The soil and water Nexus for sustainable livelihoods.

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Abstract

Interactions between soil and water play a crucial role in soil degradation, the negative effects of which have been very well documented by now, as are measures to reverse soil degradation. Unfortunately, stakeholders and policy makers appear largely unaware of these facts and measures to effectively combat soil degradation are still not widely applied. Rather than produce yet more studies about soil and water interactions and soil degradation followed by clarion declarations about its importance, innovative approaches are needed to put soils back on the societal and policy agenda. The soil science community would be well advised to be more outward looking, connecting with other disciplines studying the major well recognized environmental issues of today, ("wicked problems") such as climate change, freshwater shortage, food security and biodiversity loss, each of which with close links to actual and potential forms of land use. Soil science is at this time characterized by a wide scatter of unrelated research topics. Focusing soil research on the seven soil functions of the EU Soil Protection Strategy would strengthen the soil science "toolkit", needed to be interesting as a partner in interdisciplinary studies. While all disciplines wrestle rather unsuccessfully with establishing true interaction with various stakeholders and policy makers, soil scientists would be in a good position to develop true *transdisciplinary* research projects dealing with "wicked"environmental problems, as they are used to interact with land users. Such studies could demonstrate the crucial role of soils, by including options without soils input as a base level for comparison. In addition, the shift in the policy arena from topdown command-and-control environmental rules to more participative and goal-oriented approaches offers particular commercial opportunities for soil scientists in jointly developing land management schemes that meet environmental goals,

interacting with land users. But talking time is over. Only specific case studies will be convincing to our scientific colleagues and societal partners.

Introduction

An issue-meeting during EUROSOIL 2012 in Bari, Italy, focused on the question: *"Soil Science: are we facing real needs from society?"*. That question can only be answered when those real needs are defined and there are as many articulations of needs as there are people. When posed in general, people are concerned about economic conditions, health insurance, retirement age etc. Even when restricting the question to the environment, attention for soil will not qualify as a major need for the population at large. Numerous papers and reports have emphasized this fact: even though evidence is overwhelming and well documented that soil degradation has major negative effects on livelihoods, there is a: *"marked lack of public awareness of the importance of soil and the need for soil protection"* (EC, 2012a). And this, in turn, results in relatively little attention in the policy arena. There is more attention for water issues as people can more directly associate with the negative effects of floods, water shortages and lack of drinking water. The highly successful Global Water Partnership and the related Global Water Week, attracting every year thousands of participants, are a clear demonstration of the great attention that water related issues have with the general public. Despite this great attention to water, only few see the functional link with soils. At the same time there is rising awareness in society for environmental problems concerning climate change, freshwater shortages, biodiversity loss and food security and we will make a plea later in this paper to connect soils more directly with these recognized issues rather than pursuing an exclusive focus on soil degradation that has proved unsuccessful. It is time to face up to this conclusion.

The experience of “Real needs” is not a static phenomenon but a moving target, affected by the way different issues are convincingly “framed”. This paper will therefore (in line with the discussion at EUROSOIL 2012) focus on ways to improve “framing” of the importance and relevance of soils in future, rather than produce yet another dramatic listing of all negative effects of soil degradation, followed by an abstract clarion call for action as was again produced at RIO+20. “Framing” will be based on a strategic link with water science which, in our opinion, is much more effective than a strict focus of soil when studying “wicked” environmental problems. Such problems share a number of characteristics: (i) there is no definite formulation of the problem nor a single, straightforward “solution”; (ii) solutions are never true or false but only better or worse; there are only alternative “options”; (iii) there is no immediate test of any given option; (iv) every problem is unique and every attempt to derive options is significant; (v) the explanation of the problem determines the proposed solution in terms of possible options. (Rittel and Webber, 1973). Introduction of the concept of sustainable development in the 1980’s has added the additional criterium to express each option in terms of its economic, social and environmental consequences. This is useful as one-sided and unbalanced options are thus exposed.

