Soil survey enhancements for natural resource management

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ABSTRACT

This paper illustrates how both new types of data and the reinterpretation of existing data can be used to improve the quality and value of soil survey interpretations for natural resource management. New data on soil resistance and resilience to different types of disturbance can be used to select dynamic soil properties for inclusion in future soil surveys. Other factors, including data cost and quality, must be considered in the selection of dynamic soil properties. In the short-term, we discuss an example of how GIS analysis tools can be used together with spatial slope and elevation information to produce more detailed thematic maps from existing Order 3 soil surveys. We conclude that (1) future soil survey enhancements depend on the development of soil and ecological site-specific information on dynamic soil properties, and (2) soil interpretations based on integration of GIS and process-based conceptual models increase the value of existing soil survey data.

1. INTRODUCTION

The soil survey is one of the most widely used sources of information for natural resource management. In rangelands, soils are used to stratify the landscape into ecological sites, which form the basis for organizing, interpreting and communicating knowledge to land managers. As more soil survey data become available digitally, they are increasingly being applied to diverse applications including restoration, prediction and control of invasive species, assessment and prediction of carbon sequestration potential, and as the foundation for monitoring changes in soil quality and rangeland health. Concurrently, at least three significant weaknesses in current soil survey products have become increasingly apparent: (1) there is relatively little information available on the range of variability in dynamic soil properties (Tugel et al. 2004), (2) soil information is not available at the appropriate scale and interpretations included in soil surveys of existing data are limited relative to current needs, and (3) detailed information on spatial variability in specific soil properties is inadequately reflected in the definition of soil map unit components and much valuable information that is collected during the soil survey process is lost.

New concepts and new technology offer unique opportunities to address each of these three limitations. The objectives of this paper are to briefly review the first two of these three issues and to provide an introduction to selected efforts to address them in the southwestern United States.

2. SELECTING DYNAMIC SOIL PROPERTIES BASED ON EXPERIMENTAL DEFINITION OF RESISTANCE AND RESILIENCE

Information on the potential range of variability in dynamic soil properties is extremely limited. It is unlikely that it will ever be possible to characterize the range of variability for all soil properties of interest. Consequently, it is necessary to select soil properties that reflect the current capacity of a soil to function and that can be used to predict the capacity of the soil to continue to function under a range of disturbance regimes (Herrick 2000). Dynamic soil properties can be used as both predictors and indicators of resistance and resilience (Figure 1). In other words, they both (1) affect resistance and resilience (together with relatively static properties) and (2) serve as indicators of resistance and resilience (when measured pre- and post-disturbance).

An experiment was established in 1997 to quantify the response of a suite of variables to three different types of disturbance on three different gypsic soils, effectively representing three different ecological sites (NRCS, 1997). The disturbances included trampling by horses, trampling by humans wearing lug-soled boots, and wheel tracks created by a jeep. The soils included a deep sand at the margin of active dunes, a deep loam, and a shallow sand over a petrogypsic horizon. The petrogypsic horizon at the third site was occasionally exposed at the surface. Each treatment was replicated on six 10 x 30 m plots on each soil. The measurements were selected based on previously documented sensitivity to changes in soil function. Measurements included a field test of soil stability (Herrick et al. 2001), relative saturated infiltration capacity (single ring infiltrometer (Bouwer, 1986)), nitrogen fixation potential based on nitrogenase activity, chlorophyll content based on the absorption of a DMSO extract and soil lichen cover and composition. Surface roughness was measured using an erosion bridge, and a torvane apparatus and a pocket penetrometer were used to provide information on crust strength. Vegetation measurements were also completed on all plots.

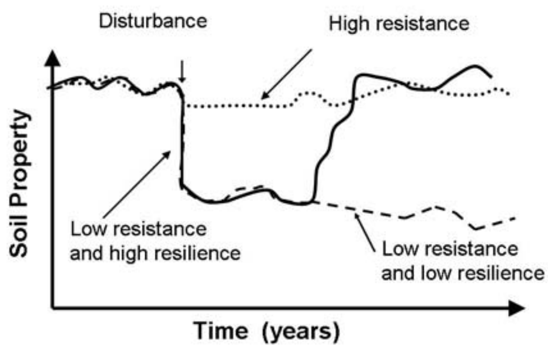

Figure 1. Conceptual diagram showing potential responses to stress or disturbance. Adapted from Seybold et al. (1999).

Preliminary analysis of the first four years of data showed that both resistance and resilience varied significantly with both disturbance type and soil. This suggests that extrapolation of disturbance response data may not be appropriate among different soils. The data also clearly showed that the recovery rate of different indicators varied widely. The implications of these differences for detecting and predicting long-term changes in soil function are currently being evaluated.

3. USING GIS TOOLS TO INCREASE THE POWER OF SOIL SURVEY INTERPRETATIONS

GIS tools are increasingly being applied to increase the amount and resolution of information that can be extracted from existing soil maps. The Raster Calculator within the Spatial Analyst Arc Map provides access to numerous tools that can be used to weight rasters and combine them as part of a suitability model, to select existing soil survey data using queries, and to apply mathematical operators and functions relevant to soil components within map units.

For example, in southern Nevada, we are applying GIS tools to increase our ability to predict soil erosion susceptibility of different map units. In the Spatial Analyst of ArcMap, using Raster Calculator, a conditional statement can be used to separate K-factors (from individual components) using slope from a digital elevation GIS layer. In our case we were interested in defining the product of the Kw or Kf and slope, and in displaying a continuous value throughout a range of slopes defined by the components within a map unit. This allows soils that have similar surface textures to be displayed using a generic index or value representing the potential water erosion, cell by cell throughout the map unit. This value is the same on the same range of slopes, but differs among map unit components.

Once the K-factor index of each map unit has been calculated, the Raster Calculator is used mosaic them back together. Most rasters that represent surfaces contain continuous values, whether the surface values represent elevation, slope, temperature, potential erosion, or vegetation density on a surface. It is often useful to display continuous surfaces with a continuous grayscale or color ramp. The Stretched option maps the low and high values in the raster to a 0–255 intensity scale. It is possible to change the way the values are mapped by changing the type of stretch used. In a pilot application in southern Nevada, This was done using a simple *stop light* color scheme, red, yellow and green, with red representing an potentially severe water erosion and green representing a relatively low water erosion potential.

4. CONCLUSIONS

We conclude that (1) future soil survey enhancements depend on the development of soil and ecological site-specific information on dynamic soil properties, and (2) soil interpretations based on integration of GIS and process-based conceptual models increase the value of existing soil survey data. While further research is necessary to define specific requirements soil and site-specific data, the pilot study reviewed here clearly demonstrates the value of these data.

5. REFERENCES

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