biological analyses are performed, and before sample archiving	ENVASSO
Sampling scheme/design		
Sampling strategy	(synonym) Sampling pattern. System of predetermined sampling points designed to monitor one or more specified sites.	ISO 11074:2005
SAR	(acronym) Sodium Adsorption Ratio	
Saturated hydraulic conductivity	(indicator) The speed by which water moves, by gravitational forces, through a soil in which pore volume is filled completely with water (air-filled pore volume = 0). The units are m d^{-1}, cm d^{-1}, or cm h^{-1}	ENVASSO
Secondary soil salinisation	See ‘soil salinisation’	
Selection criterion	A standard of judging for identification of appropriate candidates, of e.g. key issues, indicators, etc.	ENVASSO
Settlement area	Land that is developed for housing, industry, trade, transport, and other physical infrastructure, including utilities (e.g. waste disposal, water distribution, electricity supply) and military installations	ENVASSO
Significance	Significant indicators are meaningful to the problem under consideration, i.e. they must provide relevant information with regard to the respective key issue	ENVASSO
Site	A particular area of land, usually related to a specific are of ownership or activity	Van Camp et al (2004g)
Site area delineation	An individual polygon shown by a closed boundary on a map that defines the area, shape, and location of the site area within a landscape	Based on SSSA (1987)
Site sampling strategy	(synonym) sampling design. Arrangement by which a sampling programme is to be conducted Usage:	ISO 11074:2005

	The purpose of designing a sampling programme is to provide the most efficient and economical methods of reaching valid and relevant conclusions from the investigations of a site. The design is a function of many considerations such as the aim of the investigation, the homogeneity of the soil/site under consideration and the cost of performing the investigation.	
Slope intensity	Angle (or gradient) of slope measured in degrees or percentage of 90 degrees)	ENVASSO
Soil	i) (mass noun) The unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. ii) (count noun) a spatially explicit body of soil, normally one of a specific soil group surrounded by other soil groups or other demarcations like hard rock, a water body or artificial barriers. Usage: The distinction between the use of the term 'soil' as a mass noun, i.e. the material, or a count noun, i.e. a physical entity, needs to be made from the context. The count noun variety only, can be used in plural or with an article in front of it, i.e. 'soils' or 'a soil', respectively. Therefore, 'a soil contains soil'.	SSSA and ENVASSO and Needelman, B. (2006)
Soil acidification	Change in the soil's natural chemical balance caused by an increase in the concentration of acidic elements Usage: A naturally occurring process in humid climates where acid precipitation on the productivity of terrestrial plants is summarised as follows: as soil becomes more acidic the basic cations (Ca, Mg) on the soil exchange are replaced by hydrogen ions or solubilized metals. The basic cation, now in solution, can be leached through the soil. As time progresses the soil becomes less fertile and more acidic. Resultant decreases in soil pH cause reduced, less-active population of soil microorganisms, which in turn slow decomposition of plant residues and cycling of essential plant nutrients.	Based on EEA
Soil amendment	Any material such as lime, gypsum, sawdust, compost, animal manures, crop residue or synthetic soil conditioners that is worked into the soil or applied on the surface to enhance plant growth. Amendments may contain important fertilizer elements but the term commonly refers to added materials other than those used primarily as fertilizers.	SSSA
Soil auger	(see also figure 2)	
Soil behaviour	The way in which soil works or functions	ENVASSO
Soil biodiversity	The variability of living organisms in soil and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems	UNEP (1992)
Soil biodiversity decline	See 'decline in soil biodiversity'	
Soil compaction	(soil threat) The densification and distortion of soil by which total and air-filled porosity are reduced, causing a deterioration or loss of one or more soil functions	ENVASSO

