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Translating soil science into environmental policy: A case study on implementing the EU soil protection strategy in The Netherlands

Johan Bouma [a,*], *Peter Droogers* [b]

[a] *Department of Soil Science, Wageningen University, The Netherlands*
[b] *FutureWater Wageningen, The Netherlands*

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ABSTRACT

The EU Commission has proposed a way forward towards a Thematic Strategy for Soil Protection based on the distinction of seven soil functions and eight threats. A Technical Working Group on Research defined some 200 general priority research areas in the context of the dynamic DPSIR approach considering drivers, pressures, states, impacts and responses. Though quite valuable as a source document, this may be too generic and academic to be a starting point for new, effective soil research in different regions of the EU. A six-step storyline procedure is therefore proposed aimed at deriving effective operational procedures for a water management unit in a given region, using available soil expertise and defining new research only where needed. The procedure, that was illustrated for a Dutch case study, consists of defining: (i) water management units (wmu's) in a landscape context; (ii) land-use, area hydrology and soil functions (iii) soil threats and relevant soil qualities; (iv) drivers of land-use change and their future impact; (v) improvement of relevant soil qualities; (vi) possibilities to institutionalize soil quality improvement as part of the EU soil protection strategy. A focus on regional wmu's is likely to result in a strong commitment of local stakeholders and governmental officials, allowing a more specific DPSIR approach. But this will only work if local officials also receive legal powers to develop and enforce codified 'good practices', to be developed in the context of *communities of practice*. Innovative research topics can be derived from a combined analysis of experiences within different communities of practice in different wmu's and should not be left to researchers to define.

1. Introduction

Before discussing relations between soil science and environmental policies, at least some attention should be paid to relations between science and policy in more general terms. In well functioning democratic systems, policies are driven by the majority of citizens and not by scientific considerations. Nor is science primarily inspired by political considerations. The pursuit of truth – the prime driving force of true science – may well lead to results that are quite unattractive for politicians. The real question, of course, is whether or not results are attractive to the taxpayers. Painful conditions may arise when governmental agencies fund research which does not yield results these agencies would like to see. Also, research based on

* Corresponding author.
E-mail address: johan.bouma@planet.nl (J. Bouma).
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public demands may not yield results that the public would like to see. So be it. There is general agreement in scientific circles that being ''his paymasters voice'' does not match with scientific integrity. But problems reach beyond financial aspects: individual scientists may have strong opinions about certain matters and when research results point into different directions than the ones they believe in, they may find it difficult to adjust. But adjust they should because the pursuit of the truth usually does not match with pre-conceived, fixed ideological points of view. Bouma (2005) suggests therefore to consider a study object, such as a soil, from three separate perspectives: (i) as an objective entity (''it''); (ii) reflecting personal experiences (''I''), or (iii) being part of a societal context (''we''). When considering policy issues from a democratic point of view, approach (iii) is clearly most relevant but the other two perspectives remain relevant. How do they relate? Bouma (2005) suggests to consider the interaction between points (ii) and (iii) as being central because this expresses the interaction between citizens and their society and government: the very foundation of democracy. The primary role of independent science (i) is then to *facilitate* this interaction and *mediate* between conflicting opinions of various partners in the debate using science-generated knowledge as a negotiation tool or – when needed – as a weapon.

For soil science the above distinctions certainly apply and this will be illustrated by discussing the unique challenge faced by soil science in Europe, now that a ''Thematic Strategy for Soil Protection'' is adopted by the EU Commission. This may include a legally binding *framework directive*. Adoption of such a strategy at EU level is to be followed by implementation at the national level. The ongoing discussion as to how national priorities are served by EU *framework directives* and how these directives reflect such national priorities according to the *subsidiarity* principle, is a permanent feature of the European discourse. Some countries prefer a detached ''view from Brussels'' and much local autonomy, others worry about the stagnating effects of too much impact of local interests and favour a stronger role for the EU. Anticipating the introduction of the Soil Protection Strategy at EU level, the Dutch Government has started to plan its implementation at the national level.

Options for implementation of the Strategy at national level are still to be explored in the various EU countries because even though there is general agreement about the principle of soil protection, the manner in which national rules and regulations are to be defined is still unclear. Also, the role of research in making the Framework operational is as yet not clear. The European Commission (EC) (DG-Environment) has, in close contact with the soil research community, been quite effective in setting the agenda by organizing six Technical Working Groups (TWGs) that have defined prime areas of interest and research needs, to be followed by the policy arena when further defining the Framework (Van-Camp et al., 2004). Now, however, the next step has to be taken to translate generic principles in specific actions and indicators that can inspire national, regional and local stakeholders and policy makers and guide the regulatory process. In this paper, three issues will be discussed: (i) the preparatory process in developing the strategy, with particular emphasis on the role of soil science research; (ii) implementation of the Framework at national level, in this case in The Netherlands; (iii) the role of research in future in developing effective soil protection, following the guidelines of the strategy. Whether this requires classic top-down rules and regulations or whether new ways of implementation can be found is a subject of discussion.

