A framework for European soil monitoring

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Abstract
The ENVASSO project has developed a framework for monitoring European soils. 27 indicators were selected for erosion, organic matter decline, contamination, compaction, salinisation, decline in biodiversity, soil sealing, landslides and desertification. A monitoring network with a density of 1 site per 300 km^2 covers most soil type and land use combinations. 20 indicators were qualified for implementation, covering soil erosion by water, decline in soil organic matter, soil contamination, soil sealing, compaction, salinisation and desertification. Methods for monitoring wind erosion, tillage erosion and carbon stocks in peat soils were found to be inadequate. A tiered approach to implementation of soil monitoring is recommended.

Keywords
Monitoring, Indicators

Introduction

Serious threats to soil throughout Europe have been identified (European Commission, 2002 and 2006). However, more evidence is needed to support stronger soil protection policy and to target and monitor its implementation. This requires a European soil monitoring network. Some national networks exist (Jones et al., 2005) but many have not been re-sampled. The Environmental Assessment of Soil for Monitoring (ENVASSO) project (Kibblewhite et al, 2008) aimed to define a European soil monitoring system and describe its potential implementation.

Methods

Indicator selection (Huber et al, 2008) was based on international recommendations (OECD, 2003). 188 issues and 290 indicators were evaluated. The principal criteria were relevance, methodological soundness, measurability and policy relevance. Priority indicators were chosen (one for each of three key issues per threat) from an initial selection of 27 key issues and 60 indicators. Where possible, performance criteria (e.g. minimum detectable change, background values and indicator thresholds) were defined (Arrouays et al, 2008). Methods for within-plot sampling and for parameter measurement were documented (Jones et al, 2008). Geo-referenced information was collated on existing soil monitoring networks and inventories that could be re-sampled (Arrouays et al, 2008). The number of additional sites needed to adequately monitor soil type and land use combinations was estimated (Morvan et al, 2008). Data management requirements were defined (Baritz et al, 2008) and a prototype database system (SoDa) constructed with web-based inter-operability. Procedures for estimating 22 indicators were tested in 28 pilot studies (Micheli et al, 2008) covering representative regions and land uses.

Results

Table 1. Threats, issues and indicators

Threat / Issue	Indicator
Qualified ENVASSO indicators	
Soil erosion	
Water erosion	Estimated soil loss by rill, inter-rill, and sheet erosion
Decline in soil organic matter	
Soil organic matter status	Topsoil organic carbon content (measured)
	Soil organic carbon stocks (measured)
Soil contamination	
Diffuse contamination	Heavy metal contents in soils
	Critical load exceedance by S and N
Local soil contamination	Progress in management of contaminated sites
Soil sealing	
Soil sealing	Sealed area
Land consumption	Land take [to urban and infrastructural development]
Brownfield re-development	New settlement area established on previously developed land
Soil compaction	
Compaction, structural degradation	Density
	Air-filled pore volume at specified suction
Causes of compaction	Vulnerability to compaction
Decline in soil biodiversity	
Species diversity	Earthworm diversity and biomass
	Collembola diversity
Soil microbial respiration	Microbial respiration
Soil salinisation	Salt profile
	Exchangeable sodium percentage
	Potential salt sources
Desertification	
	Land area at risk of desertification
	Land are burnt by wildfire
Non-qualified ENVASSO indicators	
Soil erosion	
Wind erosion	Estimated soil loss by wind erosion
Tillage erosion	Estimated soil loss by tillage erosion
Decline in soil organic matter	Peat stock
Landslides	Occurrence of landslide activity
	Volume/mass of displaced material
	Landslide hazard assessment
Desertification	Soil organic carbon content in desertified land

Of the 27 priority indicators, 20 were qualified (table 1) but measurement methods are not available or were considered inadequate for 7 others. Better methods are required for continental scale estimation of wind and tillage erosion. Estimation of peat stocks requires reliable methods for estimating the distribution of peat depths and to account for variability in peat composition. A minimum spatial density of 1 site per 300 km^2 is recommended (Morvan et al 2008), which approximates to a regular grid with sampling sites set at nodes 16 to 17 km apart. This is representative of most combinations of soil types and land uses. The site area should be (Arrouays et al, 2008) between 100 m^2 and 1 ha with homogeneous soil profile development. A minimum of 4 and preferably between 10 and 100 sub-samples fixed depth sub-samples should be taken, depending on the site area and soil profile variation. Pedogenic horizon sampling adjacent to the sample area usefully supports site characterization. The time interval between sampling events needs to be long enough to allow for changes that can be detected within measurement errors. Analysis (Arrouays et al, 2008; Morvan et al, 2008; Saby et al, 2008) indicates that a minimum interval of 10 years is required.

Discussion

Two types of indicators are implemented more easily. Group A are those for which there are existing networks i.e. *topsoil organic carbon contents, heavy metal contents in soils, critical load exceedance by sulphur and nitrogen, salt profile, exchangeable sodium percentage and potential salt sources*. Group B rely on existing remote-sensed data and / or spatial information i.e. *estimated soil loss by rill, inter-rill and sheet erosion, sealed area, land take, vulnerability to compaction, land area at risk of desertification* and *land area burnt by wild fire*. These groups provide a basis for monitoring soil erosion, decline in soil organic matter, soil contamination, soil sealing, compaction, salinisation and desertification. Some indicators require inventories that do not exist in all regions or lack harmonization i.e. *progress in the management of contaminated land, new settlement area established on previously developed land* and *occurrence of landslide activity*. Other indicators are compromised by uncertainties in relating site measurements to estimates over space and time, these are *soil density, air capacity, earthworm diversity, Collembola diversity* and *soil microbial respiration.*

A two-tiered approach to implementation is recommended. The first tier should establish a network with a site density of 1 per 300 km^2, for estimation of indicators in groups A and B. The second tier should be a sub-set of first tier sites with more extended and intensive monitoring, addressing requirements that cannot be implemented feasibly at the first tier, or for which fewer sites are needed. Examples are (1) when measurement procedures are too demanding for general implementation (e.g. some biological, gaseous flux and physical measurements, including measurement of soil erosion), (2) where intensive sampling is needed to describe soil processes to interpret indicator levels and trends (e.g. detailed assessment of sub-soil and lower horizons, or connectivity to landscape processes such as catchment inputs and outputs), (3) special investigations of error sources (e.g. intensive collection and testing of sub-samples to determine an optimum number for application in the first tier), or (4) when performing proficiency exercises to assess variability associated with different field teams (e.g. estimates of stone contents and texture). The second tier network could also provide reference sites for soil typological units.

Conclusions

There is a sufficient density of existing sites for continental soil monitoring over much of the European Union and the number of new sites required is relatively limited and confined to a few member states. There is an adequate technical basis to implement a successful monitoring system for a majority of the threats to soil resources. Current methods are inadequate for assessment of carbon stocks in peat soils, wind erosion and tillage erosion. The ENVASSO manual of procedures and protocols (Jones et al, 2008) is a valuable reference for future soil monitoring.

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