IUSS 2006. PO Box 353, 6700 AJ Wageningen, The Netherlands. The Future of Soil Science / edited by Alfred E Hartemink. Wageningen: IUSS International Union of Soil Sciences.

Future of Soil Science (pages 51-53)
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To address the future of soil science requires understanding its historic roots, societal needs and knowledge gaps. This brief article provides an outlook on the future of soil science in a postmodern technology-driven world that is faced with limited earth resources.

Soils vary gradually in geographic space and through time and form complex patterns in dependence of multiple interrelated environmental factors and anthropogenic and natural forcing functions. Soil science research has been focused on the genesis of soils, their composition, factors that influence them, and their geographical distribution. Numerous specialized soil science sub-disciplines have developed including soil mineralogy, microbiology, chemistry, physics and pedology to name only a few. This segregation into separate units has generated detailed understanding of soils. Future challenges will include unifying soil science knowledge within the discipline and other closely related disciplines, such as hydrology and environmental sciences, to move toward understanding the complex ways in which various separate earth compartments are interacting with each other at landscape scales. Modern soil scientists will need to effectively participate in interdisciplinary studies without loosing their own roots and identity. It will be important that soil scientist play an active role not only in generating soil datasets and information but transfer and share knowledge with stakeholders, decision makers, land use planners, politicians and others. Soil science must continue to expand beyond its traditional identification with agriculture as it becomes a partner in the earth, ecological and environmental sciences.

Multiple conceptual soil-landscape models have been developed to formalize knowledge on soils. For example, factorial soil-formation models use functions to relate environmental factors such as climate, topography, land cover, geology, and others to soils. Historically rooted in geology and anatomy, numerous soil taxonomies have been developed. Soil surveys have been focused on mapping of morphological soil characteristics and taxonomic classes derived from field observations. This double crisp approach segregates the soil continuum into crisp map units (polygons) and aggregates multiple soil characteristics to derive taxonomic data. Numerous soil classification schemes are used world-wide to group soils into different categories. But it might be too simple to assume that we can accommodate the needs for society at large by aggregating pedon descriptions and taxonomic map units often too coarse for site-specific applications. The demand for high-resolution, site-specific soil attribute data is enormous to address a variety of local, national and global issues. These include but are not limited to precision agriculture, assessment of environmental quality, conservation management, sustainable land resource management, carbon sequestration and global climate change and others.

Global connectivity, knowledge and information sharing have motivated holistic studies that focus on understanding functional relationships among ecosystem components. In this context, soil science plays a major role providing knowledge on soil patterns, processes and landscape dynamics. Ecosystem services characterize the functions that are useful to humans and contribute to ecosystem stability, resilience, sustainability and integrity. These services are diverse ranging from physical (e.g. best management practices that reduce nutrient leaching) to socio-economic (e.g. crop production, cultural values) and aesthetic. Ecosystem services provided by multi-functional and multi-use landscapes are affected by the type, intensity, and spatial arrangement of land use and human activities as well as soil-landscape properties. Soil science has the potential to contribute to the valuation of ecosystem services.

There are three major areas that have contributed to a gradual shift from qualitative to more quantitative soil-landscape characterization: (i) *Novel mapping tools and techniques* such as soil sensors (e.g. electromagnetic induction, diffuse reflectance visible/near/mid-infrared spectroscopy), global positioning systems, airborne and satellite based remote sensing, and Light Detection and Ranging (LIDAR), etc. (ii) *Data management* - Geographic Information Systems and database management systems, (iii) *Computing power* to process multidimensional environmental dataset and (iv) *Methods* - advanced multivariate statistical and geostatistical methods, three-dimensional reconstruction techniques to create soil-landscape models, and algorithms that describe pedogenic processes. Digital soil mapping and modeling techniques have shown much promise for rapid and cost-effective soil mapping at high spatial resolutions covering large regions. These methods often combine advanced mathematics and statistics to process comprehensive, multidimensional environmental datasets in concert with measured soil observations. A comprehensive overview of digital soil mapping and modeling was presented by McBratney et al. (2000; 2003) and Grunwald (2006). Pedometrics, defined as the application of mathematical and statistical methods for the study of the distribution and genesis of soils, will play a critical role to shape the future of soil science. It integrates soil science with other disciplines such as GIScience and mathematics and facilitates spatially and temporally explicit mapping of soil attributes. Recently, pedometrics was adopted as a new Commission of the International Union of Soil Sciences. A more quantitative approach to soil science will enable to close knowledge gaps and improve our understanding of pedogenic processes at micro-, meso- and macro-scales, non-linear behavior of ecosystem processes, biogeochemical cycling at multiple spatial and temporal scales, and assess effects of human activities and natural forcing functions on soil quality. To incorporate uncertainty into soil science applications will be important to optimize sustainable land resource management. Although generic relationships between soil attributes and environmental factors have been identified, they are domain specific and may change through time. Thus, no universal equation or model exists that fits all soil-landscapes. There is ample opportunity for soil scientists to fill these research gaps using deductive and inductive scientific techniques.

Interdisciplinary educational programs will be pivotal to train the next generation of soil scientists. Future soil scientists require broad training rooted in traditional soil science (physics, chemistry, microbiology, and pedology) complemented by analytical, quantitative and geospatial modeling skills. The web-based distribution of 2D soil maps and data will continue to play a major role to disseminate information widely. Scientific visualization and reconstruction techniques to create 3D and 4D soil-landscape models will facilitate to better communicate knowledge on soils to the general public. Finally, we should not forget that the future of soil science does not only dependent on data and facts but requires genuine motivation and enthusiasm for the subject matter.

References

Grunwald, S. (ed.) 2006. Environmental Soil-Landscape Modeling – Geographic Information Technologies and Pedometrics. p. 488. CRC Press, New York.

McBratney, A.B, I.O.A. Odeh, T.F.A. Bishop, M.S. Dunbar, and T.M. Shatar. 2000. An overview of pedometric techniques for use in soil survey. Geoderma 97: 293-327.

McBratney, A.B., M.L. Mendonça Santos, and B. Minasny. 2003. On digital soil mapping. Geoderma 117: 3-52.