	Usage: Soil compaction may reduce soil functions by: decreased soil permeability; increased soil strength; partly destroyed soil structure; altered soil fabric and soil behaviour characteristics. Anthropological soil compaction can be initiated by e.g. wheels, tracks or rollers, the passage of cultivation machinery, and the passage of draft or grazing animals	
Soil conservation	(i) Protection of the soil against physical loss by erosion or against chemical and biological deterioration; that is, excessive loss of fertility by either natural or artificial means. (ii) The branch of soil science that deals with soil conservation.	ENVASSO based on SSSA
Soil conservation practice	A combination of all management and land use methods that safeguard the soil against depletion or deterioration by natural or by human-induced factors.	ENVASSO based on SSSA
Soil contamination	(soil threat) The accumulation of pollutants in soil above a certain level, causing a deterioration or loss of one or more soil functions. Usage: Contamination can be diffuse or local and may be due to many anthropogenic activities, such as industrial production, traffic, farming practices and waste disposal	Jones *et al.* (2005)
Soil degradation	The process of one or more soil threats acting and thereby deteriorating or deleting one or more soil functions, thereby reducing the specific and/or overall soil quality	ENVASSO
Soil erosion	(soil threat) The wearing away of the land surface by physical forces such as rainfall, flowing water, wind, ice, temperature change, gravity or other natural or anthropogenic agents that abrade, detach and remove soil or geological material from one point on the earth's surface to be deposited elsewhere. When the term 'soil erosion' is used in the context of it representing a soil threat it refers to 'accelerated soil erosion'. Usage: The following types of erosion have been identified: Water erosion, by rill and inter-rill, gully, snowmelt, and of banks in rivers and lakes; Tillage erosion by tillage, land-levelling, harvesting of root crops, trampling and bur-rowing animals; Wind erosion, by the action of strong dessicating wind; Geological erosion: internal subterranean erosion by groundwater, coastal erosion and land-slides	Based on SSSA (2001)
Soil functions	A subset of ecosystem functions: those ecosystem functions that are maintained by soil Usage: Five functions are proposed in the HIPER soil function scheme: 1) Habitat function 2) Information function 3) Production function 4) Engineering function 5) Regulation function	ENVASSO
Soil group	A collection of soils that occur over wide areas and have similar diagnostic WRB horizons, properties and materials	ENVASSO;
Soil horizon	A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, and biological properties or characteristics such as colour, structure, texture, consistency, kinds and number of organisms present,	SSSA

	degree of acidity or alkalinity, etc.	
Soil information system	Computer-based system which is designed to capture, store and process soil information for end-users	
Soil inventory	A 'complete' list of soil properties for a given area, e.g. country in 'national soil inventory' Usage: One practical aspect in which a soil monitoring system differs from repetitive soil inventories is that soil parameters, for which exist compelling evidence of static values, i.e. do not (measurably or significantly) change over time, may not be selected for a soil monitoring system, although they are part of a soil inventory.	ENVASSO
Soil microbial decomposition	The process of the breakdown of organic matter from more complex molecular structures to more simple ones by the soil fauna and soil flora	
Soil microbial respiration	(indicator) the quantity of carbondioxide that is produced by the microbial decomposition processes in a sample of topsoil during one hour (mg CO_2.(kg dry soil)$^{-1}$ h^{-1}) Usage: Heterotrophic respiration refers to the part of respiration caused by all soil flora and fauna but not plant roots, where autotrophic respiration refers to the part of respiration caused only by plant roots (and not by soil fauna or flora).	ENVASSO
Soil monitoring	Continuous or repeated observation, measurement, and evaluation of soil and/or related environmental or technical data for defined purposes, according to prearranged schedules in space and time, using standardised methods for data collection and analysis.	ENVASSO
Soil monitoring network	A spatial arrangement of soil monitoring sites, designed to be representative of soil type, land use and climatic zones; the spatial arrangement maybe random or on a regular grid.	ENVASSO
Soil monitoring site	A relatively homogeneous area of land in which investigations will take place and that fulfils the conditions: 1. the georeference of the site is known with an accuracy of less than 10 m. 2. one or more measurement campaigns have been done, or a future campaign is planned following an initial one, or could be done on the site (excluding where the site is now in a built-up area) Usage: The above conditions are the minimum conditions required to consider a site as a monitoring site. The quality of the soil monitoring network (SMN) will be enhanced, if the following conditions are fulfilled: 1. a composite sample or several replicates are sampled on the site to take into account the spatial variability 2. accuracy of georeferencing must be less than the half of the site area	ENVASSO
Soil monitoring strategy	A particular conceptual approach to soil monitoring. Usage: In ENVASSO the strategy is to approach soil monitoring from a soil threat perspective.	ENVASSO
Soil monitoring system	The sum of all soil monitoring components that are harmonised in design, measurement and reporting to form a single overall operational system.	ENVASSO