The dynamic character of the: ”needs from society” has been well reflected in the development in time of environmental soil policies. After the Second World War emphasis was on agricultural production, ignoring environmental side effects. Gradually, soil, water and air quality received more attention since the 1970’s emphasizing, amongst others, the need for soil protection. Recently, soil is seen as integral part of the ecosystem that should be managed in a sustainable manner, as reflected in the EC Soil Protection Strategy of 2006 (EC 2006) that deserves much more attention by the scientific community than it receives. This emphasis on ecosystems and the realization that studying soils in isolation is less effective than cooperating with other disciplines studying “wicked” environmental problems, is (very) slowly gaining ground within the soil science community, as evidenced by the new sub discipline of *Hydropedology,* where the expertise of soil scientists studying soils in the field is combined with the process knowledge of hydrologists and soil physicists. (Lin et al, 2006, Bouma, 2012). A hydropedological approach will be followed in the remaining paper: *"soil without water is like a man without blood; water without soils is like a man without bones".*

When making an attempt to more effectively "frame" the need for improved soil management leading to more sustainable livelihoods, one realizes that much information is already available. The SoCo report (JRC 2009) concluded that there is a wide range of farming practices available to farmers throughout the EU for mitigating or even reversing soil degradation processes. In addition, there is a range of measures within the current rural development policy (footnote: http://ec.europa.eu/agriculture/rurdev/index_en.htm) that are appropriate for supporting sustainable soil management. For example, WOCAT has defined in detail 450 effective soil conservation measures (WOCAT, 2010). There are numerous other reports documenting effective soil management practices that can improve one or more of the soil functions as defined by EC (2006), leading to more sustainable livelihoods. More recently, the report by the EC on the implementation of the Soil Thematic Strategy (EC 2012b) and the "Guidelines on best practice to limit, mitigate or compensate soil sealing" (EC 2012c) have highlighted the effective implementation of sustainable soil management practices, the potential benefits of the systematic adoption of the proposed way forward by the Soil Thematic Strategy and the sustainable management of natural resources (EC 2011).

Considering the availability of all this information, the question arises whether our primary problem is not so much lack of information (even though more information in certain areas is clearly needed) but, rather, a structural inability to convince land users and politicians to internalize this information and follow it up with action on the ground. As we believe that this inability is the major problem, we will focus on this in what follows. Recently, the College of Agriculture of the University of Sydney has, in collaboration with the US Study Center in Sydney, re-vitalised the debate on the relevance of soil science in the societal environmental discours. They propose use of the term *Soil Security* and suggest a strong focus on the study of carbon in soils. This activity deserves support (Soil Carbon Initiative, 2011).

As land users and politicians often complain about the complex terminology being used by soil scientists, we will first discuss this issue followed by an analysis as to what can be done to reach effective "framing" of soils in future, including recommendations for research and teaching.

Terminology

Much effort has been and is being spent to develop soil classification systems. Two systems are widely adopted at global scale: Soil Taxonomy (US Soil Survey Staff) and World Reference Base (IUSS Working Group, WRB) (Krasilnikov, et. al., 2009). Both the US Soil Taxonomy system and the World Reference Base (WRB) have produced a rather complicated terminology that is not accessible to non-scientists. In the USA, the lowest classification level is the soil series, named after local sites. For example, the Antigo silt loam, occurs near Antigo, Wisconsin. This appeals to local people and improves communication. So do so called State-Soils, where a particular soil type is chosen as being representative for the State and is shown as a monolith in the State Capital. In the Netherlands, an attempt was made to use local terminology for major soil types (de Bakker 1979) but the names have never been used in practice. Lack of recognizable names forms a clear barrier to effective communication that is not likely to be overcome as emphasis in classification is on refining and merging existing systems. This is unfortunate as soil types are effective "carriers" of information both for existing and for "what if.." conditions. Every soil type has a "story" to tell, not only about her formation but also about her potentials and limitations. She needs our help in articulating her rich story in terms humans can understand!

The recent establishment of a new IUSS working group developing a novel approach towards a Universal Soil Classification (Taxonomy) system (Golden et al., 2010) does not seem to propose any revolutionary change in soil classification and is currently far from addressing the real need for an accessible terminology for soils allowing for filling the current communication gap between soil science and civil society.

Soil classification focuses on the effects of the soil forming factors, operating over periods of sometimes thousands of years and does (correctly) not consider short-term effects of management focusing on functionality. The latter is important for land use and Droogers and Bouma (1998) suggested therefore use of the term genoform for the first category and phenoform for the latter. Each soil genoform has a characteristic range of phenoforms and it was possible to predict organic matter contents for two major soil types in the Netherlands by not using modelling but by regressing it with past land use practices (Pulleman et al., 2000; Sonneveld et al., 2002). In each study some 50 fields on different farms were visited and sampled and land use history was documented. This represents an opportunity for soil scientists in countries were soil surveys have been completed: much information is to be gained by studying properties of phenoforms of any given genoform.