2. Developing the EU soils framework

Eight main threats to soils were defined in 2002 in a Communication on Soils by the European Commission, launching the European Soil Strategy: ''Towards a Thematic Strategy for Soil Protection'' (Van-Camp et al., 2004; http://europe.eu.int/comm/environment/soil/). The background for this document was formed by the UN Convention to Combat Desertification (1998) mentioning land degradation; the Sixth Environmental Action Program of the European Commission (2001) mentioning protection of soils against erosion and pollution and the EU Sustainable Development Strategy (2001) signalling soil loss and declining fertility as factors eroding the viability of agricultural land. The purpose of the 2002 Communication on Soils was to: (i) build political commitment to soil protection; (ii) make soil protection in Europe more systematic; (iii) describe the actual state of the soil in Europe in terms of eight defined threats to soil quality; (iv) develop a legislative basis for soil monitoring to create a knowledge-based approach for soil protection; (v) initiate actions to create a comprehensive European Soil Strategy.

Five soil functions were defined by the 2002 Communication: (i) food and other biomass production; (ii) storing, filtering and transformation; (iii) habitat and gene pool; (iv) physical and cultural environment for mankind; (v) source of raw materials. Later (Commission of the European Communities, 2006), two functions were added: (vi) acting as carbon pool, and (vii) archive of geological and archeological heritage.

Eight main threats were defined: (i) erosion; (ii) contamination; (iii) loss of organic matter; (iv) decline of biodiversity; (v) compaction and other physical soil degradation; (vi) salinisation; (vii) floods and landslides; (viii) sealing by infrastructure.

After the 2002 Communication on Soils, the EC-DG Environment decided to gather stakeholder opinions in order to formulate a Thematic Strategy for Soil Protection by forming five Technical Working Groups (TWGs) on: (i) monitoring; (ii) erosion; (iii) organic matter; (iv) contamination; (v) research. In 2004 all five TWGs delivered their final reports (Van-Camp et al., 2004; http://forum.europa.eu.int/Public/irc/env/soil/). The first four groups, covering politically sensitive issues, were mainly formed by official representatives of each Member State nominated by their government. These reports contain a wealth of information on the state-of-the-art in each field and operational procedures. Working group (v) was composed of scientists participating freely on their own expense. Each TWG focused on one or more of the eight threats to soils, described above, and they followed the DPSIR approach, which defines processes in time affecting the soil. Drivers (D) of threats result in pressures (P) and in particular states or conditions of soils (S), which, in turn, define the impact (I) of a given threat and form the basis for defining possibilities for a response (R). This approach is very

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attractive as it moves beyond a static characterization of threats, as such, by defining the underlying dynamic processes which need to be known when defining alternative land-use practices with the potential to reduce threats and alleviate the resulting problems. The TWG reports also include policy recommendations that could be incorporated into a legally binding EU Soil Framework Directive which may be adopted in future in analogy, for example, with the Water Framework Directive, adopted in 2000.

The recommendations of the TWG research (Van-Camp et al., 2004) focus on five cross-cutting and over-arching research clusters: (i) processes underlying soil functions and their quality; (ii) spatial and temporal changes of soil processes and parameters; (iii) ecological, technical, economic and social drivers of soil threats; (iv) threats influencing soil eco-services; (v) strategies and operational procedures for soil protection. Much current soil and environmental research in the various member countries of the EU already covers these recommendations.

Five key messages are presented by the TWG research: (i) a vital soil provides numerous services, fundamental to the welfare of society. Without sustainable soil use, risks will increase and economic opportunities will decrease in Europe; (ii) threats to soils cause serious socio-economic damage. All eight threats reduce the quality of life and challenge the socio-economic development of Europe; (iii) research is needed to alleviate the negative impacts on soil, air and water on food production, on biodiversity and on human health. Mutidisciplinary research in a new European scientific infrastructure is needed to achieve a sustainable use of soil and water resources; (iv) the five priority research areas for soil protection indicate that raising of funds at the national/European level is highly necessary and urgent; (v) implementation of the five priority research areas will lead to a better understanding of soil and its interaction with other environmental compartments. This understanding is needed and essential for the development and implementation of resource management policies.

These messages are quite strong and hardly convincing as such to outsiders without further specification. We live in a commercialised world that is conditioned to respond to overbearing and all-to-often empty soundbites. Soil services that are fundamental to the welfare of society? Decreasing economic opportunities and serious socio-economic damage when soil threats are not faced up to? Strong statements indeed. Key messages (iii) and (iv) repeat the mantra of needing more research and funds, avoiding the obvious suggestion that much can be gained by more efficiently applying the vast amount of available data and knowledge generated by numerous earth science disciplines over a period of more than 100 years of research. A stronger case for future research would have arisen from a clinical analysis of where current know-how would be inadequate to face future problems, logically defining new research. We will continue the discussion on needed research later in this paper.

3. Soil legislation in The Netherlands

In December 2003, the Dutch Secretary for the Environment wrote an important letter to Parliament announcing a renewal of soil policies, focusing on sustainable use of the soil. Rather than only use the soil, the user should also take care of it. The soil is no longer to be considered as a defacto static entity but as a dynamic ecosystem. So far, emphasis in soil regulations has exclusively been on chemically polluted soils and on their reclamation, reflecting the immense problems associated with still around 60,000 existing sites that are severely chemically polluted. Aside from the fact that soils from now on will be considered in a broader context focusing on sustainable development, regulatory responsibilities will also be decentralized. Local government in provincies and communities will obtain more legal powers to guide and affect land-use. More attention will therefore be required for relations between soil management and soil policies in a regional setting, focusing on agriculture, nature, water and spatial planning. The secretary states: ‘‘to support the judgement about the sustainability of soil use, I will require the development of single, measurable indicators for soil functioning and for the ability of a soil to deliver services to society’’.

