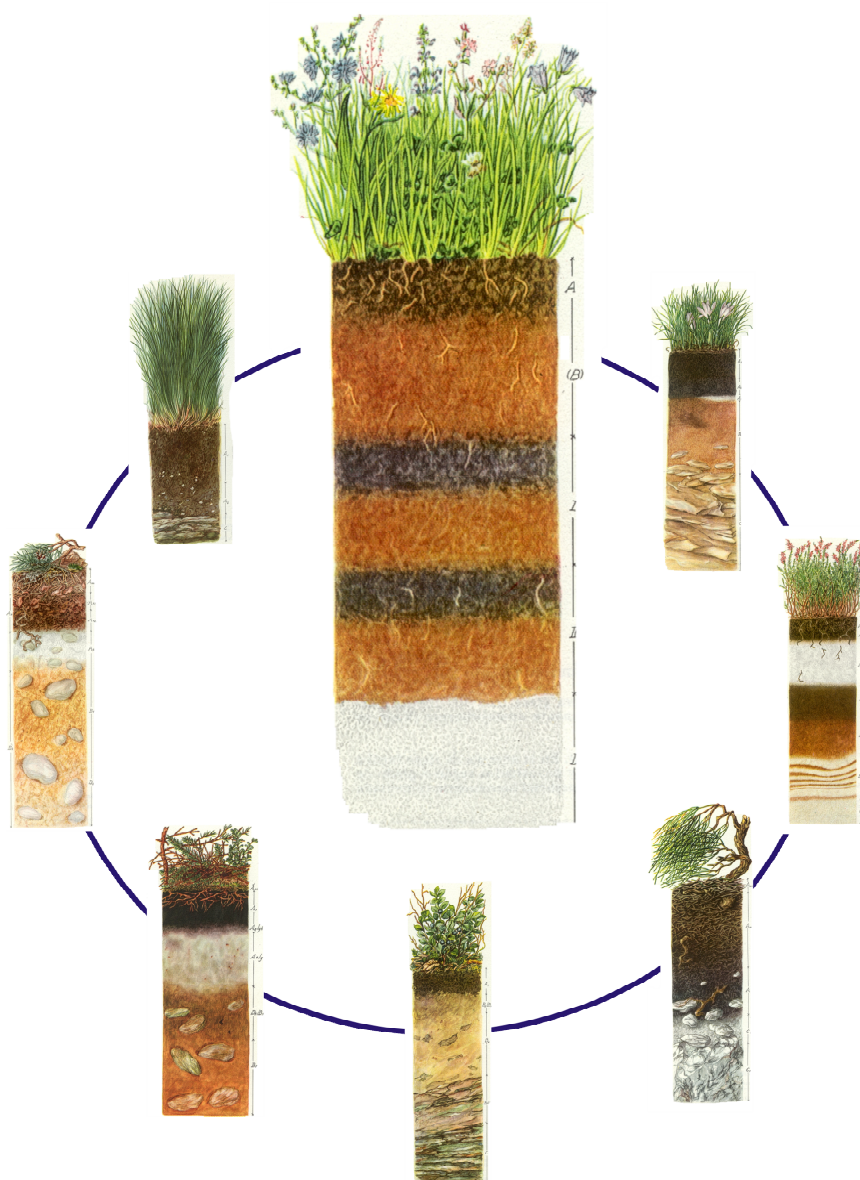JRC Scientific and Technical Reports

Environmental Assessment of Soil for Monitoring Volume IVa: Prototype Evaluation

E. Micheli, S. Bialousz, A. Bispo, J. Boixadera, A.R. Jones, M.G. Kibblewhite, N. Kolev, C. Kosmas, H. Lilja, F. Malucelli, J.L. Rubio, M. Stephens (eds)

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ENVASSO

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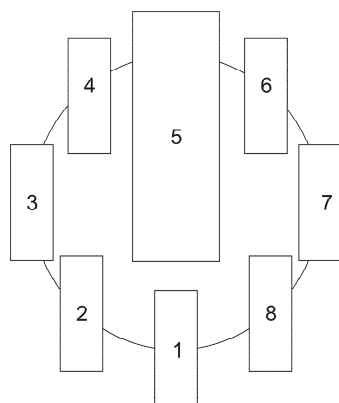
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Environmental Assessment of Soil for Monitoring Volume IVa: Prototype Evaluation

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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 6th 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 management 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 were 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 IVa, summarises the results of testing 22 indicator procedures in 28 Pilot Areas in the Member Sates. The indicator testing was successful in the majority of cases and most were judged to applicable at European scale. Overall these pilot area studies provided valuable information in support of developing a harmonised soil monitoring system for Europe. A companion Volume IVb contains the individual Pilot Area study reports, which were conducted on a wide range of soil-landscapes from the north to the south of Europe, some of which are transnational.

Professor Mark Kibblewhite
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Joint Research Centre

29 June 2008

Authors: This report was prepared under the supervision of Szent István University by Erika Michéli. Responsibilities for the contents were shared as follows:

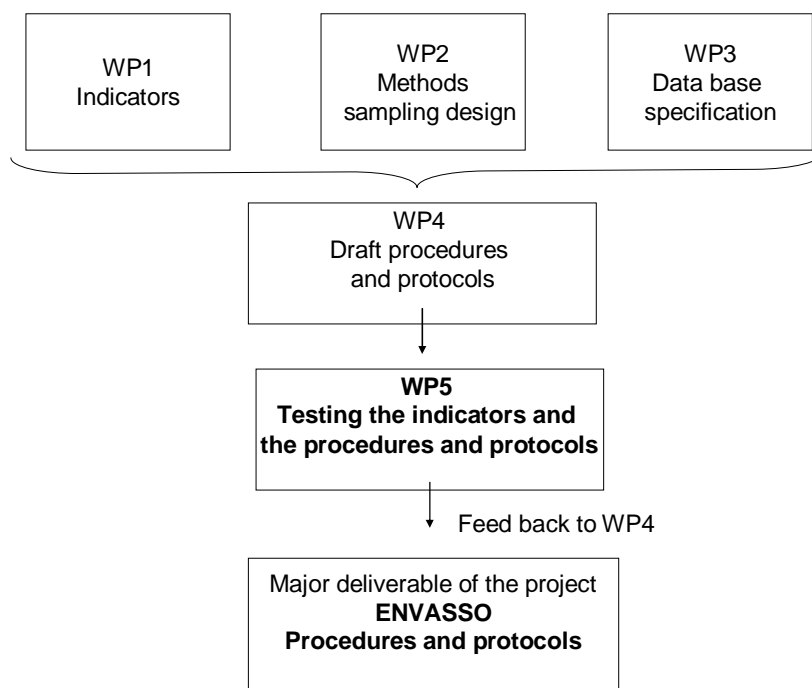| Threat	Leading author
Soil Erosion	Constantinos Kosmas (AUA)
Decline in Soil Organic Matter	Harri Lilja (MTT)
Soil Contamination	Mark Kibblewhite (CU)
Soil Sealing	Stanislaw Bialous (WUT)
Soil Compaction	Nikola Kolev (ISSNP)
Decline in Soil Biodiversity	Antonio Bispo (ADEME)
Soil Salinisation	Jaume Boixadera (SARA)
Desertification	Jose Luis Rubio (CSIC)
Landslides	Francesco Malucelli (ER)

Table of Contents

Pilot area and special study reports are described in full in Volume IIb

1   Summary and objectives

The priority indicators identified and defined in ENVASSO Volume I were evaluated in the context of the the inventory and monitoring systems described and reviewed in Volume II (a & b), using the SoDa database (Volume III) where appropriate, and the procedures and protocols defined in Volume V, accoding to the schema below:

```
┌─────────────┐   ┌─────────────┐   ┌─────────────┐
│     WP1     │   │     WP2     │   │     WP3     │
│  Indicators │   │   Methods   │   │  Data base  │
│             │   │ sampling    │   │ specification│
│             │   │  design     │   │             │
└─────────────┘   └─────────────┘   └─────────────┘

            ┌──────────────────────┐
            │         WP4          │
            │   Draft procedures   │
            │    and protocols     │
            └──────────────────────┘

            ┌──────────────────────┐
            │         WP5          │
            │ Testing the indicators and │
            │ the procedures and protocols │
            └──────────────────────┘
                        │  Feed back to WP4

            ┌──────────────────────┐
            │ Major deliverable of the project │
            │       ENVASSO        │
            │ Procedures and protocols │
            └──────────────────────┘
```

The objectives of the Prototype Evaluation in ENVASSO were to:

1. Test the indicators, methods and sampling design in selected pilot areas, using the agreed procedures and protocols;
2. Test the efficacy of the database specification (SoDa);
3. Evaluate the outcomes of the testing process and revise the approaches, procedures and protocols accordingly

The activities were organized in 28 pilot areas/studies that tested 46 indicators (in total) of the 8 threats to soil defined in the European Thematic Strategy for Soil Protection.

Four of the pilot areas were transnational and there were a further four special studies (literature studies, data provision) in support of the testing.

2 Working methodology

The prototype evaluation activities, based on existing data in the Member States and Candidate Countries, were performed in pilot areas and by study groups. Working plans and activities for pilot area/studies for each threat were defined in small workshops according to the objectives outlined above.

2.1 Evaluation process:

An expert ('Threat Leader') was identified to oversee the pilot studies for each threat;
The Pilot areas were identified and an expert (Pilot Study Leader)
to lead each pilot study identified
Small workshops were planned to guide the pilot studies
Indicators to be evaluated were reviewed
Data requirements were defined
Methods to evaluate the performance of the indicators were defined
Pilot Studies were conducted
An Evaluation workshop reviewed all the Pilot studies
Pilot study reports were prepared
A workshop attended by the Threat Leaders reviewed the results
Reports on the conclusions of the evaluation of indicators for each threat were prepared
Evaluation report summarising the work was prepared (ENVASSO Volume IV (a & b))

Pilot study and reporting structure

| Threat 1 | Threat 2 | Threat 3 | Threat 4 | | Threat 8 |

Pilot area n — Pilot area 1 (for each threat)

Pilot studies coordinated and reports completed by pilot study leaders*

| Threat 1 Report | Threat 2 Report | Threat 3 Report | Threat 4 Report | Threat 8 Report |

Threat reports completed by threat leaders**

WP5 Report

* Reports by pilot study leaders in Annex 2
** Reports by threat leaders in Annex 1

2.2 Types of pilot study participations

Pilot study participation included:

Leading threat studies (Threat Leader)
Providing pilot areas (participating institutions)
Leading pilot studies (Pilot Study or area Leader)
Participation in performance of the pilot study
Advising pilot area studies
Providing specific information (eg: reference profile/data, literature study)
Reviewing the manual of procedures

3 Pilot areas and indicators tested
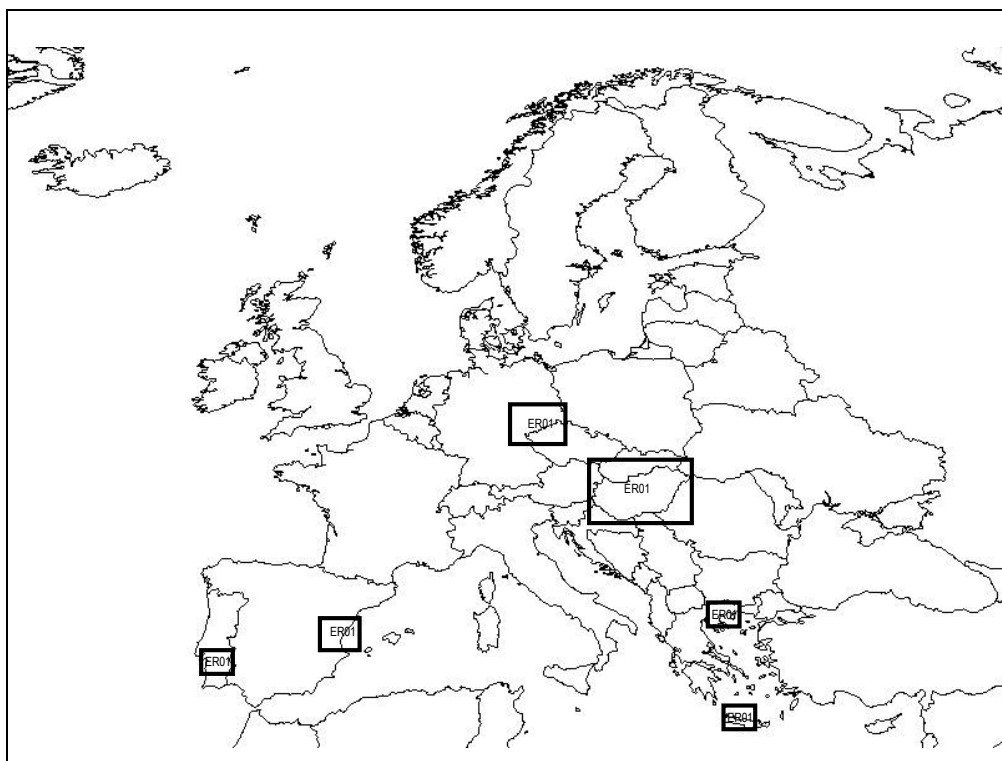
3.1 Soil Erosion (ER)

For soil erosion, pilot studies were performed only for indicator ER01 (estimated soil loss by water runoff). Six pilot areas, representing a large variation in climate, topography and parent materials (Table 1 and Figure 1) performed the evaluations successfully, however concluded that the ENVASSO suggested method (PESERA model) need further development especially in documentation. It was also learnt that data sources and scales and also definitions vary in different countries. Harmonization is essential before comparing results. Estimated soil loss by wind erosion (ER05) data is rarely available in Europe and no evaluation was performed. Further applied research is needed just as in case of the third selected indicator, soil loss caused by tillage erosion (ER07).

Table 1. Indicators evaluated in the pilot areas for threat Soil Erosion (ER)

Pilot Area Institute (Country)	Indicator 1	Indicator 2	Indicator 3	Other
	ER01 Estimated soil loss by water runoff (t ha^{-1} yr^{-1})	ER05 Estimated soil loss by wind (t ha^{-1} yr^{-1})	ER07 Estimated soil loss by tillage erosion (t ha^{-1} yr^{-1})	-
Vale do Gaio INIAP (Portugal)	X			
Chania Crete AUA (Greece)	X			
Philippi Macedonia AUA (Greece)	X			
Transect North of Valencia CSIC (Spain)	X			
Hungary SIU (Hungary)	X			
Sheet Chemnitz BGR-LfUG-CUA (Germany-Czech)	X			
Scotland Macaulay Institute	X			
Italy Emilia Romangna	X			

Since PESERA and other erosion estimation models run with their own data and programming structure, SoDa is not necessary, but it's pedotransfer functions might be useful for missing data.

Detailed evaluation is attached in the threat report on soil erosion in Annex I. Pilot area reports on testing indicators for soil erosion are included in Volume IIb.

Figure 1. Locations of the pilot areas testing the indicators of soil erosion
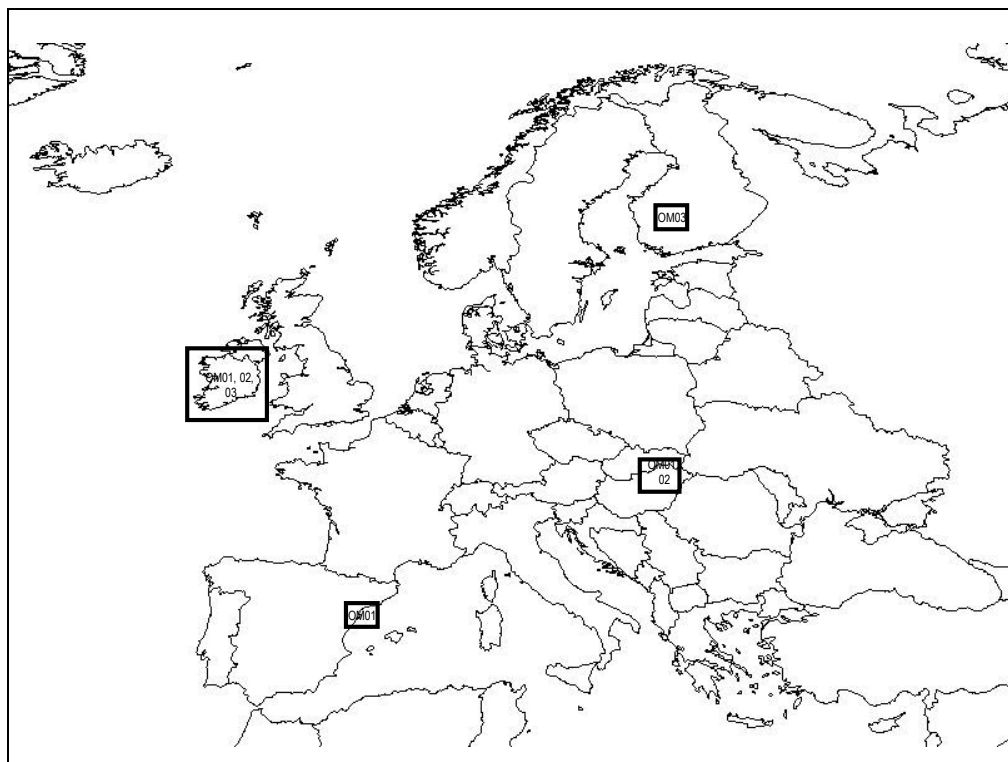
3.2 Decline in organic matter (OM)

All three indicators were tested for the decline in soil organic matter Table 2. The four pilot areas (Figure 2) that performed the evaluations represent northern, Mediterranean and continental climatic conditions. One of the pilot areas was transnational where data harmonization was exercised as well. Beside testing of indicators OM01, OM02 and OM03, two additional special studies supported the evaluation; one with broad literature study and comparative measurements of OC determinations with different methods, and the other on methodology for estimation of thickness of peat layers.

The indicator and method evaluations were successful. Data gaps were identified. Sampling depth specification for OM01 and OM02 should be further specified. It is recommended that sampling should be in two increments (0-15 and 15-30 cm) and for soil with deep organic matter rich layer should be sampled 30-50 cm as well to be able to monitor stock changes. Terminologies used for the threat description (OM for the threat, OC for the indicator) may cause confusion in data interpretations. The pilot studies for OM03 concluded that further research or new indicator is needed for estimation of peat stock.

Table 2. Indicators evaluated in the pilot areas for threat Decline in Organic Matter (OM)

Pilot Area Institute (Country)	Indicator 1 OM01 Soil organic matter content in topsoil (%)	Indicator 2 OM02 Topsoil carbon stock (t ha^{-1})	Indicator 3 OM03 Peat stock (Mt)	Other -
Orivesi MTT (Finnland)			X	
Republic of Ireland TEAGASC/UCC (Ireland)	X	X	X	
Terres de l'Ebre and Ebro Delta SARA (Spain)	X			
Bodrogköz UNIMIS-SSCRI (Hungary-Slovakia transnational)	X	X		

Detailed evaluation is attached in the threat report on decline in organic matter in Annex I. Pilot area reports on testing organic matter indicators are included in Volume IIb.

Figure 2. Locations of the pilot areas testing the indicators of decline in organic matter
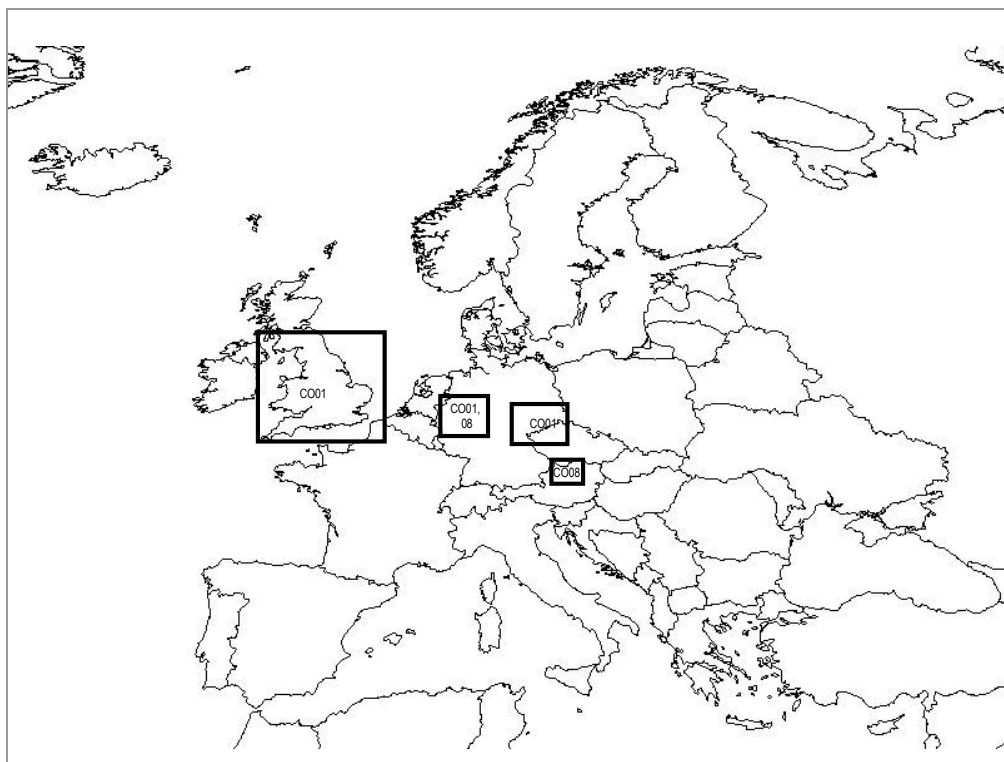
3.3 Soil contamination (CO)

Soil contamination was evaluated in four pilot areas (Figure 3), one of which is transnational. Since soil contamination is not climate or environment specific, selection of the pilot areas was based only on data availability and access. Three pilot studies evaluated CO01, and two studies evaluated CO08 (Table 3).

All of the pilots studies were successful in extending the ENVASSO procedures and protocols, however data collections on different heavy metals are very different in methods and density. The transnational pilot was of particular value, because it illustrated the difficulties of harmonizing data produced by different institutions according to different assumptions and procedures. An important conclusion of the pilot studies is that geostatistical methods should be applied to eliminate data that is representative of areas with excessive anthropogenic contamination when estimating background / baseline values for comparison with thresholds analysis of data and this is an important output for the wider project.

Table 3. Indicators evaluated in the pilot areas for threat Soil Contamination (CO)

Pilot Area Institute (Country)	Indicator 1 CO01 Heavy metal contents in soil(%)	Indicator 2 CO07 Critical load exceedance by sulphur and nitrogen (% of area exceeded)	Indicator 3 CO08 Progress in the Management of Contaminated Sites(%)	Other
Ruhr Area LANUV (Germany)	X		X	
1:250,000 Sheet Chemnitz BGR-LfUg-CUA (Germany – Czech Republic)	X			
City of Linz and Surrounding Area UBA (Austria)			X	
England and Wales CU (United Kingdom)	X			

Figure 3. Locations of the pilot areas testing indicators of soil contamination

The methodology for CO07 was adopted from the ICP „Manual of Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution". This indicator has been applied successfully, and is well established in several EU Member States and was, therefore, not included in the indicator evaluation reported here.

In addition to the indicator evaluations a special study was performed on the estimation of natural background concentration of heavy metals in soil.

Detailed evaluation is attached in the decline in the threat report on soil contamination in AnnexI. Pilot area reports on testing indicators for soil erosion are included in Volume IIb.

3.4 Soil sealing (SE)

The evaluation of the indicators for soil sealing was performed on four pilot areas(Figure 4), of which one was transnational. Three studies evaluated the applicability of the indicator 1 (sealed area), and two of them evaluated the land take percentage (Table 4. The third "top" indicator (percentage of new settlement area established on previously developed land) was not evaluated due to the lack of access of data. However an additional indicator (SE03, land consumed by settlements and transport infrastructure) was evaluated on 2 pilot sites.

Table 4. Indicators evaluated in the pilot areas for threat soil sealing (SE)

	Indicator 1	Indicator 2	Indicator 3	Other
Pilot Area Institute (Country)	SE01 Sealed area (ha or % of consumed land; $ha.y^{-1}$, $ha.d^{-1}$)	SE04 Land take (CLC) (% of initial status or ha)	SE05 New settlement area established on previously developed land(%)	SE03 Land consumed by settlements and transport infrastructure (%)
Warsaw WUT (Poland)	X			X
North Rhine Westphalia LANUV (Germany)	X			
Chemnitz LUA (German part)	X			
Chemnitz CUA (Czech part)		X		
Bodrogköz UNIMIS (Hungary)		X		X

The pilot results showed that the success of application and data harmonization of the ENVASSO suggested methodology is depending on the heterogeneity of the source materials. Direct measurements of sealed area are time and cost consuming, so models based on topographic maps, satellite images and cadastral data are recommended for elaboration and testing.

Research commissioned by EEA (European Environmenral Agency) of concerning use of satellite imagery for new survey of sealing within the EU have been reported. 1996 is to be the baseline of measurement and the output will be at a resolution of 20 m.

Detailed evaluation is attached in the threat report soil sealing in Annex I. Pilot area reports on testing indicators for soil sealing are included in Volume IIb.
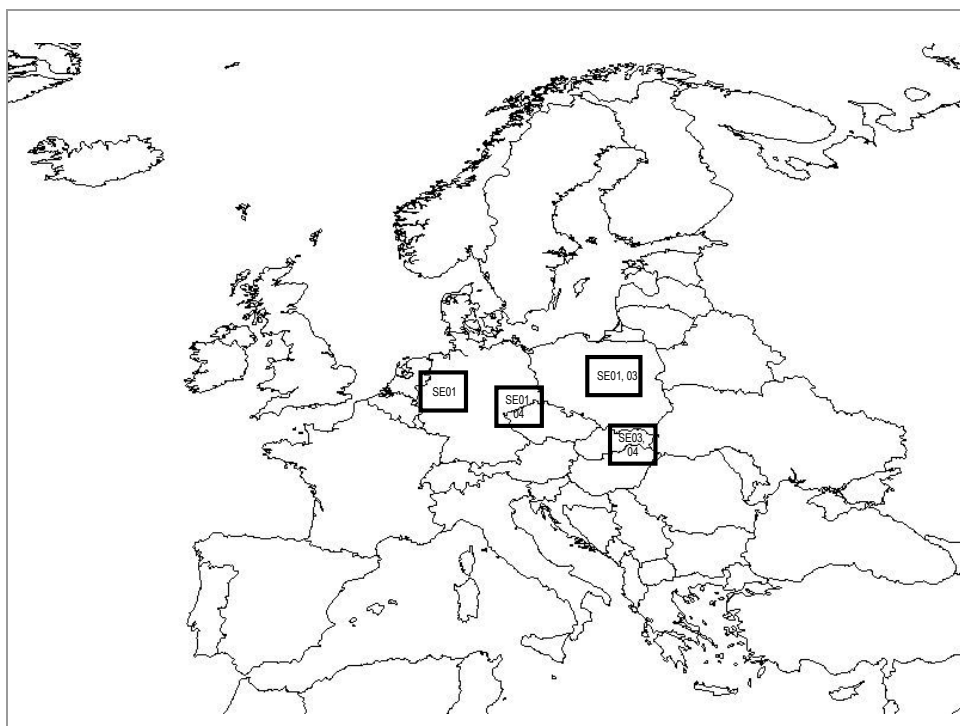
Figure 4. Location of the pilot areas testing the indicators of soil sealing
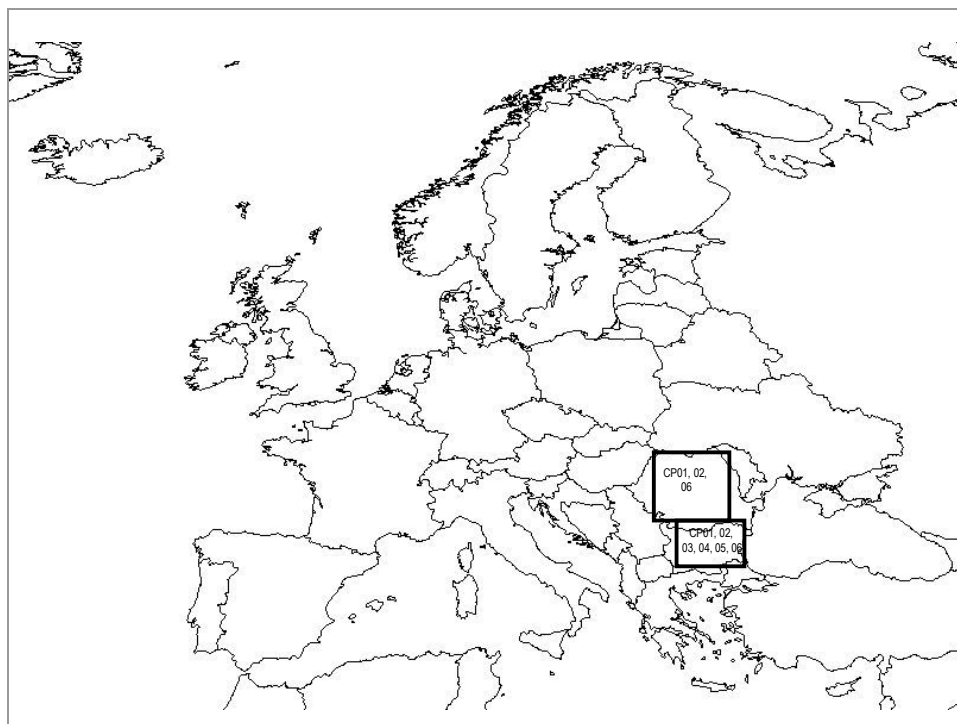
3.5 Soil compaction (CP)

Soil compaction on all the top three selected indicators were tested and evaluated on the two pilot areas. The testing and evaluations of these priority indicators were successful and were complemented with the comparison of further indicators (CP03, CP04, CP05) defined in Volume I and also with indirect models.