In terms of emphasizing functionality, the Soil Protection Strategy (EC, 2006) represents a major step forward, if only because of the easily accessible terminology. Aside from a number of soil threats, seven soil functions are defined: (1) biomass production, including agriculture and forestry; (2) storing, filtering and transforming nutrients, substances and water; (3) biodiversity, such as habitats, species and genes; (4) physical and cultural environment for humans and human activities; (5) source of raw materials; (6) acting as carbon pool; and (7) archive of geological and archaeological heritage. The condition of land in a given area can now be defined in terms of the seven qualities, requiring standards in terms of indicators allowing comparisons among soils. Also, thresholds are needed to define ecological “tipping points” beyond which any function is irreversibly changed. Soil functions can also be used to define “soil quality”, in terms of: “ the ability to perform” of any of the functions. (Bouma, 2010). Bouma (2002) defined a soil quality measure based on function 1. So far, soil quality is still an undefined, elusive term while water and air quality are well defined. Also, “ecosystem services” follow from the characterizations of the soil functions, as, when performed, every function can be seen as providing a service to society. Ideally, all functions should be satisfied in a large area, such as a country, but in smaller areas emphasis can be on individual functions when conditions for that function are particularly suitable. This can be an excellent basis for spatial land-use planning, aiming for the optimal use of land. Unfortunately, the soil function concept has so far hardly been embraced by the soil science community as a guiding principle and this is unfortunate as we face a knowledge paradox: too much of our considerable stock of knowledge remains unused. (e.g. Bouma, 2010). The move beyond agricultural production (function 1) to environmental characteristics (functions 2, 3 and 6) and socio-economic ones (functions 4,5 and 7) reflects societal developments as mentioned in the introduction. All functions also reflect without exception the impact of water and they are therefore quite useful for Hydropedology (Bouma, 2012).

Reconnecting the wide range of soil expertise.

As many other scientific disciplines, soil science tends to be rather self-centred. Other related professions, nor land users or politicians were present at EUROSOIL 2012 and this is true for other comparable soil conferences. Most papers presented cutting-edge results obtained with modern techniques and there is no question as to whether or not this represents excellent research. It does. If, however, our main problem is communication with the outside world, as mentioned above, we need to at least raise the question as to how we might possibly re-connect soil science with society. The knowledge diagram in Figure 1 (Bouma et al, 2008) may be helpful in this context, defining five types of knowledge (K1-K5) in terms of two ranges of characteristics: from qualitative to quantitative and from empirical to mechanistic. K1 represents user expertise, sometimes referred to as *tacit knowledge.* K2 is broad expert knowledge from practitioners or applied scientists. The still essentially empirical character of this knowledge is supported by a better understanding of the underlying processes and may still be considered *tacit in* nature. K3-K5 represents increasingly specific scientific knowledge. K3 represents e.g. empirical statistical . An example are widely used pedotransferfunctions that relate basic soil characteristics, such as texture, organic matter content and bulk density, to flow parameters needed for simulating soil water regimes, (e.g. Bouma, 1989, Pachepsky and Rawls, 2004). The underlying physical processes are increasingly expressed in quantitative terms in K4 by simple, operational models. An example is the application of the hydrological SWAT model in the Green Water Credits study in Kenya (Bouma et al, 2011; Hunink et al, 2012; Kauffman et al, 2013). Finally, K5 represents cutting-edge science, a favourite and almost exclusive entry point for publishing in international scientific journals. An example is the work of Murphy et al (2009) on modelling soil moisture conditions applying Digital Terrain Models. Droogers and Bouma (1999) calculated the moisture supply capacity of a prime agricultural soil in the Netherlands, comparing the results of K3, K4 and K5 methods. They reported significant differences, allowing choices to be made among the methods, considering a steep rise in costs from K3-K5. .

Two types of arrows are shown in Figure 1: from K1 to K5 indicating use of tacit knowledge when planning research and from K5 to K1 indicating the flow of knowledge from research to practitioners, experts and politicians. The latter used to be considered in terms of extension services when dealing with farmers but they have been privatized in many countries and have become less effective.

