CATRINA (2008), 3 (2): 59 -68
© 2008 BY THE EGYPTIAN SOCIETY FOR ENVIRONMENTAL SCIENCES

Is Soil Science Dead and Buried?
Future Image in the World of 10 Billion People

El-Sayed E. Omran
Soil and Water Department, Suez Canal University, 41522 Ismailia, Egypt

ABSTRACT

Is there a future for soil science? Yes, of course there is. The visions and images of soil science are changing. Human demand for environmental resources is quickly growing around the world. Food production must increase to meet the needs of an additional 3.5 billion people over the next 40 years. Population facing water scarcity will be doubled over the next 40 years. Land degradation and desertification problems, land use issues, global climate change, air and water quality, for example, are connected to soil. This incomplete list identifies a number of major challenges which are sufficient for any soil scientist to be interested in them. The aim of this vision paper is to through the light on the future image of soil science. The future image is not so bright if it is business as usual of traditional soil science. It is necessary to re-looking for the role of soil science in the society. Soil science plays an important role in detecting and solving environmental problems. In order to do so, and to successfully address these challenges, soil scientists will need to effectively participate in interdisciplinary and multidisciplinary studies without losing their own roots and identities. I do foresee the future of soil science if it is integrated with other fields. If we need to maintain our identity as soil scientists, there is a suggestion for a new type of soil science that is more holistic and in close relation with society needs.

Keywords: Future soil science, environmental sustainability, environmental problems, farmer participatory, future generation research.

Introduction

During the last two decades, mankind has appropriated a large proportion of the environmental resources. The global changes such as strong increase in pollution of water, air and soils, biodiversity loss, and a substantial decrease of natural resource reserves (Frossord, 2006) are being largely discussed in the public and received attention from funding agencies. The importance of the soil is less recognized.

Soil science provides the basic information for human to better manage their environment and thereby ensure a favorable quality of life for present and future generations. Soil science based on pedology, founded by Dokuchaev, is less than 150 years old. Since then most national soil surveys have adopted pedology as a main descriptor in soil mapping. Until recently, the major task for soil survey organizations is to produce regional and local information for agricultural production (Breuning-Madsen, 2006).

The role of soils can be viewed as a set of trade-offs among the various functions of soils as determined by current society. If conservation and rational use of soil resources are not important enough for society in the next few decades, then the trade-offs may keep us headed toward the “tragedy of the global commons”. If, however, the trade-offs are for environmental sustainability, then the opportunities are golden for imparting the knowledge and wisdom of soil science. The focus of soil science future in the world has changed significantly with the societies from agricultural production towards environmental issues (Bouma, 2005). Many environmental problems are so complex that require cooperation with other scientists, e.g., biologists, chemists, and specialists in computer modeling. This development makes it necessary for soil scientists to change the focus of their research in the future towards environmental impact assessments and how to solve environmental problems. Accordingly, the aim of this vision article is to through the light on the future image of soil science. We should have a revised concept of soil that will broaden the old conceptual barriers and open new horizons.

Is Soil Science In Crisis?

Is soil science in crisis? There is no simple answer to this question. There are soil science’s own “ongoing” businesses that lead to the present level of soil science development. The “ongoing” businesses involve the generation of information and data to strengthen the advances in science and management innovations that have been made over the years. Three examples serve to illustrate this.

First, every few months, it seems, another soil science department changes its name to one in which the word “soil” no longer appears (Baveye *et al.*, 2006). Growing numbers of researchers are also lobbying for new expressions like "Hydropedology" or "Environmental Science" to replace the out-of-date term of "Soil Science". These trends are concomitant with a sharp decrease in the clientele of most soil science programs (Baveye *et al.*, 2006). Results of institutional and graduate student surveys carried out in 2004 indicated that enrolment in MSc and PhD programs in soil science in U.S. and Canadian universities has dropped on average by about 40% (Baveye, 2006). Similar declines are also manifested in other countries. In terms of

---

* *Corresponding author: e.omran@scuegypt.edu.eg*

publications, even though the number of peer-reviewed articles on soils-related issues published every year has grown exponentially in the last two decades, less than 15% of these articles are authored by individuals who are affiliated with a research unit that includes the term “soil” or “soils” in its name (Baveye *et al.*, 2006). Clearly, all of these statistics indicate that the discipline of soil science is losing market share and visibility at an alarming pace.

Second, there have been suggestions for a new type of soil science that is more holistic (Bridges and Catizzone, 1996). Soil science has split up into different special areas (Frossord, 2006), with a danger (within 10-20 years) of losing track of the holistic view of soils. There is much fragmented and self-centered sub disciplinary work (“atomization, specialization”). Through the development of new research concepts, soil science has developed into very specific areas dealing with all aspects of the weathering crust above rock material, at different scales, from the macro-scale, *e.g.* regional soil mapping and soil taxonomy, to very small soil particles and their reactions at nano-scale. The question here is not about the scientific quality or relevance of that work but the main problem is that the pieces do not fit together anymore. Only specific aspects of soil are investigated thoroughly which losing track of the overall functions of soil for human and the environment. The vision of International Council of Science Union (ICSU) to the world is clear: “where science is used for the benefit of all…and where scientific knowledge is effectively linked to policy making”.

Third, soil science might probably have problems to maintain itself in the community. A major road block in advancing soil science is the negative perception of soil held by the general public and the scientific community at large. The public view of the soil is generally associated with “dirt,” “mud,” and “farming”. This view leads to low value, low appreciation, and thus low priority.

How to Rise to the Challenge? Orientation of Soil Science in the world of 10 Billion People

It is not easy thinking about the future without considering the past and current trends. The prediction of the future is always hazardous, even when based on an extrapolation from the past.