The pilot studies concluded that measured and modelled data provide different results and that vulnerability evaluation should be further refined considering the climatic conditions. The ENVASSO indicators focus mainly topsoil parameters, but subsoil compaction conditions greatly influence soil functions. Just as in other threats, the geo-statistical principles in sampling and analyses are important in the evaluation, harmonization and presentation of the results. SoDa was tested and performed well for data organization and CP indicator calculations.

Table 5. Studied indicators on the pilot areas for threat soil compaction (CP)

Pilot Area Institute (Country)	Indicator 1	Indicator 2	Indicator 3	Other
	CP01 Density (bulk density, packing density, total porosity) (g.cm^{-3} or kg m^{-3}; %)	CP02 Air Capacity (volume of air-filled pore at a suction of 5 kPa) (%)	CP06 Estimated Vulnerability to Compaction is based on texture, density, climate, land use	CP03 CP04 CP05 Indirect methods
Tsalapitsa ISSNP (Bulgaria)	X	X	X	X
ICPA Romania	X	X	X	X

Detailed evaluation is attached in the threat report on soil compaction in Annex I. Individual pilot area reports on testing indicators for soil erosion are included in Volume IIb.

Figure 5. Locations of the pilot areas testing indicators of soil compaction
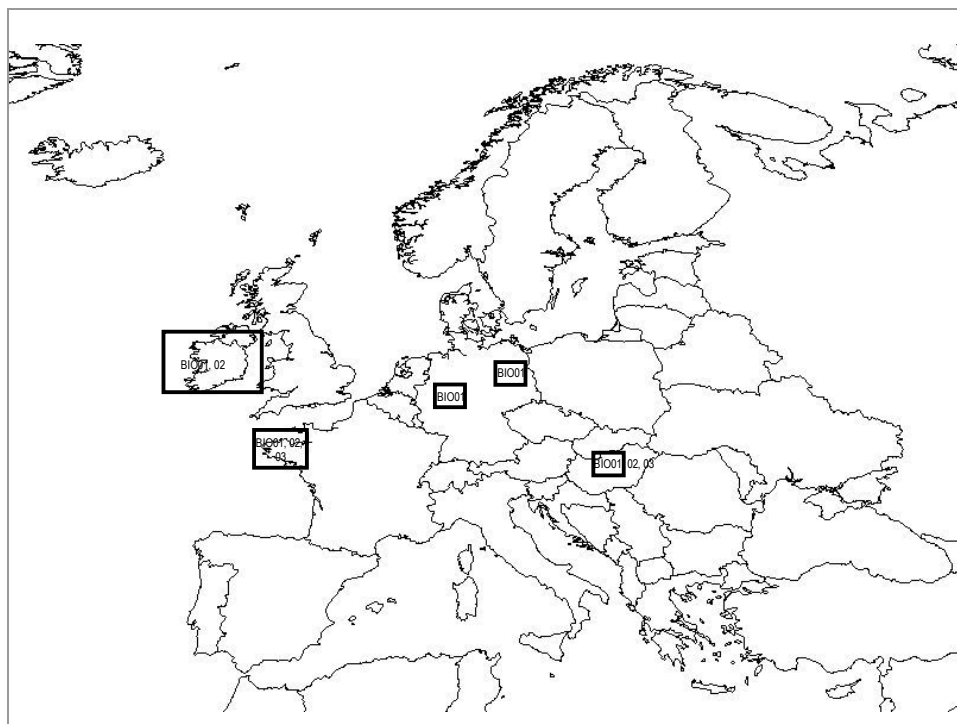
3.6 Decline in biodiversity (BI)

For decline in biodiversity, all the three selected indicators were tested and evaluated. Three pilot areas very different in size and different in expert background, performed detailed evaluations. Two pilot studies tested all three and one tested two of the indicators. In addition to the pilot studies, special contributions on methodology and additional data analyses were supplementing the ENVASSO prototype evaluations.

Table 6. Studied indicators on the pilot areas for threat decline in soil biodiversity (BO)

Pilot Area Institute (Country)	**Indicator 1** BI01 Earthworms diversity, abundance and biomass (or Enchytraeids diversity if no earthworms are expected) (No .$^{-2}$, g fresh weight m^{-2}	**Indicator 2** BI02 Collembola diversity and abundance (No m^{-2}, g fresh weight m^{-2})	**Indicator 3** BI03 Microbial respiration (g CO_2.kg^{-1} soil (DM))	**Other** -
RMQS Biodiv ADEME (France)	X	X	X	
Józsefmajor SIU/RISSAC (Hungary)	X	X	X	
Republic of Ireland TEAGASC/UCD (Ireland)	X	X		

The procedures and protocols were found feasible and applicable, however the performance of a systematic harmonized sampling (period, size, method etc.) across Europe on the main soil types and main land uses is necessary before making conclusions on baselines and thresholds. The development of common presentation of the results is also recommended to be part of the ENVASSO methods.

SoDa was tested and special requirements for biodiversity data structure and data presentation were identified for the system.

Figure 6. Locations of pilot areas testing indicators of decline in soil biodiversity

Detailed evaluation is attached in the threat report ondecline in soil biodiversity in Annex I. Pilot area reports on testing indicators, and the special studies on methodology and additional data on biodiversity studies, are included in Volume IIb.
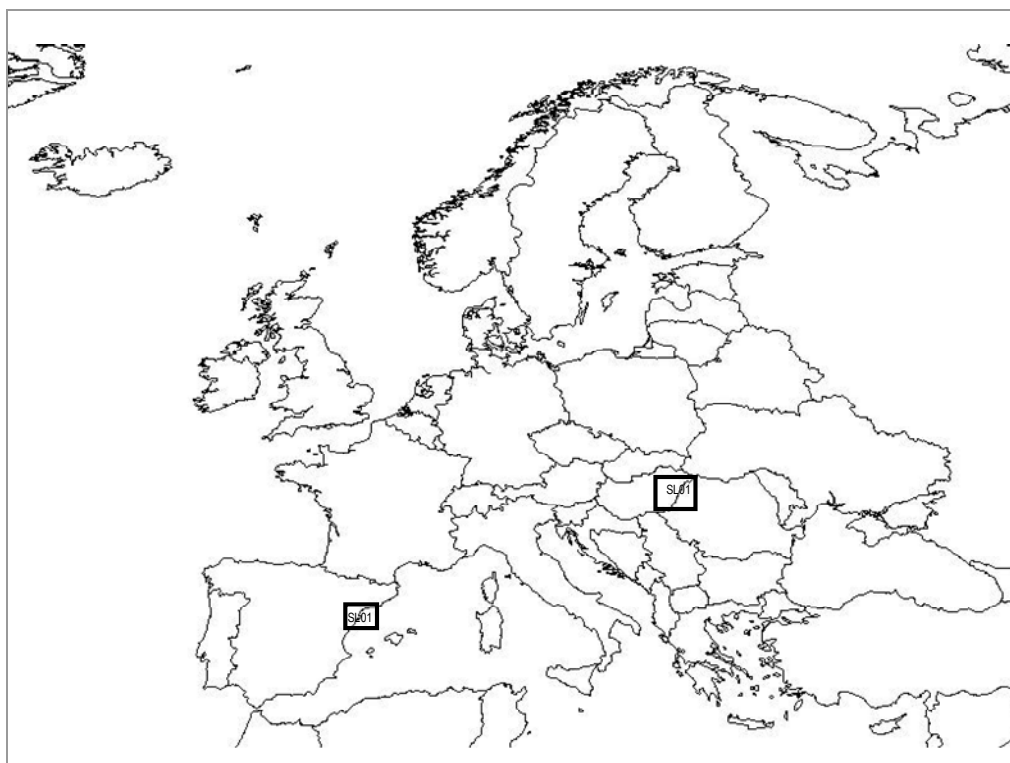
3.7 Soil Salinisation (SL)

Three pilot areas tested and evaluated the indicators on soil salinisation. Two of them were at a border area (Romania – Hungary), where soil classification and methodology harmonisation was performed as well. The testing of indicator SL01. and SL02. were successful. It was concluded that the sources of the salts are important in the definition of sampling periods and depth.

The applicability of indicator SL03. was discussed in different evaluation meetings and it was concluded that more scientific and technical progress is needed before this indicator is suitable foe implementation. In addition to the ENVASSO procedures defined, electromagnetic sensor-based measurements for salinity monitoring were performed successfully in the Spanish pilot area and hence it is suggested that they be included in ENVASSO's Procedures and Protocols (Volume V) to complement the analytical methods.

Table 7. Studied indicators on the pilot areas for threat salinisation (SL)

Pilot Area Institute (Country)	Indicator 1	Indicator 2	Indicator 3
	SL01 Salt profile (total salt content: %; electrical conductivity: S m^{-1})	SL02 Exchangeable sodium percentage (ESP) (pH unit ESP: %)	SL03 Potential salt sources (groundwater or irrigation water) and vulnerability of soils to salinisation/sodification (Salt content: mg L^{-1}; SAR: calculated ratio)
Körös-Berettyó Basin RISSAC/ICPA Hungary	X	X	
Oradea region (Bihor county) ICPA Romania	X	X	
Northern bank of Ebro Delta, Catalonia SARA, Spain	X	X	

SoDa was tested and proved to be useful for data capture and organisation, and the Salinity (SL) indicator calculations

Figure 7. Locations of the pilot areas testing indicators of salinisation

Detailed evaluation is attached in the threat report on soil salinisation in Annex 1. Pilot area reports on testing indicators for soil salinisation are included in Volume IIb.
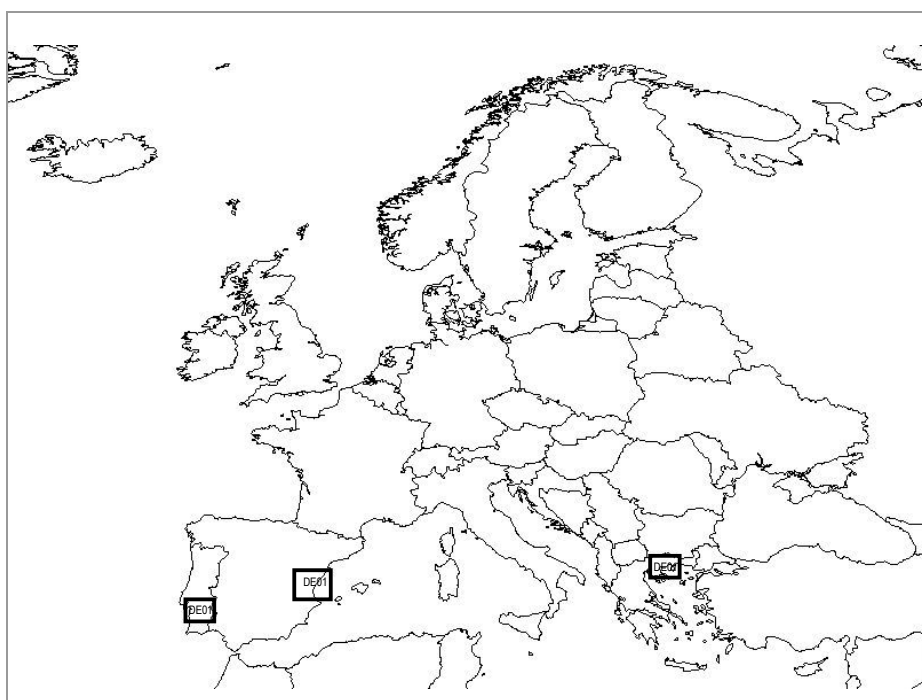
3.8 Desertification (DE)

For desertification only indicator DE01 (land area at risk of desertification) was tested using the MEDALUS model (see Volume V). Three test areas applied the model successfully at different scales. The common conclusion was that further development is needed for standard procedures to integrate the ENVASSO data specification system in a GIS environment. Harmonisation of input data is also an important requirement for results from different regions to be comparable.

Land impact of forest fires can vary more broadly than the ENVASSO indicator SE02 'land area burnt by wild fire' expressed in $km^2 \, yr^{-1}$ may suggest. The complex information on the impact of fires and the resilience of the environment need further research before this indicator can be applied. Indicator SE03 (topsoil soil organic matter content in desertified land) was implicitly evaluated, as OM01, see Decline in Organic Matter section in this volume.

Table 8. Studied indicators on the pilot areas for threat desertification (DE)

	Indicator 1	Indicator 2	Indicator 3	Other
Pilot Area Institute (Country)	DE01 Land area at risk of desertification (km^2)	DE02 Land area burnt by wild fire $(km^2 \, yr^{-1})$	DE04 Topsoil soil organic matter content in desertified land (%)	
Transect North of Valencia CSIC (Spain)	X			
Vale do Gaio watershed INIAP (Portugal)	X			
Philippi- Macedonia AUA (Greece)	X			

As for other specific models, MEDALUS has defined data input and programming structures that obviate the need to use SoDa at this stage. However, SoDa might be useful for estimating missing data using its pedotransfer functions.

Figure 8. Locations of the pilot areas testing indicators of desertification

Detailed evaluation is attached in the threat report on desertification in Annex I. Pilot area reports on testing desertification indicators are included in Volume IIb.

3.9 Landslides (LS)

The candidate indicators for landslides were defined as follows by work package1:

LS01: Occurrence of landslide activity (ha (or km^2) affected per ha (or km^2))
LS02: Volume/weight of displaced material (m^3 or tonnes of displaced material)
LS03. Landslide hazard assessment

Because of the lack of data, LS01 'Occurrence of landslide activity' was only indicator tested. It was applied in Samoggia, a pilot area in northern Italy and it was found to give a good picture of landslides as a threat in the Italian Appenines. Analysis of the results of using LS01 highlighted areas with the major problems and discriminated between the different types of landsliding activity. A crucial point is scale and the experience from Samoggia, where data at a resolution of 100 m was available, suggests this level of detail is not practicable at European scale.

The results from the Samoggia pilot study area described in Volume IIb.

4 Pilot Area Reporting

4.1 Pilot Area and Threat reports

The major outputs from the prototype evaluation undertaken by ENVASSO () are included as *pilot area reports* and *threat reports* in Volumes IVa & b. These provide important information on the performance of the selected indicators and important suggestions incorporated in ENVASSO's final Procedures and Protocols (Volume V).

The other important outputs were the contirbutions from the meetings and workshops listed in Table 9 that supported the planning, harmonisation, performance and evaluation of the pilot studies. In addition, some results have been published in scientific journals and presented at conferences.

4.2 Evaluation Meetings

4.2.1 Planning meetings

The first planning meeting and field exercise was held in Latvia and Lithuania, 31 July - 4 Aug, 2006, during which the objectives and working methodologies were discussed. In addition, a cross border soil classification exercise was undertaken that helped to solve correlation problems between the two countries.

A second planning meeting was held during the ENVASSO consortium meeting, 28-29 September, 2006, Prague, at which the experts were identified as 'Threat Leaders', the pilot areas were selected, and the pilot study leaders were nominated.

Table 9. Workshops and field meetings for indicator evaluation

Workshop	Venue	Country	Date
Workshop on Soil Compaction	Sofia	Bulgaria	27 February 2007
Workshop on Desertification and Erosion pilot studies for the Mediterranean countries	Athens	Greece	1 March 2007
Workshop on Decline in Organic Matter and Biodiversity	Wexford	Ireland	8 March 2007
Workshop special study on correlation of data on Organic Carbon measurements	Vienna	Austria	14 March 2007
Workshop on Decline in Organic Carbon pilot study and soils data harmonization	Slovak-Hungarian transnational pilot area	Bratislava	16 March 2007
Workshop on Soil Contamination	Ljubljana	Slovenia	27 March 2007.
Workshop on Soil Salinisation	Cluj	Romania	18 April 2007.
Workshop and filed exercise on performing biodiversity assessments and measurements	Rennes	France	2-4 May 2007.
Workshop on technical details on Desertification and Erosion models and planning discussion on Sealing and Landslides	Lisbon	Portugal	3-4 May 2007.
Workshop and field exercise on Slovak-Hungarian transnational pilot area	Miskolc and Bodrogköz	border area fields	10-12 May 2007
Workshop and field exercise on the Romanian-Hungarian transnational pilot area on Soil Salinisation	Budapest and border area fields		8-20 July 2007.

At each workshop:
- top 3 priority indicators of the threats were reviewed,
- input parameters for indicator calculations and evaluations were defined
- data availability was discussed
- data structure specification (SoDa) was presented and discussed
- working plan and schedule of pilot studies were defined.

4.2.2 Pilot result evaluation meeting

The results of the Pilot Studies were evaluated and field demonstrations on soil description and biodiversity assessment were organised in Sofia, Bulgaria, 11-14 June, 2007. During this meeting, the evaluation process and pilot area reporting was discussed.

4.2.3 Threat-leader meeting

Forssa, Finland 27-28 September, 2007
During this meeting the pilot reports were reviewed and the threat reporting was discussed.

4.3 ENVASSO results

The results of the ENVASSO project have been disseminated at conferences on related topics and via the literature.

4.3.1 Published papers

DOBOS E., MICHELI E., BIALKO T. (2007): WRB qualifier based mapping of soils. A case study in Hungary. *5th International Congress of the European Society for Soil Conservation. Palermo, 25-30 June, 2007.* Book of abstracts p. 531.

HEGYMEGI P., SPIEGEL H., FILCHEVA E., GÁL A., VERHEIJEN F.G.A. (2007): Review and comparison of methods used for soil organic carbon determination Part 2. Laboratory study. *Soil Science Agrochemistry and Ecology* 41. (4), p. 19-25.

JONES, R.J.A. (2008). Identifying risk or priority areas for soil degradation by erosion in Europe. In: Y. Heui Lee and W. Bückman (eds), Europäischer Bodenschutz –Schüsselfragen, des nachhaltigen Bodenschutzes, p.169-186. Universitätsverlag der TU Berlin {ISBN 978-3-7983-2095-6}.

KIBBLEWHITE, M., RUBIO, J-L., KOSMAS, C., JONES, R., ARROUAYS, D., HUBER, S., and VERHEIJEN, F. (2007). *Environmental Assessment of Soil for Monitoring Desertification in Europe.* Eighth session of the Conference of the Parties (COP 8) to the United Nations Convention to Combat Desertification (UNCCD), Madrid, Spain, 3 - 14 September 2007. ISBN 1-871315-97-2, Cranfield UK, 62pp.

MICHELI E., DOBOS E., JONES A. (2007): The diagnostic categories and the qualifiers of the World Reference Base for Soil Resources (WRB) as information sources for identifying threats to soil functions. *5th International Congress of the European Society for Soil Conservation. Palermo, 25-30 June, 2007.* Book of abstracts p. 507.

MORVAN, X., SABY, N.P.A., ARROUAYS, D., LE BAS, C., JONES, R.J.A., VERHEIJEN, F.G.A., BELLAMY, P.H., STEPHENS, M., KIBBLEWHITE, M.G. (2008). Soil Monitoring in Europe: a review of existing systems and requirements for harmonisation. *Science of the Total Environment* 391, 1-12.

SABY, N.P.A., BELLAMY, P.H., MORVAN, X., ARROUAYS, D., JONES, R.J.A., VERHEIJEN, F.G.A., KIBBLEWHITE, M.G., VERDOOT, A., BERENYI-ÜVEGES, J., FREUDENSCHUß, A. and SIMOTA, C. (2008). Will European soil-monitoring networks be able to detect changes in topsoil organic carbon? *Global Change Biology* 14, 1-11.

SPIEGEL H., FILCHEVA E., HEGYMEGI P., GÁL A., VERHEIJEN F.G.A. (2007): Review and comparison of methods used for soil organic carbon determination Part 1. Review of the methods. *Soil Science Agrochemistry and Ecology* 41. (4), p. 3-18.

WALTNER I., JONES R., MICHELI E., DOBOS E. (2007): Adoption and validation of a pedo-transfer function based model for estimating soil organic matter content in the soils of Hungary. *5th International Congress of the European Society for Soil Conservation. Palermo, 25-30 June, 2007.* Book of abstracts p. 237.

4.3.2 Conference presentations

CREAMER R., BISPO A., DOMBOS M., FUCHS M., GRAEFE U., PAULO SOUSA J., PERES G., RÖMBKE J., RUTGERS M., WINDING A. (2008): How to monitor decline in soil biodiversity across Europe? *EUROSOIL-2008 Congress. 25-29 August, 2008 Vienna, Austria.*

GÁL A., ÁRVAY GY., SZ. KELE G., BERÉNYI-ÜVEGES J., SIMON B., HEGYMEGI P., MICHÉLI E. (2008): Soil microbial respiration and organic matter relationship at different scale measurements. *EUROSOIL-2008 Congress. 25-29 August, 2008 Vienna, Austria.*

HEGYMEGI P., SZEGI T., SZEDER B. (2007): Planning of a European level erosion monitoring system in the ENVASSO project (in Hungarian) at the *'Erosion Round Table Conference'* organized by the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences Budapest, 28. November 2006.

JONES, R.J.A. (2006). ENVASSO Project and the forthcoming European Soil Framework Directive. ISO/TC 190 Soil Quality Meeting, Bristish Standards Institute, London, 9 October 2006.

JONES, R.J.A. (2008). Indicators for Soil Monitoring in Europe. EuroSoil-2008 Congress, 25-29 August 2008, Vienna, Austria.

KIBBLEWHITE, M.G. (2007). Environmental assessment of soil for monitoring desrtification in Europe. Eighth Conference of the Parties (COP8) of the United Nations Convention to Combat Desertification (UNCCD), 3-14 September 2007, Madrdi, Spain.

KIBBLEWHITE, M.G. (2007). Soil monitoring in Europe. INFO-SOL Soil Group, Dept of Sustainable Development, December 2007, Paris.

MICHELI,E. (2007): Efforts for harmonized assessing and monitoring soil properties in Europe (in Hungarian). National Environmental Protection Conference, Balatonfüred, Hungary, 10-16 October, 2007.

MICHÉLI E., GÁL A., SIMON B., HEGYMEGI P., ÁRVAY GY. (2008): Comparison of harmonized European and national level monitoring of soil organic matter and microbial respiration *7th Alps-Adria Scientific Workshop 28. April - 1 May, 2008 Stará Lesná, Slovakia.*

VAN DEN AKKER, J.J.H. (2008). Soil quality indicators and risk assessment methodologies for subsoil compaction. EuroSoil-2008 Congress, 25-29 August 2008, Vienna, Austria.

5 Summary Conclusions and Recommendations

The testing of the indicators on the 28 pilot areas was mainly successful and provided useful bacgground for a proposed harmonised Soil Monitoring System for Europe. Most priority indicators, for the eight threats identified in the European Thematic Strategy for Soil Protection, performed well and could be applied in the Pilot Areas selected. In some cases, specific modifications to the Procedures and Protocols were proposed.

Several pilot studies (mainly the transnational ones) concluded that data sources (methods, scale, etc) vary among Member States to an extent that makes harmonisation of results difficult. Development and application of geo-statistical principles in sampling and analysis are important in the evaluation, harmonisation and presentation of monitoring results. SoDa proved useful for indicators that are not based on models. It may serve as a common data platform and tool for data harmonisation in future.

Annex I: Prototype Evaluation

Summary results from

Pilot Area Studies

Table of Contents

1 Soil Erosion

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1.1 Introduction

Soil erosion has been considered as a threat to soil. The following indicators have been defined for soil erosion risk assessment (1) estimated soil erosion by water runoff (ER01), (2) measured soil erosion by water runoff (ER02), and (3) estimated soil erosion by wind (ER05). Measured soil erosion data by runoff water are limited, therefore soil erosion risk has been assessed in eight representative pilot areas throughout European Union using the Pan-European Soil Erosion Risk Assessment model PESERA (Kirkby *et al.*, 2004, 2008). One of the main criteria for selection of the pilot areas was the availability of the necessary data.

1.2 Description

Soil erosion is considered 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 in the context of it representing a soil threat it refers to 'accelerated soil erosion'.

The following types of erosion have been identified:

- Water erosion, by rill and inter-rill, gully, snowmelt, and of banks in rivers and lakes;
- Translocation erosion by tillage, land-levelling, harvesting of root crops, trampling and burrowing animals;
- Wind erosion, by the action of strongly moving air, which is often dessicating;
- Geological erosion: internal subterranean erosion by groundwater, coastal erosion and landslides

1.3 Indicators

1. ER01 - Estimated soil erosion by water runoff
2. ER02 - Measured soil erosion by water runoff
3. ER05 - Estimated soil erosion by wind

Table 1-1.List of Pilot Areas and indicators studied

Pilot Area	Reason for Selection	ER01	ER02	ER05	Model used
Vale do Gaio INIAP, Portugal	Data availability	X			PESERA_GRID
Chania Crete AUA, Greece	Data availability	X			PESERA_GRID
Philippi Macedonia AUA, Greece	Data availability	X			PESERA_GRID
Transect North of Valencia, CSIC, Spain	Data availability	X			PESERA_GRID
Hungary SIU, Hungary	Data availability	X			PESERA_GRID
Sheet Chemnitz BGR-LfUG-CUA Germany-Czech	Data availability, trans-national	X			PESERA_GRID
Scotland	Data availability	X			PESERA_GRID
Samoggia SSGS-RER, Northern Italy	Data availability	X			PESERA_GRID

1.4 Indicator Evaluation

1.4.1 ER01 Estimated soil erosion by water runoff.

The following parameters are used: soil textural class for estimating soil erodibility, soil water storage capacity, soil crusting, initial surface water storage, roughness reduction, land cover type, plant cover, standard deviation of elevation, monthly rainfall, monthly temperature, monthly temperature range, coefficient of variation of rainfall per rain day for each month, mean rain per rain day for each month, and monthly potential evapotranspiration (ETo). The data used to assess soil erosion were collected by conducting a regular soil and vegetation semi-detailed survey (1:30,000). The majority of the above parameters can be extracted from the ENVASSO databases.

ENVASSO procedures and protocols for erosion (see Jones *et al.* 2008) are applied in the pilot areas but some data required are not provided by the existing ENVASSO databases, which with respect to soil are based on profiles, i.e. points in the landscape. The assessment of soil erosion risk for a specific field site can be estimated using the ENVASSO procedures but this cannot be achieved for a region where assessment is based on mapping units not on soil profile data. The assessment of soil erosion also requires the use of detailed or semi-detailed soil, vegetation and land management maps.