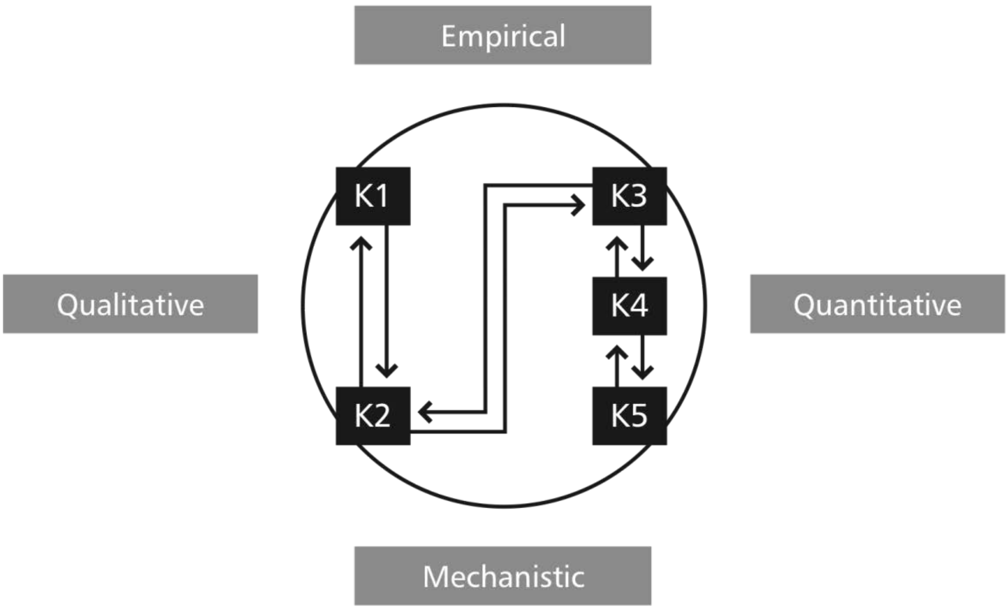

Figure 1. Knowledge diagram, defining five types of knowledge as a function of four criteria, as indicated. Soil survey activities or field pedology (K2) and soil physical – hydrological research (K5) combine into hydropedology.

The scheme of Figure 1 focuses on Field Pedology, as indicated, expressed by soil survey based on K2 expertise as hydropedology has particular links with soil survey. In pedology there is, of course, also much K5 research that is focused on soil genesis, for example dealing with clay mineralogy, geochemical techniques, C-dynamics and modelling of pedogenesis. Such work may also be relevant for the soil functions but its focus is not primarily on application. The problem we see now is that the chains in the knowledge diagram are broken. K4-K5, and particularly the latter, is disconnected from the chain and K4-K5 is hardly fed by user's expertise and questions. This would appear to be a major reason why communication of soil scientists with users of soil information is problematic. We are too self centred and have to get: *"out-of-the-box"* and reconnect the knowledge chain. Implications for research and education will be discussed later.

Implications of considering soils to be a part of ecosystems.

But reconnecting the knowledge chain dealing with soils solves only part of the problem. We are part of ecosystems (e.g. Robinson et al., 2012) and when dealing with major well recognized "wicked problems" such as climate change, water shortages, food security and biodiversity loss, international groups of scientists are active in developing computer models describing current conditions and "what-if" propositions for the future. Modeling is an indispensable tool to explore future developments and they cover "land" rather than "soils". All "wicked" environmental problems boil down in the end to the question: *”what should be done where”.* The “where” question relates to the land, which in the definition of FAO (1976) is: *”an area of the Earth’s surface, the characteristics of which embrace all reasonably stable, or predictably cyclic attributes of the biosphere, vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology. The plant and animal populations and the results of past and present human activity to the extent that these attributes exert a significant influence on the present and future uses of the land by man”.* . (see also: Bouma et al, 2012b). When simulations are made in the context of “wicked” environmental problems, the atmosphere, geosphere (including soil) and hydrosphere are all expressed in terms of flow parameters and physical boundary conditions. We rightly talk about “land” evaluation for a wide variety of land uses, and not about “soil” evaluation (Bouma 2012b).

Once “what..if” simulations have been made , results have to be translated back to the field and then only soils represent a physical presence. The atmosphere and hydrosphere are abstract constructs. One can have a handful of soil but a handful of atmosphere or hydrology remains elusive. This illustrates the special role of soils when studying the impact of different “what..if” scenario’s on the land. An attractive starting point for promoting soil science in the environmental discours.