	Usage: This may include soil inventories, a soil monitoring network and soil benchmark sites	
Soil organic matter	The organic fraction of the soil exclusive of undecayed plant and animal residues	SSSA (2001)
Soil organic matter contents	(indicator) The relative, gravimetric proportion of soil organic matter to total dry soil weight (expressed as '%' or ' g kg^{-1}')	ENVASSO
Soil organic matter decline	See 'decline in soil organic matter'	ENVASSO
Soil organic matter profile	(indicator) The vertical pattern of soil organic matter contents from the surface to a defined depth	ENVASSO
Soil organic matter quality	(key issue) the nature and the properties of soil organic matter compounds which influence soil functions, i.e. water retention, soil structural stability, porosity, nutrient retention, and nutrient source. Usage: From the quality point of view, soil organic matter is considered to encompass a set of attributes linked to soil functions rather than being a single entity. For instance, changes in soil organic matter quality may impact soil biodiversity, transport of substances within and through the soil, microbial activity, etc.	ENVASSO
Soil organic matter status	(key issue) The current organic matter contents, and trends in their changes, of European soils	ENVASSO
Soil organic matter stocks	(indicator) Absolute quantity of organic matter down to a defined soil depth (expressed as t ha^{-1}), based on measured bulk density as well as organic carbon or organic matter determinations	ENVASSO
Soil organic matter stratification ratio	(indicator) the soil organic carbon at the soil surface divided by the soil organic carbon at a lower depth (e.g. deeper than the tillage layer	ENVASSO
Soil quality	The fitness of a specified body of soil to perform (a) specified soil function(s), within its capacity and within natural or managed ecosystem boundaries	ENVASSO; Based on Karlen *et al.*, 1997.
Soil respiration rate	See 'soil microbial respiration'	ENVASSO
Soil salinisation	(soil threat) Accumulation of water soluble salts in the soil, causing a deterioration or loss of one or more soil functions. The accumulated salts include sodium-, potassium-, magnesium- and calcium- chlorides, sulphates, carbonates and bicarbonates. Usage: A distinction can be made between primary and secondary salinisation processes. Primary salinisation involves accumulation of salts through natural processes as physical or chemical weathering and transport processes from salty geological deposits or groundwater Secondary salinisation is caused by human interventions such as inappropriate irrigation practices, use of salt-rich irrigation water and/or poor drainage conditions.	ENVASSO; Based on Eckelmann *et al.* (2006)
Soil sealing	(soil threat and key issue) The destruction or covering of soil by buildings, constructions and layers, or other bodies of artificial material which may be very slowly permeable to water (e.g. asphalt, concrete, etc.), causing a deterioration or loss of one or more soil functions	Based on Burghardt *et al.*, 2004
Soil sodification	(indicator) Accumulation of Na^+ in the solid and/or liquid phases of the soil as crystallised $NaHCO_3$, or Na_2CO_3 salt	ENVASSO