Greece: Data on soils, vegetation, climate and land management have been collected during the execution of the following EU research projects: (a) OLIVERO, (b) Archimed Interreg IIIB-IMAGE, (c) Interreg IIIB Medocc – PROGECO), and (d) DESERTLINKS.

Portugal: Data available in Portugal to run the PESERA model is limited because there is no analytical database associated to the soil survey mapping. Consequently, all information on analytical soil data has to be extrapolated from representative soil unit profiles and to do that some knowledge on Portuguese soils is needed. Meteorological data have been obtained from both the "Instituto Nacional da Água" and the Meteorological Institute networks. Vegetation and land use data were extracted from the CORINE Land Cover data basis.

Spain: The following sources of data have been used to apply the PESERA in Spain: (a) vegetation from CORINE, (b) soils from LUCDEME Project soil maps, (d) climate from the National Meteorological Institute, (e) topography from the published digital maps with 20 m contour lines interval provided by the COPUT, (e) other parameters from the PESERA data basis.

Table 1-2. Description and comparison of the Pilot Areas

Pilot area	Size (km^2)	Climate	Land use	Topography	Major soils
Vale do Gaio INIAP, Portugal	513	Mediterranean	Oak tree Mediterranean woodland, Agricultural crops, Pasture	Gentle undulating	Cambisols, Luvisols
Chania Crete AUA, Greece	717	Semi-arid	Agricultural crops, pastures, woodland	Flat to very steep	Cambisols, Luvisols, Fluvisols, Regosols, Leptosols
Philippi Macedonia AUA, Greece	23	Semi-arid	Agricultural crops, pastures,	Flat to steep	Cambisols, Histosols, Leptosols, Fluvisols
Transect North of Valencia CSIC, Spain	3011	Sub-humid to Semi-arid	Natural and reforested woodland, irrigated and non-irrigated cultivation	From coastal plain to highly mountainous	Calcisols, Luvisols, Cambisols, Fluvisols, Anthrosols, Regosols, Leptosols, Phaeozems, Kastanozems
Hungary SIU, Hungary	90,030	Temperate	Various	Approx. 3/4 is low plain,1/5 hilly and 5% mountainous	Arenosol, Chernozem, Cambisol, Fluvisol, Histosol, Leptosol, Luvisol, Phaeozem, Regosol, Solonchak, Solonetz
Sheet Chemnitz BGR-LfUG-CUA Germany-Czech	15,753	temperate suboceanic to temperate-subcontinental	Cropland (36%), forest (30%), grassland (8%), urban (9%), heterogeneous agricultural land (10%), Scrubs (5%)	Level land, sloping land	Cambisols, Luvisols, Albeluvisols, Podzols, Chernozems, Andosols
Scotland Macaulay Institute Scotland	77,925	Cool temperate	CroplandGrassland, moorland, forest bog	From coastal plains to highly mountainous	Cambisols Luvisols Podzols Histosols Arenosols
Samoggia, SSGS-RER Northern Italy		Humid	Forest grassland	Sloping land	Cambisols Luvisols

Germany- Czech Republic: The following sources of data have been used for running the PESERA model in Germany: (a) land cover from CORINE, (b) climate data from the German Weather Service (DWD) and CZ Hydrometeorological Institute, (c)vegetation from CORINE Land cover map, (d) topography from the Shuttle Radar Topography Mission (SRTM) project led by NGA (National Geospatial-Intelligence Agency) and NASA (International Aeronautics and Space Administration), and (e) PESERA data basis.

Hungary: The following sources of data have been used for running the PESERA model in Hungary: (a) land cover from CORINE Land cover 2000 map, (b) topography from the Shuttle Radar Topography Mission (SRTM), (c) scale depth data derived from the Hungarian AGROTOPO database and (d) PESERA data base.

No overall *baseline* for soil erosion has been defined; the identification of such a value requires further research. A *threshold* value for soil erosion of 1 t ha^{-1}yr^{-1} can be considered as tolerable although such values can be different depending on specific site environmental conditions and vulnerability to soil erosion. More research is needed to establish a minimum detectable change.

1.4.1.1 Results

The assessment using the PESERA_GRID model can be satisfactory if detailed soil, vegetation, climate and management data are available. The application of the model in a region requires the preparation of a large number of raster layers (103 layers) which can be made by an expert on ArcGIS$^®$. The PESERA_GRID model is a valuable tool for assessing soil erosion rates under various land use types and management practices. Soil erosion rates can be predicted also under various climatic scenarios.

The application of the model can be achieved by using ENVASSO protocols for part of the data required. For example data such as: soil texture of surface layer, soil depth, soil water storage capacity, slope gradient, rainfall, land use type, plant cover can be extracted from the ENVASSO database. In addition, data such as: soil crusting, initial surface water storage, roughness reduction must be estimated from the data basis available from the PESERA model. Its predictions can be compared for different years, land use, land cover and tillage practices, enhancing soil protection practices. The model needs detailed information on soil, vegetation, climate and management data. Before running PESERA, even an ArcGIS$^®$ expert needs some hours training. The maps derived for the pilot areas (PA) can be easily compared when using a standard legend.

Results of using PESERA have been presented in the same way for all PAs. Classes of soil erosion rates have been identified based on existing experience of soil erosion rates affecting soil degradation.

Minimum detectable change (MDC) by the PESERA model is in the range of 0.2 t ha^{-1} year^{-1}.

Baseline. the baseline for no erosion is 0 t ha^{-1}yr^{-1}

A Threshold rate for soil erosion is 1–2 t ha^{-1} yr^{-1}, which can be considered as tolerable although such values can be different depending on specific site environmental conditions and vulnerability to soil erosion.

Conclusions and recommendations.
1. The application of the PESERA_GRID model in a region requires a large number of raster layers (103 layers), which are best compiled by an expert using ArcGIS.
2. The model can be run using ENVASSO protocols for part of the data required (such as: soil texture, soil depth, soil water storage capacity, slope gradient, rainfall, etc).
3. Data such as: soil crusting, initial surface water storage, roughness reduction are best estimated from the base input
4. data available for the PESERA_GRID model.

The ENVASSO project has made an excellent effort in organizing the soil database and identifying the best methodologies for assessing various soil threats using indicators. With respect to erosion, the ENVASSO system must be further improved in relation to the data availability by: (a) introducing more data into the existing databases, (b) including new data for vegetation, climate, and land management. The databases have to be organized in such a way that they can readily act as sources to support the recommended methodologies for assessing soil threats.

2 Decline in Soil Organic Matter

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2.1 Introduction

Soil organic matter, in the context of soil protection, is taken to be the organic fraction of soil, excluding non-decayed plant and animal residues. Organic matter (OM) is vitally important in many soil processes, is being lost from many soils. This report summarizes the results and experiences of four different pilot areas (PA) located around Europe, where the decline of OM was investigated following the ENVASSO procedures.

2.2 Description

Decline in Soil Organic Matter: 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.

2.3 Indicators

1. OM01 - Soil organic matter content in topsoil
2. OM02 -Topsoil carbon stock
3. OM03 - Peat stock

Table 2-1. List of pilot areas and indicators studied

Pilot Area	Selection reason	OM01	OM02	OM03
Finland,Orivesi, MTT	Data availability: digital data in different scales, historical data Representative: northern peat lands			X
Republic of Ireland TEAGASC-UCC Ireland	Data availability: digital data in existing (monitoring) system Representative: northern aspect of indicator 1 and 2	X	X	X
Spain, Terres de l'Ebre and Ebro Delta. SARA	Data availability: digital data in existing (monitoring) system Representative: Southern aspect of indicator 1	X		
Hungary-Slovakia Bodrogköz UNIMIS-SSCRIS	Data availability: Cross border aspect of indicators 1 and 2	X	X	

Table 2-2. Description and comparison of the Pilot Areas

Pilot Area	size (km^2)	climate	land use	topography	Majors soils
Finland,Orivesi, MTT,	800	Boreal-Continental	FN1 (major)	Hilly, lakes 80-160 AMSL, hills max 200m.	Leptosols, Regosols, Arenosols, Podzols
Republic of Ireland TEAGASC-UCC Ireland	69,902	Temperate maritime	H (Major) AP, HE, HI, FP, U	Flat to Undulating Lowland, Rolling Lowland, Mountain and Hill, Drumlins, Hill	Histosols, Gleysols, Luvisols, Podzols, Cambisols, Leptosols
Spain, Terres de l'Ebre and Ebro Delta. SARA	400 & 350	Typical Mediterranean (Csa according to the Köppen classification)	Dry land: Olive tree, cereal crops and vineyard Irrigated land: Fruit-trees, citrus and vegetable Paddy rice, vegetables	Flood plain and terraces of Ebro river, glacis of Mora and marls and limestone hills	Fluvisols, Calcisols, Kastanozems Regosols, Luvisols, Leptosols, Cambisols, Arenosols, Histosols and Solonchaks
Hungary-Slovakia Bodrogköz UNIMIS-SSCRIS	1457	Temperate	A (Major)	Alluvial plain	Vertisols, Arenosols, Gleysols, Luvisols, Fluvisols

2.4 Indicator Evaluation

2.4.1 OM01 Soil organic matter content in topsoil

Positive: The ENVASSO procedures and protocols proposed (see Volume V, Jones *et al.*, 2008) are feasible and easy to apply. Determination of the indicators is also simple.
Negative: In soils with high carbonate content, the first proposed procedure (dry combustion) is not possible. The second procedure (Walkley Black method) is inefficient in hydromorphic and organic soils because it overestimates the real SOM% (Hegymegi *et al.*, 2007; Spiegel *et al.*, 2007). The depth of the topsoil should be accurately measured because the SOM content (%) will change depending to the depth.

The required parameter is soil organic carbon content (%), determined by dry combustion organic carbon analyser (with humidity column). The depth of the topsoil should be accurately known because the organic matter content could change depending on the depth. Data for each pilot area was based on samples collected from national monitoring sites.

Baseline. It is unsound to define a single baseline for soil organic carbon (SOC) content in all topsoils. SOC and soil organic matter (SOM) contents depend strongly on geo-climatic factors (Jones *et al.*, 2005), land use (McGrath and Loveland, 1992; Arrouays and Pelissier, 1994), soil type and clay content (Arrouays *et al.*, 2001, 2006), clay contents and precipitation combinations (Verheijen *et al.*, 2005), and on management practices (i.e., Carter 1992; Soussana *et al.*, 2004). Therefore, the baseline values should be area specific (i.e. the value measured over an area for a given date). Ranges of reference values specified for different land uses, clay content, and climate can be derived from soil data by analysis of inventories (i.e.

Verheijen *et al.* 2005). There is also some consensus that there is a well-defined relationship between lower limits for SOC in a soil and its texture (specifically, its clay and fine silt content).

Threshold. Although the lower threshold of 2% soil organic carbon has been widely used (Kemper and Koch, 1966; Greenland *et al.*, 1975), it is clear that a large proportion of intensively cultivated soils of Europe have already reached of fell below this content (Loveland and Webb, 2003; Arrouays *et al.*, 2001, 2006). Even where the majority of soils have less than 2% SOC, i.e. for sandy soils in the relatively dry parts of England, there is no conclusive quantitative evidence of marked effects on other soil properties and crop yields (Verheijen, 2005). However, there is some suggestion that below a threshold of ca. 1% soil organic carbon, and without addition of exogeneous soil organic matter and fertilizers, a disequilibrium in N-supply might occur, leading to a decrease of both SOM and biomass production (Körschens *et al.*, 1998).

Whatever the threshold, the depth of sampling is a major issue, because of the strong gradients in SOM with depth, and because the soil properties of interest might be important for the upper few centimeters (e.g. risk of erosion linked to aggregate stability) or for the whole arable layer (e.g. nutrient availability) or even to greater depths (e.g. available water capacity). The thresholds, if any, should depend on the properties and functions of soil that SOM influences (crop production and nutrient availability, cation exchange capacity, available water capacity, aggregate stability, porosity, etc). Although some studies proposed ranges of values, i.e. lower and upper limits increasing with increasing clay content (Körschens *et al.*, 1998), Loveland and Webb (2003) concluded in a review that there is no quantitative evidence for critical thresholds for SOM in relation to crop yields.

2.4.1.1 Results

OM01 was evaluated in three Pilot Areas: In Spain, Ireland and Hungary/Slovakia. In all pilot areas the procedures and protocols were found to be feasible and easy to apply. Determination of the indicator values was also simply. However the suggested methodologies can give erroneous results in hydromorphic conditions and on saline soils.

Following indicator testing, no *minimum detectable change* has been defined.

Conclusions and recommendations.
1. In soils with high carbonate contents, dry combustion is not always possible; the Walkley Black method is not efficient for hydromorphic and organic soils because it overestimates the true SOM% (Hegymegi *et al.* 2007; Spiegel *et al.* 2007).
2. There are several dry combustion methods but no particular method is recommended.
3. The topsoil depth of 0-30 cm is controversial, there should be maximum specied, because the SOM (%) calculated dependst on the depth.
4. The maximum depth of topsoil should be recorded together with the depth of sampling. The procodure for OM01 is only suitable for mineral soils.

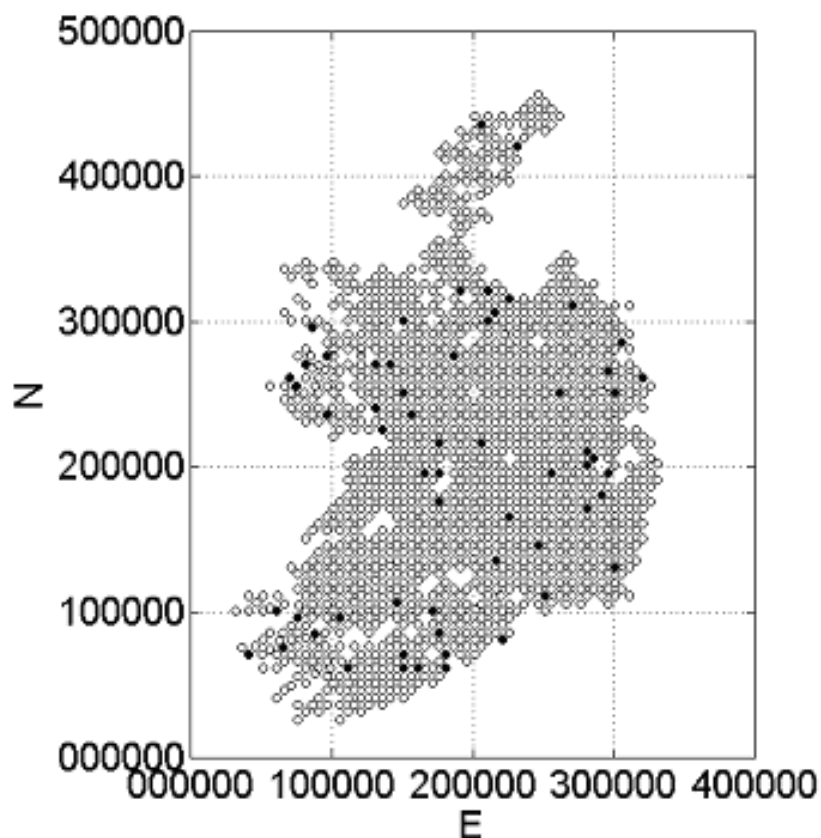**Figure 2-1. Location of Pilot Area Terres de l'Ebre and Ebro Delta, Spain**

Figure 2-2. Location of the Irish Pilot Area with 60 representative sampling sites, Republic of Ireland
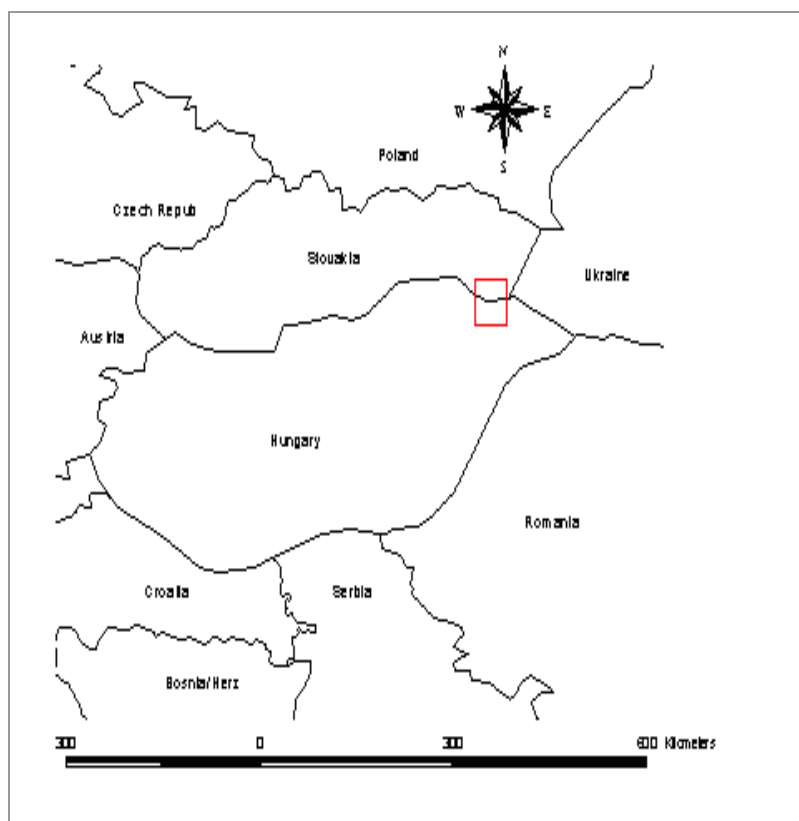

Figure 2-3. Location of the Hungary-Slovakia Transnational Pilot Area

2.4.2 OM02 Topsoil carbon stock

Positive: The ENVASSO procedures and protocols proved to be feasible and easy to apply. Determination of the indicator values also proved to be simple.

Negative: However, the interpretation of the indicator, values in the case of OM02, might lead to false conclusions if accurate soil depth data are not available. In the case of deep soils with high OM content, the loss of OM rich soil may not be detected as change in stock if only the top 30 cm is monitored.

Table 2-3. Parameters

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

preferred parameters are in black, alternative parameters are in grey; A=Actual, M=Modelled

Baseline. For the same reasons as those cited in OM01, no single baseline value for topsoil carbon stocks is proposed. It is even more difficult to establish comparisons between soils because of the combined influences of soil depth, bulk density and texture on stocks. But if enough data are available, it is possible, using statistics, to propose ranges of values using the same method as described above for topsoil SOC contents (see Arrouays *et al.*, 2001, 2006; Verheijen *et al.*, 2005).

Threshold. If we consider only the 'carbon sink' function in relation to greenhouse gas inventories, then we might consider a threshold that could be used at a large geographically aggregated scale, which would ensure that the carbon stock balance between two dates is not negative.

No *minimum detectable change* has been defined.

2.4.2.1 Results

OM02 was evaluated in two Pilot Areas (PA): Ireland and Hungary/Slovakia. In both pilot areas the procedures and protocols were found to be feasible and easy to apply. Again the topsoil depth issue was deemed critical:.the interpretation of indicator values in the case of OM02 might lead to false conclusions unless accurate soil depth data are available. In case of deep soils with high OM content, the loss of OM rich soil might not be detected as change in stock if only the top 30 cm is monitored.

The depth of of the of monitored layer of OM02 should consider the depth of OM rich top soil. In case of soils with deep and high OM content, the loss of OM rich soil may not be detected as change in stock if only the top 30 cm is monitored. It is recommended to sample the soils at least down to 50 cm. It is necessary to consider course fragments in SOC stock. The definition of the organo-mineral layer should be established in the procedures and protocols.

2.4.3 OM03 Peat stock

Positive: The methods defined by the ENVASSO procedures and protocols were found to be feasible and easy to apply.

Negative: Depth of peat cannot be measured accurately in practice because the resources required to measure peat depths would be too costly under current research budgets. The area of peat deposits in Europe can be more easily measured using remote sensing techniques but converting such measurements into volumes (stocks) of peat depends on accurate values of peat thickness. Gamma radiometry can be used only when making initial evaluations and data are still lacking on the delination of peat areas. In Finland, only geological mires more extensive than 20 ha were used in the evaluation process.

Table 2-4. Parameters

preferred parameters are in black, alternative parameters are in grey; A=Actual, M=Modelled

Required parameters	Units	Type	Spatial Resolution
Depth of peat	m	A	
Area of peat	m^2	A	2 km
Bulk density of peat	t m^{-3}	A / M	

Because of the difficulty in implementing indicator OM03, OM05 (Changes in Land Cover) should be considered as a replacement in Finland/Related countries.
Both Pilot Areas used CORINE and soil maps as source material. The Republic of Ireland pilot area has developed and tested a model to predict peat depth, while bulk density was estimated from available literature data in the literature.

There is some uncertainty about the exact area and depth of peat in Europe (Montanarella *et al.*, 2006). However applying the 'precautionary principle', peat should be protected,*per se.*

A *baseline* and *threshold* values at the European scale could be the present total volume of peat (area x depth).

Based on the Orivesi pilot studies, the minimum detectable change (MDC) is proposed as: Relative change in land use of peat areas inside soils_scape, MDC 0,1%.

2.4.3.1 Results

The Peat stock indicator OM03 was evaluated in two pilot areas: Orivesi (Finland) and Republic of Ireland. Both evaluations were based on GIS methods using Corine Land Cover and Soil Maps as source material.

The evaluation in Ireland used a model that fitted indicator OM03. The evaluation in Finland did not fit OM03, but was related to OM05 (changes in land cover).
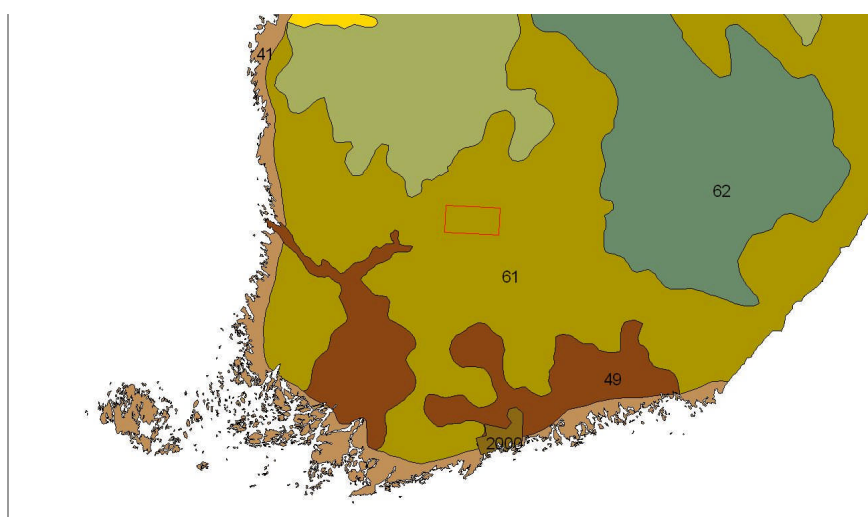
**Figure 2-4. Localization of the Orivesi Pilot Area (rectangle)
and Soil Regions map, Finland**
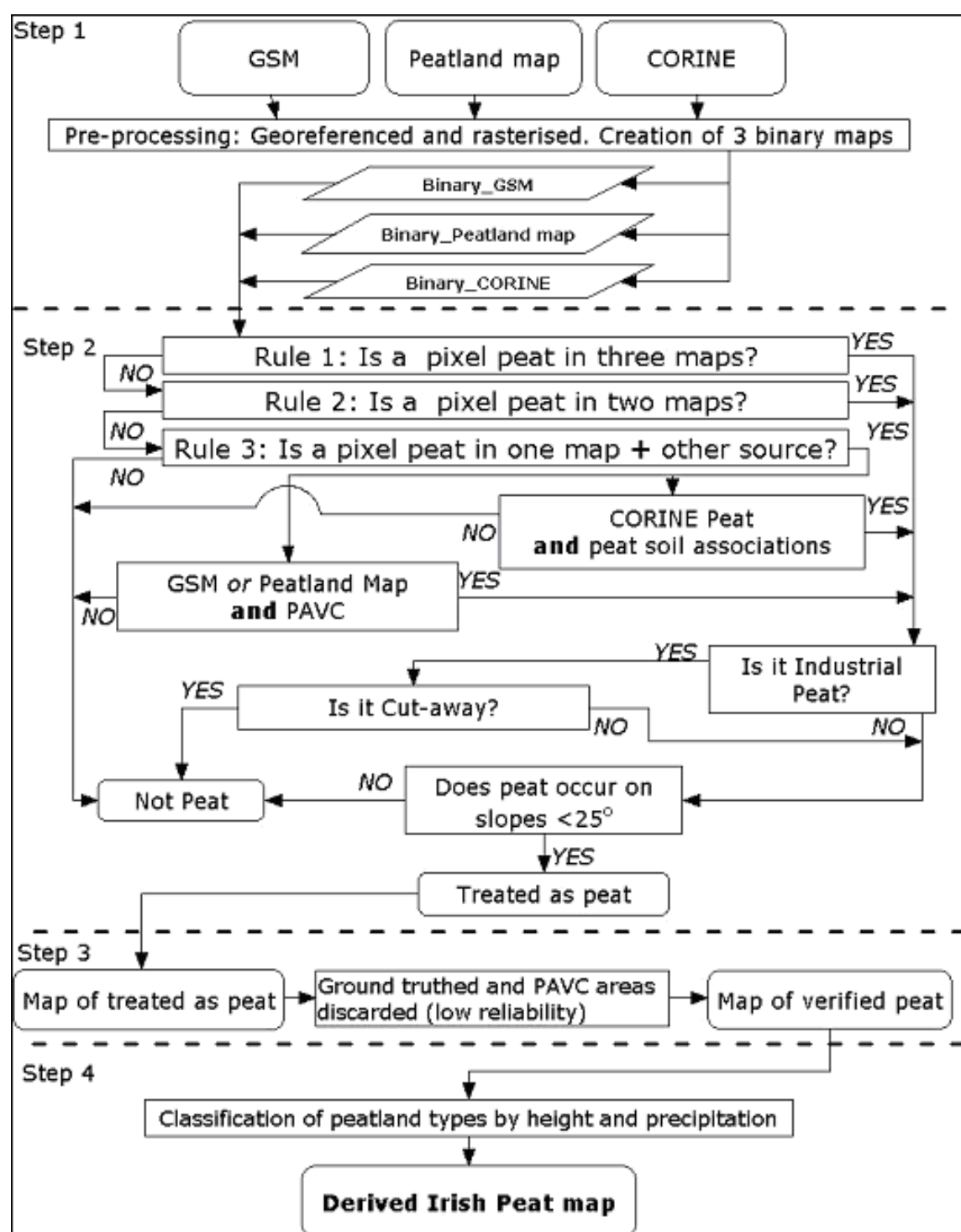
**Figure 2-5. Irish model to evaluate the spatial extent of contemporary peatlands
(Connolly *et al.*, 2007)**
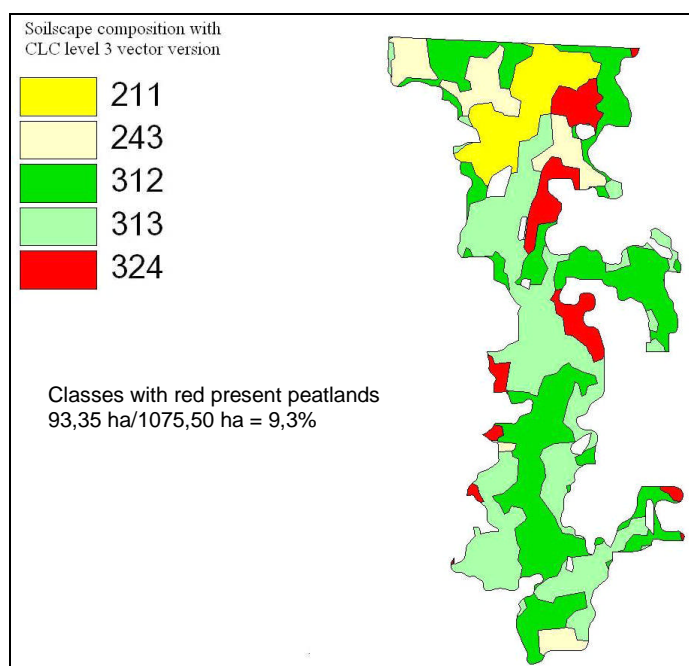
Figure 2-4. Example of land cover change monitoring inside the soilsscape (polygons in polygon analysis)

Conclusions and recommendations

1. Clarification of the definition of peat areas is needed for example, in Finnish evaluations only geological mires (extending to > 20 ha in surface area) have been used.
2. Depth of the peat cannot be measured or modelled consistently over large areas because of economic constraints. Gamma radiometry can be used only for initial evaluations.The existing models are not capable of monitoring changes in peat stocks, because land use can change at too fast a rate (because of peat extraction, erosion etc.)
3. A new indicator is needed to estimate peat stocks

3 Soil Contamination

Authors
This report was prepared under the supervision of Cranfield University by Mark Kibblewhite.