Even though these environmental simulation models are highly complex, they still represent a strong simplification of reality. So every contributing discipline has to simplify their modules, which is one of the most painful acts a scientist can experience: he has to deny part of his knowledge. If you are not part of the interdisciplinary team, you are simplified by the others. This appears to happen to soil science. In our own reports and papers we convincingly “prove” the importance of soils for the major global issues and propagate, again, soil action in our own reports and many international agencies support us in words. But in the models being used by international agencies soils are often poorly represented. For example, many hydrological models don't contain soils, only slopes and lengths of slopes, to be easily derived from Digital Terrain Models. Or, soils are highly schematized (e.g. Bouma et al, 2011b). One climate model for Europe assumes that sands with a depth of 1.7 meters occur everywhere. The widely used Decision Support System for Agrotechnology Transfer (DSSAT) (Jones et al., 2002) has a highly sophisticated plant production module but soils are represented by concepts of the 1930's ("available water" and "tipping bucket"). In biodiversity, soils seem to be better integrated in the general discourse (e.g. Jeffery et al., 2010; Wall et al, 2012). Of course, the dynamic behaviour of ecosystems is determined by many factors and in some ecosystems soils may very well play a minor role. But in others they do not and certainly when operating from the viewpoint of the soil functions, there will always be relevance of the soil factor. As long as we are not active partners in interdisciplinary teams studying the major environmental problems of the future, we will be marginalized. Another urgent reason to get: "out-of-the-soil-box". But this is easier said then done. You have to be attractive as a partner and, frankly, the wide scatter of current research activities in soil science is often not convincing to the other partners of the team. Bouma (2010) propagated, therefore, a focus of soil research on the soil functions including re-establishment of the knowledge chain for each of them. When presenting this as our: "Toolkit", we may be more interesting as a partner than we are now. In getting involved, we should be prepared for a major struggle because interests of participating partners go beyond the pure scientific domain. So rather than argue for a battle against soil degradation, as relevant as it is, it may be more pragmatic to systematically show the importance of soils and its degradation when studying the major, recognized issues of climate change, freshwater shortage, food security and biodiversity loss. This includes a zero-run of the models, where soil information is left out. We never do that, because we focus on the newest techniques, models and data but to be convincing about the importance of soils we should be able to show what happens if soil is not included in the modelling. As is, we are unable to show this.

In all fairness we have to acknowledge that we have contributed to the feeling by other disciplines that they can take care of soils by themselves by developing accessible soil databases and pedotransfer functions (e.g. Bouma, 1989. Pachepsky and Rawls, 2004). The latter relate simple soil characteristics to parameters needed to simulate soil moisture regimes. Use of these functions by non-scientists can yield very poor results: an experienced soil scientist cannot be replaced by a model subroutine.

Hydropedology: an urgent need to move:"out-of-the-box".

Soil and water research face a devilish dilemma as developments "in-the-box" deviate strongly from what happens "out-of-the-box". Internally, a convincing plea is made to better integrate soil survey information when modelling water regimes in soils. Data on particular soil horizons, information provided by redoximorphic features and phenomena associated with macropore flow can be derived from soil survey information and can improve modeling results of field soils, also at watershed level. This has recently been summarized by Bouma, (2012) and will not be repeated here. On the other hand we see that externally, most hydrological simulation models , being used in policy processes, supporting , for example, implementation of the EC Water Guideline, don't either use soil information at all or use highly simplified expressions with no need of input by soil expertise.(Bouma et al, 2011b). By being too much focused on soil and by not being actively engaged in the adjacent field of hydrology, has been a costly mistake. The only way forward now is to engage in cutting-edge hydrological modelling studies and demonstrate the importance of soils input, by also showing what happens if no up-to-date soil data are included. The

Green Water Credits study in Kenya is an example of such an approach (Bouma et al, 2011b; Hunink et al, 2012; Kauffman et al, 2013).