Throughout the history of soil science over the past 150 years, two factors boosted the development of the science and should not to be ignored: discipline-oriented and process-oriented soil science. The former is the most essential factor for affecting and orienting the development of soil science. In the first phase "discipline-oriented" approaches with the classical sections like soil physics, soil chemistry, soil biology, or soil pedology should prevail. Following "process-oriented" aspects played an increasing role considering the growing demands for understanding the functions of soils for crop production and the environment.

Human demand for environmental resources is quickly growing around the world. Population facing water scarcity will be doubleed over the next 40 years. Food production must increase to meet the needs of an additional 3.5 billion people over the next 40 years. Feeding world population of 6.5 billion in 2006, 7 billion in 2010, 8 billion by 2025 and 10 billion by 2050 (Lal, 2006) is beyond mandates that soil quality be restored and enhanced. Despite the concrete achievements of soil science, upcoming demands in respect to sustainable manage our natural resources (to mitigate environmental problems and to fight worldwide soil degradation) are major challenges remaining. In conjunction with these demands, soil science has to further contribute to an overall understanding and problem solving. A major shift in the paradigm for soil scientists should change to undertake "demand-driven" projects with innovative and original approaches. Table (1) shows a typology of future soil science. This table was organized based on the following paragraph.

"As we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know."

This was (in) famously said by Donald Rumsfeld, the US Defence Minister at a Whitehouse press briefing on February 12th 2002 (McBratney, 2006). Table (1) gives us some clear categories of knowledge which we can use to think about the future of any knowledge based enterprise, be it psychology or soil science.

Originality, dedication and problem solving skills of soil scientists are the most important scientific contributions (Table 1). Scientific rigor and quality are always enhanced by bigger and tougher challenges, which are going to be in the world of 10 billion people, and scarcity of natural resources which are already under great stress.

To meet these complex challenges soil scientists need to become more holistic in their approach. Soil science must strengthen the shift toward farmer participatory as technological solutions can only be adopted if they are flexible to the local environment. While continuing with physical, chemical and biological researches, they will need to utilize dynamic simulation and modeling to further understand the interaction of these with one another as well as other components of the production cycle.

Equally important, all these research achievements must be communicated clearly and efficiently to planners and practitioners (Table 1) in order to ensure they are implemented and used for the benefit of soil users as well as the entire society. Soil scientists should be encouraged to disseminate research results to practitioners and not only to their scientific colleagues.

Table (1): A typology of future soil science (adopted from McBratney, 2006).

	Known	Unknown
Known	**Basic Research**	**Normal Research**
	▪ This is the basic of soil science that all professional soil scientists more-or less know.	▪ This is what most people think of as research. Normal (filling in the gap) research. It's about coloring in a black-and-white picture, or putting flesh on the bones, of our knowledge.
	▪ Isn't it time Jenny was superseded? ▪ Is the concept of soil quality fake or just a dead end?	▪ We know we need a thorough understanding of biological soil function, discovery of the real structure and function of organic materials, a quantitative theory (not description) of soil variation. ▪ Technology is there to help us answer the questions, not to be an end in itself.
	▪ About 5 % of our effort should expend in this category. (At the moment it's probably <1%).	▪ About 50 % of our effort needs to be placed here, but it should not be much more than that.
Unknown	**Future Generation Research**	**Exciting Future Research**
	▪ This is about education – making others aware of what we know and what we can do.	▪ This is real science and real research. Governments and institutions do not understand this place. It is difficult to get money to do this. We need time however and lots of it, because it requires deep thought.
	▪ We need to combine and synthesize our knowledge and then disseminate it to our fellow scientists, the new generations, policy makers and the public.	▪ The new ideas here will give the researchers of Category (known-unknown) something to do for 30 or more years after these advances have been made. ▪ I cannot tell you what these will be, but they could be weird heretical things like bacteria produce clay minerals or soil thickness is a key control of the global ecosystem.
	▪ We need to expend 40% of our effort here.	▪ We need to spend much more time thinking and we need to devote at least 5% of our effort here.

To ensure balanced views and optimum dissemination soil scientists should be prepared to cooperate with other specialists. While working in close association with for example anthropologists, sociologists, economists, entomologists, plant pathologists and weed and other crop agronomists they will need, as John Hanks once put it, to 'keep one foot in the field.

The question arises now "what are our opportunities in the future and how can we rise to the occasion?" Let us think over as to what 'Soil Science' is expected to do in the future generation research (Table 1). The author suggests two approaches:

1) Combat "atomization" by starting projects with an integrated analysis of soil processes in a landscape context, which still leaves room for cutting-edge disciplinarily in the end.
2) Facilitate linking up with interdisciplinary projects by defining our expertise at different knowledge levels, ranging from tacit and descriptive to cutting-edge quantitative (Bouma, 2001).

The author believes that in the future generation research soil scientists will be called upon to answer more complex questions and that too in a precise manner.

1) What should we do to maintain our relevance within the scientific community and within society in general?
2) How to develop approaches for characterizing, monitoring, predicting, and managing soil changes at both spatial and temporal scales?
3) How do we do integrative science at landscape and watershed levels?
4) What can we do to increase the visibility of soil science?
5) What are the tools required to make suitable predictions about soil and landscape conditions and sustainable land use?
6) How do we develop strategies to study landscape-soil-water interrelations across scales?
7) How can we develop approaches for characterizing the health of soils?

What are the Expected Challenges and Opportunities for Future Soil Science Development? The Road Ahead

Soil science, as one of the bio-and geo-science components, shares the same opportunities and challenges as other disciplines of Earth science. The suggested challenges for the future generation research image of soil science may include the following questions:

What is the Expected Risk Assessment of Soil Threats for Sustainable Soil Resources?