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3.1 Introduction

The objectives of the pilot studies were to

- Compare sampling and testing methods for heavy metal contents in soil with those recommended by ENVASSO
- Explore and evaluate methods for establishing baselines and estimating background ranges, and for determining exceedance of thresholds, for heavy metal contents in soil (taking account of differences in natural and anthropogenic sources)
- Demonstrate the application of methods recommended by ENVASSO for assessing progress in the management of contaminated sites

3.2 Description

Soil contamination is the occurrence of pollutants in soil above a certain level, causing a deterioration or loss of one or more soil functions

3.3 Indicators

1. CO01 - Heavy metal contents in soil
2. CO07 - Critical loads exceedance by sulphur and nitrogen
3. CO08 - Progress in the Management of Contaminated Sites

Table 3-1. List of PA areas and studied indicators

Pilot Area	Selection reason	CO01	CO07	CO08
Ruhr Area LANUV-BGR (Germany)	Highly populated industrial area with good data sets	X		X
1:250,000 Sheet Chemnitz BGR-LfUg-CUA (Germany – Czech Republic)	Large transnational area including historic and current industrial activities with good data sets	X		
City of Linz and Surrounding AreaUBA (Germany)	Highly representative of contaminated areas with good data sets			X
England and Wales CU (United Kingdom)	Large area including historic and current industrial activities with good data sets	X		

Table 3-2. Description and comparison of the Pilot Areas

Pilot Area	Size (km^2)	Climate	Land use	Topography	Major soils
Ruhr Area LANUV-BGR (Germany)	1052	Atlantic	Settlement / industry (28%); Farming (17%); Forestry (7%)	Plain	Technosols, Cambisols, Luvisols, Anthrosols
1:250,000 Sheet Chemnitz BGR-LfUg-CUA (Germany – Czech Republic)	15,753	Transitional: subatlantic to subcontinental	Cropland (36%); Forest (30%); Grassland (8%); Urban (9%); Other (15%)	Level land, sloping land	Cambisols, Luvisols, Podzols
City of Linz and Surrounding Area UBA (Germany)	556	Cfb zone labeled "Mid-Latitude, Uniform Precipitation, Warm Summer"	Agriculture(65%); Artificial surfaces (20%); Forest (13%); Water (2%)	Sloping land / medium-gradient mountain	Luvisols, Fluvisols, Cambisols, Leptosols, Gleysols, Podzols
England and Wales CU (United Kingdom)	150, 000	Temperate Oceanic	Crops (30%); Grass (40%); Forest (10%); Urban (20%)	High hills and rolling plains	Cambisols, Luvisols, Leptosols, Podzols, Fluvisols, Gleysols, Histosols Stagnosols

3.4 Indicator Evaluation

3.4.1 CO01 Heavy metal content in soils

Initially, ENVASSO Procedures and Protocols (see Volume V, Jones *et al.*, 2008) proposed extraction by *aqua regia* from soil samples taken at fixed depths.

In the Chemnitz pilot study, some of the data (CUA) were from samples taken at fixed depths whereas others were from soil (pedological) horizons (LfUG). Although there may be some advantage with horizon sampling, such as observation of differential concentration of metals between organic and other horizons, this approach is not consistent with that of previous recommendations. Moreover, different methods were,used for testing, with the LfUG data being derived from a more sophisticated digestion employing hydrofluoric acid instead of *aqua regia* recommended by ENVASSO. Although a correction factor was applied to data to allow comparison with the CUA data set, this depends on the proportion of silica-bound metals, which are only released by hydrofluoric acid, being constant. This illustrated the difficulties of harmonizing data produced by different institutions and the need for applying an agreed common standard.

Ruhr pilot area: data for metal contents of soils were derived from many different studies that are likely to have used a wide range of sampling and testing procedures.

Chemnitz pilot area: see above for discussion of sampling and testing procedures – the data from LfUG and CUA both derived from systematic surveys with well-documented procedures.

England and Wales: these data were substantially compliant with the ENVASSO recommendations.

The current procedures and protocols do not describe the necessary geostatistical methods for estimating baseline or background ranges / values. Jones *et al.* (2008) recommend that the thresholds applied should be those advised by local/regional/national authorities.

The geostatistical methods for estimating minimum detectable change (MDC) are not described in the procedures and no attempt was made to do this in the pilot studies reported here.

3.4.1.1 Results:

The three pilots were more successful in assembling data for cadmium and lead than for mercury, reflecting the fact that data for the latter metals are more costly and in some respects more difficult to obtain, so they are found less commonly in existing databases.

The transnational pilot study was of particular value, because it illustrated the difficulties of harmonising data produced by different institutions according to different assumptions and procedures. Although a careful effort was made to harmonise the data sets, to take account of different sampling and testing procedures, this has to be viewed as only partly successful.

All of the pilot studies were successful in extending the ENVASSO procedures and protocols to include geostatistical analysis of data and this is an important output for the wider project. The use of maps based on Kriging of data was successful and valuable for illustrating the spatial distribution of heavy metal contents in soils and exceedance of baselines/background and thresholds.

Baseline. The three CO01 pilots all applied geostatistical techniques and from these a general and important conclusion is that categorization of samples by land use / land cover and geology (but probably not soil type) is essential to allow meaningful data interpretation. The Ruhr pilot study applied a standard method for identifying plots that are representative of baseline / background and not expected to have anthropogenic additions that are non-representative of the region being assessed. A preliminary approach for this process was also explored in the England and Wales pilot study, however, it is recommended that the formalised "Guideline for the creation of soil quality maps in urban areas" (LANUV, 2007), which was applied in the Ruhr pilot area be adopted by ENVASSO.
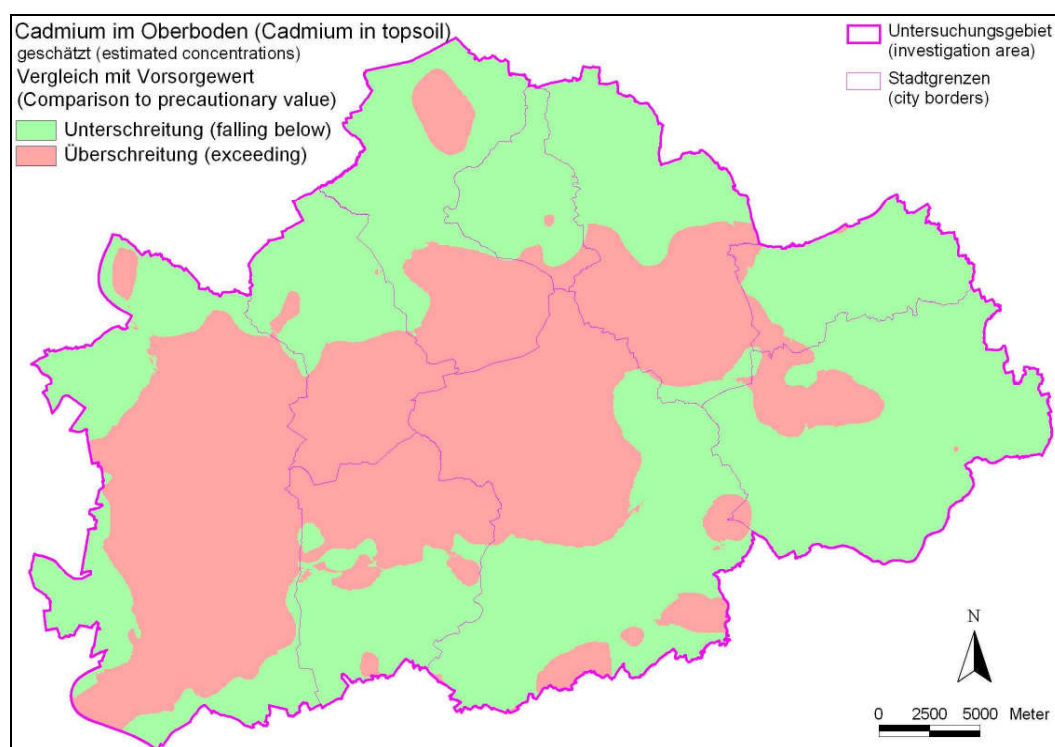
Figure 3-1. Comparison of the estimated regional cadmium concentrations from the soil quality map for the Ruhr pilot area against the local precautionary values.

Table 3-3. Estimated background ranges of lead in soil (mg/kg) categorised by land cover for the England and Wales pilot area.

Land Cover	Geology	Mean +/- 2 standard deviations	Median +/- 2 median absolute deviations	10th to 90th percentiles
Artificial (Urban)	All	11 - 370	17 – 210	28 -180
Agriculture	All	10 - 150	14 – 92	19 -84
Semi-natural / forest	All	11 – 450	16 -290	26 -230

This can be summarized as follows:

- Step 1: Investigation and preparation of spatial data (land use, flooding, contaminated sites, etc)
- Step 2: Development of concept map
- Step 3: Preparation and rectification of soil data
- Step 4: Statistical analysis of valid soil data (descriptive statistics, outliers)
- Step 5: Geostatistical analysis of valid soil data (variogram analysis)
- Step 6: Interpolation (block-kriging)
- Step 7: Interpretation of estimated concentrations, supported by GIS

A more basic approach, based on application of ISO 19258: 2005 to estimate background ranges by reference to the median, should also be presented in Jones *et al.* (2008) with a note recommending that data are first categorized according to land use and geology.

Threshold. The Ruhr pilot successfully compared estimates of background values with thresholds, clearly identifying areas of exceedance and demonstrating the efficacy of the method that was applied. The Chemnitz pilot was also able to assign sample data to being above or below threshold values and relate this to soil texture, before developing a valuable commentary on the origin of elevated cadmium contents of soils in certain locations. It is recommended that the method applied in the Chemnitz pilot is adopted by ENVASSO.

Conclusions and recommendations

1. Compliance with a standard procedure for sampling and testing is critical to allow comparison between data sets.
2. Categorisation of data according to land use and geology is needed to support meaningful assessment of baselines / background
3. Geostatistical methods should be applied to eliminate data that is representative of areas with excessive anthropogenic contamination when estimating background / baseline values for comparison with thresholds.
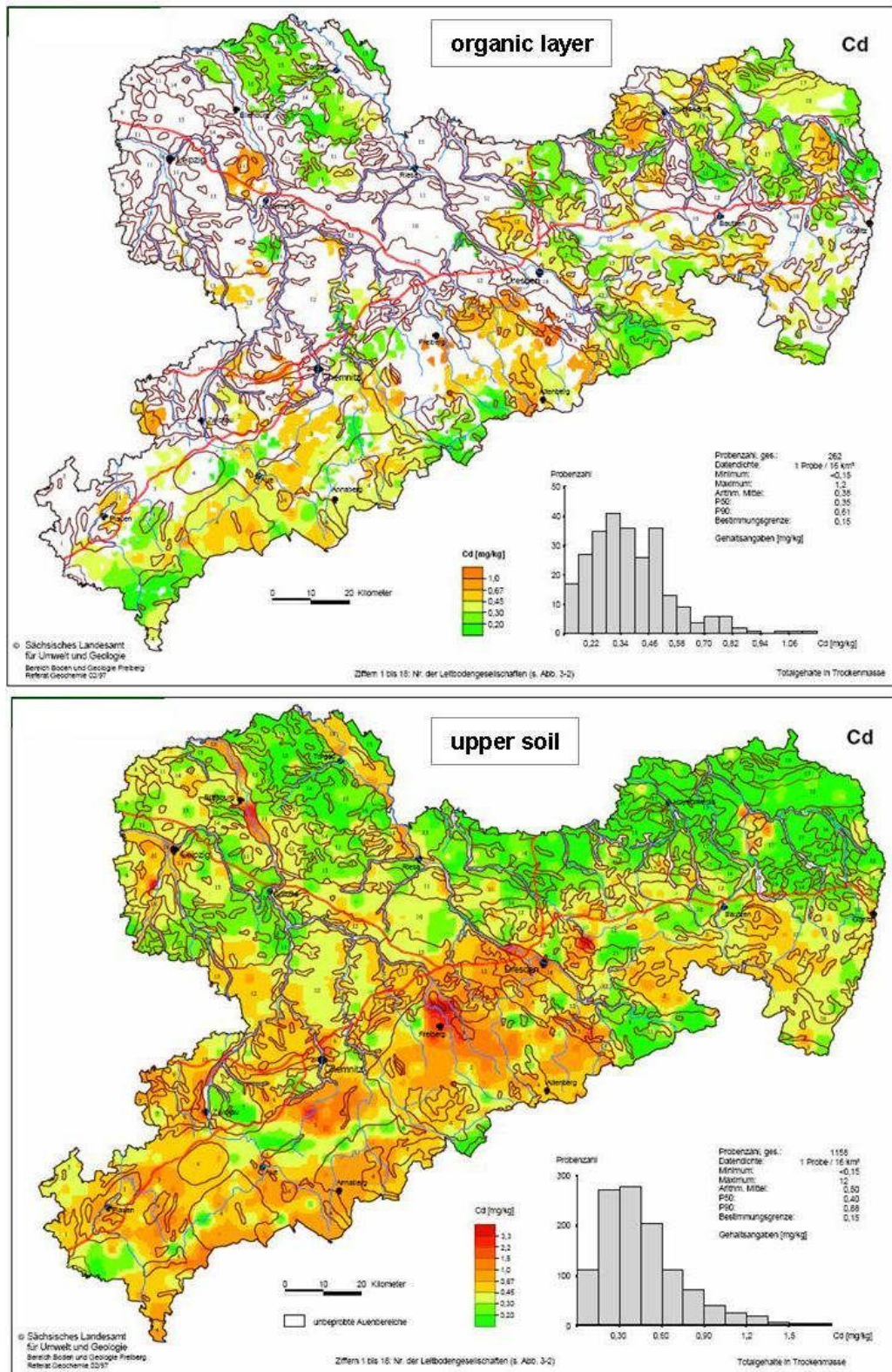
Figure 3-2. Cadmium content in the organic layer and the upper soil derived from the data of the 4 km x 4 km grid for the Chemnitz pilot area.

3.4.2 CO08 Progress in the management of contaminated sites

Both pilot studies were able to implement the procedure described in the factsheet.

Ruhr pilot area: data were extracted from the database of the State Agency for Nature, Environment and Consumer Protection

City of Linz and surrounding area: data were extracted from the Database on Contaminated Sites maintained by the Austrian Federal Environment Agency.

The *baseline* is a reference year after which subsequent progress is estimated.

Thresholds between tiers are defined in terms of actions taken and completion or non-completion of these assessed using expert judgement. This does not pose any apparent problem in the pilots being reported.

3.4.2.1 Pilot results

CO08: Progress in the Management of Contaminated Sites in the Region Linz and Sourrounding Area

	Completed	estimated total:
Tier 1: Completion of Preliminary Studies	13%	1.654 sites
Tier 2: Completion of Preliminary Investigations	10%	400 sites
Tier 3: Completion of Main Site Investigations	9%	212 sites
Tier 4: Implementation of Remediation Measures	9%	102 sites
Tier 5: Completion of Remediation Measures	4%	102 sites

General evaluation

Both pilot studies were able to analyse and interpret available data, to provide a clear profile of progress in the management of contaminated sites. Significantly, the two pilots used data collected by authorities operating under the jurisdiction of different Member States, supporting a view that the indicator could be made operational in all Member States (subject to data being collected and made available for analysis).

Presentation of results

The results from both pilot areas were presented graphically as a histogram of the percentage of identified sites currently at each management tier, which is straightforward and easily understood.

Conclusions and recommendations

Five tiers were identified in the factsheet, but the results of the pilot study suggest that little useful information would be lost if this was reduced to three tiers, namely: identification and preliminary study, main site investigation and risk assessment, and completion of remediation measures.

4 Soil Sealing

Authors
This report was prepared under the supervision of the Warsaw University of Technology by Stanislaw Bialousz.

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4.1 Introduction

Soil is sealed when agricultural or other rural land is taken into the built environment (land consumption) and is also a continuing process within existing urban areas, especially where urban population and the density of built structures is increasing and residual inner-city green zones are reduced. Soil sealing occurs as a result of the development of housing, industry, transport and other physical infrastructure, including utilities (e.g. waste disposal and water distribution) and military installations, i.e. as a result of the wider process of land consumption.

Both processes – soil sealing and land consumption – are closely interrelated, usually occur in parallel, and denote different degrees of intensity of human soil consumption. In both cases, natural, semi-natural and rural land is turned to urban and other artificial landcovers, which causes adverse effects on, or loss of, soil functions. Therefore, when the term 'Soil Sealing' is used in the context of it representing a soil threat it refers to both processes. Key issues have also been selected for major consequential impacts of soil sealing and land consumption and for related response strategies.

4.2 Description

When 'Soil Sealing' is used as a key issue, it is defined by the ENVASSO Glossary of Key Terms as: "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). In contrast, 'land consumption' is a broader concept that – according to the ENVASSO Glossary of Key Terms (Jones *et al.*, 2008) – "relates to all land development for settlementrelated human activities by which previously undeveloped land is urbanised, i.e. agricultural, forest or natural land are turned into built-up areas". Thus, land consumed comprises both sealed and unsealed areas.

4.3 Indicators

1. SE01 - Sealed area
2. SE04 - Land take (CLC)
3. SE05 - New settlement area established on previously developed land

Other indicator studied:
      SE03 - Land consumed by settlements and transport infrastructure

Table 4-1. Pilot areas and indicators tested

Pilot Area (PA)	Selection reason	SE01	SE04	SE05	Other
Warsaw WUT Poland	Representative for metropolitan region, data availability	X			SE03
North Rhine Westphalia LANUV Germany	Most densely populated German federal state	X			
Chemnitz BGR-LfUg German part	Cadastral data, statistical data	X			
Chemnitz CUA Czech part	Common Czech/German test area		X		
Bodrogköz UNIMIS Hungary	Historical data available		X		SE03

Table 4-2. Description and comparison of the Pilot Areas

Pilot Area (PA)	Size (km$^{2)}$)	Climate	Land use	Major soils	Data description
Warsaw WUT Poland	518	7,8°C 493mm precipitation	Settlements, Industry, Farming, Forestry	Anthrosols, Fluvisols, Aronosols	Large scale maps (1:500), topo maps (1:10 000), satellite images, statistical data
North Rhine Westphalia LANUV Germany	34,000	5-9°C, 600-900 mm Precipitation	Farming, Forestry, Settlement	Canubisols, Luvisols, Planosols	…..
Chemnitz BGR-LfUg German part			Farming, Forestry, Settlement		Statistical data, cadastral data, remote sensing data
Chemnitz CUA Czech part			Farming, Forestry, Settlement		Corine Land Cover
Bodrogköz UNIMIS Hungary	350	10°C 550 mm percipitation	Farming, Forestry, Settlement	Vertisols, Aronosols, Gleysols, Fluvisols	Historical maps

4.4 Indicator Evaluation

4.4.1 SE01 Soil sealing

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. The method applied is described by Jones *et al.* (2008). The indicator was calculated in:

1. Warsaw: by modeling and samples taken from maps 1:500
2. North Rhine: cadastral classes of land use
3. Chemnitz/Germany: cadastral classes of land use
4. Chemnitz/Czech: aggregation of respective classes CLC
5. Bodrogkoz: scanning and digitizing historical maps

Differences are caused by content of cadastral maps.
Baseline. Generally, a baseline of 1990 or 2000 is used for data selection.
Threshold. Not appropriate for this indicator.

4.4.2 SE03 Land consumed by settlements and transport infrastructure

The method adopted:
➢ step 1: determine built-up areas
➢ step 2: express indicator value

This is described by Jones *et al.* (2008). The results are expressed in ha and %. Differences in parameter values vary with the reference year (1990, 2000, 2005) and spatial resolution of the data source.

Baseline. Reference year 1990 (2000)

4.4.2.1 Results

Warsaw
Cadastral data in Poland are not useful for estimating sealed area. For Warsaw, a model for estimating the sealed area was elaborated. The proportion (%) of sealed area was calculated for different classes of built up land, using large scale maps at 1:500 and topographic maps 1:10,000. Polygons of classes of built up areas were delineated on satellite imagery of very high resolution. Total area of sealed soil inside of each of the classes and total area of sealed areas for Warsaw were calculated. This model with sampling can be applied for other cities.

Poland
Additionally, estimation of indicator SE03 – 'Land consumption' – for Poland was calculated from statistical data.

  i. area of agricultural land designated for non-agricultural purposes and forest land designated for non-forest purposes,
 ii. evaluation of sealed areas for rural region
iii. evaluation of sealed areas under transport network
 iv. anticipated land consumption by new transport network
  v. anticipated land consumption related to a new housing 2008-2015

North Rhine – Westphalia
The determination of the sealed area was based on a survey of actual land uses, conducted by all states in accordance with agrarian statistics law. The following land use classes are included by areas used for settlement and transport

- areas covered by buildings and open space
- plant areas exclusive of digging and mining areas
- recreation areas

Percentage of sealed area for each of the classes above was determined. The increase of sealed area in NRW between 2000 and 2006 was calculated

Chemnitz/Germany

Statistical and cadastral data of the 230 municipalities in the Saxon part of the pilot area were used to calculate sealing parameters for the period 2000-2006.

Calculated parameters:
- area of the municipalities
- area of settlement and transport
- sealed area
- percentage of sealed area in the municipalities
- absolute increase of sealed area from year to year
- realtive increase of sealed area from year to year
- growth rate in ha/d and ha/year

As supplementary source materials, cadastral data, IRS 1C and IKONOS satellite images were used. Area obtained from statistical data and from satellite images were compared. The results from the IRS data fit with statistical data. A map of soil sealing in the Saxon part of the pilot area was elaborated.

Chemnitz/Czech

The analysis of the extent of sealed soils was based on CORINE Land Cover data from years 1991 and 2001. Seven classes of land cover according to CLC comprise sealed areas. Diagrams showing percentage of these 7 classes for the pilot area were prepared. Cadastral maps for this regions are not in digital form, so they were not used.

Bodrogkoz – Hungary

Analysis was based on topographical maps (historical and actual) and remote sensing data. The oldest maps were established in the period 1763-1787.

Applied methods:
  i. digitizing, georectification and georeferencing of maps
  ii. screen-based vectorization of the settlement borders
  iii. calculation of the total coverage of the settlement areas (SE01)
  iv. calculate the increase compared to the first datasource (1783)
  v. calculate the percentage of built up area (SE03)

Increase of settlement areas for the period 1783-2005 was 775%

Evaluation of the results

Sealed area of Warsaw was measured using large scale (1:500) city maps. In other pilot studies, sealed area was estimated using land use maps, cadastral maps, percentage of sealed area inside of built up areas. The results show that there is a methodological problem caused by heterogeneity of source materials.

Conclusions and recommendations

- SE01 (Sealed area) and SE02 (De-sealing) – proposed procedures and protocols in Jones et al (2008) were found to be feasible
- SE03 (Land consummed by settlement and transport) and SE04 (Land take) – differences not clear, the CORINE Land Cover data are at too low a spatial resolution to be useful
- SE05 (Brownfield redevelopment) – more precise data and technological progress is needed before the procedures and protocols can be implemented
- SE06 (Fragmentation) – is efffectively the domain of landscape analysis and organisation of rural territory

Research conducted by EEA concerning use of VHR satellite imagery for new land cover database was not accessible to ENVASSO. Direct measurment of sealed area is time consuming and therefore costly, so models based on topographic maps, satellite images and cadastral data are recommended for elaboration and testing.

5 Soil Compaction

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5.1 Introduction

The activities for evaluation the soil compaction (CP) indicators followed the input requirements for pilot area studies according to the fact sheets in ENVASSO Volume I (Huber *et al.*, 2008) and the procedures in Volume V (Jones et al 2008). The locations of PAs and data availability were discussed during the CP meeting in Sofia, 27-28 February 2007. The Bulgarian partner (ISSNP) carried out geo-referenced soil sampling and new analyses of six CP indicators in the PA, performed during the WP5 Workshop in Bulgaria (11-14 June 2007). The Romanian partner (ICPA) performed analyses and comparisons of direct and indirect estimates of three priority compactionindicators, based on the existing soil databases for the Romanian arable and grass lands.

5.2 Description

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.

5.3 Indicators

1. CP01 - Density (bulk density, packing density, total pore volume).
2. CP02 - Air Capacity (volume of air-filled pore at a suction of 5 kPa).
3. CP06 - Estimated Vulnerability to Compaction, based on texture, density, climate, land use.

Table 5-1. Pilot areas and indicators tested

Pilot Area	Selection reason	CP01	CP02	CP06	Other
Bulgaria - Tsalapitsa, Fluvisol, field scale	New data; past studies; evidence for compacted layers	X	X	X	CP03 CP04 CP05
Romania - arable and grassland soils, national scale	Available database (PROFISOL and RO-MONITORING)	X	X	X	Indirect methods

Table 5-2. Description and comparison of the Pilot Areas

Pilot Area	size (km²)	climate	land use	topography	major soils
Bulgaria - Tsalapitsa	0.016	temperate continental transitional with Mediterranean influence	arable	Alluvial flat plain	Fluvisols and Luvisols (soil map 1:10,000)
Romania - arable and grassland soils	238,391	temperate continental	arable and grass land	31% mountains, 36% hills and plateaus, 33% plain and meadows	Soil map (1:200,000)

5.4 Indicator Evaluation

5.4.1 CP01 Density (bulk density, packing density, total porosity).

Bulk density (D_b) is determined from undisturbed cores of soil sampled in the field.
The measurement procedure was followed according to ISO 11272:1998

Total Porosity (T) is calculated by

$$T = (1-D_b/D_p)*100$$

Packing density (PD) is calculated from bulk density and clay content and is closely related to porosity.

$$PD = D_b + 0.009\ C, \hspace{3cm} (1)$$
D_b – measured soil bulk density, Mg/m^3
D_p - particle density, Mg/m^3
C - clay (particles size <0.002 mm) content (%w/w)

Soil texture was transformed from the textural scheme of Katschinski to FAO & CEC.

As site specific for the Bulgarian PA, two profiles were chosen on a temporary beaten track and on cultivated land. The strict scheme of core samples collection throughout the profile depth for each soil layer was applied after Jan van den Akker (Table 5-3). Bulk density data are provided on soil genetic horizons in PROFISOL and RO-MONITORING databases for the Romanian pilot study.

Baseline. Historical data – before the period when heavy machinery began to be used or field data for a site that had never been trafficked by farm machinery.