But there is in addition also room for a pro-active approach. Even though climate change, water and food security and biodiversity loss are well recognized environmental problems also in terms of established legislation, the disciplines of climatology, hydrology and biology struggle, like all others, in realizing true *transdisciplinary* research , resulting in successful programs in the real world. Interaction with a wide variety of stakeholders and dealing with often contrasting legislative and policy demands is a time consuming cumbersome activity as was documented for a major research program on sustainable agriculture in the Netherlands (Bouma et al 2011a). This could be a future “niche” to be explored by soil scientists who have affinity with the land and who have a tradition of working with land users. Also, we see a shift in environmental legislation from topdown command and control measures to more participatory approaches with an emphasis on environmental goals to be reached rather than on measures to reach these goals (Bouma, 2011). This opens up attractive commercial opportunities for soil scientists to work with land users developing management schemes that would satisfy environmental goals for the particular conditions being faced by each land user. These two potential opportunities for soil science , in which soil-water interactions play a key role, will be further explored in the following sections.

How to better engage stakeholders and politicians.

Improving connections in the knowledge chain, as discussed earlier, will function to better engage stakeholders but only when soil scientists are serious about this effort and don’t stop after asking their questions and then follow their own agenda’s. Effective communication implies willingness for joint learning and, particularly, listening, which is time consuming. Showing more clearly how important soils are in studying the major environmental issues of the future will also create engagement with colleagues in adjacent scientific areas. But there is more. In terms of the policy arena the following approaches may be considered:

1. Assuming that the underlying assumption of democracy is still valid in terms of politicians reflecting the opinions of their citizens, a major effort is needed to

educate the public about the importance of soils, starting with young kids. Much is going on already (see Gabrielle Broll in Bouma et al. 2012a).

2. The major environmental issues are highly complex in nature. They represent “wicked” problems, where many stakeholders are involved with often highly contrasting interests (Bouma et al., 2011a). There are no single, magic solutions to “wicked” problems. Traditionally, soil scientists are engaged with solving problems in a rather straightforward and linear manner: the problem is defined, methods for study are selected, research is done and the result is presented. “Wicked” problems require a different approach by formulating options to “solve” the problem. Any mentioned option should be investigated, however unreal they may seem at first sight. The role of the scientist is to objectively show the economic, social and environmental consequences of any option, reflecting the basic premises of sustainable development. Others have to choose. This way he will maintain his independence and not be tied to any particular option. Of course, a certain degree of pragmatism is useful in this context: options considered should include the favourites of particular political parties, politicians and NGO’s. One particularly valuable action is to debunk the broadly experienced opinion that what is good for the environment is bad for business. In many cases the reverse is true and this can provide a highly convincing argument to stakeholders and politicians to support environmental measures. The recent Rio+20 Conference on Sustainable Development has indeed put the accent on the need to rapidly move towards a “green economy” reconciling economic growth with environmental protection (UNCSD, 2012). Unfortunately the global community couldn’t agree on measurable targets in Rio that could allow assessing success or failure of such an expression of good will. A remarkable exception was the agreement on a common goal “towards a land degradation neutral world”. It remains to be discussed how such an ambitious goal could be achieved in the near future.
3. We see a gradual movement from top-down, command-and-control legislation to more bottom-up, participatory approaches where stakeholders are involved and engaged in development. A recent example is the newly established Global Soil Partnership of FAO as a participatory approach to global soil protection (Montanarella, 2012). The main goal is to encourage more commitment of stakeholders when implementing legislation. Also, many

stakeholders complain about the role of government that seems to infringe on entrepreneurial independence. An example: the EU nitrate guideline for groundwater quality presents the indicator: ”nitrate concentration” and a threshold of: ”50 mg/ liter”. Legislation, however, requires farmers to limit fertilization with manure to the equivalent of 170 kgN /hectare, clearly a management measure. Farmers feel that government (“Brussels”) tells them what to do while they would prefer to have clear guidelines on quality goals and the freedom to reach these goals by their favourite management procedures. Indeed, there are several ways to reduce nitrate loading of groundwater so this objection is sensible (e.g. Bouma, 2011). Defining clear goals for soil, water and air quality plus easily measurable indicators and threshold values would be popular in the field, as this would leave the land user room for his professional approaches. And no two farmers are alike! This approach is particularly attractive for soil scientists as they can assist farmers to develop innovative procedures, closing the knowledge chain as discussed above in a practical manner. An important source for future job opportunities for soil scientists. Bouma et al (2011b) have referred to this activity in terms of Extension 2.0 that is quite different from traditional extension where research results were communicated directly to farmers.

