Soil Management and Some Solutions for Soil Change

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Abstract: *Soils represent a considerable part the natural resources. Consequently, rational land use and proper soil management – to guarantee normal soil functions – are important elements of sustainable development, having particular significance both in the national economy and in environment protection.*

Introduction

We believe one of the most critical natural resource management needs of the 21st century is information about the dynamic nature of soil, or simply, soil change. This concern is prompted by the increasing evidence and awareness about human impacts on the condition of the nation's resources and the tacit demand for sustained use of soil. To meet this need, information about how soils change as a result of natural factors and human activities should be added to surveys of the National Cooperative Soil Survey (NCSS). The objectives of this paper are to present the soil change concept and to propose a strategy for meeting information needs related to soil change.

The soil, as the major medium for plant growth, is the basic resource for all land use and development. Ecologically sustainable development is not feasible unless it includes, as a basic concept, the conservation and sustainable use of soils.

Soils are products of interactions between abiotic processes, including physical and chemical weathering, temperature regimes, hydrology etc., and biotic processes, including the production of organic matter (plants) by photosynthesis, uptake of water and nutrients by plants and the eventual return of this organic matter to the soil through decomposition.

Land management and soil change

Today's land managers and policymakers require information about how soils change to compare alternatives and make decisions that balance goals for production, economics, sustainability, and the environment. Soil change data are needed to

(i) establish quality criteria and measures of performance;
(ii) interpret assessment and monitoring results;
(iii) predict management effects on resource condition;
(iv) support management of sustainable production systems;
(v) prevent soil and land degradation; and
(vi) support restoration and remediation activities.

We define soil change as temporal variation in soil properties at a specific location. The temporal variation may be determined for a variety of time scales and is driven by natural factors, human use and management, or their combined impacts. Soil changes through time, although change is not caused by time. Soil properties emerge as a result of pedogenesis, are affected by historical land use, and are currently changing in modern ecosystems that have increasing human influence. The increasing human influence, however, has dramatically altered the type, intensity, and rate of change for many soils.

Almost all soil properties change eventually. Dynamic soil properties vary across space as well as through time. In this paper, we do not refer to the "changes" in soil properties across a soil boundary line or through the gradient of an ecotone. For that context, we use the terms "differences" or spatial variability. Dynamic soil properties such as water and organic matter content or salinity generally have greater spatial variability than more stable properties such as soil texture and mineralogy. Changes in the spatial distribution of dynamic soil properties, such as the increased concentration of SOC in the surface layer under shrubs and its corresponding depletion in intershrub spaces following shrub invasion of semiarid grasslands, result in increased spatial variability at the map unit scale and are important indicators of changes in ecological processes. Some types of spatial patterns resulting from human impacts are currently addressed in soil survey through naming conventions and classification. Phase (e.g., erosion, deposition) and soil taxon names (e.g., Arents), however, only reflect the results of past management and do not provide information related to the dynamics of soil behavior.

The ability of a soil to resist disturbances (resistance) and to recover functionally (resilience) is an important ecological concept for managed and unmanaged ecosystems and agricultural systems. The resistance and resilience of a specific soil to a disturbance depend on relationships between processes and relatively static and dynamic properties. Thus, the development of interpretations for soil change requires the integration of pedological and ecological studies. We generally study pedogenic and geomorphic processes to explain the formation, composition, morphology, and distribution of soils and landscapes. Studies of primary ecological processes including energy flow, the hydrologic cycle, and nutrient cycling are also needed to determine dynamics, fluxes, and functional capacities of soil systems.

The importance of soil change is that it affects soil function. The ultimate consequences of change depend on its reversibility. With knowledge of cause and effect relationships regarding detrimental soil change, land managers can choose practices and policymakers can establish programs that promote positive changes in the soil resource and the environment. Through improved understanding of soil resistance and resilience, decision makers will also be able to develop management strategies to protect soil functions that may be important in the future.

Changes in dynamic soil properties can be measured over time through long-term studies or monitoring. They can also be estimated by the careful substitution of space-for-time by comparing locations (having the same soil but different current conditions) where

(i) the past conditions are known or can be inferred with sufficient precision and
(ii) an operational model that hypothesizes causes and effects of change is available.