Threshold for packing density (PD):

class (units)	low	medium	high
PD (Mg m^{-3})	<1.40	1.40-1.75	>1.75

Minimum detectable change (MDC).
0.01 Mg m^{-3} for bulk and packing density or 1% for total porosity

Table 5-3. Scheme of data requirement selection and collection

Layer no.:	Description			Texture	SOC	Dry bulk density	Particle density	Air-filled pore volume	Sat. Hydr. Conductivity	Penetrometer resistance	Visual classification	Depth	Precompaction stress	Ploughing depth
				%	%w/w	t/m3	t/m3	%v/v	cm/d	Mpa	-	cm	kPa	cm
1	Topsoil	? cm		X	X	X	x			X	x	X	(x)	X
2	Ploughpan mixed with topsoil	5 cm		x	X	X	x	X	X	X	x	X	x	
3	Ploughpan	5 cm		X	X	X	x	X	X	X	x	X	x	
		5 cm								X	x			
4	15 - 20 cm below top ploughpan (layer 3)	5 cm		(x)	(x)	X	x	X	(x)	X	x	X	(x)	
		5 cm								X	x			
5	25 - 30 cm below top ploughpan (layer 3)	5 cm		x	x	X	x	X	x	X	x	X	x	
		5 cm								X	x			
6	35 - 40 cm below top ploughpan (layer 3)	5 cm		(x)	(x)	X	x	X	(x)	X	x	X	(x)	
		5 cm								X	x			
7	45 - 50 cm below top ploughpan (layer 3)	5 cm		(x)	(x)	(x)	(x)	(x)	(x)	X	x	(x)	(x)	
		5 cm								X	x			
		5 cm								80 cm	80 cm			
		5 cm								x	(x)			
		5 cm								x	(x)			
		5 cm								x	(x)			
										100 cm	100 cm			
8	Compacted Horizon			x	X	X	x	X	X	X	x	X	x	

		Dry bulk density	Penetrometer resistance
Soil profile description	Soil survey with auger	X	X = REQUIRED
	Soil survey with soil pit	(x)	x = medium priority
			(x) = low priority
Drainage condition	Class	X	decadal -
	Groundwater level (winter/summer)	x	
	Groundwater level (highest/lowest)	x	
Landuse	Arable/Pasture/Forest/Nature	X	
	Crop	x	
Soil management and tillage	Ploughing/loosening/no-till (depth)	X	
	Deep-loosening (depth)	X	
Machinery / Ground pressure	Machinery used (type / brand)	x	
(of heavy machinery)	Tires used (type/brand)	x	
	Weight	X	
	Load per wheel	X	
	Width tire	X	
	Inflation pressure	X	
Climate	Name and coordinates weather station	X	
	Mean percipitation (summer/winter)	X	
	Mean evapotranspiration (summer/winter)	X	
	Mean precipitation (month or decade)	x	
	Mean evapotranspiration (month or decade)	x	
	Air temperature (summer/winter)	x	
	Air temperature (month or decade)	(x)	
Air-filled porevolume (% v/v)	at a suction of 3 kPa	x	
(depths: see above)	at a suction of 5 kPa	X	
	at a suction of 6 kPa	(x)	
	at a suction of 10 kPa	x	

Bulk density (D_b) is a direct measure of soil compaction, which is tested in the case of the temporary beaten track and compacted layer formation in arable field in Bulgaria. The comparison between the actual values of packing density and the baseline for topsoil and subsoil (Romanian PA) shows the increase of packing density for the actual (measured) soil profiles of arable and grass land in Romania. Two approaches for evaluating the packing density classes (indirect method using Equation 1 and direct - according to Hodgson (1997) from soil structure and particle size class) for 80 soil profiles from South-West Romania (Timis county) show that the direct evaluation of packing density classes underestimates the measured classes with one class in 29 cases of 80, and with 2 classes in 2 cases of 80.

Taking into account the specificity of the pilot areas (PA), the results are presented in different forms – profile curves (Fig. 5-1) and tables for the Bulgarian PA and – histograms and maps for the Romainan PA. Basic statistical analyses were performed on the data from both pilot studies.

a) temporary beaten track   b) arable field
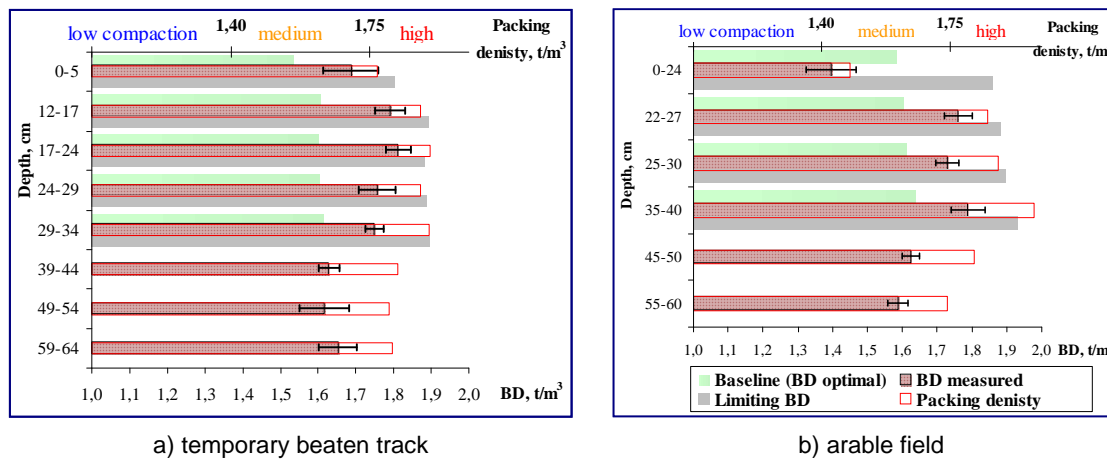
Haplic Fluvisol (Eutric), Tsalapitsa, village, ENVASSO WP 5: Bulgaria, 2007.

Figure 5-1. Density indicator of studied soil profiles

Baseline. Both PAs use local models for determing baseline values for the density indicator. In the Bulgarian PA – the optimal bulk density with 20% (or 15% for fine textured soils) drainage aeration pores (at 30 kPa) is estimated for surface and subsurface horizons taking into account textural class and organic matter content (Kercheva, Dilkova, 2005). In the Romanian PA baseline for packing density is calculated using soil mechanics based model SIDASS (Simota *et al.*, 2005). The baseline values derived from both PAs relate to different soil typological units and different climate and scale and could not been compared directly. Ideally they should be tested on one and the same data set.

Threshold. There is a good agreement between the results of applying the ENVASSO method and a local model (Kercheva, Dilkova, 2005) for estimation of soil density of subsoil layers in the Bulgarian PA. The dependence of reference values of bulk density on humus content in surface horizons suggests applying packing density and its threshold values initially as an indicator for subsoil compaction.

In both PAs it was possible to detect the *minimum detectable change* (MDC).

Conclusions and recommendations
The methods proposed by ENVASSO are well described and usable on a wide range of existing soil data. The calculated packing density (PD) using equation 1 was always found to be equal to or larger than the PD determined using the Hodgson (1997, p47-49) procedure (see Jones *et al.*, 2008, p. 70-72). The threshold values of packing density could be used initially as an indicator for subsoil compaction.

5.4.2 CP02 Air Capacity (air-filled pore volume at suction of 5 kPa)

This indicator measures the oxygen diffusion capacity, volume of macro pores, hydraulic conductivity and rootability of soil under wet conditions. The Air-filled pore volume is determined using core samples of 100 cm^3 volume.

In the Bulgaria Pilot Area (PA), air-filled pore volume is determined by a suction plate method, similar to that proposed in ISO 11274:1998, in two stages:
   Stage 1. Wetting of soil samples at 0.02 kPa on a sand bath.
   Stage 2. Drainage of the wetted samples at 1, 3, 5, 10 kPa using a suction type apparatus (Shot filters).

The air capacity is the difference between total porosity and the water content at a given suction. Two profiles were chosen one on a temporary beaten track and a second on cultivated land. The air capacities at suctions 1, 3, 5, and 10 kPa are determined according to the scheme proposed by Jan van den Akker.

In the Romanian PA, soil water content at soil water matric potential values of pF=1.4, 1.6 and 2.0 are stored for soil genetic horizons in the PROFISOL and RO-MONITORING databases. The soil water content corresponding to a soil water matric potential of 5kPa (pF=1.7) was evaluated using the soil water retention curve fitted through the measured values using van Genuchten closed-form approach.

Baseline: Air capacity measured on land that had never been trafficked before by farm machinery.

Threshold: Ca=10%

Minimum detectable change (MDC) 1%

5.4.2.1 Results

The reduction in air capacity at both profiles in the Bulgarian PA corresponds to the profile curves of bulk density – starting from the top, under the temporary beaten track, and with a sharp change in the plough pan under the plough layer of arable plot. The air capacity at 5 kPa is less than the threshold of 10% only in some replicates, wheras the packing density values are high indicating a high degree of compaction in almost all layers except the uppermost layer of the arable plot. The structure of this soil is much better than expected from the packing densities. This is because there are large pores that break up the generally very dense matrix.

The comparison between measured and indirect evaluation of soil water content at 5 kPa using the tables provided by Wosten *et al.* (1998) shows that in most cases the estimated water contents are larger than the measured values. The results are presented in different forms profile curves and tables for the Bulgarian PA and histograms for the Romanian PA. Basic statistical analyses were performed on the data for both PAs. The minimum detectable change (MDC) was achieved in both Pas.

However, no measured or estimated *baseline* values were available for this indicator in either PA. In structured soils the threshold value of 10% air-filled pore volume is rather high. Recommended is to use the threshold value of 10% as a first approximation and to use Table 7.3 in Volume I for structured soils (Huber *et al.* 2008).

Conclusions and recommendations

A threshold value depending on soil texture is much more appropriate for the evaluation of this indicator, because texture can be considered as an indicator of the structure (structure forming processes as shrinkage is strongly related to clay and OM content)

5.4.3 CP06 Estimated Vulnerability to Compaction is based on texture, density, climate, land use.

This indicator combines several controlling factors into a single vulnerability assessment.
The two-stage methodology described in ENVASSO procedures and protocols (Volume V, Jones *et al.*, 2008) was applied to the data from both the Pilot Areas. The assessment of inherent susceptibility (Stage A) is based on the measured data for soil texture, bulk density and estimated packing density of subsoil for loose and firm state of top soil. 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.

Climate zones are determined according to the values of potential soil moisture deficit (PSMD) using meteorological data for annual precipitation and potential evapotranspiration. Potential evapotranspiration is calculated according to the Thornthwaite method.

In the Bulgarian PA, soil data from two representative soil profiles were used. The climatic data for different periods were used to determine the vulnerability class:
- for the period of contemporary climate 1961-1990;
- for six years period (e.g., 1985-1990);
- for average, wet and dry year;

The representative years are determined on the basis of probability of exceedance of annual precipitation (90% of dry year, 50% for average year and 10% of wet year) determined for 70-years period (1931-1970).

In the Romanian PA, soil data (packing density and texture) were provided by PROFISOL and RO-MONITORING databases. Climatic data (temperature, precipitation, potential evapotranspiration calculated according with Thornthwaite-Mather method) are provided for the baseline 1961-1990 in a 10' x 10' longitude x latitude grid network, on a monthly base

No baseline or threshold is applicable. No minimum detectable change can be determined.

5.4.3.1 Results

The vulnerability to compaction was calculated for: the international standard (climatic) period 1961-1990;, for 6 years; and for wet, dry and average years. Only in the case of the wet year in the Bulgarian PA did the vulnerability to compaction class change.

The ENVASSO method for estimating the vulnerability to compaction was compared with a method based on soil mechanical properties (pre-compression stress, concentration factor) proposed by Horn *et al.*. 2005. For the dry-climate areas of Romania the ENVASSO based algorithm for the calculation of the vulnerability to compaction gives values of vulnerability (Moderately vulnerable) less than the algorithm based on effective soil loads (Unstable/Additional plastic deformation). For areas with low water deficit or with water excess ENVASSO algorithm predicts high vulnerability (Extremely vulnerable) compared to the other algorithm predicting moderate values of vulnerability (Stable/Unstable).

The results are presented in Tables, figures and maps (e.g. Figure. 2).

Conclusions and recommendations
The method for calculating potential evapotranspiration and the period for determination vulnerability class must be clearly specified. If this indicator is to be estimated for monitoring purposes, for example at 6-year intervals, it should be calculated for each year separately, otherwise the effect of wet years (as well as wet seasons in the year) on soil compaction will be obscured.

The method proposed for estimating indicator CP06 was developed in north-west Europe and it needs to be further developed for application in drier regionsof the Mediterranean and south-east Europe.
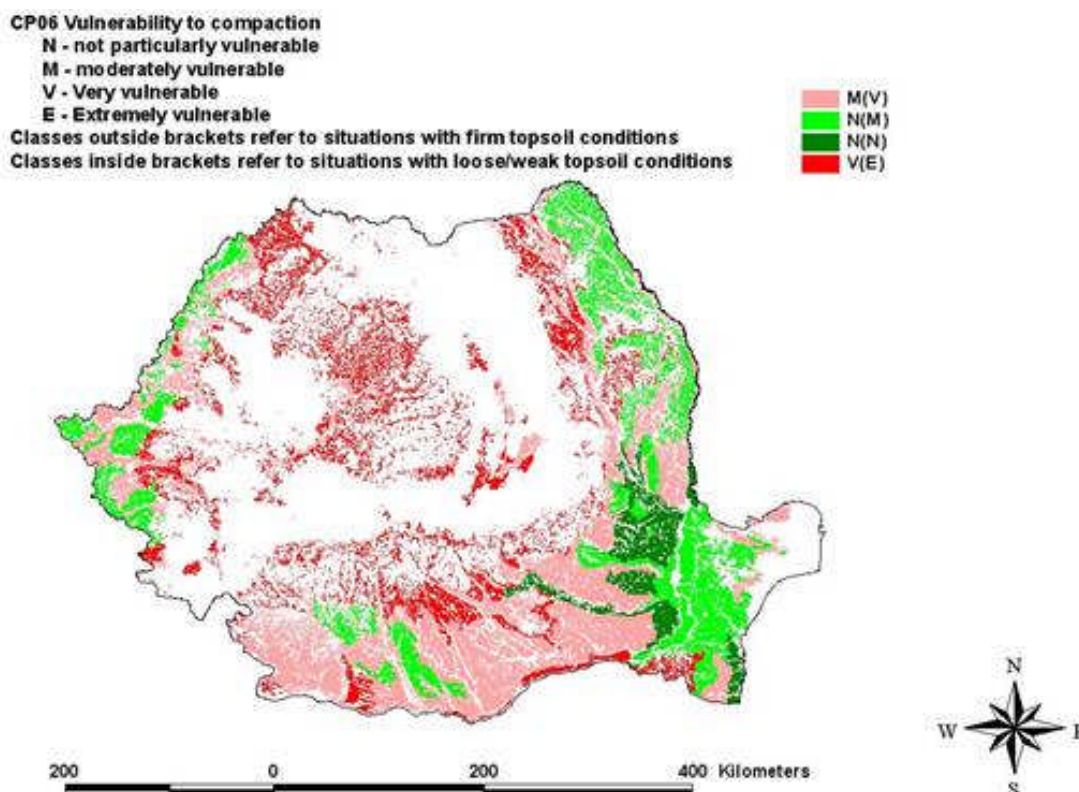
Figure 5-2. Vulnerability to compaction for arable soils in Romania.

A major problem with Indicator CP06 - (Vulnerability to compaction) is that already compacted subsoils are considered less vulnerable than non-compacted subsoils. This is logical because, if compaction is just considered as an increase in bulk density, the more a subsoil is compacted the less susceptible does it become to further compaction. An alternative view is the effect on the quality of the subsoil.

Assessing vulnerability to compaction should take into account that:

- if subsoil is compacted, it means that the soil was originally susceptible to compaction;
- a small increase in density of a dense soil can result in a greater decrease in soil quality than a small increase in density would cause in a loosely packed porous soil;
- an overcompacted layer can increase in thickness;
- the natural recuperation of a soil will decrease strongly the denser the soil becomes (the compacted soil remains wet (so less shrinkage) and the possibilities for rooting and soil fauna are limited).

One solution for this dilemma could be to focus much more on the change of soil quality and soil structure (e.g. expressed in the saturated hydraulic conductivity or the air conductivity at a certain suction). So a soil is considered very vulnerable if a small increase in density results in a strong decrease in required soil properties (as Ksat).

Another solution could be to consider not the actual density but a desired density or a baseline density and to use this in the vulnerability assessment methodology. categorise the inherent vulnerability of the subsoil.

It is recommended that at least saturated hydraulic conductivity (Ksat) should be included as a viable indicator, in addition to the three priority indicators, because it is a very important soil property and because it is a good indicator of soil structure. Another very useful indicator is the *resistance to penetration* because, it correlates well with rooting possibilities, it is relatively easy

and cheap to measure, it delivers a large amount of of data and thus it can be used in statistically relevant investigations.

If this study were to be repeated in the near future, soil sampling suitable for geo-statistical analyses should be conducted, including adjacent areas of the same soil type never trafficked before. The latter should provide a local density baseline for the pilot area.

6 Decline in Soil Biodiversity

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This report was prepared under the supervision of the French Agency for Environment and Energy Managemen (ADEME) by Antonio BISPO.

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6.1 Introduction

The biodiversity group met three times to share experiences on sampling and existing data on the decline of soil biodiversity in:

- Wexford (Ireland) at TEAGASC in March 2007
- Paimpont (France) at University of Rennes 1 in May 2007
- Sofia (Bulgaria) at ISSNP in June 2007

6.2 Description

Decline in soil biodiversity is the 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

6.3 Indicators

1. BI01 - Earthworms diversity, abundance and biomass (or enchytraeid diversity if no earthworms are occurring)
2. BI02 - Collembola diversity and abundance
3. BI03 - Microbial respiration

Earthworms are very important soil-inhabiting animals, very well studied in terms of ecology and taxonomy. They have several advantageous influences on soil properties. For instance, earthworms influence positively soil structure, aeration, water holding capacity, litter decomposition, and nutrient cycling. Thus, they increase soil fertility and help to build up good soil structure. Moreover earthworms are very good indicators for soil degradation in most soils. They are rare or even missing in acid and water-logged soils where they are replaced by enchytraeids, a group of taxonomically related but usually smaller worms.

Collembola (commonly known as springtails) are one of the most studied groups in soil ecology since they have very high abundance and diversity in soil and in litter as well. They take part in organic matter decomposition acting mainly as selective grazers on fungal fungal hyphae, promoting the succession of microbial colonization of decomposing plant material. By doing so, they also play an important role in influencing soil respiration. They are sensitive to physical soil degradation since they cannot make their own burrows, thus they depend on the pore space of the soil, provided by burrowing organisms. In this sense they can indicate soil compaction by

the decrease of their abundance and diversity. Moreover they are also used as indicators of changes in soil quality due to management activities both in forests, pastures or crop areas. Changes in habitat configuration (mainly in the upper organic horizon) due to management options usually lead to a decrease in diversity.

Microbial respiration is a pivotal aspect of the living soil, addressing major flows of carbon and energy conversions. In this process, organic substances are oxidized, mainly by bacteria and fungi, to the end products carbon dioxide and water, with concurrent uptake of O_2 for aerobic microorganisms. The soil respiration is measured by the determination of O_2 consumption and/or by CO_2 release.

Table 6-1. Pilot areas and indicators tested

	Selection reason	BI01	BI02	BI03
RMQS BIODIV (France)	French experimental area with 115 sites (grid 16x16 km)	X	X	X
Szent István University (Hungary)	Eastern Central European loess areas with very high organic matter	X	X	X
Republic of Ireland	60 sites being representative of land use and soil type	X	X	
Brandenburg (Germany)	Coniferous forests on sandy, poor soils	X (Enchytraeid)		
North Rhine-Westphalia (Germany)	Soil monitoring	X (Earthworm and Enchytraeid)		
Portugal	Impacts of reforestation with *Eucalyptus glubulus*		X	

Complementary to these Pilot Areas M. Rutgers and A.W.M. Eijs sent a publication about the Dutch soil monitoring network.

6.4 Indicator Evaluation

6.4.1 BI01. Earthworm species diversity, abundance and biomass (or Enchytraeids diversity if no earthworms are occurring)

Earthworms were sampled according to ISO 23611-1: 2006. This method is based on a combination of two different methods: hand-sorting and formalin extraction. Sampling should be done at times of the year when the animals are not forced by the environmental conditions (i.e. low soil moisture and/or high or low temperatures) into lethargy (i.e. are not reacting to formalin because they are not active). In temperate regions, such unfavourable sampling times are winter and, in particular, midsummer periods. Moreover, sampling should be done when soil moisture is optimal (i.e. at field capacity) whereas sampling for earthworms when soil conditions are saturated or close to saturation means the repellent will not infiltrate the soil, instead pooling on the surface, and in dry soil, the repellent solution will either not penetrate the soil or disappear down large cracks (Clapperton et. al, 2007). Earthworm species diversity, abundance and biomass are calculated and reported.

Enchytraeid species are sampled according to ISO 23611-3: 2006. Soil sampling is performed with a split corer (diameter usually 3 cm to 6 cm) and the enchytraeids are extracted from the soil sample by means of a wet extraction method. After extraction, the enchytraeids are

identified alive and, if required, preserved in such a way that they can be stored in a collection indefinitely. Enchytraeid species and abundance are calculated and reported (biomass can be estimated).

Table 6-2. Description and comparison of the Pilot Areas

	size	climate	land use	topography	major soils
RMQS BIODIV (France)	Region 27,208 km²	Oceanic	Crops, pastures	20 – 400 m	Cambisols, Luvisols
Szent István University (Hungary)	Farm 270 ha	Continental	Crops	100 – 350 m	Cherbozems calcisol
Republic of Ireland	Country 69,902 km²	Temperate maritime	Pastures, forestry, crops	0 – 1040 m	Histosols, Gleysols, Luvisols, Podzols, Cambisol, Leptosols
Brandenburg (Germany)	Federal state 15,000 km²	Continental	Forestry	30 – 150 m	(poor) sandy soil
North Rhine-Westphalia (Germany)	Federal state 34,085 km²	Oceanic	Natural forest, grazing, recreation use	16 – 675 m	Cambisol, Planosols, Podzols, Arenosols, Gleysols, Luvisols
Portugal	Several pilot areas over the country (minimum 1ha each)	Atlantic, Mediterranean, Sub-tropical moist	Natural forest, exotic tree plantation	10-550 m	

When comparing the protocols used on each Pilot Area (PA) the following differences can be underlined:

- most of the sampling campaigns were performed during favourable periods (e.g. spring or autumn) except in Hungary where earthworms were extracted when soil moisture was not optimal,
- sampling area was from 0.25 m² to 1m² grid, depending on land use,
- chemical expellant: formalin is recommended in procedures and protocols, but mustard oil based on allyl isothiocyanate was used in Ireland.
- except for the sampling period, these differences were already accommodated in ENVASSO's procedures and protocols (Volume V, Jones *et al.*, 2008) thus there was no need to alter the protocol initially proposed.
- Procedures and Protocols used in the pilot area (PA) for enchytraeid species are not completely the same as those defined by Jones *et al.* (2008) because the PA was established many years before ISO standardisation. However, the differences are so small that the results of the PA studies are comparable to those gained when using the ISO protocol.

Data for each pilot area (PA) were based on samples collected from monitoring sites rather than obtained from the literature. No baseline or threshold was defined but a method was proposed. A *minimum detectable change* (MDC) of between 15 and 25% was expected.

6.4.1.1 Results

Each pilot area (PA) was very different in size, soil type, land use and climate. As all these parameters are determining soil biodiversity, it is impossible to compare directly the results obtained for each PA. Nevertheless it is possible to compare how the results are presented. In addition, the experiences have been used to enhance the ENVASSO procedures and protocols. For each PA a time trend analysis can be performed when results are available for a time period.

a) abundance

b) biomass

c) taxonomic richness
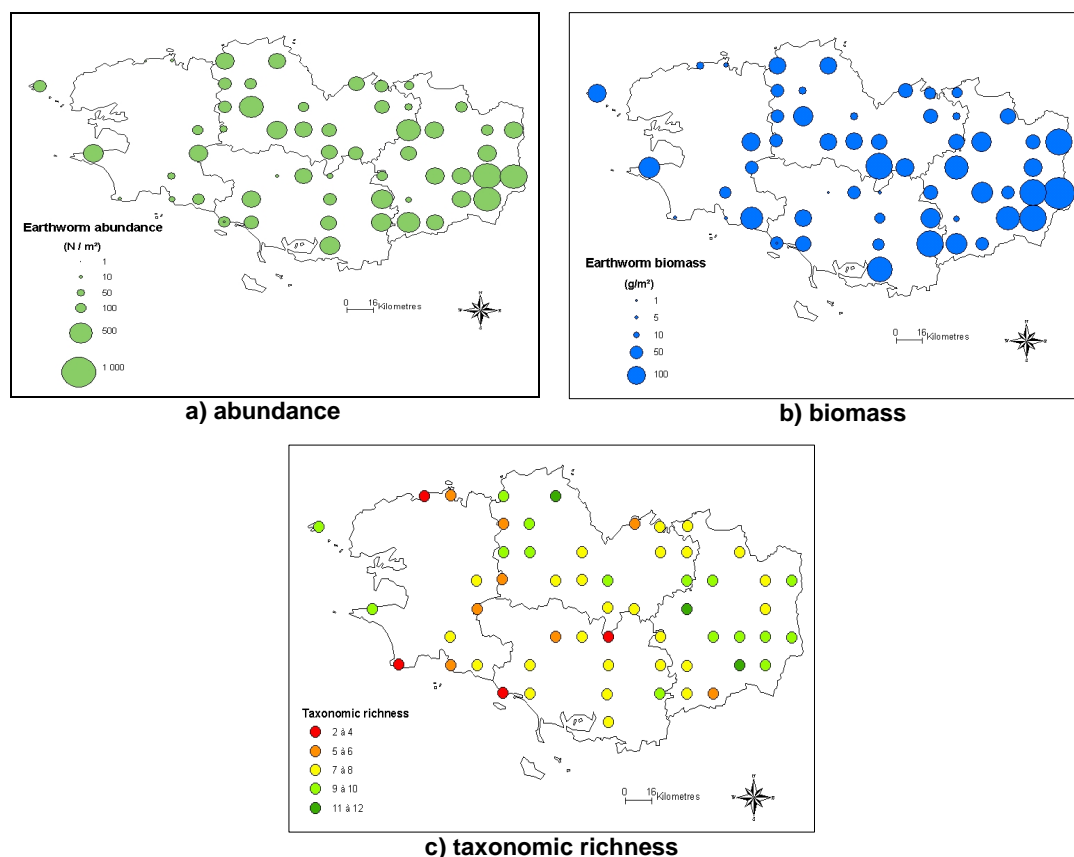
Figure 6-1. Maps of results for BI01 (from RMQS BIODIV, France)

Several ways were used to present the results (maps, graphs, box-and-whisker plots). Correlations between Indicator BI01 and other soil parameters (e.g. soil organic matter) were also produced. Based on the PA reports it seems important to:

- use representations such as maps which can give a spatial distribution of soil biodiversity or box-and-whisker plots which give an overview of the variability of data
- express the data depending on soil type and land use.