The world has changed and the priorities have been shifted from agricultural production towards environmental issues. Soil science did not establish its role in environmental studies, until now (Mermut, 2006). Sustainable use of soil resources in a broad global perspective will be an important challenge for future soil science. The overexploitation e.g. of resources in agriculture has led to environmental degradation: soil erosion, the greenhouse effect, and decreasing biodiversity. The assessment and mapping of the soil risk can contribute to sustainable use of soil resources aimed at mitigating soil degradation and increasing crop production (Castrignano *et al.*, 2008). Five threats were identified representing the most important hazards endangering the functioning of soils: soil organic matter decline, soil erosion, soil compaction, salinization and landslides (Eckelmann *et al.,* 2006). Protection against the threat is critical for sustainable land management. The main objective of soil protection is to maintain soil functions by appropriate land use and management. Research activities should be concentrated on finding ways that can clearly and unambiguously delineate potentials and limitations of different soils in relation to air and water protection (biodiversity maintenance). Precise measures for soil vulnerability must be created and efficient methods for (bio) remediation of degraded soils must be worked out. However, more knowledge and indicators about soil quality is required to properly estimate which soils are at a risk that leads to an unacceptable loss of soil functions. If we neglect one aspect, we will risk the whole efforts.

Is the Concept of Soil Quality for Sustainable Land Management Fake or Genuine?

Soil quality which serves as a direct link between agricultural practices and sustainability is an essential issue in soil science research. The concept of soil quality is developed to characterize the health of soils. This concept that cannot be measured directly is continues to evolve (Mermut and Eswaran, 2001). Soil quality can be inferred from soil characteristics and soil behavior under defined conditions. Land Quality Indicators (LQIs) are instruments for monitoring whether one is on the path towards or away from sustainable systems. These indicators may be developed from measurements using remote sensing, censors, and/ or well-tested scientifically sound procedures. Several soil and land quality indicators have been suggested (FAO, 1997). A minimum data set of soil characteristics must be selected and quantified (Singer and Ewing, 2000).

Better understanding of soil quality is fundamental for rehabilitation of degraded soil and environment and hence for Sustainable Land Management (SLM). SLM is defined (Dumanski and Smyth, 1994) as a system that combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns to: maintain or enhance production; reduce the level of production risk; protect the potential of natural resources; be economically viable; and be socially acceptable. However, it is not by itself a mean to achieve sustainability. Understanding the dynamics of land-management changes is critical in the context of sustainability. Progress towards sustainability also requires understanding the means of creating or influencing these changes through effective policies and through making informed and sustainable choices. Various stakeholders (policy makers, farmers, and public groups) need to have information on the performance and behavior of the land and likely future outcomes in response to potential changes in policies. A clear understanding of the links between choices and consequences will help stakeholders to make informed and sustainable choices.

Decision Support System (DSS) can assist a wide range of users in making these informed decisions based on sound technical information (Smith., 2000; Sharma *et al.*, 2006; Matthews, 2008), while also increasing public involvement in the process. In order that SLM can be used as decision support tools for sustainability, it is necessary to allow users and decision-makers to explore alternative futures (Sharma *et al.*, 2006). Nevertheless, the capability to ‘explore and scan’ futures at different scales is necessary because there is no single ‘right’ path (or set of choices) for achieving sustainability.

Is Scale Matters?

One of the most difficult aspects of soil science is the wide range of scales it encompasses, both spatial and temporal (Kirk, 2006). It covers spatial scales from the molecular to the landscape, often together in the same problem, and temporal scales from instantaneous processes to soil formation processes.

Dealing with scaling issues will be central to progress in modeling. Translating information about soil and, *e.g.* hydrologic processes across scales has emerged as a major theme in soil science and hydrology (Western *et al.*, 2002; Pachepsky *et al.*, 2003). Properly corroborated models of particular processes can be used as sub models in larger-scale models, coupled to datasets at the available resolution. But this process of ‘up-scaling’ or ‘down-scaling’ brings particular problems associated with error propagation and interactions between various input parameters and non-linearity in models. For example, there may be discrepancies between the spatial scale at which a process is modeled (*e.g.* the pedon), the scale at which information on input variables is available (*e.g.* a generalized value for a soil map unit) and the scale at which a policy maker needs to make decisions (which may be field scale, farm scale, regional/ catchment’s scale or national scale). Such discrepancies cause particular problems when the model depends on non-linearly key variables or additional processes intervene at scales between the pedon and the unit of interest. But, the application of pedometric methods and techniques of spatial analysis to such issues will help resolving some of these difficulties.

Are the Conventional Soil Maps Will Pass into Oblivion?

In the context of a growing demand of high-resolution spatial soil information for environmental planning and modelling. Traditional soil mapping, the paper map, appears to be increasingly irrelevant to many users and does not have a market with land managers and policy makers at different scales (Omran, 2007). One of the newest and hottest topics in soil resource inventory today is the pedometrics (a new emerging discipline in the field of soil mapping). Quantitative pedology, so-called pedometric, is defined as: “the application of mathematical and statistical methods for the quantitative modelling of soils, with the purpose of analyzing its distribution, properties and behaviors”. It covers a great portion from digital soil mapping techniques to modeling of soil processes and variables. Pedometrics have accounted for 18% of the subject matter in articles published in Geoderma (Hartemink *et al.*, 2001). The development of models and database to deal with the spatio-temporal variation of soils is the focus for pedometric research (McBratney *et al.*, 2000; 2003) for Predictive Soil Mapping (PSM). Until recently, our understanding of soil processes was organized by a set of qualitative rules, which we believe to be true and explain the nature and properties of soils in a given environment. Pedometricians try to quantify these rules and relationships to test the rules themselves, to explain the spatial and temporal variability and changes of soil properties, and to forecast trends of the future. The future of PSM lies in using pedometrics to model spatial soil variation from more easily mapped environmental variables.