For spatial planning, the ‘‘layer-model’’ has been proposed (VROM, 2005) consisting of a basic first ‘‘layer’’ defining dynamics of the soil/water/biotics system, a second ‘‘layer’’ of transport routes on land and water and a third ‘‘layer’’ with settlements. The concept requires that, when making land-use plans, conditions in the first layer should always be considered first, including the effects of possible land-use changes and, having considered this, attention is to be paid to conditions in the second and third layers. This offers, in principle, an attractive starting point for soil science, certainly when combined with hydrology as proposed in hydropedology (e.g. Lin et al., 2006).

In his letter, the Secretary of the Environment also cites the urgency of integrating soil expertise in different disciplines. Research in agriculture, nature, water and spatial planning is scattered among different Universities, Ministeries and Research Institutes. Much would be gained by more interaction and joint activities combining the various forms of expertise and it is proposed to establish ‘‘knowledge platforms’’ to more effectively mobilize available soil expertise. This presents a real challenge to soil science and this paper will explore the possibilities for realizing this integration by using the: ‘‘layer model’’ to be applied in a given region as a basis for interdisciplinary studies on land-use change considering social, political, economic and environmental drivers.

Although formulated in a more general fashion, the letter of the Secretary is in line with the debate around the European Soil Strategy, as discussed above. Dutch regulations can be specified following the requirements of the Strategy, providing a good example of subsidiarity. This process has evolved differently in the past. In 1991, the Nitrate Directive was adopted by the EU to combat groundwater pollution by manure and chemical fertilizers that was seen as a major environmental problem. Since that time much progress has been made: N and P applications in agriculture have been reduced by at least 50%. However, the rigid EU Directive only allowing a maximum application of 170 kg nitrogen/ha from manure has haunted Dutch agriculture ever since and has restricted development of innovative practices (e.g. Sonneveld and Bouma, 2003).

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4. The role of research in developing effective soil legislation

4.1. Recovering the forest from the trees

The five TWGs each focused on the eight soil threats and followed the DPSIR approach. Each TWG had three to ten task-groups that produced a large number of conclusions and policy recommendations. Overall, some 200 ''priority research areas'' have been defined for soil protection in volume VI of the report by the 65-member committee on research consisting of ten task groups (Van-Camp et al., 2004). Also the other TWGs produced numerous recommendations.

Though quite valuable, the question may be raised as to how such a shotgun array of diverging opinions and recommendations can possibly form a fertile basis for public and political understanding of soil problems and how it can be the foundation for transparent rules and regulations to be focused on soil protection. A unified procedure (an appealing ''storyline'') will somehow have to be developed to allow presentation of a coherent procedure that covers specific soil problems in different regions of the EU and is convincing to stakeholders and politicians alike. Above all, if rules and regulations do not somehow tap a widely perceived public fascination with soils and trigger their imagination, their fate is likely to be rather problematic. The shopping lists of Van-Camp et al. (2004) are a highly valuable resource, but to the outside world they run the risk of triggering negative Pavlov reactions of policy makers and the public at-large: researchers yet again claiming more funds for research.

Using the valuable material presented by Van-Camp et al. (2004) we will therefore try to formulate a storyline that can be more effective in engaging our indispensable societal partners.

4.2. A prototype operational procedure to guide soil protection in a given region

The letter by the Dutch secretary of the Environment and the results of the TWG working groups can be the basis for a proposed operational ''storyline'' procedure to guide soil protection containing a logical sequence of six steps, as follows:

(i) Select a water management unit (wmu) such as a watershed.

(ii) Characterize land-use, soil types and hydrological regimes in the area (defining the dynamics ''in the first layer'') (the S of DPSIR). Define relevant soil functions.

Consider soil protection in the context of dynamic ecosystems occurring in regions that form water management units (wmu) in a landscape, such as watersheds or ''water management areas'' (''waterschappen'' in Dutch). Characterize water regimes (defining ''the first layer'') by monitoring and modelling and determine the land-use and soil types that occur in the area by using existing soil maps, but also modern techniques such as satellite data. Here, report V on monitoring of Van-Camp et al. (2004) can be quite helpful.

(iii) Define soil threats in major soil types in the area (the S and I of DPSIR) and define soil qualities for relevant soil functions.

Document existing soil conditions in terms of erosion, contamination, status of soil organic matter and biodiversity, compaction and other soil physical degradation, salinisation, occurrence of floods and landslides and sealing (the eight threats of the EU Soil Strategy) and determine which threats are relevant for the particular region. This will require tapping of available information and use and development of various monitoring procedures. Next, relevant soil qualities have to be defined for actual conditions of particular soils within the wmu.

(iv) What are the drivers for land-use change and their impact? (The D, P and I of DPSIR.)

Determine drivers of land-use change in the area. One approach is to check current legislation. For example, certain regions in The Netherlands have been designated as nature areas (the ''ecological main structure''), others as 20 national landscapes where cultural heritage is to be protected; others are seen as areas where agriculture has lasting future potential. Here, application of the EURURALIS model (http://www.eururalis.nl/) may be helpful. This model defines drivers of land-use on EU level and indicates probable development pressures in certain sub-areas and their possible impact, following various politically inspired scenarios. Drivers for land-use change can only be derived from studies on EU or world level in our globalizing world. Another driver for the entire country is the politically supported notion to safeguard characteristic geological or man-made landscape features as part of our cultural heritage (see also annex II in Volume VI of Van-Camp et al. (2004).

(v) How can soil quality be improved?