Several examples of results,extracted from pilot area reports in ENVASSO Volume IVb (Stephens *et al.*, 2008) are given below.
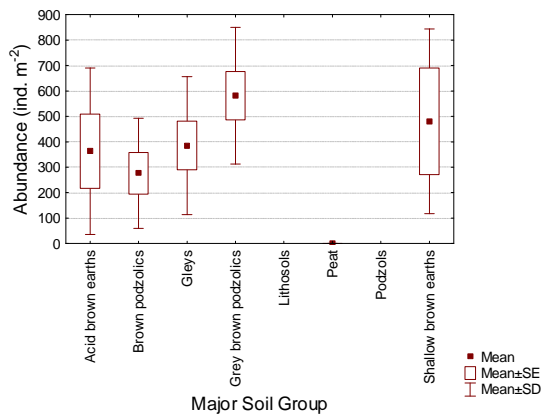
a) abundance by major soil group
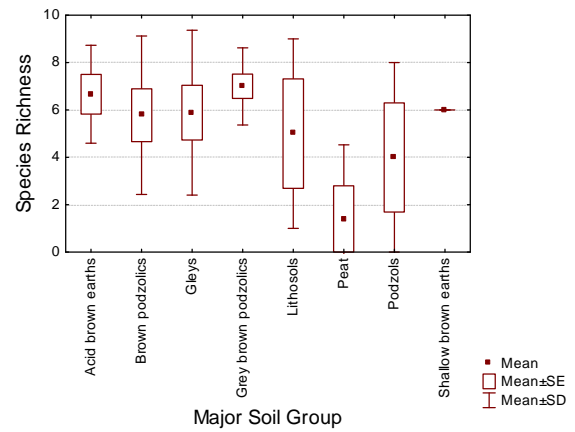
b) species richness by major soil group
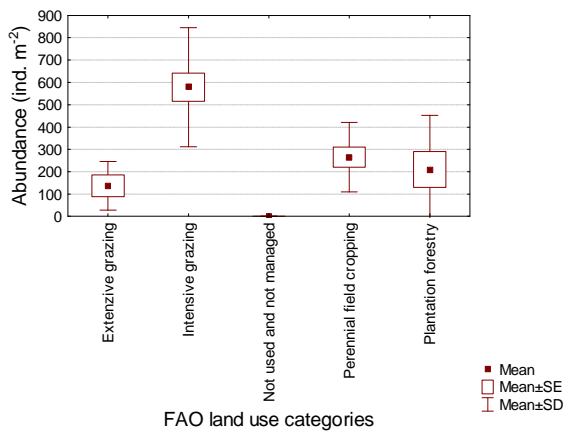
c) abundance by FAO land use category
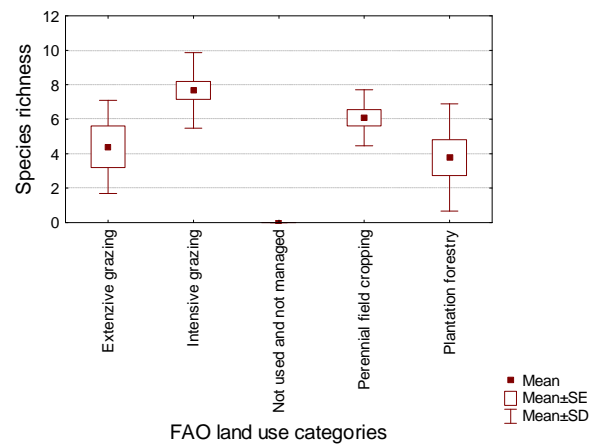
d) species richness by FAO land use category

Figure 6-2. Soil type and/or land use vs. BI01 (Republic of Ireland)
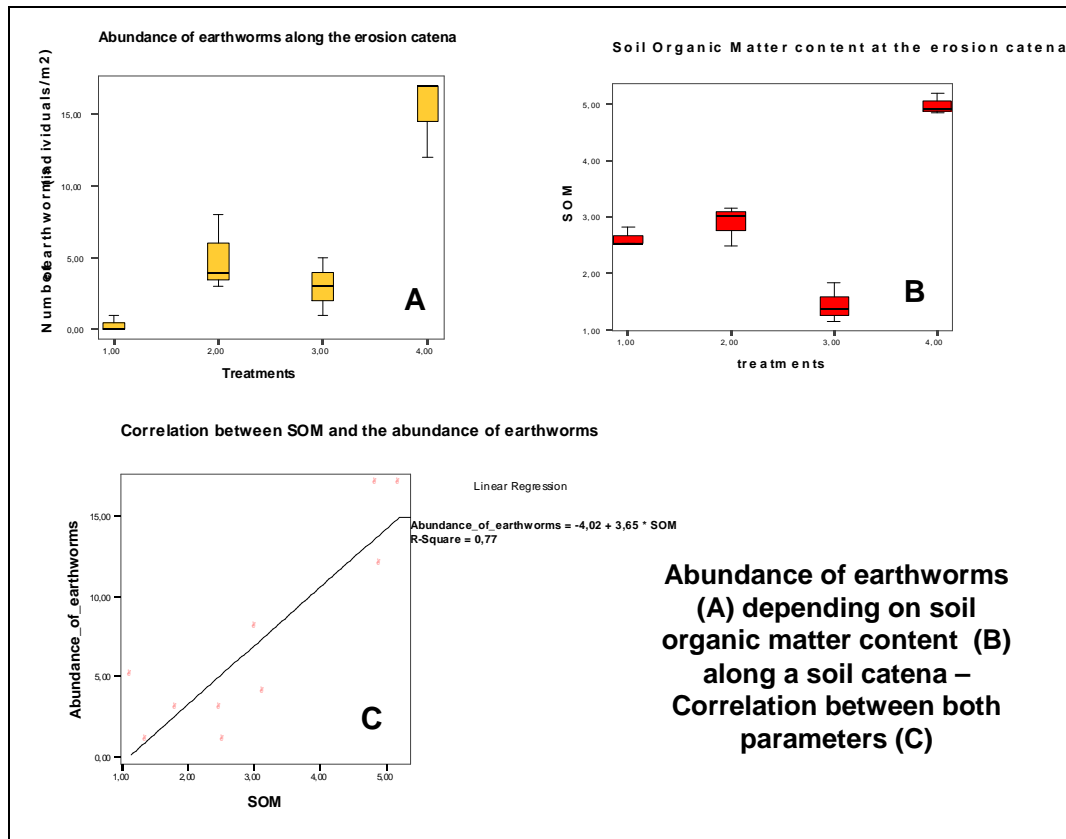
Figure 6-3. Soil erosion and decline in soil organic matter vs. Indicator 1 (BI01)
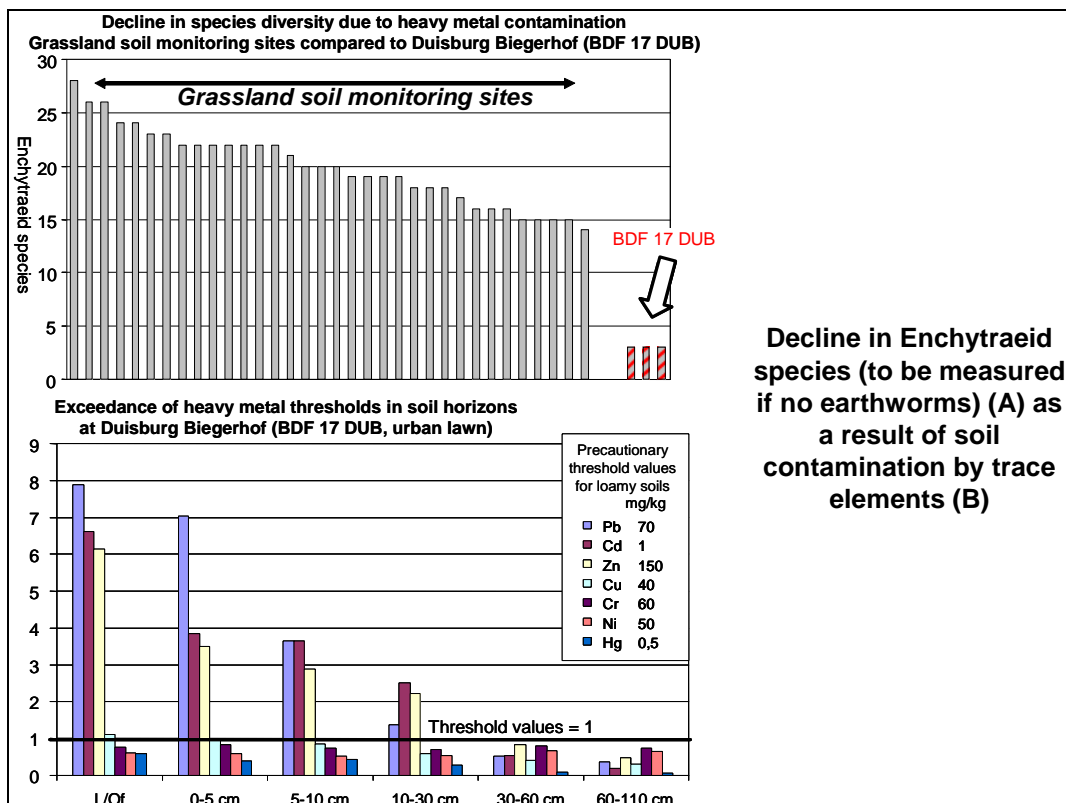
Figure 6-4. Soil contamination (North Rhine-Westphalia, Germany) vs. Indicator 1 (BI01)

Minimum detectable change (MDC)

Based on assumptions and on literature reviews, a MDC of 15 to 25% was expected. Regarding the results obtained on Brandenburg PA where the abundance, biomass and diversity of enchytraeid species were measured over several years, it appears that the MDC varies depending on the parameter being reported. It can be seen that the number of species, and the species structure given by the most abundant species, are rather stable when performing two consecutive samplings whereas the abundance, and the biomass, are more variable. Thus further development is recommended to increase the amount of data and to derive an MDC for each parameter.

Site	Parameter	November 2001	March 2002
Weizgrund	Abundance (Ind/m²)	55920 ± 52444	110793 ± 97799
	Number of species	9	10
	Most abundant species	*A. affinoides C. sphagnetorum,*	*A. affinoides, C. sphagnetorum*
Beerenbusch	Abundance (Ind/m²)	71617 ± 34533	54555 ± 31634
	Number of species	12	12
	Most abundant species	*A. affinoides, C. sphagnetorum*	*A. affinoides, C. sphagnetorum*
Kienhorst	Abundance (Ind/m²)	75394 ± 70214	54873 ± 36907
	Number of species	9	11
	Most abundant species	*M. clavata, C. sphagnetorum*	*M. clavata, C. sphagnetorum*

Baseline values

Baselines were not defined prior to evaluation (see Huber *et al.*, 2008) but two methods were proposed to determine such values:

One way is to consider the baseline as the value of the initial (1st) sampling. Thus those values obtained initially for each PA area can be considered as the baseline.

The other way is to consider the box-and-whisker plots where the box represents the distribution of 50% of the values obtained. Taking the lower and upper limit of the box will provide the range of what may be considered as the main variation obtained considering soil type and land use. Such exercise was performed for Indicator BI01, on the basis of the results coming from the RMQS BIODIV PA.

By doing such an exercise on 39 sites of the RMQS BIODIV PA the following table is proposed. These values are found similar to those obtained from an unpublished literature review for Central European crop sites and grasslands, not distinguishing between soil types (right column of the table shown above) (Römbke, pers. comm. 2004).

		Main soil texture		Lit. - Review
	Land use	Sandy	Silty	Central Europe
Biomass (g /m²)	Crops	< 20	50 - 120	48 (1 – 121)
	Meadows	10 - 80	10 - 300	80 (36 – 122)
Abundance (nb/m²)	Crops	<25	15 - 500	75 (1 – 187)
	Meadows	100 - 200	50 - 600	270 (85 – 700)
Species (number/m²)	Crops	2 - 5	6 - 9	4 (1 – 7)
	Meadows	5 - 8	7 - 12	6 (3 – 9)

Comparable numbers for enchytraeids in (mainly German) grasslands for loamy soils with a pH < 5.5 were found in a literature review: mean density: 41.400 ± 20.200 ind/m2; mean species number: 8.3 (Römbke *et al.* 1997).

Parameter	Reference for dairy farming
	Average (n=6)
Earthworm density (n / m2)	64
Earthworm diversity (number of taxa)	5
Enchytraeid density (n/m2)	20700
Enchytraeid diversity (number of taxa)	9
Soil acidity (pH-KCl)	5.2
Organic matter (%dry weight soil)	6.8
Water soluble P (as mgP2O5/l)	41
Extractable P (as mg P2O5/100g)	43

These tables may be used as a starting point to define baseline values for Indicator BI01. Nevertheless due to lack of data such tables cannot be generated for all regions of Europe. To produce robust baseline values for Europe, new sampling campaigns have to be performed and new data have to be processed and interpreted.
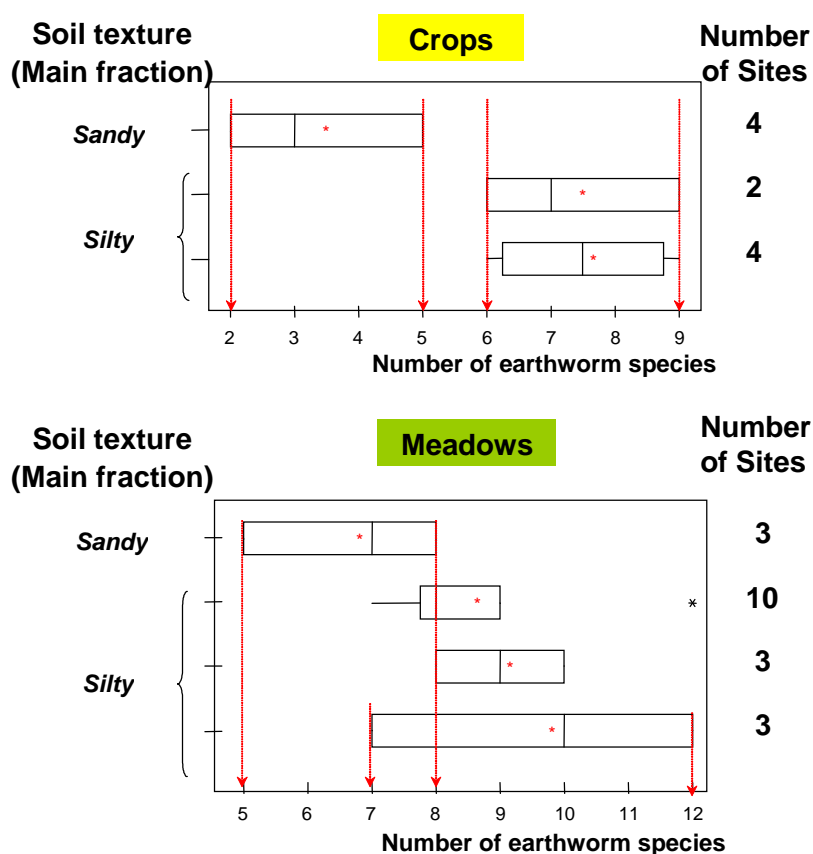
Figure 6-5. Number of earthworm species depending on land use and soil texture

Such work was also performed with the data of the Dutch soil monitoring network (SMN) where as a 1st step reference situations were selected (e.g. depending on land use, soil type, climatic conditions, biogeographical region) according to expert judgement. Then from these reference situations baselines can be calculated as the min or the max or the mean values for each indicator (see following table, adapted from Rutgers and Eijs, 2007).

Threshold values

Threshold values were not defined prior to evaluation (see Huber *et al.*, 2008) but a method was proposed to derive such values. As an example, taking into account the baselines previously discussed, a significant deviation from the baseline value can be considered as a threshold value.

Conclusions and recommendations

From the reports for all the pilot areas, the ENVASSO procedures and protocols (see Volume V, Jones *et al.*, 2008) were very easy to apply because initially they were well described and presented.

The procedure to extract earthworms from the soil (based on ISO 23611-1) is easy either by hand-sorting and/or formalin extraction. However, it is time consuming and season sensitive. The measurement of earthworms' abundance and biomass is easy to perform whereas the determination to species level has to be learned and needs expertise and time. However, since the number of species per site in Europe is usually relatively low (e.g. up to 10 in Central Europe) and taxonomic keys are available, this determination seems to be feasible in comparison to other soil organism groups.

Several advances to the initial procedures and protocols have been proposed and successfully tested (such as changing the chemical expellant or the size of the sample).

The main recommendations for future implementation are:

1. put more emphasis on the sampling period as the soil moisture is an important parameter which influences earthworms activity (and thus their response to repellent application) and the infiltration capacity of the repellent,
2. present the results according to soil characteristics (e.g. soil type, soil texture, soil depth[1]) and land use. In order to develop a soil biodiversity monitoring over Europe, the classification of land use should be the FAO one.
3. use the box-and-whisker plots to describe the data, together with the mapping of the results,
4. convert the data collected into additional relevant parameters that sometimes better assess the diversity as abundance and biomass of ecological groups (epigeic, endogeic, anecic), abundance and biomass of species, determination of the age structure of the population (e.g. the adult/juvenile[2] ratio). These data are rather easy to obtain as more or less informed by the species level. The specific structure could also be completed by some diversity index (ex: Shannon-Wiener index). The interest to look at earthworm communities through the ecological groups is because these information's should allow to asses the modification of soil functioning and thus should give some soil functioning indicators.

In general, the same statements concerning sampling (ISO 23611-3) can be made for enchytraeids as well, while the effort of species determination depends on the sampling region (i.e. only Northern and central Europe are well studied so far).

To use such biodiversity data for soil monitoring, the main point is to perform a systematic sampling across the EU on the main soil types and main land uses to derive baseline and threshold values and to define MDC.

6.4.2 BI02 Collembola diversity and abundance

Soil samples are collected using a split corer. The corer is then opened and the soil core is separated into the litter layer (including the humus horizon) and the upper 10 cm of the mineral soil. Generally 5 cm layers are used for the upper part of the mineral horizon. Each layer is then

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[1] Depth is critical and therefore it is essential to measure this (auger depth to 1 m or soil profile pit); however, <u>horizon</u>(s) depth(s) in soil profile would be preferable.

[2] Juvenile : nonclitellate individuals

conditioned in plastic tubes; these are sealed with caps, labelled, and stored for transportation to the laboratory. The time lapse between sampling and extraction should not exceed a few days, in order to avoid undesirable side effects due to confinement and shifts in mesofauna populations (see ISO 23611-2: 2006)

Data for each pilot area were based on samples collected from monitoring sites (not obtained from literature). No baseline or threshold is defined but a method was proposed. The minimum detectable change (MDC) is assumed to be 15 to 25%.

6.4.2.1 Results

Each PA was very different in size, soil type, land use and climate. As all these parameters are determining soil biodiversity it is impossible to compare the results directly obtained for each PA. Nevertheless it is possible to compare how the results are presented. In addition, the experiences could be used to enhance the procedures and protocols. For each PA a time trend analysis can be performed when results are available for a time period.

Several ways were used to present the results (tables, graphs, box-and-whisker plots). Correlations between Indicator BI02 and other soil parameters (e.g. soil organic matter, pH) were also produced. Based on the PA reports it seems important to:
- use representations such as box-and-whisker plots which give an overview of the variability of data
- express the data depending on soil type and land use.

Several examples of results, extracted from the PA reports in ENVASSO Volume IVb (Stephens *et al.*, 2008) are given below.

Table 6-3. Soil characteristics vs. BI02 (Szent István University)

R-Square					
	SOM %	Depth of humus layer	pH (H$_2$O)	pH (KCl)	Acari abundance
Collembola abundance	0.81	0.43	0.38	0.4	-
Species number	0.42	0.22	-	-	0.59
Acari abundance	0.51	0.2	-	-	-

$r^2 < 0.04$	no correlation
$0.04 < r^2 < 0.16$	slight correlation
$0.16 < r^2 < 0.36$	moderately strong correlation
$0.36 < r^2 < 0.64$	medium strong correlation
$0.64 < r^2 < 0.81$	strong correlation
$0.81 < r^2$	very strong correlation

A = Collembola abundance, B = Species diversity

Figure 6-6. Land use vs. BI02 (RMQS BIODIV)

Legend:
Oak (several oak forests)   nm: not managed
Pine (*Pinus pinaster* plantations)   lm: low management
intensity
Euc (*Eucalyptus globulus* plantations)   hm: high management
intensity
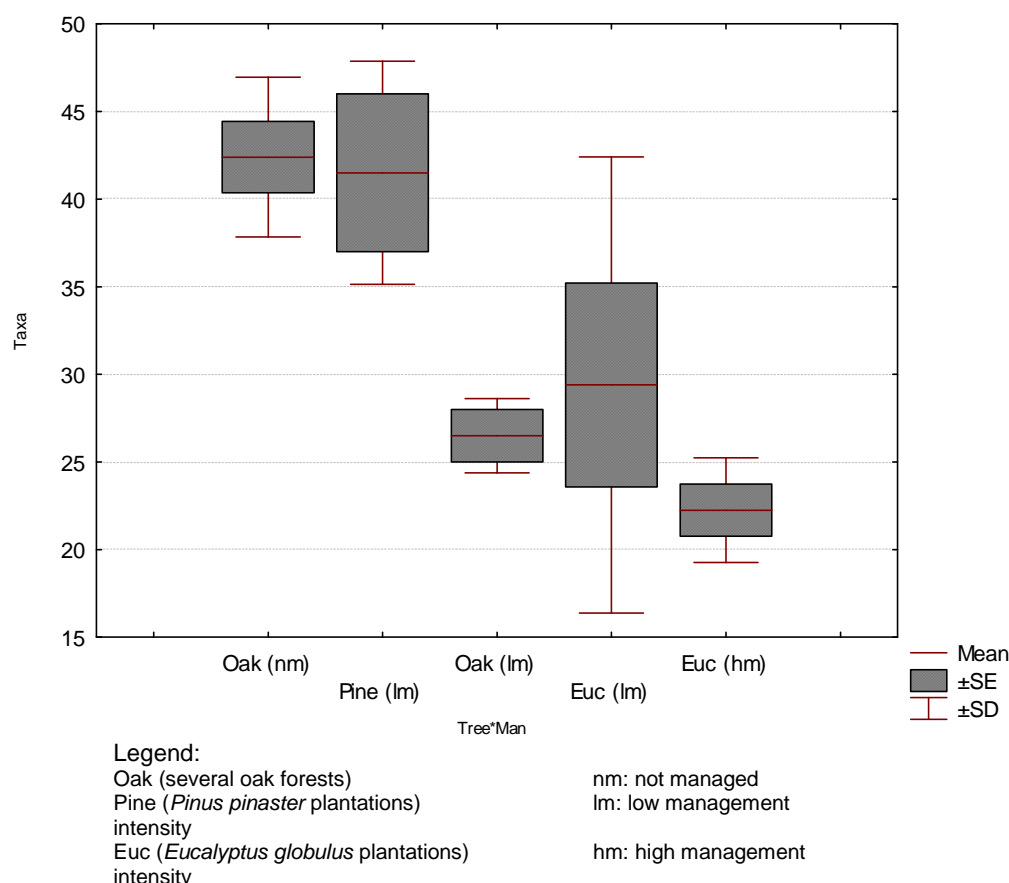
Figure 6-7. BI02 vs management intensity and tree plantation. Species richness (average + SE + SD) of Collembola according to tree and management intensity (Portugal)

6.4.3 BI03 Microbial respiration

Soil samples were collected and sent to the laboratory for the measurement of microbial respiration (basal and induced) according to ISO 16072 and ISO 17155: 2002. These methods are widely used in soil ecology to characterize the status and activity of soil microbes as well as the available pool of organic carbon.

The procedures and protocols in Volume V (Jones *et al.*, 2008) were followed with some deviations mainly based on:
- the amount of soil used in the assay and consequently the size of the vessel (already included in the manual)
- the temperature used for the incubation (from 15 to 28°C),
- the method used to measure respiration (e.g. O_2 consumption, CO_2 trapped in NaOH or measured by Infrared gas analyser)
- the expression of results (e.g. mg CO_2/100 g dry soil.h^{-1}, mg CO_2.kg^{-1} dry soil.day^{-1}, mg O_2 consumption.g^{-1} dry soil.h^{-1})

Data for each pilot area were based on samples collected from monitoring sites. No baseline or threshold value was defined at the outset but methods for both were proposed. Based on assumptions and literature review, a Minimum detectable change MDC was proposed.

6.4.3.1   Results:

Each pilot area (PA) was very different in size, soil type, land use and climate. As all these parameters are determining soil biodiversity, it is impossible to compare the results directly obtained for each PA. Nevertheless it is possible to compare how the results are presented. In addition, the experiences could be used to enhance the procedures and protocols. For each PA a time trend analysis can be performed when sufficient results are available.

Several ways were used to present the results (maps and graphs). Correlations between Indicator BI03 and other soil parameters (e.g. soil organic matter, pH) were also produced. Based on the PA reports in Volume IVb (Stephens *et al.*, 2008), it is important to express the data depending on soil type and land use.
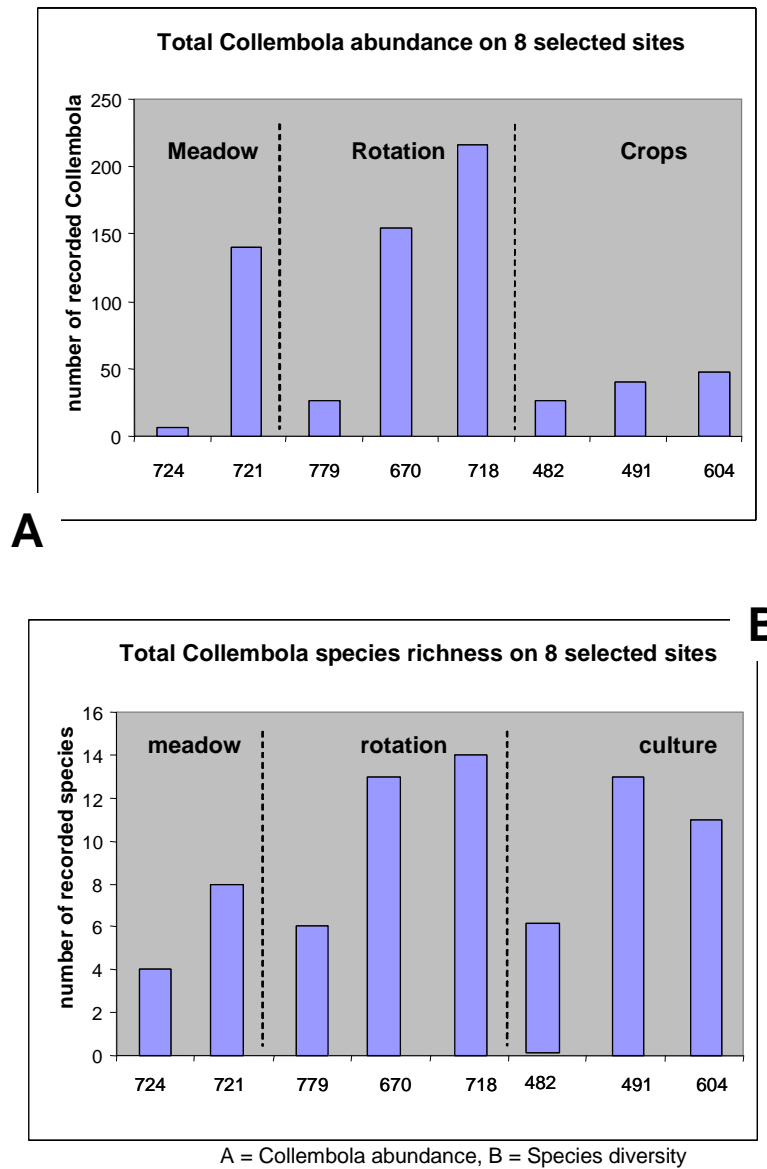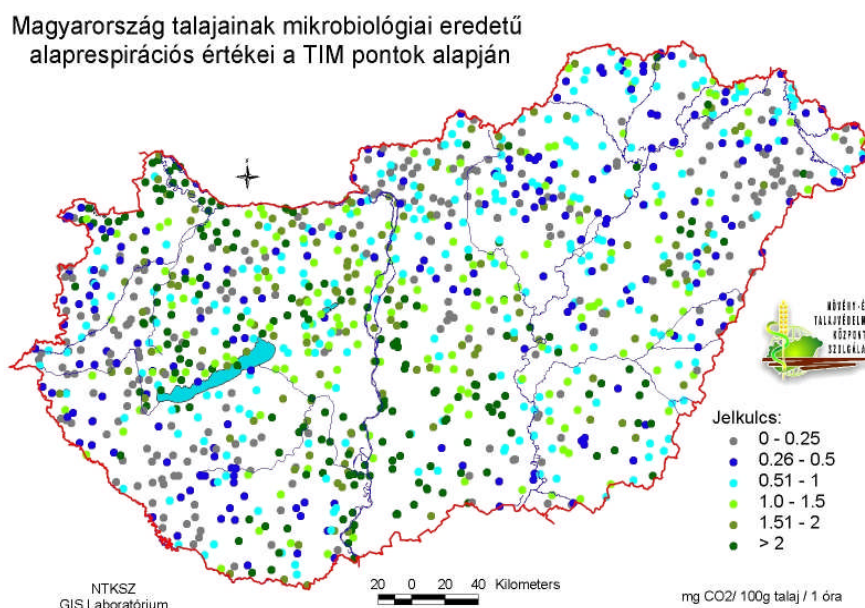

**Figure 6-8. Mapping the results at national scale of Indicator 3 (BI03)
(TIM points, Hungary)**
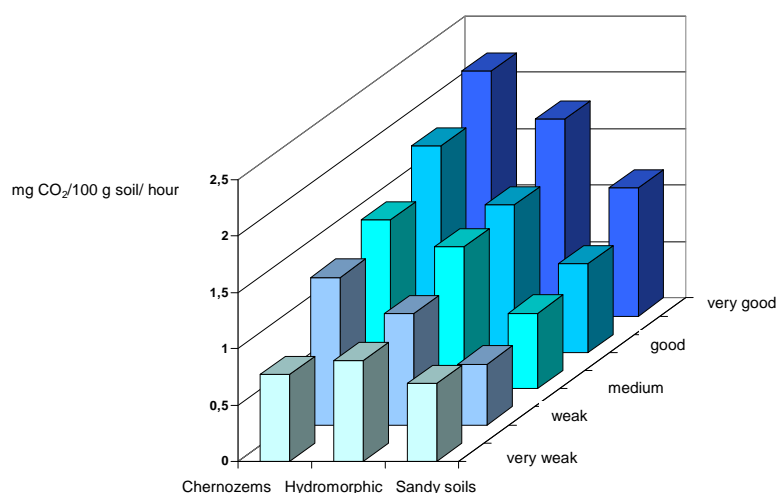
Humus categories for Hungarian soils, regardless of soil type:
very weak : 0-1.0 % // weak : 1.01-1.50 % // medium : 1.51-2.50 %
good : 2,51-4,00 % // very good : >4,00%
Soil organic matter vs. Indicator BI03 (Szent István University)

Figure 6-9. Soil type vs. Indicator 3 (BI03) (TIM points, Hungary)

O2_consumption = 0,00 + 0,00 * SOM
R-Square = 0,60
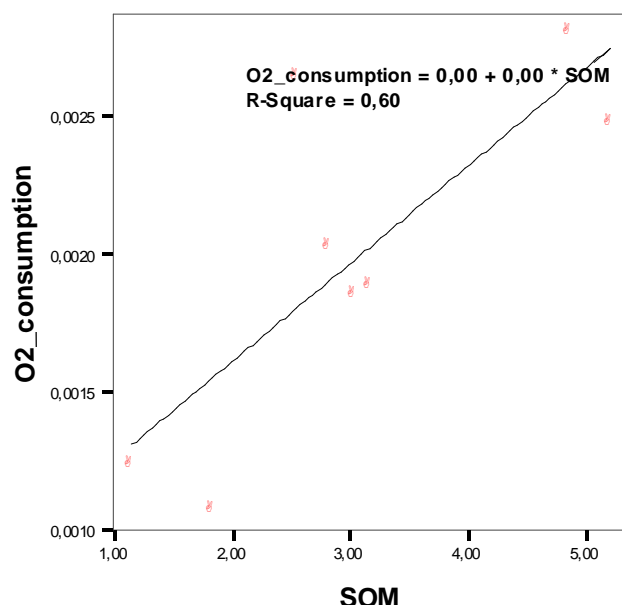
Figure 6-10. Correlation between SOM and O$_2$

Minimum detectable change (MDC)

The results already obtained on the PA can not contribute to the confirmation or the revision of the MDC. Further samplings and data will be needed to provide this value. Neither baseline nor threshold values were defined in ENVASSO Volume I, but a method was proposed to achieve such values. Unfortunately too few data was available to produce such data.