A PSM technique, as additional tools for spatializing the soil variability and diversity, is integrated into traditional toolset of soil mapping. Soil variables vary not only horizontally but also in depth, not only continuously but also abruptly. Soil horizons and soil types are fuzzy entities, often hard to distinguish or measure. Sampling strategies are adapted for digital soil mapping and can be optimized to minimize prediction errors and maximize sampling efficiency (Heuvelink *et al.*, 2004; Hengl *et al.*, 2003). The development of such updated database will lead to the creation of sound theoretical and methodological frameworks for soil information acquisition.

Do We Have Appropriate Soil Information System to Contribute for Different Application?

While soil survey in its traditional role is diminishing, the need for soil information is becoming important in terms of sustainable land management. Many soil information and maps are not being used for research because they are not available in digital formats (Omran, 2005; Omran *et al.*, 2006). A soil resource inventory, i.e. a map showing distribution of soils and its properties accompanied by a soil survey report, is the end product of a soil mapping project (Rossiter, 2001). There are many policy issues for which it requires good soil information and rapid answers, e.g. erosion, organic matter content, and heavy metal pollution.

The soil resource inventory data is organized into a thematic type of a geoinformation system (GIS) called a Soil Information System (SIS). The question arises “Do we have enough and appropriate soil data to contribute to the variety of application fields emanating from an increasing societal demand?” Available soil data often fails to provide answers needed to manage our environmental resources. A leading scientist recently concluded that widely used soil erosion models essentially yield empirical results due to lack of good basic soil data (Stroosnijder, 2005). This challenges our scientific pretensions. Updating soil inventories is one of the main fields where new technologies should facilitate data samplings and acquisition. New high quality of soil data is needed to complement existing databases and to provide spatial detail required by the users.

Do Users Ignore Soil Map Quality?

Accuracy assessment and quality assurance are related in that a product subjected to well-defined quality assurance procedures is likely to be of higher accuracy. Data quality describe consistency of data base on one hand and is structured to main indicators like completeness, legal consistency, positional, temporal, and thematic accuracy on the other (Devillers *et al.*, 2005). Three aspects of quality are identified in the literature: adequacy, data quality, and usability. Several studies have shown that the adequacy, quality and usability of soil maps have often been over estimated or neglected (Bishop *et al.*, 2001). Groot (1993) estimated that 80% of soil information in the world is unusable due to low accuracy. The quality of soil applications and hence the reliability of decisions depend largely on the quality of soil information. For example, soil class maps (choropleth maps) can have beautiful colorful appearance, while at the same time they can be rather inaccurate (low quality). This leads to a conclusion that the maps are almost never 100% correct. So the questions that still not answered yet are: “How reliable is the map?”, “Do we need new ways of assessing quality?”, “What is the impact of the map quality on soil applications?”, “Does the soils map convey sufficient information on the properties of the mapped land?”, and “Is low usability caused by the wrong combination of data, algorithms or models for a given application, or is it simply a matter of poor communication?”

How Can Soil Scientists Meet the Ethnopedological (Anthropogenic) needs of Soil Science?

Although the topic of soil classification is an old one, it is not resolved yet. Current soil classification focuses on natural soils (genoforms) and this is a limitation when studying land use. Current Soil Taxonomy does not relate soils to landscapes well. It does not consider dynamic soil properties (such as hydraulic properties and those effected by short-term land management). Soil Taxonomy is viewed by many as too complex for nonpedologists. Soil survey has focused on classifying soils and thus neglected the quantification of variability (or specific range of soil properties) within taxonomic categories and soil map units, leading to a common assumption of “homogeneity” within soil taxa and map units by nonpedologists. Quantification of map unit purity for different scales of soil maps is an area needing improvements in modern soil surveys (Lin *et al.,* 2005a). So, soil survey can be extended to effects of soil management on any given soil series by distinguishing phenoforms (Bouma, 2005). But, the question arises “How do farmers classify and manage their soils?”

The efforts of understanding local soil classification, which were based on ethnoscientific methods, have not been very successful in relating local soil categories to “soil management processes” such as enhancement of soil fertility, soil erosion and its control, and conservation of soil/water in farming. Ethnopedology is a part of ethnoecology, the study of indigenous environmental knowledge (Toledo, 1992), and a hybrid discipline structured from the combination of natural and social sciences (Barrera-Bassols *et al.,* 2006). There have been suggestions for a new type of soil science that is part of a network society (Bouma, 2001) and geared towards a soil care approach (Yaalon, 1996) or in close relation with society (Yaalon and Arnold, 2000). To keep the soil science alive we have to remain relevant and produce results that are meaningful to society. Soil science was strong when benefiting society was its major goal (social and societal demands-driven). Our future depends on our ability to engage the public in decisions about the science. Soil science could be more effective in the society if different sub-disciplines of soil science are integrated.

Solid examples of just how to integrate scientific and local knowledge in land management practice are what is missing from the literature. Local soil knowledge does not exist in a social vacuum, and needs to be understood within a particular socioeconomic, historical, and cultural context. Knowledge and practice may well be linked to historical procedure, and in order to understand current local soil knowledge, researchers need to be aware of past historical and socioeconomic situations. Thus the establishment of a new local soil classification system is of paramount importance. So how can soil scientists meet the social demands for soil science development if they ignore anthropogenic soil studies driven by social demands in the future? Future farmer’s demands are to integrate information- and farming system to increase long term farm production efficiency, productivity and profitability while minimizing negative environmental impacts.