Based on observed best practices and both experimental and modelling studies, define alternative land management procedures for the area that allow soil quality to be maintained at or to be improved to acceptable levels in the context of sustainable development. Such work needs to be done in close interaction with stakeholders and policy makers. Soil quality, as such, should not be defined in isolation but only in a socio-economic context which is needed to decide whether or not certain land-use scenarios can be expected to result in sustainable land-use.

(vi) How to institutionalize improvement of soil quality in the context of soil protection? (The R of DPSIR.)

How should improvements be realized in the real world? Does this require top-down institutionalized rules and regulations, based on EU *directives*, or can creation of a bottom-up joint learning environment in the context of a *community of practice* achieve the objectives (e.g. Bouma, 2005)?

4.3. Each soil has its own characteristic story to tell

To put soil up front when discussing a European Soil Strategy or the European Soil Research Agenda would appear to be a logical starting point. Strangely enough, however, the research document of TWG VI *does* emphasize soil processes, functions

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and threats but not the obvious fact that different types of soil, their behaviour and their resilience are quite different in different areas of the EU. General threats to soils are mentioned as are the underlying processes and the socio-economic context. Consideration of different types of soil, climates and socio-economic conditions is only implicitly acknowledged by the subsidiarity principle. Focusing attention on soil, there is not a single reference to soil classification and soil maps in any of the cited EU documents, except for the report of TWG-V on monitoring. This, however, has not been adopted by TWG-VI on research, thereby ignoring the basic fact that each type of soil reflects the effects over time of a series of unique and characteristic soil forming factors for that particular location and region. Also, each soil reacts differently to (mis)management, exhibiting characteristic forms of resilience, and each soil has unique potentials and characteristic risks when used for different purposes. When mentioning soils only in a generic manner, we loose such specifics and run the risk of only producing generalities that do not appeal to stakeholders and policy makers in a given area. And this is what appears to be happening right now. If, on the contrary, the strategy would address local or regional issues that are relevant for any given area, contacts with stakeholders and policy makers are bound to become more inspiring.

If this regionalisation is not pursued in time, we may face a future problem that generic soil quality criteria are defined for the entire EU as a basis for rules and regulations. This has happened for the Nitrate Directive (EU, 1991) focused on groundwater protection, where the rule of a maximum application rate of 170 kg N from manure/ha is applied to all areas of the EU that are defined as being vulnerable to nitrate pollution of groundwater by manure. The entire country of The Netherlands has been designated as being such a vulnerable area while in other countries only smaller areas are distinguished. Defining a maximum fertilization rate for such designated areas is wonderful for enforcement agencies because control and enforcement of directives becomes very easy this way. The mentioned N application rate corresponds with approximately two cows/ha and cattle densities can be derived from existing agricultural databases. But such an approach has no relation with the potential for creative manure management nor with the capacity of different soils in different climates to accept manure, transmit the N to plant roots and leach the surplus, if any, to the groundwater. It would have been more realistic to start with defining criteria for groundwater quality (the internationally accepted 50 mg/l nitrate-N) and then define management procedures for different soils in different climate zones that would not exceed the set groundwater quality criteria. An identical analogy applies to soils: define soil quality criteria (which is more difficult than defining water quality criteria) and let farmers decide how they will reach these criteria. The challenge is now to inspiringly implement the subsidiarity principle and make specific interpretations for soils in different regions of the EU.

We therefore propose to start with a landscape in which different types of soil are found (point (i) above) and consider their dynamic hydrological behaviour in space and time within that particular landscape using modern monitoring and modelling techniques defined in the context of hydropedology (e.g. Lin et al., 2006; Vepraskas et al., 2006; Pennock and Veldkamp, 2006). However, we need to be realistic here. Long-term monitoring is quite expensive and is hardly done, while models are as yet often more focused on plots and fields than at regions. Next, we need to make two modifications in our usual approach to soil classification: (i) combine different genetic soil types into functional types that exhibit essentially identical behaviour, and (ii) distinguish effects of management in terms of genoforms and phenoforms. This relates directly to several of the threats, correctly identified by the EU Soil Strategy.

4.4. *Soils with different classifications may show identical behaviour*

When studying water movement in soils, Wosten et al. (1985) could reduce the number of soil units to be distinguished in a given study area by 40% comparing the hydrological behaviour of different soil types, as shown on the soil map, and by lumping the ones with identical behaviour. Breeuwsma et al. (1986) did the same for chemical soil characteristics, such as cation exchange capacity and P-sorption and reduced the number by 30%. A comparable analysis was done more recently for precision agriculture (van Alphen and Stoorvogel, 2000). This means that even though many soil units are found at a 1:50000 soil map of a region, a significant reduction of the number of units is possible.

4.5. *Genoforms and phenoforms*

Droogers and Bouma (1997) introduced the concept of genoforms and phenoforms, defining the genetic soil type (the genoform) and various effects of management in that particular genoform (phenoforms). A problem with applying soil classification and soil maps to land-use problems, has always been that pedology had to consider genetic soil types, formed by long-range processes. If a classification of soil would change after each land-use change, it would be of little value. We find, however, that soil management drastically changes soil properties even within a given soil type, often without necessarily changing the soil classification. This was the reason to establish the phenoform concept which leaves the existing soil classification structure intact and expands on it in a way that makes existing soil expertise more relevant for practical applications.