	(salt 'efflorescens') ions in the highly alkaline soil solution (alkalisation), or exchangeable ions in the soil absorption complex (ESP). Usage: Salt-affected soils can be classified as: 1) Soils in which high salt content dominates the problems (Saline soils); 2) Soils in which high sodium content dominates the problems (Sodic soils); 3) Soils with specific characteristics in certain environmental conditions may be in risk of salinisation (acid sulfate soils, etc.)	
Soil Store	A building designed for storing soil samples. Usage: A soil store should: i) minimise temperature and humidity fluctuations ii) maintain an easy reference system for identification of samples iii) be designed for sufficient future sample storage, taking into account the recommended sample size of approximately 3 kg 	
Soil strength	The resistance to crushing forces of an unconfined cube of natural soil material about 3 cm across. Usage: Soil strength can be determined at all soil-water states from air-dry to wet. Soil strength is a structural property; classes of soil and ped strength (some peds are >3 cm) are defined by Hodgson (1997, p. 57-59)	ENVASSO Hodgson (1997)
Soil survey	The systematic examination, description, classification, and mapping of soils in an area	SSSA (1987)
Soil threat	A phenomenon that causes a deterioration or loss of one or more soil functions. A soil threat consists of a number of key issues, which may have one or a number of indicators. Usage: ENVASSO uses the eight main threats to soil identified by the EC (2002) with the addition of desertification. In ENVASSO these are termed: 1. Soil erosion 2. Decline in soil organic matter 3. Soil contamination 4. Soil sealing 5. Soil compaction 6. Decline in soil biodiversity 7. Soil salinisation 8. Landslides 9. Desertification	ENVASSO; EC (2002)
Soil type	Colloquial term for a level of classification of soils Usage: Dependent on the soil classification system used. In ENVASSO 'soil type' is used as a synonym for soil group (WRB)	
SOM	(acronym) Soil Organic Matter	
Spade	A hand-held soil sampling implement used for digging soil pits	

		
Species diversity	(key issue) The number and variety of species found in a given area in a region	EEA
Species richness	(indicator) The number of species within a region Usage: A term commonly used as a measure of species diversity, but technically only one aspect of diversity	EEA
Spiral auger	A soil sampling implement that takes external cores of soil (Figure x). Also referred to as a screw auger. 	
Stratified directed sampling	(see also figure 1)	
Stratified random sampling	(see also figure 1)	
Stratified systematic sampling	(see also figure 1)	
Straw burning	(indicator) The practice of controlled burning of straw from combinable crops for perceived benefits in cultivation, weed and pest control, and nutrient release.	ENVASSO
Subsoil compaction	Soil compaction of any layer underneath the topsoil	
Substrate instability	(key issue)	
Susceptibility	Sensitivity	
Threat to soil	See 'soil threat'	
Threshold	An indicator value at which a critical soil status is reached, causing a deterioration or loss of one or more soil functions (e.g. guideline value for heavy metal content, limits for crop production or soil remediation, etc.) Usage: A threshold is a point or level which if being approached or exceeded then policy or other actions should be considered in order to alleviate adverse impacts either on the environment or people's health	ENVASSO; EEA (2005)
Tillage action	The specific form or forms of soil manipulation performed by the application of mechanical forces to the soil with a tillage tool (disc, harrow or tine), such as cutting, shattering, inversion, or mixing.	SSSA
Tillage erosion	(key issue) The wearing away of the land surface by tillage operations, including the quantities of soil removed by harvesting root crops such as potatoes and sugar beet.	ENVASSO
Tillage layer	(Ploughed horizon or A_p) The greatest depth of soil exhibiting mixing or inversion by surface tillage operations.	SSSA
Tillage operation	Act of applying one or more tillage actions in a distinct mechanical application of force to all or part of the soil mass.	SSSA
Tillage practice	(indicator) The combination of tillage operations used on a	ENVASSO