Conclusions and recommendations

The procedures and protocols, proposed by ENVASSO for assessing decline in biodiversity, were found well documented and relatively easy to apply. The procedure for measuring microbial respiration (based on ISO standards) is straightforward but, since a variety of methods may be used providing results in different units, it is difficult to make comparisons. Nevertheless it should be possible to convert and unify the different units.

The main recommendations from the testing process were to:
- present the results according to soil type (e.g. soil texture) and land use;
- use the same unit;
- homogenise pre-incubation and incubation temperatures (a list of recommended choices for temperatures and equilibration duration was proposed, from 15°C to 28°C)

To monitor biodiversity, the main aim is to sample systematically across the EU on the main soil landscapes, to derive baseline and threshold values and to define MDC.

With more time for evaluation, the following actions could have been undertaken:
- discuss and compare the advances in protocols to quantify possible deviations,
- select Pilot Areas according to different schemes (e.g. identification of main EU soil types and main land uses across EU, selecting the same soil types but various land uses across EU);
- sample all the TOP 3 indicators;
- consider several ways for expressing the results, treating data and deriving baseline/threshold values. An example of such work is given by the paper from Rutgers and Eijs (p 10-18).

With all previous actions it would have been possible to start defining baseline and threshold values at EU level and to investigate the complementarities of the selected indicators.

7 Soil Salinisation

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This report was prepared under the supervision of the Generalitat de Catalunya by Jaume Boixadera.
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7.1 Introduction

Indicators for the threat soil salinisation have been tested in three pilot areas: Hungary (A), Romania (B) and Catalonia (Spain) (C).

Two specific meetings were organised to address indicator testing for soil salinisation:

- Cluj/ Napoca (Romania), April 2007
- Hungary-Romania transnational PA meeting and field work, July 2007

In addition, further specific discussions took place at meetings in Athens (March, 2007), Budapest (July, 2007) and Sofia (June, 2007).

7.2 Description of the threat

Soil salinisation is the increase of water soluble salts in the soil, causing a deterioration or loss of one or more soil functions. The accumulated salts include chlorides, sulphates, carbonates and bicarbonates of sodium, potassium, magnesium and calcium..

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.

Soil sodification is the accumulation of Na^+ in the solid and/or liquid phases of the soil in the highly alkaline soil solution (alkalisation), or exchangeable ions in the soil adsorption complex.

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.)

7.3 Indicators

The following indicators are identified and described in ENVASSO Volume I (Huber *et al.*, 2008):

1. **Salt profile (SL01)**
   The horizontal and vertical distribution in soil of the accumulated salts and their chemical composition – namely chlorides, sulphates, carbonates and bicarbonates of sodium, potassium, magnesium and calcium.,
2. **Exchangeable sodium percentage (SL02)**
   Exchangeable sodium (Na+) fraction expressed as a percentage. Acronym =ESP.

3. **Potential salt sources (groundwater or irrigation water) and vulnerability of soils to salinisation/sodification (SL03)**.

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.

Table 7-1. Pilot areas and indicators tested

Pilot Area	Selection reason	SL01	SL02	SL03
Körös-Berettyó Basin, Hungary	Data availability in time series and pilot area is representative.	X	X	
Oradea region (Bihor county), Romania	Data on salt affected soils are available and it is representative for salt affected soil threat	X	X	
Northern bank of Ebro Delta. Catalonia (Spain)	Data availability in time series and pilot area is representative.	X	X	

Table 7-2. Description and comparison of the Pilot Areas

Pilot Area	Size km^2	Climate		Land use	Topography	Majors soils
		Mean temperature (°C)	Average Annual Precipitation (mm)			
Körös-Berettyó Basin, Hungary	370	10.4	540-570	Arable land, pasture	Flat, alluvial plain	Solonetz, Vertisols, Phaeozems, Cambisols
Oradea region (Bihor county), Romania	360	10 - 11	550-600	- Arable land (non-irrigated) - Pasture (mainly in saline area)	Plain (flat)	Chernozems, Phaeozeoms, Fluvisols, Gleysols and Solonetz
Northern bank of Ebro Delta. Catalonia (Spain)	102	25 (July – August) 9 (iJanuary – February)	530	Paddy rice	Northern part of Ebro Delta	Fluvisol calcaric, Arenosol calcaric, Calcisol

7.3.1 Definition of baseline:

SL01 - The characteristics of a soil without any specific influence of salts and sodium are considered as a 'general baseline'. These soils do contain some salts in the 0-150 cm layer as a result of weathering processes and land use practices. In such cases the total amount of soluble salts in the saturated soil paste is less than 0.05% or the electrical conductivity of the saturated paste extract (ECe) is less than 2 dSm^{-1}.

SL02 - The baseline for the exchangeable sodium percentage (ESP) is 5%; for the sodium adsorption ratio (SAR) a value less than 4, and for pH a range of 5 to 8. These values can be taken as background values.

SL03 - The baseline for irrigation water is < 500 mg l^{-1} salt content or 0.5 dS m^{-1} EC; < 4 SAR.

7.3.2 Definition of threshold:

Thresholds are highly specific for various salts, because their impacts are different and depend on various land use practices and cropping patterns.

SL01 Salt profile
0.15% total salt content or 6 dS m^{-1} ECe in the 0-30/50 cm soil layer, depending greatly on ion composition and pH.

SL02 Exchangeable sodium percentage (ESP)
        ESP > 15
        SAR >10
        pH > 8.5 in the accumulation horizon

For practical purposes we use the following thresholds:

        ESP value:
        ESP < 5   no sodification symptom
        ESP 5-15   slightly sodic (solonetzic) soil
        ESP 15-25   strongly sodic (solonetzic) soil
        ESP > 25   sodic (solonetzic) soil

        Depth of Exchangeble sodium accumulation
        < 7 cm   shallow sodic soil
        7-15 cm   medium sodic soil
        > 15 cm   deep sodic soil

SL03 Potential salt sources
The baseline can be taken as the threshold because, in the case of a baseline exceedance, the water cannot be used for irrigation without special precautionary measures. The critical depth or critical regime of groundwater can be quantified (Kovda *et al.1967; FAO, 1975*). The critical depth of groundwater depends on the chemistry of groundwater (salt concentration and ion composition), the salinity status of the soil profile and the character of the salt balance. As general threshold 1000 mg l^{-1} salt concentration and 10 SAR can be used.

7.4 Indicator evaluation

7.4.1 SL01 Salt profile

The suggested parameters in ENVASSO Volume V (Jones et al, 2008) are:
- pH
- ion composition

The sampling methods adopted are:
- excavate a soil profile (12 points) to the depth of salt accumulation or groundwater level and test with a hand-held EC sampling device every 10 cm
- if one or more points show an EC above the threshold value (6 dS/m) then sample (with an auger) at 12 randomly positioned points in the monitoring site each 10 cm.

The test methods used were:
- field: a hand held EC device
- lab.: ISO standards

The parameters and methods proposed at the outset of the ENVASSO Project were confusing. A two-stage approach was proposed that is problematic in practice: open 12 pits in the monitoring site to test the salinity *in situ* and later sample with an auger if the soil has an EC above 6 dS/m.

The explanation for this is to identify the saline sites and in these sites apply the costly analytical methods of salinity.

In the meeting in Sofia (June 2007) it was agreed that:
- EC should be a parameter
- Sampling depth should be up to about 1 m

In the end the methods used in each Pilot area were different:
- Pilot area A (Hungary): the procedures and protocols in Jones *et al.* (2008) were followed, but not step 1 (open 12 soil pits)
- Pilot area B (Romania): a single pit was excavated and sampled at vertical intervals of 10 cm .
- Pilot area C (Catalonia, Spain): a completely different approach was used:by augering at 5 points per site up to 120 cm depth; measurement made with an electromagnetic sensor EM_{38}

The reasons for changing the original procedures were in:
- Pilot area A: it is not practical to use Step 1 (see Procedures and Protocols in Jones *et al.*, 2008), even less in a saline area. In spite of that the hand held device was tested in 4 profiles.
  - In Hungarian pilot area has been followed the methods used in the Hungarian monitoring system.
- Pilot area B: used information from a single soil pit per site. In this pilot area the hand held device was also tested.
- Pilot area C. The existing information was collected in the manner described above, partly because some data were historical. In addition to that, the well established technique using an electromagnetic sensor allows rapid measurement of a large volume of soil.

Pilot area A.   Historical data from the Hungarian monitoring system
Pilot area B.   Results from a new sampling and historical data from Romanian.
Pilot area C.   Historical data from the monitoring system and a new sampling from the Catalan (Spain) monitoring system. The baseline is set at ECe= 2 dS/m in the saturated soil paste extract (0.05 % of soluble salts). An ECe larger than 6 dS/m in the saturated soil paste extract (0.15% of soluble salts) is an acceptablme. The minimum detectable change was not addressed in this project.

7.4.2 SL02 Sodification

The sampling scheme is similar to the Step 2 for salt profile (SL01); in fact the suggestion is to use the same samples to measure this indicator (Exchangeable sodium percentage).

The analytical method is to analyse exchangeable cations.
- Pilot area A and B used the recommended procedures for analysis and they computed SAR with the equation (Richards, 1954) provided by the procedures and protocols (Jones *et al.*, 2008).
- Pilot area C used SAR instead of ESP. Using SAR for the situation of Pilot area C is cheaper and quicker because the SAR is measured from the saturated paste extract and it is not necessary to analyze the cations; also it avoids the problems to work with excess salts when measuring exchangeable cations.

Pilot area A.   used historical data from the Hungarian monitoring system
Pilot area B.   used results from a new sampling and historical data from Romanian.
Pilot area C.   used historical data from the monitoring system and a new sampling from the Catalan (Spain) monitoring system.

Baseline: Exchangeable sodium percentage (ESP) is 5% ;
                 Sodium adsorption ratio (SAR) < 4 ;
                 5 < pH < 8

Threshold

ESP > 15 ;
SAR >10 ;
pH > 8.5 in the accumulation horizon

7.4.3 SL03 Potential salt sources

The sampling methods described in ENVASSO Volume V (Jones *et al.*, 2008):

- Sample ground water and irrigation water.
- Perform cation concentration (Na, Mg, Ca) analyses
- Calculate ESP and SAR

The test methods were:

- Ground water and irrigation water sample: ISO standards
- Laboratory methods: ISO standards

The baseline can be taken as the threshold because, in the case of a baseline exceedance, the water cannot be used for irrigation without special precautionary measures. As a general threshold, 1000 mg l^{-1} salt concentration and 10 SAR can be used. Minimum detectable change for SL03 was not addressed by this project.

7.4.4 Results for the three priority indicators

Most of the results were presented in graphical or tabular form. They are clear and easy to read, but it is not easy to draw conclusions from them.

Results are summarized and tabulated using average Ece (pilot area C) or % salts (pilot area A) making comparisons possible. Also in the case of pilot area C, it is possible to draw maps using geostatistical techniques because there are enough points.

Baselines defined for these indicators are universal ones, especially for SL01. For SL02 the saturation may vary. The definition of *thresholds* for salinisation emphasises the unfavourable physical and hydrological consequences associated with a specific land use and soil characteristics. Different *threshold* values are used in the pilot areas, probably because there are few historical data, the areas are saline and the land uses are well adapted to such conditions (Pilot area A & C) or only exists one type of land use (rice, Pilot area C).

Some of the pilot areas did some work, but the results were of a preliminary nature. The applicability of indicator SL03 was discussed within the ENVASSO Project and it was concluded that this indicator is not easy to apply because it is not enough adequately defined. Furthermore, it was concluded that the three pilot areas are not suited to testing the indicator SL03.

Conclusions and recommendations

The soil salinisation indicators provide information about this threat in areas currently not saline but which may become saline due to climate change, land use change or both. If a monitoring network exists, such as the system in Hungary, it could be very useful to use the EC$_{1/5}$ as a first stage assessment; this is a rapid, inexpensive test that gives a preliminary indication about salinisation, which may be used in connexion with sampling soil for other threats such as soil organic mater decline.

The two first indicators for the threat soil salinisation SL01, Salt profile and SL02, Exchangeable sodium percentage, have been tested in three pilot areas – Hungary (Körös-Berettyó Basin), Romania and Spain – where salt affected areas exist. The third indicator (SL03) requires more scientific and technical progress before it can be applied at European scale..

All the three pilot areas were selected because they had historical data. The Hungarian pilot area followed the original protocols and procedures very closely whereas the other pilot areas made significant changes to these procedures and protocols.

The experience of indicator testing has led to the following procedural changes now incorporated in ENVASSO Volume V (Jones *et al.*, 2008):

1. In non saline areas, where there is some risk of salinisation due to climate change or land use change, existing monitoring networks, for instance for organic matter monitoring, may be used to monitor salinity, by measuring EC and pH in a 1:5 soil-water extract. This is a rapid, inexpensive and useful method.

2. Electrical conductivity of the saturated paste extract (ECe) should be preferred to % soluble salts as indicator SL01 because there are situations where the % of salts gives many analytical problems (soils with calcium carbonate, gypsum, …) and also because ECe is easier and cheaper to measure.

3. For saline soils, SAR is precise enough and is much easier to measure than ESP; in non saline soils SAR may produce large errors of measurement. It is recommended to use SAR in all cases, except in non-saline soils (ECe < 4 dS/m) where ESP should be used. In all cases convert SAR figures should be converted to ESP values using the standard equation.

4. Hungarian data, from the only pilot area with a long historical record, suggest that short-term changes are meaningless; and measuring every 3 to 5 years should be recommended.

5. Results of Pilot Area C show clearly the usefulness of electromagnetic sensors for salinity monitoring, in agreement with available data in literature. This method should be introduced into the ENVASSO Procedures and protocols together with laboratory methods.

8 Desertification

Authors
This report was prepared under the supervision of the Centro de Investigaciones sobre Desertificacion (Consejo Superior de Investigaciones Cientificas, Universitat de Valencia, Generalitat Valenciana) by Jose Luis Rubio.

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8.1 Introduction

Desertification involves the degradation of land, water, vegetation and other resources that can affect in different ways the possibilities of sustaining ecosystems and human beings. Because of its importance worldwide, the United Nations has formulated the Convention to Combat Desertification (UNCCD), to which the European Union is a signatory.

In Europe, the extent of desertification is in continuous progression, mainly in the eastern and Mediterranean regions that are already seriously affected and more than 300,000 km^2 are identified as suffering desertification processes. On this basis, the development (or refinement) of a standardised methodology, to assess the extent and risk of this process in the European context, is needed. The ENVASSO project provided the opportunity to develop and validate an indicator approach.

8.2 Description of the threat

Desertification (key issue) is 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.

8.3 Indicators

DE01 - Land area at risk of desertification
DE02 - Land area burnt by wild fire
DE04 - Topsoil organic matter content in desertified land

8.4 Indicator Evaluation

Indicator DE01 was tested in four pilot areas.

Indicator DE02 was not subjected to testing by ENVASSO for a number of reasons: Forest fires are currently monitored at national level and the data pooled at European level (Jones *et al.*, 2008). The impact of wild fires is very variable depending on fire severity, and the specific vegetation, soil and geomorphologic characteristics of the affected area, under a particular climate conditions. The effects of fire on desertification can vary from slight impacts, to strong consequences that trigger desertification. The many factors involved require detailed evaluation in the field, over sufficient timescales, using comprehensive methodologies that allow comparison, which was not possible within the timescale of the ENVASSO Project. There is a also a lack of harmonised information and evaluation of existing data needs further research.

Indicator DE04 was not tested because it is covered by the testing of indicator OM01 topsoil organic carbon content. The ENVASSO consortium concluded that this third priority indicator should eventually be replaced by a soil degradation index that would encompass decline in soil organic matter, decline in soil biodiversity, and salinisation.

Table 8-1. Pilot areas and indicators tested

Pilot Area	Selection reason	DE01	DE02	DE04
Transect North of Valencia CSIC Spain	Representative of different landscape and environmental conditions	X		
Vale do Gaio watershed INIAP Portugal	Representative of areas with hot and dry climatic conditions and scarce vegetation	X		
Chania-Crete AUA Greece			X	
Philippi-Macedonia AUA Greece			X	

Table 8-2. Description and comparison of the Pilot Areas

Pilot Area	Size (km^2)	Climate	Land use	Topography	Majors soils
Transect North of Valencia CSIC Spain	3011	Sub-humid to Semi-arid	Natural and reforested woodland, irrigated and non-irrigated cultivation	From coastal plain to highly mountainous	Calcisols, Luvisols, Cambisols, Fluvisols, Anthrosols, Regosols, Leptosols, Phaeozems, Kastanozems
Vale do Gaio watershed INIAP Portugal	513	Sub-humid to Humid	Oak tree Mediterranean woodland, Agricultural crops, Pasture	Gentle undulating relief	Cambisols, Luvisols, Regosols
Chania-Crete AUA, Greece	716.67	Semi-arid	Irrigated and non-irrigated tree crop cultivation, irrigated cultivation, intensive pastures, woodland	Hilly	Cambisols, Regosols, Luvisols, Leptosols
Philippi-Macedonia AUA Greece	23	Semi-arid	Agricultural crops, pastures	Flat to steep	Cambisols, Histosols, Leptosols, Fluvisols

8.4.1 DE01- Land area at risk of desertification

ENVASSO procedures and protocols, following the Medalus methodology (Kosmas *et al.*, 1999; Jones *et al.*, 2008) have been applied in the four pilot areas but some data required are not available from existing databases. ENVASSO soil data derive from soil profiles, thus, the assessment of land desertification risk for a specific field site can be estimated using these data but they cannot be applied across a whole region.

Table 8-3. Parameters

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

A=Actual, M=Modelled; Complete list in Table 8-4

Table 8-4. MEDALUS Methodology: Parameters needed for computing 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	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

The assessment of soil erosion and land desertification requires the use of detailed or semi-detailed spatial soil, vegetation and land management data that relate to soil mapping units not to specific soil profiles.

8.4.1.1 Data sources

Transect North of Valencia, Spain: Data on soil texture, rock fragments, soil depth and drainage were obtained from the LUCDEME Project soil maps (Spanish Ministry od Environment), at 1:100,000 scale. Data on parent materials were based on the digital map of lithologies published by the Consejería de Obras Públicas, Urbanismo y Transportes (COPUT) of the Valencian Community, at 1:50,000 scale. The slope gradients were obtained from the digital maps published by the COPUT of 20 m contour lines. Rainfall and Aridity Index data were obtained from the existing data series and publications of the Meteorological National Institute.

The aspect layer was elaborated from the digital maps published by the COPUT of 20 m contour lines. Data on fire risk, erosion protection, drought resistance and plant cover were taken from the Corine Land Cover – CLC– (2000). Land use type and land use intensity data were extracted from the CLC (2000). Data on policy enforcement were based on the published digital maps of natural protected areas (Consellería de Territorio y Vivienda), agricultural protected (COPUT) areas and non protected areas (COPUT), all of them at 1:50,000 escale.

Vale do Gaio watershed, Portugal: Soil data, such as, textural classes of the surface layer, water holding capacity, soil depth and drainage conditions, were extrapolated from representative soil profiles of the Portuguese Soil Survey Service and from the Soil Science Department of INIAP-EAN. The parent material was defined according to the geological map of the area (scale 1:50000) supplied by the Portuguese Geological Service. Slope gradient was determined using the Digital Elevation Model (grid format 250m x 250m). Vegetation data were based on the CLC_2001. Climatic data were obtained from Vale do Gaio meteorological station.

Chania-Crete and Philippi-Macedonia, Greece: The data used to assess land desertification were collected by conducting a regular soil and vegetation semi-detailed survey (1:30.000). The following parameters were described related to soil: soil texture of the surface horizon, drainage conditions, presence of rock fragments, depth to bedrock, degree and direction of soil development, slope gradient, slope aspect, and parent material. These land parameters were studied in a dense network of field observations and were recorded on each mapping unit. The boundaries of the mapping units were drawn on ortho-photo maps.

The parent material was defined according to the geological map of the area (scale 1:50,000) supplied by the Greek National Institute of Geology and Mineral Exploitation (IGME). Slope gradient was described using the topographic maps. Vegetation was described on the basis of: (a) land use type, and (b) pant cover. The type of land use and the percentage cover by each type of vegetation was defined in classes by aerial ortho-photo-interpretation and field survey at a scale of 1:30.000, and were described using the FAO classification system. Long term climatic data (period of 40 years) for the study areas were available from the meteorological stations located in or nearby of the study areas.

No *baseline*, *threshold* or *minimum detectable change (MDC)* has been defined for desertification.

Due to the heterogeneity shown between the pilot areas and the characteristics of each one, with the different balance between the parameters involved in the methodology, more field data and research are needed for defining baselines, thresholds and MDC for desertification.

8.4.1.2 Results

Transect North of Valencia, Spain

The diverse circumstances that interact in this pilot area and the threat of desertification are clearly reflected by the results obtained. The *Non Threatened* and *Potential* ESA categories are not represented, which emphasises the *fragile* status of the desertified transect. In this sense, the variation in the ecological and anthropogenic characteristics along the transect gives place to a different balance on the incidental factors influencing the threat of desertification.

The results (see Table 8-5 & Figure 8-1) show that more than 90% of the pilot area is under the *Critical* type of ESA. In addition, almost 60% of the pilot area corresponds to ESAs of the most extreme *critical* type (C3), which mainly affects the central and eastern part of north Valencia. The study area covers the extensive coastal plain and the central zones of dry farming along the transect. These zones experience the most intense human pressure through intensive farming, industrial activity, increasing urbanization, sealing, etc. Another crucial factor is intensive use of water and its restricted availability. This last constraint is not only affected by a drier climate, with less rain towards the coast, but also by the overexploitation of aquifers and the low quality of water, which in many cases creates salinisation problems.

Table 8-5. Distribution of environmentally sensitive areas to desertification in the North Valencia transect

ESA Type	Subtype	Surface	
		Area (Ha)	%
Fragile	F2	1398.1	0.5
	F3	10009.3	3.3
Critical	C1	13706.5	4.5
	C2	89505.6	29.7
	C3	174249.1	57.8
	Urban Areas	11432.3	3.8
	Water Bodies	1273.1	0.4
	Total	301574.0	

C1 and C2 type ESAs, covering 34.2 % of the pilot area, are mainly in the mountainous parts, steep zones characterized by shallow soils with high stoniness developed on Dolomites and limestone. These units cover the mountainous parts of the Racó d'Ademuz, Els Serrans and L'Horta Nord regions, and are located mainly in the last foothills of the Sierra Calderona towards the sea, and the ridges of Javalambre and Negrete. These zones accommodate the greater part of the marginal land characterized by terraces, most of them abandoned due to socio-economic changes and to the EC Common Agricultural Policy. Another important pressure is the increasing construction of tourist accommodation and second residences that are found on these lands. In addition, the remaining area is characterized by sparse forest and Mediterranean shrub-land developed after repeated damage by wild fires. All these characteristics make them prone to water erosion and other degradation processes.

