CHAPTER 9

Assessing Dynamic Soil Properties and Soil Change

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Dynamic soil properties (DSPs) are properties that change with land use, management, and disturbance over the human time scale (decades to centuries). In contrast, inherent soil properties (e.g., soil texture) change little, if at all, with changes in land use and management. The term "dynamic soil properties" was used by Tugel et al. (2005) to describe soil properties that can be documented as a part of soil survey activities. The procedures for measuring and recording DSPs were later outlined in the *Soil Change Guide* (Tugel et al., 2008). The term DSPs has gained common usage among soil scientists when referring to properties that can be changed intentionally or inadvertently through human land use and management, either directly (as through tillage) or indirectly (as through causing acid rain). While many soil properties (such as moisture, temperature, and respiration) are dynamic on daily, or smaller, time scales, information about them is not included in current soil survey products. The DSPs addressed by soil survey include properties that reflect soil functions and can serve as indicators of soil quality (or health) or indicators of ecosystem services. Dynamic soil properties are more pronounced at or near the soil surface and can be used to evaluate changes and departure from a benchmark or set of reference soil properties. Conceptually, this allows DSPs to be correlated with map unit components used in traditional soil survey (see chapter 4).

Importance of DSPs

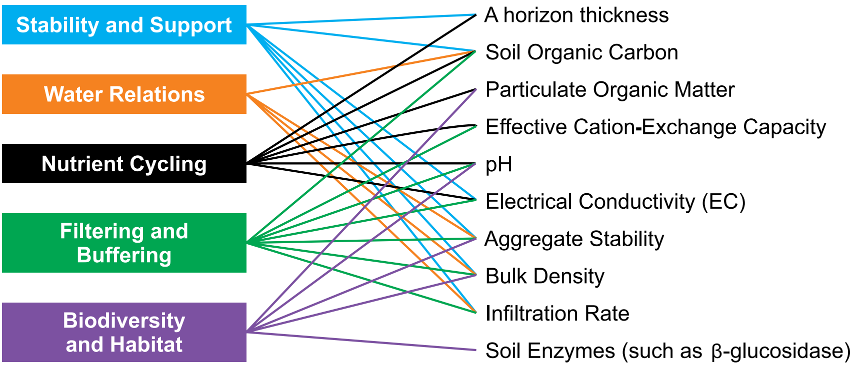
Many land and water conservation programs in the U.S. depend upon management of dynamic soil properties. Proven conservation practices are used to maintain the soil's productivity, health, and long-term sustainability. Conservation planning relies on the knowledge of the current state of the soil resource and what is achievable through conservation practices. DSP assessments provide a range of potential soil property values that define what is achievable.

DSP data is used to document, explain, and predict the effects of land use and management on soil and ecosystem functions. It is collected in a way that documents both soil properties and classifications along with information on land use and management, then stored in an organized database. Information about past and current land use and management can be used to explain current soil properties. It can also be used, through inference or modeling, to predict future soil properties and functions.

Soil function is a way of describing the role of soil in the environment and has been used to define the concept of soil quality and soil health. Essential soil functions include nutrient cycling, water storage and release, biodiversity and habitat, filtering and buffering, and physical stability and support (simplified from Mausbach and Seybold, 1998). Soil stores and moderates the cycling of nutrients and other elements. It regulates the drainage, flow, and storage of water and solutes (N, P, and pesticides). It supports biodiversity and habitat and promotes the growth of plants, animals, and microorganisms. It serves as a filter and buffer for toxic compounds and excessive nutrients and protects the quality of water, air, and other resources. It provides physical stability and support, allowing the passage of air and water through its porous structure, serving as a medium for plant roots, and providing an anchoring support for human structures. While many soil functions are complex and difficult to measure, some key soil properties can be considered indicators of specific soil functions (fig. 9-1) (Doran et al., 1996; Karlen and Stott, 1994; Mausbach and Seybold, 1998). These indicator properties are the focus of soil survey DSP collection.

The framework of soil survey offers an opportunity to collect and disseminate information about how DSPs (and the soil functions they support) change with vegetation, land use, and management across space and time (Wills et al., 2016). DSP data, such as bulk density values under various grazing schemes, enhances soil survey information by providing soil property potentials under various land use and management scenarios. By combining DSP information with spatially linked soil survey information (e.g., soil map unit components), soil survey provides spatial context (maps, areas affected, etc.) to land users, researchers, and decision makers regarding the expected impacts of changes in land use and management. Soil property and function potentials along with collated DSP datasets provide greater specificity of soil interpretations, target values for soil quality and health assessment, guidelines for indicator monitoring, and data for calibration and validation of resource modeling.

Figure 9-1



Relationship between soil functions and some dynamic soil properties (modified from Tugel et al., 2008).