	particular field	
TOP3	A group of 3 priority indicators, selected by perceived importance of experts	
Topsoil	Upper part of a natural soil that is generally dark coloured and has a higher content of organic matter and nutrients when compared to the (mineral) horizons below excluding the humus layer Usage: For arable land, topsoil refers to the tilled soil depth; for grassland, it is the soil layer with high root content.	Based on ISO 11074
Topsoil organic carbon content	(indicator) the gravimetric proportion of carbon, as part of soil organic matter, in dry topsoil (%, $w\ w^{-1}$)	ENVASSO
Topsoil organic carbon stock	(indicator) the mass of carbon, as part of soil organic matter, in dry topsoil ($t\ ha^{-1}$)	ENVASSO
Total pore space	See 'pore volume'	
Undisturbed samples	Samples of soil taken in the field with minimal disturbance, for example using a coring device such as that described by Hall *et al.* (1977).	Based on Hall *et al.* (1977)
User requirement	Property that the user of the data generated by an indicator needs in order to detect changes of soil threats which are meaningful in relation to severity of the problem or the measures that have been taken against it. Usage: The two dimensions of the changes are the amount of change of the indicator and the time period in which it happens	ENVASSO
Volume/mass of displaced material	(indicator) the volume or mass of soil that has been displaced by landslides in a specified area over a specified time period ($m^3\ ha^{-1}\ yr^{-1}$, $t\ ha^{-1}\ yr^{-1}$).	ENVASSO
Vulnerability	Liability to injury or damage	
Water erosion	(key issue) The wearing away of the land surface by rill, interrills, gullies and sheet wash as a result of excess surface runoff.	ENVASSO; SSSA
Web Feature Service (WFS)	An OGC standard for the interchange of spatial data Usage: describes data manipulation operations ('methods') and requires description of the query and data transformation operations; thus, it supports access to and the dynamic exploitation of feature data and associated attributes. WFS exchanges data in GML format (e.g. as GeoSciML)	
Web Map Service (WMS)	An OGC standard which produces maps of spatially referenced data dynamically from geographic information. Usage: This international standard defines a 'map' to be a portrayal of geographic information as a digital image file suitable for display on a computer screen. A map is not the data itself. WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM) formats. This is in contrast to a Web Feature Service (WFS), which returns actual vector data and a Web Coverage Service (WCS), which returns actual raster data	Wikipedia
Web mapping	portraying spatial information quickly and easily to most users via the Internet	

Web Mapping Service (WMS)	An OGC standard for the interchange of spatial data: Usage: Set of interface specifications to provide uniform access by Web clients to maps, allows basic queries (about map content), and informs other programmes about the maps produced. Hence, in the first instance it delivers a picture. ISO 19128 Web Map Server Interface/OpenGIS Web Map Server (WMS) specifications: enables visual overlay of complex and distributed information (maps) simultaneously, over the Internet; more about viewing the delivered data	
Web service architecture	Patterns used to design the Web Mapping System, to generate map feature styles, the rendering of the map layers and the presentation of map images	ENVASSO
Web Soil Service (WSS)	Web-based soil information system	Stolz *et al.* 2005
Wildfire	(indicator) An unplanned fire or a planned fire of vegetation under non-agricultural land use. Usage: This includes: arson and accidental burning of arable crops and/or their residues; forest, grass and shrub fires caused by arson, accidental, or natural causes; and planned forest, grass and shrub fires (e.g. upland heath burning)	ENVASSO
Wind erosion	(key issue) The wearing away of the land surface by aeolian forces; the process of wind erosion occurs when particles of soil are loosened and dislodged from the surrounding mass of surface soil by moving air and the dislodging or abrasion of surface material by the impact of particles already airborne.	Dictionary of Physical Geography, Penguin & ENVASSO.
WRB	(World Reference Base for soil resources) framework for harmonized soil classification by international agreement on the major soil groups to be recognized at a global scale as well as on the criteria and methodology to be applied for defining and separating them	FAO (2006)
XML	(acronym) eXtensible Markup Language	