Is Image Analysis Quantifying the Environmental Impacts of Solute Transport?

Agricultural management, soil remediation and groundwater protection require ways of quantifying transport processes in the unsaturated zone between the soil surface and the groundwater table. Solute transport and leaching of chemicals in the unsaturated zone which is highly irregular and difficult to simulate or predict remains an important research topic in soil science (Vanderborght *et al.,* 2002). The concern is mainly about the environmental impact of chemicals applied, stored, dumped, or accidentally spilled at or near the soil surface. Commonly used procedures to monitor the leaching process are in situ extraction of soil solution using suction samplers or extraction of soil samples that were taken from the field and laboratory columns. An alternative for soil solution samplers is the Time Domain Reflectometry (TDR) technique that infers the concentration from the in situ measured bulk soil electrical conductivity (Vanclooster *et al.,* 1993; Ward *et al.,* 1994). The main problem with these methods is the solutes travel along pathways of different transport characteristics and that the spatial arrangement and scale of these pathways are not known.

To investigate transport processes in soils, detailed information about the spatial distribution of solutes is required. We need test solutes that probe the dominant properties of the travel routes. These environmental probes must, at the same time, be detectable with a high spatial and spectral resolution. Digital image analysis is well suited and focuses on developing a method to quantify flow patterns which allows an objective comparison of infiltration patterns observed at different sites or under different treatments. Imaging analysis acquires both spectral and spatial information (Liu *et al.,* 2006) to detect some subtle features for visualizing and quantifying solute infiltration into soil. Using spectral imaging techniques with image processing algorithms and multivariate analysis may opens a new avenue for quantifying solute transport and hence for precision farming.

What Is Wrong with Conventional Soil Models for Precision Agriculture?

Over the past few decades agricultural production has progressed from the machinery age to the information age which has been known as precision agriculture. Precision agriculture is “an integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing negative environmental impacts” (Kaleita and Tian, 2002).

Precision agriculture aims to vary the inputs of agrochemicals to individual fields to avoid over-application, which can lead to under-production, decreased profitability and adverse environmental effects (Castrignano *et al.*, 2008). To achieve this goal, a more detailed resolution of the variation in certain soil properties for site-specific application (Wetterlind *et al.*, 2008) and accurate maps of the soil properties likely to influence crop yield within fields are needed. The inability to obtain soil characteristics rapidly and inexpensively remains one of the biggest limitations of precision agriculture (Adamchuk *et al.*, 2004). Geospatial technologies including geographic information system, global positioning system, and remote sensing are extensively utilized in precision agriculture to understand the dynamic soil-water relation.

Is Pedology Dying or Thriving? Bridging the Gap through Hydropedology

The emphasis of pedology is now shifting from classification and inventory (geology-rooted classical pedology) to understanding and quantifying spatially and temporally variable processes (a hydrology-driven approach with a landscape perspective) upon which the water cycle and ecosystems depend. The integration of the two disciplines, pedology and hydrology, is suggested in recent literature and professional activities (*e.g.*, Lin *et al.*, 2005b, 2006; Bouma, 2006; Wilding and Lin, 2006). Hydropedology has been suggested as an intertwined branch of soil science and hydrology that synergistically integrates the classical pedology with soil physics and hydrology to study the pathways, fluxes, storages, residence times, and spatiotemporal organization of water in the root zones (Lin *et al.*, 2005a). Lin *et al.* (2005b) have provided a comprehensive summary of the role of hydropedology in bridging bio- and geosciences at multiple scales in the unsaturated zone. They suggest that hydropedology contributes to a better understanding of a wide variety of environmental, ecological, geological, agricultural, and natural resource issues of social importance. As examples, these include water and soil quality, landscape processes, watershed management, nutrient cycling, contaminate fate, waste disposal, precision agriculture, climatic change, carbon sequestration, and ecosystem functions.

Soils are often represented as static entities in most soil resource assessment (Bell, 2005). Certain soil characteristics important for land-use management can be changed considerably through time in response to variations in climate. Various soil hydromorphological features are signatures of hydrology in the unsaturated zone. As such, the dynamic nature of soils is ignored or minimized as we use traditional soil maps to represent spatial, but not temporal variations. Multiple conceptual dynamic soil-landscape models are necessary to formalize knowledge on soils. The major link to understand soil–landscape is hydropedology. Hydropedology, in combination with hydrogeology, suggests a more integrated and holistic approach to study water–soil–rock interactions. While hydroclimatology, hydrogeology, and ecohydrology are now well recognized, an important missing piece of puzzle is hydropedology that focuses on the interface between the hydrosphere and the pedosphere. Hydropedology closes this gap and emphasizes flow and transport processes in situ soil systems as landscape bodies (i.e., soils that have distinct characteristics of pedogenic features, structure, layering, and soil–landscape relationship). This integration suggests a renewed perspective and a more integrative approach to study dynamic landscape-soil-water interactions across scales, and their relationships to climate, ecosystem, and land use.

Soil science should position itself to utilize advances in landscape science using remote sensing and GIS tools (Shepherd and Walsh, 2006) that enable more rapid construction of diagnostic soil maps at scales that will bring out appreciation of the diversity. By recognizing the dynamic nature of soils in mapping, we are able to provide valuable information for the use and management of soils and hence sustainable use of soil resources. It would seem apparent that hydropedology is a useful framework for modern soil survey and its updates. Hence, significant potential exists for enhancing soil classification and inventory that ties soils to landscapes in a more systematic and quantitative fashion.

Are Pedologists Overlooking Unconventional Soil Science?