By contrast, the *Fragile* zones occupy only 3.8% (F2 and F3) of the total area being restricted to the mountainous forest land, mainly in the inner parts of the transect (regions of Racó d'Ademuz and Els Serrans). The area covered by these ESAs is located in the upper part of the Sierras and ridges above, which support the remaining forest of pines and oaks that in the greater part have been declared as protected zones by the regional government. However, these zones suffer, to a lesser extent, some of the restrictions and threats observed in the mountainous areas of the transect (shallow soils, steep slopes, forest fire risks, etc). The F1 *fragile* type does not appear in the whole area.
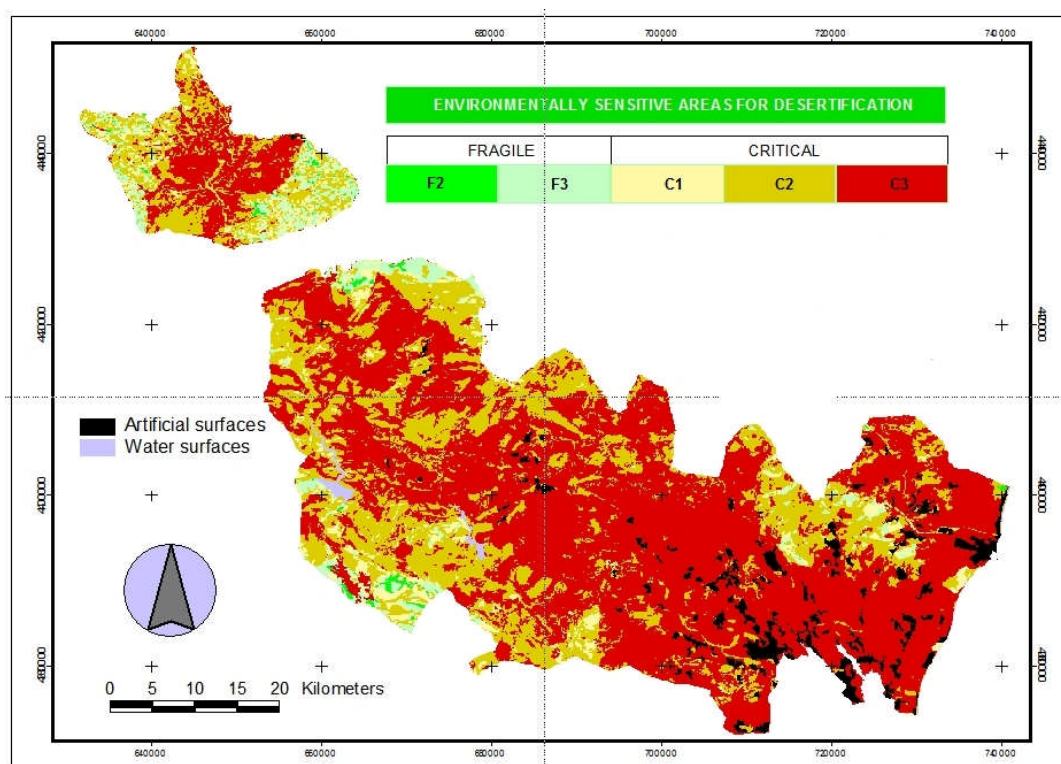
Figure 8-1. Map of the environmentally sensitive areas of desertification, based on the application of the MEDALUS III methodology to the North Valencia transect

Vale do Gaio watershed, Portugal.

Based on the results obtained (Table 8-6) the greatest part of the area (68.4%) is characterized as *Fragile* to desertification. *Critical* areas cover 25.9% while only 3.9% and 1.8% are characterized as *Potential* and *non-threatened* to desertification, respectively.

The Soil Quality Index (SQI) has shown that most of the soils in the area (82.4%) have a moderate quality, while only 16.7% can be considered as having a high quality (Figure 2). With an annual rainfall of 584 mm and a Bagnouls-Gaussen aridity index of 132, the climate in the region can be considered as moderate (74.1%) if the slope has north exposure and as low quality (25.9%) on the south-facing slopes. The existing vegetation is characterized as high quality, covering 88.8% of the area. Plants like Cork and Oak trees are resistant to drought and fire due to their medium to low distribution in the landscape and the Oak tree Mediterranean woodland system, in which they provide some erosion protection to the soil. In the remaining area, vegetation is characterized as having a moderate quality (11.2%). Concerning the Management Quality Index, since not much information is available in Portugal for this region, the areas having a slope gradient >2% and a more intensive land use were characterized as low protected (18.6%). The remaining area was considered as having a moderate protection.

Table 8-6. Distribution of environmentally sensitive areas to desertification in the Vale do Gaio watershed

Area (%)	Environmentally sensitive areas (ESAs)							
	Non-threatened	Potential	Fragile			Critical		
	N	P	F1	F2	F3	C1	C2	C3
	1.8	3.9	17.1	24.8	26.5	10.4	13.1	2.4

After analyzing and processing the different data layers, it is shown that *Critical* environmentally sensitive areas (ESAs) to desertification are mainly located in the zones with the south-facing slopes, and in the south and north-eastern areas of the watershed (Figure 8-2) previously defined as having higher land use intensity.

Potential and *non-threatened* areas are located where soil is considered to have a higher quality, especially south of the Vale do Gaio water reservoir and in the south-eastern part of the watershed. In these areas, climate, vegetation and management are rated moderate or high quality helped reducing the risk of land degradation. *Fragile* ESAs (F1, F2, and F3) are widely distributed all over the remaining area, the lower class F1 being more dominant in the western and south-eastern part of the watershed, where Oak tree Mediterranean woodland prevails, and in the most fragile class is distributed around the centre and north-eastern parts of the study area. These *fragile* areas are very sensitive to changes in land use, climate and vegetation cover. Any changes in land use, fires resulting in the loss of vegetation cover, prolonged droughts, and increase in soil erosion, are likely to exacerbate land desertification and progressively move the areas characterized as *Fragile* to *Critical*.
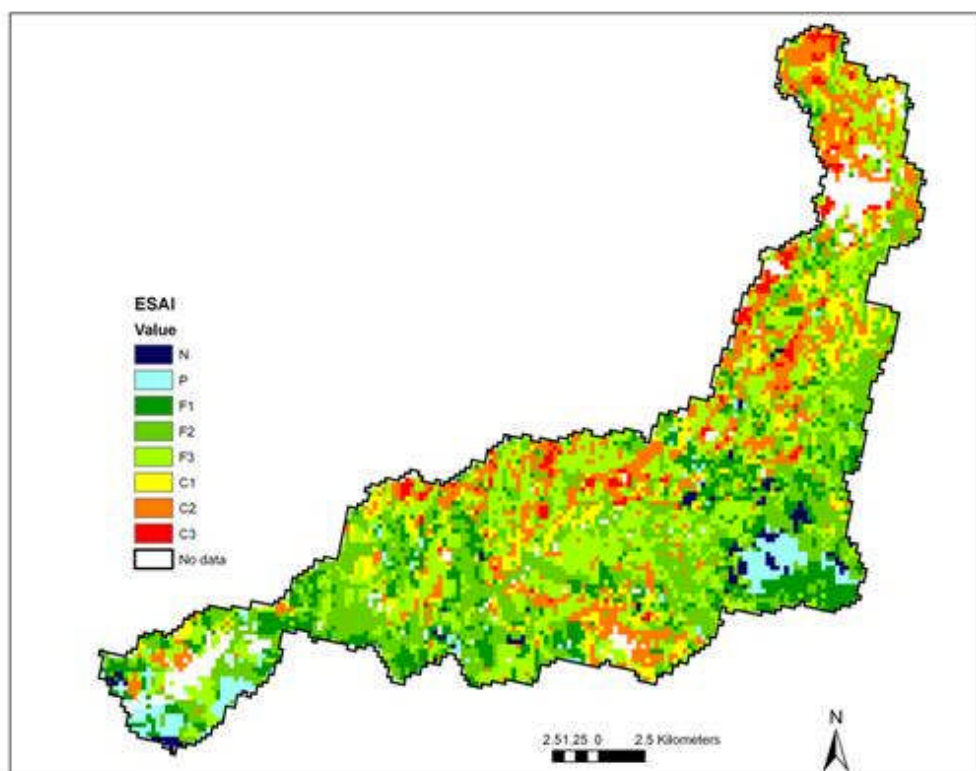
Figure 8-2. Map of environmentally sensitive areas to desertification in the Vale do Gaio watershed, Portugal

Chania-Crete, Greece

Four categories of environmentally sensitive area (ESAs), according to the state of land degradation and the sensitivity to desertification, were found in the Chania study area: *Fragile*, *Critical*, *Potential* and *Non-threatened* (Figure 8-3). The most extensive ESAs areas are characterised as *Fragile* (66.1% of the total area) followed by *Critical* (15.5%), *Potential* (10.8%) and least extensive are *Non-threatened* areas (7.7%) (Table 8-7).

Fragile ESAs (F1, F2, F3) are widely distributed over the whole area (Figure 8-3). These areas are very sensitive to degradation, with any change in the delicate balance of climate and land use. Any change is likely to reduce biological potential resulting in the loss of the remaining vegetative cover and consequent exposure to greater erosion forces. This land is threatened by higher rates of degradation under: (a) slight climate change, and (b) if existing types of land use, such as the well adapted olive groves, are replaced by less suitable systems. Due to the relatively good vegetative cover, the soils of this zone are moderately deep (50-100 cm) to deep (>100 cm), well vegetated with olive trees or shrubs, slightly to moderately eroded.

N=non-threatened, P=potential, F1, F2, F3=fragile, and C1, C2, C3=critical areas to desertification

**Figure 8-3. Map of environmentally sensitive areas to desertification
of the study area of Chania**

Critical areas (C1, C2, and C3 in the map) covering 15.5% of the total area (Table 8-7), are mainly located in the central and southern part of the study area (Figure 8-3). They are badly degraded with very shallow (0-15 cm) to shallow (15-30 cm) soils severely to very severely eroded, and poorly vegetated. These areas have soils formed on limestone or shale, used mainly as pastures. Burning and overgrazing of these climatically and topographically marginal areas constitutes a degradation-promoting land use, further deteriorating the existing land resources. This area is very sensitive to low rainfall and extreme climatic events.

**Table 8-7. Distribution of environmentally sensitive areas to desertification
in the Chania pilot area**

Area (%)	Environmentally sensitive areas (ESAs)							
	Non-threatened	Potential	Fragile			Critical		
	N	P	F1	F2	F3	C1	C2	C3
	7.7	10.8	15.1	29.6	21.4	9.0	6.4	0.1

Potentially sensitive areas are mainly located in the northern part covering 7.7% of the study area (Table 8-7). They are nearly flat to gently sloping land (slope <12%). Soils are moderately fine-textured, free of rock fragments or stony, very deep, mainly well drained, and formed mainly on marl, conglomerates or alluvial deposits. The climate is mainly dry sub-humid with rainfall greater than 660 mm, and a very dry aridity index (AI >150). These areas are usually found on north facing-slopes or they are flat. The dominant vegetation is mainly olives, and in some cases vines or citrus. The existing vegetation is characterized by good to moderate erosion protection, mainly high resistance to drought, low fire risk and vegetation cover usually greater than 90%.

Areas *not threatened by desertification* are confined to nearly flat land in valleys with very deep soils, usually well-drained, mainly free of rock fragments, formed mainly on alluvial deposits, and covering 7.7% of the study area (Table 8-7). The climate is mainly dry sub-humid with rainfall 660 mm, and a very dry aridity index (AI>150). The dominant vegetation is olives or citrus characterized by low fire risk, high erosion protection, high to moderate resistance to drought, and vegetation cover usually greater than 90%. These areas are mainly under

moderate land use intensity and enjoy complete enforcement of the policy on environmental protection.
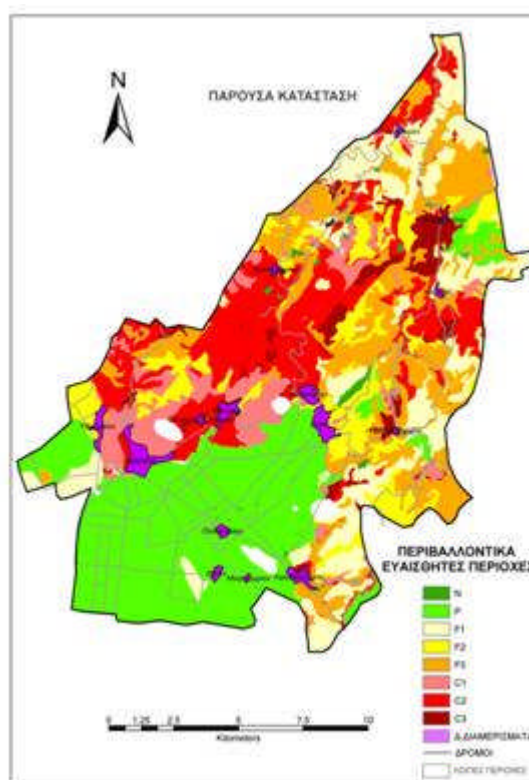
Philippi-Macedonia, Greece

Based on the MEDALUS III methodology, the greatest part of the area (42.2%) is characterized as *Fragile* to desertification (Table 6, Fig. 8-4). Critical areas to desertification cover 28.7%, while the rest of the area (28.5%) is characterized as *Potentially* threatened by desertification.

Table 8-8. Distribution of environmentally sensitive areas to desertification in the Philippi-Macedonia area

Area (%)	Environmentally sensitive areas (ESAs)							
	Non-threatened	Potential	Fragile			Critical		
	N	P	F1	F2	F3	C1	C2	C3
	0.3	28.5	14.6	9.6	18.2	7.7	17.3	3.8

Fragile environmentally sensitive areas (ESAs) to desertification are mainly located in hilly areas with moderately deep soils (soil depth 30-60 cm), steep slopes (slope gradient 35%), with shrubby or forestry vegetation. Climate is characterized as semi-arid with annual rainfall 650 mm and Bagnouls-Gaussen aridity index 128. They are mainly located in south-facing slopes. The existing vegetation is characterized as sensitive to fires, resistance to drought and plant cover .75%. They are subjected to moderate land use intensity. The main process of land desertification is soil erosion. These areas are very sensitive to degradation if any land use change occurs.

Figure 8-4. Map of environmentally sensitive areas to desertification in the Philippi-Macedonia area, Greece

Critical ESAs are mainly found in the hilly areas characterized by degraded shallow soils (soil depth 0-30 cm), with steep slopes (slope gradient .35%), severe to very severely eroded covered with poor shrubby vegetation.The climate is characterized as semi-arid with annual rainfall of 650 mm and Bagnouls-Gaussen aridity index 128. The main processes of land

desertification are soil erosion and water stress. The existing type of vegetation is characterized by high sensitivity to wildfires, moderate erosion protection to the soils, and high resistance to drought. These areas are subjected to moderate to high land use intensity and with low measures applied for environmental protection.

Potential ESAs to desertification are mainly found on the agricultural plain. Soils are very deep well to poorly drained moderately fine to fine textured, with organic matter content greater than 2% in the surface horizon. The main process of land desertification is soil salinization.

General evaluation

Land desertification was assessed in all pilot areas based on the methodology developed by the MEDALUS III EC research project (Kosmas *et al.*, 1999). This methodology allows the definition of Environmentally sensitive areas (ESAs) by preparation and application of a base of 15 raster layers including the indices for each parameter and each grid, which can be completed with additional data layers. This fact favours the potential improvement by further inclusion of new parameters, and gives the flexibility needed for its evolution and improvement. In this way, Land desertification can be easily assessed for an area using simple environmental properties that are generally available.

The use of ESAs favours the application and management of indicators of desertification, in a easily understandable way. The values of the various indices can be easily interpreted although , mainly for the allocation of sub-classes that leaves some margin of subjectivity.

However, this methodology requires some improvement taking into consideration parameters related directly to the processes of land degradation, such as soil erodibility, rain erosivity, water deficit, soluble salt accumulation, etc. One the main necessities is validation of the results, which, at this stage, is difficult because of the lack of field data and observations, mainly on soil related aspects. This is one of the main drawbacks of the MEDALUS III methodology, the necessity of having sufficient data sources at the level of detail needed to feed the MEDALUS system.

In general, the results fit fairly well with those shown by the available cartography on desertification and with the field observations made in the different pilot areas. In this way, land desertificiation assessment, using the MEDALUS III methodology, can be considered as a valuable tool at local, national and European level for defining environmentally sensitive areas to desertification using simple soil, vegetation, climate and land management characteristics provided by regular survey reports and included in the ENVASSO protocols. This methodology can be easily applied using a GIS tool, such as ArcMAP[®.]

Conclusions and recommendations

There is a consensus about the program performance. The ENVASSO methodology (Jones *et al.*, 2008) represents an excellent effort in organizing the soil data groups (or sets of information) and identifying the best methodologies for assessing various soil threats using indicators. The MEDALUS III procedures on desertification have proved to be successful when being applied in different European environments (from Greece to Portugal) and scales (from 23 to 3011 km[2]).

Further work to be developed could be contemplated at three levels:
1. Development of a set of standard procedures to integrate the ENVASSO system into a GIS mechanism, or similar development as a stand-alone informatics' application.
2. Establishment of data standards to develop a minimum harmonized data set to feed the model with information, at least at European level.
3. Refinement of some components of the model to allow for better description of the individual data layer, e.g. climate.

Specific recommendation should be:

    A. Soil quality factors: The use of sufficiently detailed soil maps that will integrate into their associated databases the required information by the ENVASSO procedures (rock fragments, soil depth, drainage, parent material, etc). An in-depth evaluation of the contribution of the digital elevation model (DEM) according to pixel size and slope gradient classes incorporate into the model.

    B. Climate quality factors: Better definition of climate factors, or incorporation of new data. Aspect classes need to be more detailed.

    C. Vegetation quality factors: Development of a European wide vegetation-land cover legend with standard considerations according to the ENVASSO procedures, including indicators related to 'Management quality' module.

    D. Management quality factors: Policy enforcement factor needs to be adapted to the local reality, and needs to be more versatile.

In general, the main factor that capitalizes on the functioning and application of the MEDALUS methodology for assessing desertification is the availability of data. There are no harmonised data sources and scales amongst the different European countries, at any level, on the different topics (soils, vegetaion, climate, land uses, etc.). Taking this position into account, a more versatile/flexible approach could be adopted to further develop the methodology.

9 References

Arrouays, D., Deslais, W. and Badeau, V. (2001). The carbon content of topsoil and its geographical distribution in France. Soil use and Management 17, 7-11.

Arrouays, D., Saby, N., Walter, C., Lemercier, B. and Schvartz, C. (2006). Relationships between particle-size distribution and organic carbon in French arable topsoils. Soil Use and Management 22, 48-51.

Burghardt, W., Banko, G., Hoeke, S., Hursthouse, A., de L'Escaille, Th., Ledin, St., Marsan, F.A., Sauer, D., Stahr, K., Amann, E., Quast, J., Nerger, M., Schneider, J. and Kuehn, K. (2004). Sealing soils, soils in urban areas, land use and land use planning. Report of Task Group 5, Vol. VI. Research, sealing and cross-cutting issues. In. Van-Camp. L., Bujarrabal, B., Gentile, A-R., Jones, R.J.A., Montanarella, L., Olazabal, C. and Selvaradjou, S-K. (2004). Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection. EUR 21319 EN/6, p.771-817. Office for Official Publications of the European Communities, Luxembourg.

Carter, M.R. (1992). Influence of reduced tillage systems on organic matter, microbial biomass, macro-aggregate distribution and structural stability of the surface soil in a humid climate. Soil and Tillage Research 23, 361-372.

Clapperton M.J., Baker G.H., Fo70x C.A. (2007) Soil biological analysis: earthworms. In: Soil sampling and methods of analysis. Cater M.R. and Gregorich E.G.(Eds) Canadian Society of Soil Science, 415-426.

FAO. 1975. Land evaluation in Europe. FAO Soils Bulletin 29. Rome, Italy

Greenland, D.J., Rimmer, D. and Quirk, J.P. (1975). Determination of the structural stability class of English and Welsh soils, using a water coherence test. Journal of Soil Science 26, 294-303.

Hegymegi P., Spiegel H., Filcheva E., Gál A., Verheijen F.G.A. (2007): Review and comparison of methods used for soil organic carbon determination Part 2. Laboratory study. *Soil Science Agrochemistry and Ecology* 41. (4), p. 19-25.

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

Horn, R., Fleige, H., Richter, F.-H., Czyz, E.A., Dexter, A., Diaz-Pereira, Dumitru, E., Enarche, R., Mayol, F., Rajkai, K., De la Rosa, D., Simota, C., 2005 SIDASS project Part 5: Prediction of mechanical strength of arable soils and its effects on physical properties at various map scales. Soil Tillage Research 82, 47-56.

Huber, S., Prokop, G., Arrouays, D., Banko, G., Bispo, A., Jones, R.J.A., Kibblewhite, M.G., Lexer, W., Möller, A., Rickson, R.J., Shishkov, T., Stephens, M., Toth, G. Van den Akker, J.J.H., Varallyay, G., Verheijen, F.G.A., Jones, A.R. (eds) (2008). Environmental Assessment of Soil for Monitoring: Volume I Indicators & Criteria. EUR 23490 EN/1, Office for the Official Publications of the European Communities, Luxembourg, 338pp.Jones et al 2008

Jones, R.J.A., Hiederer, B., Rusco, F. and Montanarella, L. (2005). Estimating organic carbon in the soils of Europe for policy support. European Journal of Soil Science 56, 655-671.

Jones, R.J.A., Verheijen, F.G.A., Reuter, H.I., Jones, A.R. (eds) (2008). Environmental Assessment of Soil for Monitoring Volume V: Procedures & Protocols. EUR 23490 EN/5, Office for the Official Publications of the European Communities, Luxembourg, 165pp.

Kemper, W.D. and Koch, E.J. (1966). Aggregate stability of soils from Western United States and Canada. USDA Technical Bulletin n° 1355, Washington DC, USA.

Kercheva M. and Dilkova R. (2005). Bulk density as indicator of soil aeration conditions. In: Management, Use and Proceedings National Conference with International participation, R. Dilkova, et al.(eds). 15-19 May 2005, Sofia, Bulgaria. PublirhScieSet-Eco, Sofia: 241-270 (In Bulgarian).

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.

Kirkby, M.J., Irvine, B., Jones, R.J.A., Govers, G. and the PESERA team. (2008). The PESERA coarse scale erosion model for Europe: I – Model rationale and implementation. European Journal of Soil Science 59, 1293-1306.

Körschens M., A Weigel and Schulz, E. (1998). Turnover of Soil Organic Matter (SOM) and Long-Term Balances – Tools for Evaluating Sustainable Productivity of Soils. J. Plant Nutr. Soil Sci. 161, 409-424.

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.

Kovda, V. A., van den Berg, C., Hagan, R. M. (Eds.) (1967). International Source-book on Irrigation and Drainage of Arid Lands in Relation to Salinity and Alkalinity. FAO–UNESCO.

Loveland, P.J. and Webb, J. (2003). Is there a critical level of organic matter in the agricultural soils of temperate regions: a review. Soil and Tillage Research 70, 1-18.

McGrath, S.P. and Loveland, P.J. (1992). The soil geochemical atlas of England and Wales. Blackie Academic, Glasgow, UK, 101pp.

Richards, L.A. (1954). Diagnosis and improvement of Saline and Alkali Soils. US dept. Agric. Handbook No. 60 USDA. Washington, D.C.

Römbke, J., Beck, L., Förster, B., Fründ, C-H., Horak, F., Ruf, A., Rosciczewski, K., Scheurig, M. & Woas, S. (1997): Boden als Lebensraum für Bodenorganismen und bodenbiologische Standortklassifikation - Literaturstudie. Texte und Berichte zum Bodenschutz 4/97. Landesanstalt für Umweltschutz Baden-Württemberg (Karlsruhe). 390 pp. + Annexes.

Rutgers, M. and Eijs, A.W.M.. (2007). Conservation and sustainable use of soil biodiversity: the case of The Netherlands. Submission by The Netherlands to the Convention on Biological Diversity, in response to decision VIII/23 B, para 7.

Simota, C., Horn, R., Fleige, H., Dexter, A., Czyz, E.A., Diaz-Pereira, Mayol, F., Rajkai, K., De la Rosa, D., 2005. SIDASS project Part 1. A spatial distributed simulation model predicting the dynamics of agro-physical soil state for selection of management practices to prevent soil erosion. Soil Tillage Research 82, 15-18.

Soussana, J.F., Loiseau, P., Vuichard, N., Ceschia, E., Balesdent, J., Chevallier, T. and Arrouays, D. (2004). Carbon cycling and sequestration opportunities in temperate grasslands. Soil Use and Management 20, 219-230.

Spiegel H., Filcheva E., Hegymegi P., gál A., Verheijen F.G.A. (2007): Review and comparison of methods used for soil organic carbon determination Part 1. Review of the methods. *Soil Science Agrochemistry and Ecology* 41. (4), p. 3-18.

Stephens, M., Micheli, E., Jones, A.R., Jones, R.J.A. (eds) (2008). Environmental Assessment of Soil for Monitoring Volume IVb: Prototype Evaluation – Pilot Studies. EUR 23490 EN/4B, Office for the Official Publications of the European Communities, Luxembourg, 497pp.

Wösten, J.H.M.. Lilley, A., Nemes, A. and Le Bas, C. (1998). Using existing soil data to derive hydraulic parameters for simulation models in environmental studies in land use planning. Final Report on the European Union funded project, DLO Winand Staring Centre, Report 156, 106pp, Wageningen, The Netherlands.

Verheijen, F.G.A., Bellamy, P.H., Kibblewhite, M.G. and Gaunt, J.L. (2005). Organic carbon ranges in arable soils of England and Wales. Soil Use and Management 21, 2-9.

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AGES Österreichische Agentur für Gesundheit und Ernährungssicherheit GmbH 7

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SSCRI Bratislava 32

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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. This volume (IVa) summarises the results of testing 22 procedures in 28 Pilot Areas in the Member Sates. An accompanying volume (IVb) describes each of these pilot area studies in detail; some are transnational and in total they cover a wide range of soil-landscapes from the north to the south of Europe.

The other ENVASSO volumes are listed below.
They can be downloaded from the JRC website: http://eusoils.jrc.ec.europa.eu/

ENVASSO Volume I:
Huber, S., Prokop, G., Arrouays, D., Banko, G., Bispo, A., Jones, R.J.A., Kibblewhite, M.G., Lexer, W., Möller, A., Rickson, R.J., Shishkov, T., Stephens, M., Toth, G. Van den Akker, J.J.H., Varallyay, G., Verheijen, F.G.A., Jones, A.R. (eds) (2008). Environmental Assessment of Soil for Monitoring: Volume I Indicators & Criteria. EUR 23490 EN/1, Office for the Official Publications of the European Communities, Luxembourg, 339pp. {DOI 10.2788/93515}

ENVASSO Volume IIa
Arrouays, D, Morvan, X., Saby, N.P.A., Le Bas, C., Bellamy, P.H., Berényi Üveges, J., Freudenschuß, A., Jones, A.R., Jones, R.J.A., Kibblewhite, M.G., Simota, C., Verdoodt, A., Verheijen, F.G.A. (eds) (2008). Environmental Assessment of Soil for Monitoring: Volume IIa Inventory & Monitoring. EUR 23490 EN/2A, Office for the Official Publications of the European Communities, Luxembourg, 188pp. {DOI 10.2788/93524}

ENVASSO Volume IIb
Arrouays, D, Morvan, X., Saby, N.P.A., Jones, A.R., Le Bas, C. (eds). (2008). Environmental Assessment of Soil for Monitoring: Volume IIb Survey of National Networks. EUR 23490 EN/2B, Office for the Official Publications of the European Communities, Luxembourg, 254pp. {DOI 10.2788/93617}

ENVASSO Volume III
Baritz, R., Eberhardt, E., Van Liedekerke, M.H., Panagos, P. (eds) (2008). Environmental Assessment of Soil for Monitoring: Volume III Database Design and Selection. EUR 23490 EN/3, Office for the Official Publications of the European Communities, Luxembourg, 125pp. {DOI 10.2788/93697}

ENVASSO Volume IVb
Stephens, M., Micheli, E., Jones, A.R., Jones, R.J.A. (eds) (2008). Environmental Assessment of Soil for Monitoring Volume IVb: Prototype Evaluation – Pilot Studies. EUR 23490 EN/4B, Office for the Official Publications of the European Communities, Luxembourg, 497pp. {DOI 10.2788/94364}

ENVASSO Volume V
Jones, R.J.A., Verheijen, F.G.A., Reuter, H.I., Jones, A.R. (eds) (2008). Environmental Assessment of Soil for Monitoring Volume V: Procedures & Protocols. EUR 23490 EN/5, Office for the Official Publications of the European Communities Luxembourg, 165pp. {DOI 10.2788/94366}

ENVASSO Volume VI
Kibblewhite, M.G., Jones, R.J.A., Montanarella, L., Baritz, R., Huber, S., Arrouays, D., Micheli, E. and Stephens, M. (eds) (2008). Environmental Assessment of Soil for Monitoring Volume VI: Soil Monitoring System for Europe. EUR 23490 EN/6, Office for the Official Publications of the European Communities Luxembourg, 72pp. {DOI 10.2788/95007}

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