Integrating soil change in soil survey requires advances in the science of soil change. Furthermore, advancing the science, understanding user needs, and developing technologies of soil change for soil survey is an iterative process. Six elements, which can also be considered benchmarks of progress, are included in the blueprint:
Identify user needs.

(i) Conduct interdisciplinary research and long-term studies.
(ii) Develop an organizing framework that relates data, processes, and soil function.
(iii) Select and prioritize soil change data and information requirements.
(iv) Develop procedures for data collection and interpretation.
(v) Design an integrated soil–ecosystem–management information system.

Identify User Needs

The desired outcome of this element is to define data elements and soil information requirements for different types of needs. Users are generally seeking answers to one or more questions about the potential impacts of use and management on the capacity of the soil to function. The answers to these inquiries relate to soil change and the dynamic nature of soil. Specific applications such as the example presented in this paper must be identified so that the appropriate data and information can be collected. Currently, both open-ended and direct questions posed to users will likely prompt responses of limited value because the use of soil change data is a new paradigm. Workshops users, technical specialists, and scientists are useful tools for educating different groups and identifying their needs.

Soil change as a field of study should strive to identify and quantify functionally important characteristics, called attributes of soil change, to describe and predict soil change on the human time scale. This element is designed to bridge the gap between disciplines (e.g., pedology, soil sciences, hydrology, geomorphology, biogeochemistry, soil ecology, microbiology, forest sciences, range sciences, terrestrial and plant community ecology, agronomy, sociology), many of which address the same system but from different perspectives . Traditional pedology research should be conducted collaboratively with disciplines that address the ecology and management of natural and agricultural resources. Interdisciplinary analysis at multiple scales should be followed by reductionistic basic research in relevant areas.

The form in which information on soil change is to be reported will help determine data collection and analysis procedures. Reportable parameters may include mean, median, minimum, maximum, indices, ratios, variance, confidence interval, or statistical significance in differences. Alternatively, soil survey information could be provided through a textual description of temporal variability, spatial distribution, and soil behavior. Another possibility is to provide mathematical or pedotransfer functions that allow users to calculate results from their own measurements. Appropriate reporting options should be determined through an analysis of user needs.

Many soil surveys are complete and the program of the future will focus on soil survey maintenance and upgrading activities. These activities should include data collection for soil change. Where funding is limited, efforts should focus on benchmark soils and other extensive soils. Soil surveyors will need additional sampling skills and a broader ecological background to successfully apply new soil survey protocols. The skills can be developed through training and by following standard soil survey protocols for soil change data collection and interpretation. The relative proportions of soil survey employees with specific skills may need revision with slight increases in individuals with data analysis and ecological expertise. Academic departments routinely adjust curricula to include new knowledge and technologies and should continue to make revisions corresponding to new soil survey needs.

Conclusion

Soil surveys should include information about causes of soil change over the human time scale and the resulting effects on soil function to meet user needs for decision making. The traditional application of use-neutral concepts in soil classification, mapping, and interpretations is necessary to make a consistent national inventory of the soil resource. Soils are a part of open, dynamic systems, however, and the effectiveness of managing these systems depends on the integration of information about how soils change in their environment through time. The concepts of soil change in soil survey are currently based on the pedogenic time scale. Increasing evidence shows that natural disturbances, land use, and management practices can change soil properties over periods of centuries, decades, or less. Providing information about the human impacts on soil is not enough to meet resource management needs. Land managers and other decision makers also need information about naturally driven changes that occur on the human time scale. Making new advances in soil survey through the addition of information about soil change on the human time scale is a profound and unique opportunity that will benefit generations to come. Increased availability of soil change information will expand the application of soil information in agriculture and natural resource management. It may take a generation to complete the task, but in so doing, soil scientists will develop skills and knowledge about systems and the ecological processes that comprise soil behavior. Increased understanding of soil change on the human time scale is critical to local and global issues of sustainability and the environment, both now and in the future.

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