The eight EU soil threats, discussed above, are all the result of various forms of (poor) management, so management has to be considered. Of particular interest is the threat of organic matter decline which is closely associated to the decline in soil biodiversity. Studying phenoforms, Pulleman et al. used extensive field work and regression analysis to establish a relationship between the organic mater content of the soil (SOM in %) and past land-use and management in a loamy prime Dutch agricultural soil, as follows (Pulleman et al., 2000):

$$\mathrm{SOM} = 20.7 + 29.7C_1 + 7.5C_v + 7.5M_{iv} \quad (r^2 = 0.74)$$

where C_1 is the crop type in period 1 (30–60 years ago) where C = 1 for grass and C = 0 for arable, C_v the crop type in period v (1–3 years ago) where, again, C = 1 for grass and C = 0 for arable, and M_{iv} is the management type in period iv (3–7 years ago) where $M = 1$ means organic farming and $M = 0$ is conventional farming.

Sonneveld et al. (2002) did a comparable analysis in a major sandy soil, resulting in the following relationship:

$$C_{organic}\,(\%) = 3.40 - 1.54 \times \text{maize} + 0.19 \times \text{old} + 0.55 \times \text{GWC} \quad (r^2 = 0.75)$$

where maize represents continuous maize cropping (=1), otherwise =0; old = 1 for old grassland, and =0 otherwise; GWC = 1 for groundwater class Vb and =0 for class VI.

4.6. *Developing indicators*

Different soil functions and threats have different indicators. Selection of a given wmu is followed by establishing current land-use in that particular area of land and which functions and threats are relevant. In line with the DPSIR approach, not only actual conditions in the area are considered but also possible future ones, considering soil functions and threats that could become relevant in future. An example will be presented in the following case study.

5. An application of the proposed procedure to implement the soil protection strategy

5.1. *Step (i): selection water management unit*

The example focuses on the North-East polder (Fig. 1), a distinct part of a water management area (''waterschap'') in The Netherlands. Water levels in ditches and canals and groundwater levels in the soil are controlled by water management. A number of major soil types occur in the North-East polder. For pragmatic reasons only, the discussion will focus on one genotype, the Mn25A of Dutch Soil Survey, a loamy, mixed mesic Typic Fluvaquent according to the US soil classification scheme (Soil Survey Staff, 1975) and a Calcaric Fluvisol (FAO, 1974).

Fig. 1 – Location of Noordoostpolder in The Netherlands.

5.2. *Step (ii): current land-use, soils, hydrological regimes and relevant soil functions*

This area is seen as containing prime-agricultural land and future land-use is likely to be mainly agricultural (see point iii below where this conclusion is based on a EU-wide land-use analysis). Emphasis is therefore on the *first* soil function of food and other biomass production. Implied in this is the need for adequate storage, filtering and transformation of agro-chemicals (the *second* soil function), if only to meet criteria of the EU Water Directive. Procedures of precision agriculture which result in ''applying the right amount of agrochemicals at the right time and place'' have been proved suitable to effectively avoid excessive leaching of agrochemicals and the associated surface- and groundwater pollution (Bouma et al., 2002). The key question here is not whether the quality of storage, filtering and transformation is adequate in the Mn25A soil type, because management practices will determine whether or not water quality standards will be achieved. Sometimes soils with inherently high qualities do not meet environmental standards because of poor management, while good management can sometimes achieve environmental standards in soils with inherently poor quality. In the latter case, risks are, however, higher than in the former case and this is of general interest. The cation exchange capacity and pore size distribution of the Mn25A are such that conditions for storage, filtering and transformation are relatively good, compared with other Dutch soils. We have not expressed this in a specific quality criterium.

The same is true for the *third* function, the habitat and gene pool. By following ''good'' agricultural practices, such as applying organic manure, restricting cultivation and soil traffic and applying precision agriculture, the habitat and gene pool of the soil is likely to be best protected. However, so far microbiological indicators to document this are not available. The *fourth* function defines the physical and cultural environment for man. This is new land, reclaimed from the sea in the 1930s. The physical and cultural environment is therefore quite unique. The area has, however, not been defined as being part of one of twenty ''National Landscapes'' (VROM, 2005). Still, there are cultural remnants, such as the former island of Schokland and some geological phenomena that are quite unique (relates also to function *seven*). Their value should be acknowledged and future land-use plans should preserve such features. Only the *fifth* function of delivering raw materials is less important for this area. The impact of function *six* is limited and could relate to soil management leading to higher organic matter contents.

A specific indicator will be defined here for the *first* function of food and other biomass production.

The extent of the Mn25A soil is shown in Fig. 2. Water regimes in the area including flow patterns, both in terms of saturated water movement in canals, ditches and in groundwater as well

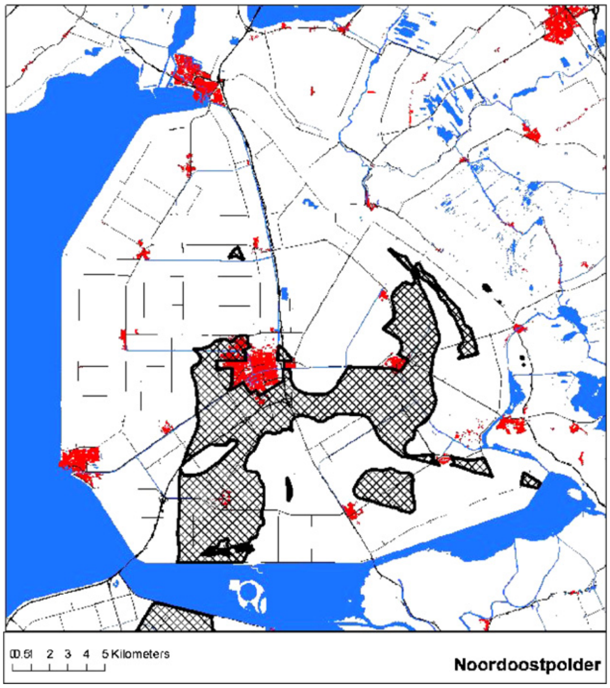

Fig. 2 – Occurrence of the Mn25A soil unit in the Noordoostpolder.