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4.4 FIGURES

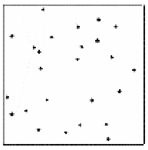
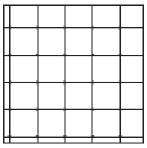
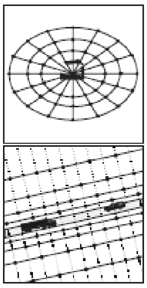
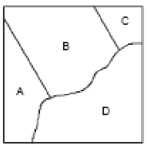
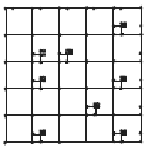
Distribution	Procedure	Advantages	Disadvantages
Random 	Distribution of the sampling sites using random numbers and with complete exclusion of professional knowledge	- the only objective procedure - every point is sampled at the same probability - small systematic error	- large number of samples necessary - time consuming procedure - number of samples not proportional to area
Systematic 	Distribution of the sampling sites on a geometrical grid: - square grid - rectangular grid - triangular grid	- small time expenditure - small number of samples - good coverage with triangular grid - even distribution of sampling sites - number proportional to area	- inappropriate grid size can cause systematic errors - triangular grid is time consuming
Judgmental 	Distribution of the sampling sites based on expert judgement and considerations of plausibility (contamination hypothesis): - point sources: polar distribution - line sources: line distribution - other sources: in accordance with contamination hypothesis - greater sampling density in vicinity of source	- smallest number of samples - in accordance with contamination hypothesis	- greatest susceptibility to systematic errors where contamination hypothesis is inappropriate - time consuming preliminary investigations
Stratified pattern 	Appropriate distribution in more homogeneous sub-areas. Number of sampling sites proportional to the area. Distribution within the area: random, systematic or directed	- in accordance with contamination hypothesis	- susceptibility to systematic errors where contamination hypothesis is inappropriate - demands prior knowledge
Nested pattern 	Systematic distribution of the sampling sites and higher local sampling density as predefined in a diagram (random or systematic)	- heterogeneity recorded at different geographical scales - suitable for geostatic evaluation (with large number of samples)	- large number of samples necessary - time consuming procedure

Figure 1: description of the different national sampling strategies (Hämmann and Desaules, 2003)

Figure 2 Dutch auger

Figure 3 Pitchfork

Figure 4 Screw Auger

Figure 4 Gouge auger

Figure 5 Soil store

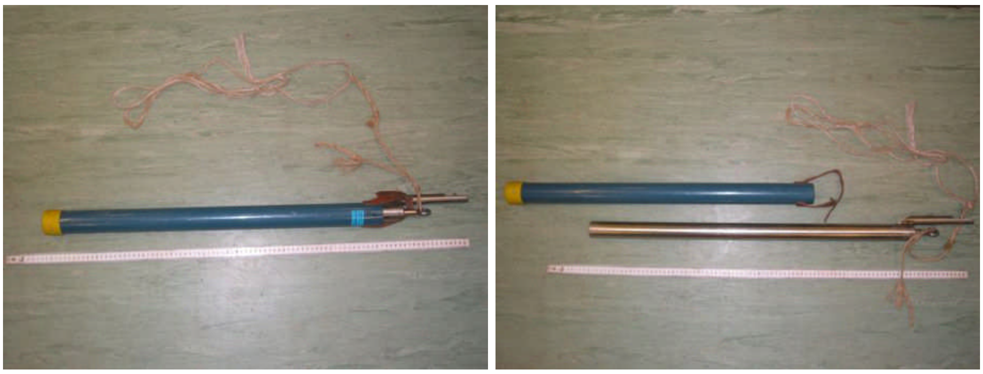


Figure 6 Piston sampler

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MTT Agrifood Research Finland 17

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie 18

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Abstract
The ENVASSO Project (Contract 022713) was funded under the European Commission 6th Framework Programme of Research, 2006-8, with the objective of defining and documenting a soil monitoring system appropriate for soil protection at continental level. The ENVASSO Consortium, comprising 37 partners drawn from 25 EU Member States, reviewed almost 300 soil indicators, identified existing soil inventories and monitoring programmes in the Member States, and drafted procedures and protocols appropriate for inclusion in a European soil monitoring network of sites that are geo-referenced and at which a qualified sampling process is or could be conducted. Volume V (this volume is one of 6) describes the procedures and protocols, needed for harmonised soil monitoring in Europe, which have been modified following the extensive testing of 22 indicators in 28 Pilot Areas of EU Member States reported in Volume IV. The results provide a foundation for implementing a soil monitoring programme in the near future but they are the scientific opinions of the ENVASSO Consortium, presented here without prejudice and in no way represent the official position of the European Commission on soil monitoring in Europe.

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