More than a decade ago, soil scientists have often focused their work on agricultural land, overlooking soils of urban, industrial, traffic and military areas that were considered unconventional to their expertise. Well informed pedologists would argue that the evolution of these soils in a function of usual formation factors just like normal soils, yet the anthropogenic factor is more intense. Enhanced environmental awareness is generated new projections and convictions. In the process, it triggers irregular transformation cycles comprising addition and subsequent mixing of exogenous materials. Thus the unconventional soils are characterized by extreme spatial heterogeneity. In addition, soils in localities may incorporate pollutants inducing environmental degradation and posing potential hazard to public health. Such problems were recognized by some scientists, and their objective was to define appropriate procedures to survey, classify, manage and utilize these unconventional soils. They also intended to prove that soil scientists can extend mutual understanding between cultures and strengthen human tolerance (Suitma, 2005).

Final Thought

These are the future challenges to be addressed by all professional soil scientists and alike to help insure the viability of the discipline. These cornerstones may be changing the image and visibility of soil science. Soil science research has contributed greatly to the world. We should not let it now be a victim of its own success. There are encouraging signs that soil scientists are extending their expertise and contributions more effectively with other bio- and geosciences. This is not intended to narrow the discipline's scope but rather to make it more inclusive. This process will likely enhance the visibility, image, and outreach of the soil science community worldwide. It should result in further employment of soil scientists within the bio and geo-science community in academic units of higher education, government institutions, agencies, and non-governmental organizations. However, its effectiveness will be limited if the knowledge of soil in educational entities continues to be institutionally eroded and/or de-emphasized. Thus, the road ahead is full of challenges and opportunities for soil scientists. The crucial question is "Are we prepared to face these challenges and benefit the opportunities?"

Conclusions and Follow-Up

Recall that the purpose of this vision paper is to draw the future image of soil science. The future image is not so bright if it is business as usual of traditional soil science. We should get out of the traditional soil science. Future challenges will include unifying soil science knowledge within the discipline and other closely related disciplines, such as hydrology and environmental sciences. Soil scientists will need to effectively participate in interdisciplinary studies without loosing their own roots and identities.

To become a bio- and geo-science leader, however, it is necessary to re-looking for the role of soil science in the society. Soil science must broaden its purview, become more encompassing, sharpen its tools, enhance communication skills, deepen its knowledge base, and effectively bridge with other bio- and geo-science disciplines. If we need to maintain our identity as soil scientists, there is a suggestion for a new type of soil science that is more holistic and in close relation with society network. A number of major questions for future image of soil science needs to be answered: risk assessment of soil threats for sustainable soil resources, soil quality indicators for sustainable land management, scale matters, pedometrics and spatial prediction of soil properties, soil information system development, accuracy assessment and quality assurance, anthropogenic of soil science, image spectroscopy and the environmental impact of solute transport processes, precision agriculture, hydropedology and dynamic soil-water interaction modeling, soil classification system, and unconventional soil science.

As soon as soil scientists begin to venture beyond the rigid limits they have themselves imposed to their work in the past, the discipline of soil science will flourish far beyond its status 30 or 40 years ago, in the prime of its "agricultural" era. This will make the soil science to be smart.

ACKNOWLEDGMENTS

Special thanks go to Prof. Dr. M. Reda, Miss. S.M. Reda and Prof. Dr. R.K. Rabie for their comments on a draft of this article.

REFERENCES

ADAMCHUK, V.I., J.W. HUMMEL, M.T. MORGAN, AND S.K. UPADHYAYA. 2004. On-the-go soil sensors for precision agriculture. Computers and Electronics in Agriculture **44**: 71–91.

BARRERA-BASSOLS, N., J.A. ZINCK, AND E. VAN RANST. 2006. Symbolism, knowledge and management of soil and land resources in indigenous communities: Ethnopedology at global, regional and local scales. Catena **65**: 118–137.

BAVEYE, P. 2006. A vision for the future of soil science. In A. Hartemink (ed.), The Future of Soil Sciences, International Union of Soil Sciences.

BAVEYE, P., A.R. JACOBSON, S.E. ALLAIRE, J. TANDARICH, AND R. BRYANT. **2006**. Whither goes soil science in the US and Canada? Survey results and analysis. Soil Science **171(7):** 501-518.

BELL, J. 2005. Dynamic soil mapping: adding the temporal dimension. Pedometric, 12-14. Florida, USA.

BISHOP, T.F.A., A.B. MCBRATNEY, AND B.M. WHELAN. 2001. Measuring the quality of digital soil maps using information criteria. Geoderma **103**: 95–111.

BOUMA, J. 2001. The new role of soil science in a network society. Soil Science **166**: 874-879.

BOUMA, J. 2005. Soil scientists in a changing world. Advances in Agronomy **88**: 67-96.

BOUMA, J. **2006**. Hydropedology as a powerful tool to environmental policy research. Geoderma **131(3-4): 275-286.**

BREUNING-MADSEN, H. 2006. The future of soil science in industrial societies. In A. Hartemink (Ed.), The Future of Soil Sciences, International Union of Soil Sciences.

BRIDGES, E.M., AND M. CATIZZONE. 1996. Soil science in a holistic framework-Discussion of an improved integrated approach. Geoderma **71**: 275-287.

CASTRIGNANO, A., G. BUTTAFUOCO, AND R. PUDDU. 2008. Multi-scale assessment of the risk of soil salinization in an area of south-eastern Sardinia (Italy). Precision Agriculture **9**: 17–31.

DEVILLERS, R., Y. BEDARD, AND R. JEANSOULIN. 2005. Multidimensional management of geospatial data quality information for its dynamic use within GIS. Photo-grammetric Engineering and Remote Sensing

71(2): 205-215.