as unsaturated flow in the soil profile above the water-table are characterized by hydrologic modelling supported by monitoring and some results of this are being shown on: http://www.zuiderzeeland.nl/agrariers/remote_sensing. Many models are available now in literature to characterize water dynamics in a given area or watershed (e.g. Vepraskas et al., 2006; Pennock and Veldkamp, 2006) allowing the dynamic characterization of water regimes in the ''first'' layer, as discussed above, both for actual and potential conditions, the latter as a result of alternative water management procedures. One interesting example has been generated for the area (Droogers and Loeve, 2003). As storage of water is very important, certainly when considering the effects of climate change, model runs were made with the SWAP model to explore the potential of water storage in the unsaturated zone of the soil, rather than in canals and ditches only. It turned out that the potential for this was high and could simply be achieved by temporarily increasing weir levels to retain water. Peak discharges were thus decreased by more than 20% and more water was adsorbed in the unsaturated zone of the soils. So-far additional storage capacity was only associated with the open water system. However, detailed analysis based on measurements and SWAP model simulations for a sub-area of 655 ha indicated that on average 75,000 m^3 of water was stored in the open water system. During very dry situations this reduced to 55,000 m^3 and during some exceptional wet periods this amount increased to 115,000 m^3. However, total amount of water stored in the unsaturated zone varied between 1,000,000 and 3,000,000 m^3. So between 93 and 97% of all water in the area is stored in the soil *and not in surface waters*! This major soil function of water storage was unknown to water managers of the area. The system to store and retain water has been implemented now and works satisfactory. Soils can thus provide additional benefits when dealing with practical water management issues.

5.3. Step (iii): define threats for major soils and soil qualities for relevant functions

Monitoring of actual soil conditions showed occurrence of three distinctly different phenoforms for the genoform being discussed here, corresponding with three forms of management (Droogers and Bouma, 1997): (i) conventional high-tech arable farming (CONV); (ii) organic farming (ORG); (iii) permanent pasture (PERM). Pictures of the three phenoforms are shown in Fig. 3. The CONV phenoform occupies an estimated 70% of the Mn25A area and ORG and PERM occupy an estimated 20% and 10%, respectively. Physical properties of these three phenoforms were significantly different (Table 1) and they express the effects of three operating soil threats: soil compaction, loss of organic matter and a decline of biodiversity. Other threats are not relevant: erosion plays no role in this flat landscape, soils are not contaminated, salinisation is no problem as the polder is surrounded by fresh water and there are no floods and landslides nor is there sealing in this rural area.

Soil quality (SQdry) is defined here for the production function used for a grass crop and has been defined earlier as: (water-limited yield/potential yield) × 100 (Bouma et al., 1998). Bouma (2002) assumed for water-limited yield that nutrients are applied optimally and that no pests and diseases occur. Water may be a limiting factor because of low precipitation or low unsaturated flow from the watertable upwards to the rootzone. Here, water-limited yield is determined for a dry year that has a probability of occurence of 10% (Droogers and Bouma, 1997; Bouma and Droogers, 1998) and is based on computer runs for a 30-year period. Potential yield is essentially determined by radiation and temperature and also assumes that the water supply is optimal. SQdry is thus governed by weather, groundwaterlevels and soil properties. Table 1 reports SQdry values of 81, 90 and 85 for CONV, ORG and PERM, respectively, demonstrating the significance of the higher organic matter contents of ORG and PERM which result in a higher moisture holding capacity. Aside from simulation modelling, satellite images for dry years can also be used to estimate yields.

5.4. Step (iv): drivers of land-use change and their impact

Drivers of land-use change are largely determined at world and EU level by political processes and they are currently being explored in an EU wide program in which four different future scenarios for agriculture are developed and compared (http://www.eururalis.nl/). Fig. 4 shows the projected areas where agriculture may disappear by 2030 assuming free world trade. Fig. 5, on the contrary, shows the effects of regional programs with a certain degree of protection for agriculture. Agricultural land-use will then be maintained in more areas. In both cases, however, land-use in the North-East polder is not expected to change. Soils represent prime agricultural land, the climate is favorable for agriculture and there is little urban pressure. Only farm size is likely to increase substantially. Other drivers will be preservation of areas that are considered to be part of our cultural heritage and of areas that exhibit unique geological phenomena (soil function iv). They will always be considered