4. Awareness of the policy chain will be helpful for scientists to avoid presentation of research results at inappropriate times. Different phases can be distinguished in the policy process: *signalling, design, decision, implementation and evaluation* (e.g Bouma, 2012). Research has a different role in the first two phases and can have a role in the last phase. Decisions are made by others and so is implementation. Sometimes it can be useful to be involved with implementation to see whether the design made is maintained. To present new and conflicting research results in phases two and three, for example, is usually not very helpful.

Possible implications for soil related activities and for research and education

Soil science cannot continue with a business-as-usual approach while complaining at the same time about lack of interest by stakeholders and politicians. Relatively minor modifications in operating procedures might be sufficient to reverse current unfavourable trends. For large soil congresses, rather than accept all submitted proposals for symposia, which results in an enormous scatter of unrelated information and in meetings that may have the character of reunions rather than challenging events, some guidance could be provided, for example by grouping papers in terms of the soil functions and asking attention for matters as to why the study was made, why existing knowledge was inadequate and how the knowledge chain has operated in practice, if at all. Also, interactive sessions with prominent stakeholders and policy makers could be planned, yielding useful outside perceptions if the right persons are identified. Outsiders producing only stereotypes or highly predictable reactions are counterproductive and should be avoided.

The Global Soil Week, in analogy with the Global Water Week, could provide the right platform for such a new approach to communication and sharing of information among stakeholders, scientists and policymakers, as well as with the general public.

Soil scientists at Universities and Research Stations are increasingly judged on their scientific quality, measured in terms of the number of publications in international, refereed journals and citation indexes. This needs to be broadened if the profession wants to really move out-of-the- box and reach out. Bouma (2005) has made a plea for *Communities of Scientific Practice (CSP)* next to the well established *Communities of Practice(CP)* in which scientists work together with stakeholders and politicians in a general sense. CSP's are necessary because the scientific community, as is, was and is ill prepared to be effective in CP's. There is work to do to get their scientific act together. In CSP's there is next to cutting-edge scientists, room for applied scientists, and scientists that are effective in connecting and working together with stakeholders and politicians (knowledge brokers, extension 2.0). In other words, an effective CSP can re-establish the knowledge chain. If the soil science community is serious about improving the interaction with society, they should develop criteria to also acknowledge the work of these other scientists in the CSP and reward them in line with their significance for the profession.

Teaching should include case studies illustrating successful interdisciplinary research efforts. The more specific these case studies are, the better. Conceptual highbrow babble about inter- and transdisciplinarity should be avoided as it turns people off and is therefore counterproductive. In teaching, the crucial importance of basic (K5) science should be emphasized and illustrated. Without such research the discipline will wither and die. But the need to connect basic research with the knowledge chain will provide a useful signal without sacrificing scientific independence and integrity.

Implications for research itself.

To revitalise the knowledge chain within the profession and to improve professional contacts with colleagues in adjacent scientific areas, hydropedological research, focused on the soil functions, is important as discussed earlier in this chapter. In addition two suggestions are made:

1. When defining and studying a problem, a step-by-step approach can be followed (also called the “salesman approach”), where first K1 opinions are collected. (Bouma, 1997). Currently many citizens are well informed, check WIKIPEDIA and are active in the social media. Then, K2 follows by consulting experts in the field that may well be the investigator himself. If this does not solve the problem, K3 first introduces the research aspect by checking availability of simple routines, such as pedotransferfunctions or existing Decision Support Systems. If this does not yield satisfactory results, existing K4 models or measurements can be applied and if this is also unsatisfactory, cutting-edge K5 work may be needed. Along with this step-by-step procedure, a simple cost/benefit analysis can be made to be able to answer the common question: why are costs as high as they are and what is the gain of every additional step on the way in terms of results obtained. There is usually a sharp rise in cost when moving from K3 to K4 and certainly when moving to K5. This approach is useful for research because researchers have the tendency to jump right away to the K5 level because that is most interesting from a scientific point of view. But sometimes problems can be very well solved at K3 level. Ideally, stakeholders or politicians involved should be engaged and informed along the way, which is crucial when studying “wicked” environmental problems, as discussed above (see also examples in Bouma et al, 2011a). The systematic K2-K5 approach implies continued and growing engagement of stakeholders and policymakers which is much better than abruptly confronting them with a finished plan.
2. When working in interdisciplinary teams, every discipline has to define the level of its expertise being offered. In modelling studies input by the different