DUMANSKI, J., AND A.J. SMYTH. 1994. The issues and challenges of sustainable land management. Procceding of the International Workshop on Sustainable Land Management for the 21st Century. In Wood, R.C. and Dumanski, J. (Eds.) Plenary Papers. Agricultural Institute of Canada, Ottawa **2**.

ECKELMANN, W., R. BARITZ, S. BIALOUSZ, P. BIELEK, F. CARRE, B. HOUSKOVA, R.J.A. JONES, M.G. KIBBLEWHITE, J. KOZAK, C. LE BAS, G. TOTH, T. TOTH, G. VARALLYAY, M. YLI HALLA, AND M. ZUPAN. 2006. Common Criteria for Risk Area Identification according to Soil Threats. European Soil Bureau Research Report No.20, EUR 22185 EN, 94pp. Office for Official Publications of the European Communities, Luxembourg.

FAO. 1997. Land quality indicators and their use in sustainable agriculture and rural development, Land Water Bulletin, 5, Rome.

FROSSORD, E. 2006. The future of soil science: the role of soils for the society and the environment. In A. Hartemink (Ed.), The Future of Soil Sciences, International Union of Soil Sciences.

GROOT, R. 1993. Making information technology work. ITC Journal **3**: 228–235.

HARTEMINK, A.E., A.B. MCBRATNEY, AND, J.A. CATTLE. 2001. Developments and trends in soil science: 100 volumes of Geoderma 1967–2001. Geoderma **100**: 217-68.

HENGL, T., D.G. ROSSITER, AND A. STEIN. 2003. Soil sampling strategies for spatial prediction by correlation with auxiliary maps. Australian Journal of Soil Research **41**: 1403-1422.

HEUVELINK, G.B.M., D.J. BRUS, AND J.J. DE GRUIJTER. 2004. Optimization of sample configurations for digital soil mapping with universal kriging, Global Workshop on Digital Soil Mapping, Montpellier.

KALEITA, A.L., L. TIAN. 2002. Remote sensing of site-specific soil characteristics for precision farming. ASABE Paper No. 021078. St. Joseph, Mich.: ASABE.

KIRK, G. 2006. Views on the future of soil science. In A. Hartemink (ed.), The Future of Soil Sciences, International Union of Soil Sciences.

LAL, R. 2006. Soil science in the era of hydrogen economy and 10 billion people. In A. Hartemink (Ed.), The Future of Soil Sciences, International Union of Soil Sciences.

LIN, H., D. WHEELER, J. BELL, AND L. WILDing. 2005a. Assessment of soil spatial variability at multiple scales. Ecol. Modell. **182**: 271–290.

LIN, H., J. BOUMA, L. WILDING, J. RICHARDSON, M. KUTILEK, AND D. NIELSEN. 2005b. Advances in hydropedology. Advanced Agronomy **85**: 1–89.

LIN, H., J. BOUMA, Y. PACHEPSKY, A. WESTERN, J. THOMPSON, R. VAN GENUCHTEN, H.J. VOGEL, AND A. LILLY. 2005. Hydropedology: Synergistic integration of pedology and hydrology. Water Resources Research DOI 10.1029/2005 WR 004085.

LIU, Y., Y.R. CHEN, C.Y. WANG, D.E. CHAN, AND M.S. KIM. 2006. Development of hyperspectral imaging technique for the detection of chilling injury in cucumbers; spectral and image analysis. Applied Engineering in Agriculture **22(1)**: 101-111.

MATTHEWS, K.B., G. SCHWARZ, K. BUCHAN, M. RIVINGTON, AND D. MILLER. 2008. Wither agricultural DSS? Computers and electronics in agriculture **61**: 149-159.

MCBRATNEY, A. 2006. Musings on the future of soil science (in ~ 1 k words). In A. Hartemink (Ed.), The Future of Soil Sciences, International Union of Soil Sciences.

MCBRATNEY, A.B., M.L. MENDONCA SANTOS, AND B. MINASNY. 2003. On digital soil mapping. Geoderma **117**: 3–52.

MCBRATNEY, A.B., I.O.A. ODEH, T.F.A. BISHOP, M.S. DUNDAR, AND T.M. SHATAR. 2000. An overview of pedometric techniques for use in soil survey. Geoderma **97**: 293-327.

MERMUT, A. 2006. The future of soil science. In A. Hartemink (Ed.), The Future of Soil Sciences, International Union of Soil Sciences.

MERMUT, A.R., AND H. ESWARAN. 2001. Some major developments in soil science since the mid-1960s. Geoderma **100**: 403-426.

OMRAN, EL.E. 2005. Spatial Data Infrastructure to Support Land Evaluation Applications in Egypt. MSc Thesis Report GIRS-2005-016, Centre for Geo-Information, Wageningen Univesity, The Netherlands.

OMRAN, EL.E. 2007. Spatial Data Infrastructure to Support Land Evaluation Applications (SDILEA) in Egypt. Geoderma, (under review).

OMRAN, EL.E., J. CROMPVOETS, AND A.K. BREGT. 2006. Benefits and bottlenecks for SDI development in Egypt. GIS Development **2(1)**: 32-35.

PACHEPSKY, Y.A., D.E. RADCLIFFE, AND H.M. SELIM. 2003. Scaling methods in soil physics, CRC Press, Boca Raton, Florida.

ROSSITER, D.G. 2001. Methodology for Soil Resource Inventories. 2nd edn. ITC Lecture Notes SOL.27. Enschede, the Netherlands.

SHARMA T., J. CARMICHAEL, AND B. KLINKENBERG. 2006. Integrated modeling for exploring sustainable agriculture futures. Futures **38**: 93–113.