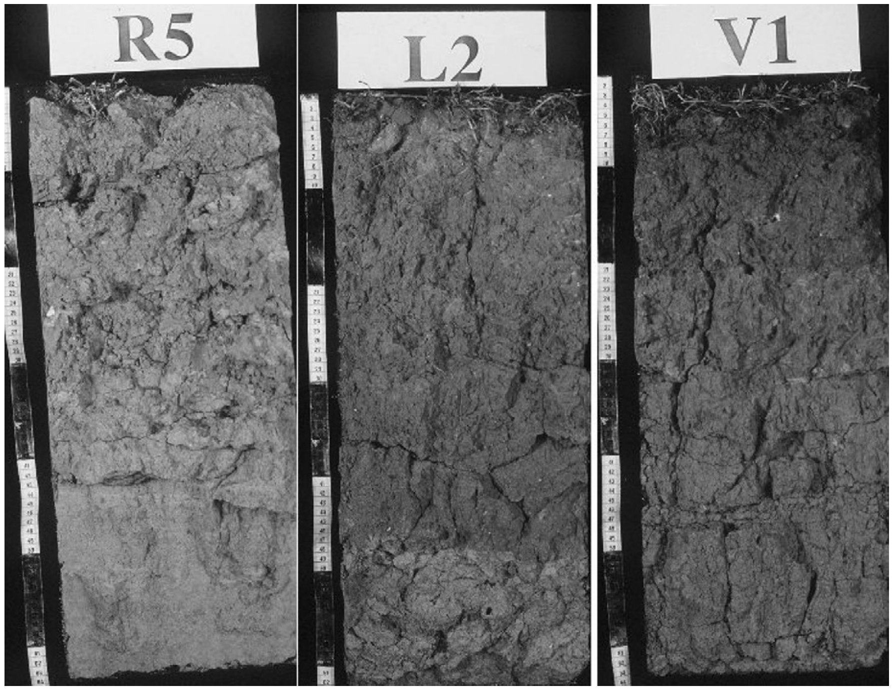

Fig. 3 – Pictures of the three phenoforms, as discussed in this paper. From left to right: CONV (R5), ORG (L2) and PERM (V1).

5.5. *Step (v): how to improve soil qualities?*

Two conclusions arise considering the soil quality analysis, presented in point (iii): (i) higher contents of organic matter result in a higher water supply capacity and higher yields. This is particularly evident in dry years. Soil quality can be significantly improved when management is focused on increasing the organic matter content of surface soil. Experiences with the ORG management schemes can help to define improved management for CONV in this particular soil; (ii) compaction of arable soil in CONV is not so bad here to impede deep rooting of crops which would severely reduce yields. However, good contact between roots and soils is essential and formation of large soil clods by compaction can strongly diminish this contact with soil inside the clods leading to less efficient water uptake (Droogers et al., 1997). Not only water ''availability'' should therefore be considered, which is defined by the volume of water between field capacity and wilting point, but also water ''accessibility''. In addition, a higher content of organic matter is associated with ''stronger'' soil and makes the soil less susceptible to compaction, other circumstances being equal (Droogers et al., 1996). Farmers in the area are quite aware of these effects of soil structure and they are currently experimenting with fixed-track tillage, using GPS to define permanent driving tracks. This type of management avoids compaction of soil by tractors driving on the soil between the tracks and may be an attractive future form of management.

Table 1 – Different soil properties and qualities, as defined in text, for three phenoforms of the genoform: Mn25 (Loamy, mixed, mesic Typic Fluvaquent according to Soil Taxonomy 1975)

Phenoform	Bulk density (kg/m^3)	Organic matter (%)	SQdry
CONV	1.68 ∓ 0.061	1.7 ∓ 0.05	81
ORG	1.47 ∓ 0.065	3.3 ∓ 0.59	90
PERM	1.38 ∓ 0.109	5.0 ∓ 0.57	85

Even though current soil quality for CONV is not critical, there certainly is room for improvement, focusing on increasing the organic matter content of soil and avoiding compaction. A SQdry value of at least 90 should be aimed for, which implies a necessary rise of about 10% for phenoform CONV.

5.6. *Step (vi): how to institutionalize improvements?*

Perhaps it is time now to shift away from top-down rules and regulations that follow the ''command-and-control'' mode and invest in bottom-up activities by convincingly demonstrating the advantages of improving soil quality thereby stimulating adoption by farmers and other land-users of alternative forms of management. This will require an innovative education effort and open, interactive communication of results, perhaps through the Internet. The focus on a water management unit and on separate soil types within that unit, as proposed here, is to be preferred above an approach where soils, their functions and threats to which they are subjected, are discussed in general terms. Stakeholders cannot identify with such a generic approach. Creating a learning environment in which scientists work together with stakeholders, policy makers and water managers might become the road to follow in future when trying to realize soil protection (e.g. Bouma, 2005).

This approach should, however, be coupled with new forms of legislation which allows responsibilities and controls by local government. The Dutch government intends to de-centralize

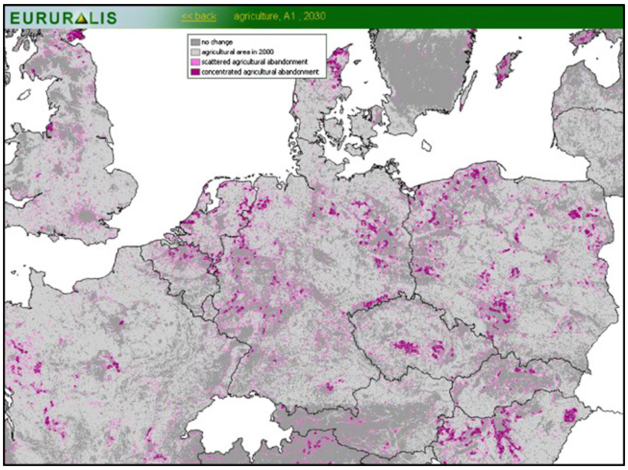

Fig. 4 – EURURALIS land-use scenario for Europe showing the predicted effects by 2030 of free trade on agricultural land-use.

the decision making process but progress is slow as changing classical top-down legal structures turns out to be very difficult.