disciplines should roughly correspond in terms of detail. If not, the calculated effects of different processes on ecosystems may be distorted. For example, we discussed earlier the DSSAT models where the plant production modules are at K5 level while the soil module is at K3. It is therefore important for any scientific discipline to have a: “Toolkit” for the different K levels, allowing them to “shift gears” as they are involved in research negotiation processes. . As discussed, soil scientists would be well advised to specify and differentiate this in terms of the seven soil functions. With such a “Toolkit”, flexibility is created that is useful when closing the knowledge chain and when interacting with colleagues, stakeholders and politicians. The most deadly remark by scientists is to plead for more data, “because we don’t know enough”. The common question by stakeholders and policy makers is next what “they having been doing the last 100 years?”. It is preferable to state that there is an answer to any question but that answers are sometimes lousy. They can, however, be improved by the step-by-step approach discussed above.

Conclusion: The need for convincing examples in the real world

This paper faces the same trap as so many others in the past. Analyses and suggestions may be excellent and appealing to readers but they all too often evaporate and do not result in visible results in the real world. Bouma et al (2011a) have illustrated this for a major research program (60 million euro) on sustainable agriculture in the Netherlands. Thirty programs, all with a “wicked” character, were suggested bottom-up by a wide variety of practitioners. In the end, after six years, only twelve were successful and could – after a protracted struggle- show convincing results in the field. The others sometimes generated many scientific papers but all too often died in beauty or by disintegration. The same can be said of many EU funded research programmes on soil related research. Lack of an soil science-policy interface, allowing for effective translation of outstanding research results into applicable measures and actions by policymakers, prevents many projects to be fully beneficial to the wider stakeholder community. Building up an effective soil science-policy interface for the European Union should be a priority for the future “Horizon 2020” research and innovation programme of the EU (Van den Hove et al., 2012). A similar science-policy interface is also needed at global scale and there are high expectations on the implementation of the Global Soil Partnership and its related Intergovernmental Technical Panel on Soils (ITPS) to bridge the existing gap between soil science and the policy-making community (Montanarella et al., 2012).

We appear to have reached a point in soil science where documentation of soil degradation, including all its consequences and possible solutions, followed by clarion calls for action, are not adequate anymore. What, then, is the alternative?

Recommendation

We suggest to organize a workshop where case studies on watershed or catchment level are presented covering "wicked" environmental problems. Emphasis would be on the manner in which soil and water were handled and should also focus on the question whether studies have ultimately resulted in effective real-world arrangements, accepted by all stakeholders as a "solution". If not, reasons should be explored. As discussed above, "Wicked" problems have no silver-bullet "solutions" but can at most lead to a series of possible options, each one a compromise including trade-offs between environmental, social and economic objectives. Here the procedure of: "*connected value development"* can be followed successfully (Bouma et al, 2011a) but other procedures may work as well. As is, research in this field is scattered and comparing experiences may result in more insight into these complex processes and should result in protocols that can advance these types of studies with a special focus on the role of soils. Specifically, the following seven issues should be addressed:

1. What is the problem being studied? Is it "wicked" in character? Who articulated the problem? Which stakeholders are involved and are there links with environmental rules and regulations? Or is the research "curiosity driven?".
2. What are the objectives and goals of the study and who defined them? Have they shifted as the study proceeded?
3. What can be seen as the particular input of soil science when studying the problem and which soil functions are relevant? Does the perception of soil scientists about the possible role of soil science differ from perceptions in other disciplines?

4. How are soils represented in the procedures being followed, which may include but is not restricted to modeling? Is a zero-option included in which soils are not represented?
5. If models are used, how are they calibrated and validated?
6. How are uncertainties, associated with using soil data, expressed in results obtained? Are they?
7. Are attempts being made to extend the study beyond technical aspects, aiming for connected value development? If yes, how is this organised and how did it proceed? What are the consequences for the manner in which soil science was involved in the study?

Documenting the crucial importance of soils when deriving options would represent effective promotion of soils. This approach, putting soil science in context and following the recommendations presented in this paper, may be an effective way to draw attention to soil science in future.

The central role of the land when studying "wicked" environmental problems, is a major reason to hypothesize that injecting soil science in inter- and transdisciplinary studies of "the land", focused on major environmental problems of the future, may be a significant mechanism to put soil science back on the societal and policy agenda. Talking time is over: we need specific examples of such studies and the development of protocols to move forward!

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