SHEPHERD, K.A., AND M.G. WALSH. 2006. Diffuse reflectance spectroscopy for rapid soil analysis. In R. Lal (Ed.), Encyclopaedia of Soil Science, Taylor and Francis Books, NY.

SINGER, M.J., AND S. EWING. 2000. Soil quality. In M.E. Sumner (Ed.), Handbook of Soil Science, CRC Press, Boca Raton, pp. G-271–G-298.

SMITH, C. 2000. The precautionary principle and environmental policy. Science, uncertainty and sustainability. International Journal Occupational and Environmental Health **6**: 263–265.

STROOSNIJDER, L. 2005. Measurement of erosion: is it possible? Catena **64**: 162-174.

Suitma. 2005. Third International Conference on Soils of Urban, Industrial, Traffic, Mining and Military Areas.

Toledo, V.M. 1992. What is Ethnoecology? Origins, Scope and Implications of a Rising Discipline. Etnoecologica I **1**: 5-21.

Vanclooster, M., D. Mallants, J. Diels, and J. Feyen. 1993. Determining local-scale solute transport parameters using time domain reflectometry (TDR). Journal Hydrology **148**: 93–107.

Vanderborght, J., P. Gahwiller, H. Wydler, U. Schultze, and H. Fluhler. 2002. Imaging Fluorescent Dye Concentrations on Soil Surfaces: Uncertainty of Concentration Estimates. Soil Science Society of America Journal **66**: 760–773.

Ward, A.L., R.G. Kachanoski, and D.E. Elrick. 1994. Laboratory measurement of two-dimensional saturation fields measurements of solute transport using Time Domain Reflectometry. Soil Science Society of America Journal **58**: 1031–1039.

Western, A.W., R.B. Grayson, and G. Bloschl. 2002. Scaling of soil moisture: A hydrologic perspective, Annual Review. Earth Planet Science **205:** 20-37.

Wetterlind, J., B. Stenberg, and M. Soderstrom. 2008. The use of near infrared (NIR) spectroscopy to improve soil mapping at the farm scale. Precision Agric **9**: 57–69.

Wilding, L., and H.S. Lin. 2006. Advancing the frontiers of soil science towards a geoscience. Geoderma **131(3-4)**: 257-274.

Yaalon, D.H. 1996. Soil science in transition-Soil awareness and soil care research strategies. Soil Science **161**: 3-8.

Yaalon, D.H., and R.W. Arnold. 2000. Attitudes toward soils and their societal relevance: Then and now. Soil Science **165**: 5-12.

Received June 17, 2008
Accepted August 29, 2008

هَلْ مات عِلْمُ الأراضى ودُفن؟
الصورة المستقبلية فى عالمِ العشرة بليون شخصِ

السيد عويس عمران
قسم الأراضى والمياه، كلية الزراعة، جامعة قناة السويس، الإسماعيلية، مصر

الملخص العربى

هلْ هُناك مستقبل لعِلْم الأراضى؟ بالطبع نعم، فمع زيادة عدد السكان وزياده متطلباته يجب أن يكون هناك زيادة فى إنتاج الغذاء لمواجهة إحتياجات ما يقرب من 3.5 بليون شخصٍ زيادة متوقعه فى عدد السكان خلال الأربعين سَنَة القادمة. كما أن هذه الزياده الهائله فى عدد السكان سوف تواجه العديد من المشكلات والتحديات خلال تلك الفترة، مثل نُدرة مصادر المياه، والتصحر وتدهور الأراضى، وإستخدامات الأراضى المختلفه، والتغير فى المناخ العالمى، وفى نوعية وجودة الماء والهواء، كل هذه المشكلات والتحديات لها علاقة مباشرة بالتربه وتمثل جزء بسيط من التحديات المستقبلية التى يجب أن تحظى بإهتمام علماء الأراضى.

المستقبل ليسَ لامعاً جداً إذا ظل علمُ الأراضى عِلْم تقليدى كما هو. واذا ظل علم الأراضى بصورته الحاليه فانه لن يواجه التحديات السابقه. لذا فإنه من الضرورى أن يُعاد التفكير والبَحث عن دور عِلْم الأراضى فى المجتمعِ. حيث يَلْعب عِلْم التربة دوراً هاماً في إكتِشاف وحلّ المشكلاتِ البيئية. لذلك فإن علماء الأراضى بحاجة إلى المزيد من التعاون والمُشَارَكَة فى الدراسات والأبحاث العلمية المتعددة حتى يتمكنوا من مواجهة هذه التحديات بنجاح مع حرصهم على المحافظة على جذورهم وهويّاتِهم كعلماء أراضى وبالتالى سيكون هناك مستقبلَ أفضل لعِلْمِ التربة خاصة إذا كان مرتبطاً بالعلوم الأخرى.

إذا كنا نريد الإبْقاء على هويتِنا كعلماء للأراضى، فهناك إقتراح لنوع جديد مِنْ عِلْوم الأراضى أكثر شمولية وعلى علاقة وثيقة بمتطلبات وإحتياجات المجتمع. إن صورة عِلْم التربة المستقبلية يجب أن تَتضمّن الدراسات والأبحاث فى المواضيع التالية: النماذج الرياضيه والديناميكيه للتربة، تقييم مهددات ومخاطر التربة، الإستخدام الأمثل لمصادر التربه، الهيدروبيدولوجى، التنبؤ بخرائط التربه الرقميه، تطوير نظام معلومات التربة، عِلْمِ التربة وعلاقته بالمجتمع، دلائل لجودة التربة للاستخدام الأمثل، الزراعة الدقيقه، نظام لتصنيف وتقسيم التربة، علم التربة غير التقليدى.