6. Identification of necessary research

The TWG Research, consisting of nine Task Groups, presented some 200 priority areas for soil research in future (Van-Camp et al., 2004, vol. VI). It is not clear how this can result in a coherent, innovative soil research program. The proposed six-step procedure builds on what has been reported by Van-Camp et al. (2004) but extends the procedure by starting with a particular water management unit where usually only a limited number of soil functions and threats are relevant for both actual and future conditions. This creates affinity with local stakeholders and policy makers. Characterizing soil water regimes in a landscape context and defining soil qualities is based on using widely available existing expertise

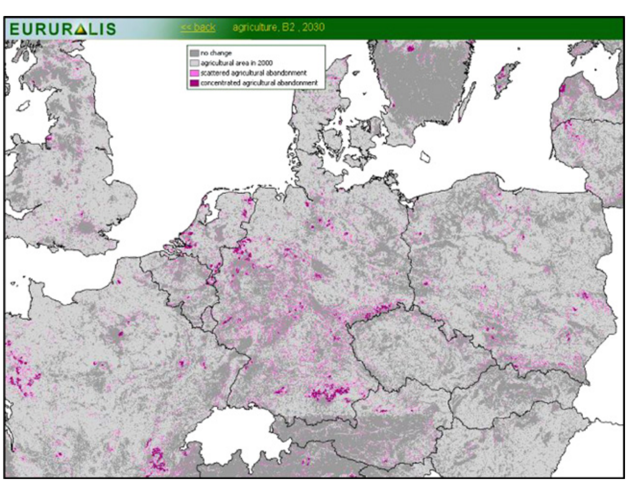

Fig. 5 – EURURALIS land-use scenario for Europe showing the predicted effects by 2030 of a regional development scenario on agricultural land-use.

and technology. But this analysis also points out where knowledge is lacking, requiring more research. In our case study additional research would be needed to: (i) increase the organic matter content of the particular soils being studied and (ii) define accessibility of water as a function of soil structure. Of course, the study area of the North-East Polder in The Netherlands was quite unique because agriculture was and is likely to remain the most important soil function in the entire area. In other areas other functions may become important, requiring definitions of other soil qualities.

As different studies are started in different water management units, new research questions will gradually accumulate and they should be assembled and studied in joint workshops as part of the activities of the different communities of practice involved. Even though such workshops would be problem – rather than science – driven, they would certainly produce issues and topics requiring basic research. In this way they would guide the research process. This procedure is preferred over the traditional one where the research agenda is determined by scientists themselves which all too often results in self-serving shopping lists.

7. Conclusions

1. The EU Commission has proposed a way forward towards a Thematic Strategy for Soil Protection based on the distinction of five soil functions and eight threats. A technical working group on research identified some 200 priority research areas for soil protection in the context of a DPSIR approach considering drivers, pressures, states, impacts and responses. This is essential information but too complex, abstract and academic to lead to an effective operational research program. An appealing storyline is needed.
2. We suggest, therefore, to focus the implementation strategy on specific water management units (wmu) in a landscape context and by focussing on the dynamic behaviour of major soil types occurring within those units. The proposed strategy consists of six points based on the DPSIR approach applied to a particular wmu and starts with the "first-layer" concept of Dutch spatial policy which defines water fluxes and ecological conditions in the soil/water system. Each wmu has characteristically different soil functions and experiences different threats. Stakeholders and policy makers can better identify with such an approach than with generalized descriptions of soils, functions and threats.
3. An agricultural soil quality measure (SQdry) is proposed for the particular case study discussed to express effects of different forms of soil management within a given soil type on food and other biomass production. Critical SQdry values can be defined for any given soil in future.
4. Rather than impose top-down rules, an attempt should be made to initiate bottom-up activities by showing specific advantages of improving soil quality, using modern modelling and communication techniques in a joint learning mode involving scientists, stakeholders and policy makers in communities of practice. New laws are needed to allow local control.

5. The proposed scheme satisfies, in principle, the requirements of the Dutch secretary of the environment. Soils are considered in a regional setting, within a water management unit, and are structurally linked with water regimes, satisfying the ''three layer concept'' of Dutch law. Soils are considered as dynamic ecosystems and sustainability is expressed by future land-use scenarios at EU level. The basic and attractive requirement that users should not only use their land but take care of it as well, is satisfied by considering management effects expressed in terms of phenoforms. Indicators for the soil production function have been proposed (SQdry). Finally, the desired integration of various disciplines is assured by implementing the DPSIR approach which is highly interdisciplinary in character.
6. Joint learning as a basis for achieving soil protection in the real word requires ''knowledge platforms'' as proposed by the secretary, which can become innovative sources of effective bottom-up procedures. Such platforms should function as communities of practice.

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Johan Bouma worked at the University of Wisconsin, USA, from 1969 to 1975 after obtaining his PhD at Wageningen University, The Netherlands. He is emeritus professor of soil science at Wageningen University (1986–2003) and member of The Netherlands Royal Academy of Sciences. He was a member of the Scientific Council of Government Policy in the Hague (1998–2003). His field is pedology, applied soil physics and land evaluation with increasing emphasis on policy aspects of land-use issues and stakeholder interaction. He was also involved with research in various developing countries.

Peter Droogers is an expert on integrated water resources management at different spatial scales with emphasize on water for food issues, climate change, decision support systems, soil-water relationships, simulation modelling in combination with data mining and remote sensing. He has over 15 years of experience working in The Netherlands and Overseas and is currently senior researcher at FutureWater, Wageningen, The Netherlands.