How to Collect DSPs for Soil Survey

DSP projects organize data collection and analysis around specific soils, soil groups, and land management systems. The scope, specificity, and replication of each DSP project depend on the goals for that project. The overarching goal of data collection in a DSP project is to document the range and central tendencies of DSPs for a given set of soils and land management conditions (such as reference and degraded states or best and typical crop management practices). The project should provide information about typical and potential DSP values for soil map unit components and ecological site descriptions. With adequate replication, these projects can be conducted as soil change comparison studies (Tugel et al., 2008) in which alternate conditions are used in a space-for-time substitution framework to make inferences about how soils have changed over time under specific management scenarios. In this approach, all places with the same soil (or group of soils) are assumed to have had the same properties at time zero (i.e., before the specific land management practices were applied). The assumption is that any differences observed are due to management and not inherent spatial variability. Multi-scale replication limits the influence of any spatial variability observed when making conclusions about soil change. DSP projects may also seek to document baseline conditions (such as ecological site reference conditions), best and worst case management scenarios, or alternate conditions of interest.

DSP information for soil survey must be collected, organized, and used in a way consistent with the soil survey protocols and standards used for inherent properties. Data collection for soil survey can be characterized in two ways: dispersed and project based. *Dispersed* DSP data collection refers to the integration of DSP data collection with other routine soil survey project operations. As a result, DSP and land management information is documented throughout a wide range of soil survey activities. Efforts are not concentrated on any single land use or management system but are dispersed throughout all situations in which the soil occurs. In contrast, *project-based* DSP data collection is designed to intensively evaluate specific land management conditions. The most robust DSP data collection includes both approaches and so provides both spatial and land management representation (from dispersed efforts) and detailed comparisons of management scenarios in specific soil landscapes (from project-based efforts). DSP data can be used to evaluate the soil data representativeness (across land use and management systems) and assess spatial variability.

The goal of dispersed DSP collection is to build on other soil survey activities and increase the general knowledge of DSPs across all soils and land management conditions. In this context, "land management condition" is a general term that captures a range of possible situations, including ecological states and vegetative communities, land use, and specific crop and pasture management systems. Advantages of dispersed data collection are that it requires little additional resources and provides information on a wide range of soils and conditions to managers, modelers, and policy makers. Analysis of this data can be used to group soils and land management conditions for further evaluation through DSP projects. It can also be used to validate summaries and predictions made from completed projects.

Dispersed DSP Data Collection

At the location of each observation, it is important to record, at minimum, information on the site, pedon, and land management condition and practice. This data includes any known information about general land use, ecological state, type and amount of vegetation, and cropping systems; e.g., tillage, crop rotation, and pesticide or fertilizer applications. Additional soil properties may be assessed on samples near the soil surface, e.g., enzyme activity and aggregate stability. Procedures and terminology for recording this information should be standardized. Robust soil information systems include data elements related to indicators of soil function and land use and management condition.

Project-Based DSP Data Collection

Project-based DSP data collection requires thorough planning and typically is the most intense type of data collection. The type of project determines how data collection will proceed. Projects can be planned to meet multiple project goals. Site and pedon replication should be planned to meet all project goals on the smallest unit of soil and land management condition targeted. It is helpful if all stakeholders of the project (those who will collect and use the information) can meet to determine the DSP project goal(s) and the target soil(s) and condition(s).

Determining DSP Project Goals

Project goals vary depending on the kind of project. Three kinds of projects are described below and examples are given for each.

DSP range study.—The goal of this kind of project is to evaluate the entire range of values for DSP properties and so provide soil component information regardless of land management or use. A single soil or group of closely related soils is selected. Land management conditions are not closely controlled (i.e., not specifically targeted in sampling) but should be well documented. This type of project requires the least amount of replication. Therefore, while results apply across the area of interest (soil group), the data typically is not sufficient for statistical comparisons between land management conditions.

> Example: The soil of interest occurs in an area used for rangeland, pastureland, and cropland. A DSP range study would sample a range of management systems across all three land uses, including those that are expected to have the smallest and highest DSP values.

> Example: A Midwestern U.S. State wanted to know typical values of DSPs across a region. For 2 years, all projects included sampling for DSPs as well as documentation of land use and management information for at least one pedon. The data provided a general idea of relative conditions across the region. There were no pairs or replications that could be used to make statistical comparisons because this was not the purpose of the project.

DSP baseline or reference study.—The goal of this kind of project is to establish baseline or reference DSP levels for a limited number of reference or land management conditions. The baselines can be used to interpret onsite assessments of soil health as a starting point for modeling or monitoring projects. Results apply across an area (a soil or group of soils) and the land management conditions of interest. Extrapolation beyond these conditions requires expert knowledge and depends on the extent and representativeness of the selected land management conditions. This type of project requires an intermediate level of replication across target soils and land management conditions.

> Example: Kirkland soil has particularly high soil function in a grazed native prairie with occasional fire (this is the reference condition of its ecological site). A reference DSP study would target this condition, and future evaluations and assessments could be compared to the baseline, or reference, levels.

DSP soil change study.—The goal of this kind of project is to assess soil change using the technique of space-for-time substitution. Instead of evaluating the effects of a management system in one location over an extended period of time, this technique compares two different locations that have had different management systems over the same period of time. It assumes that soil properties at the two locations were the same before the management system was applied. Typically, this type of study also serves as a baseline or reference study for a soil or soil group. In addition, soil change studies require the careful selection of land use and management conditions that represent a reference state and an alternative state. Robust multi-scale replication is required to make statistical conclusions about the soil change caused by land management. Pickett (1989) gives the theoretical background of space-for-time substitution, and Tugel et al. (2008) discuss the implementation of this technique in soil survey.

> Example: A group of soil scientists in Michigan wanted to investigate dynamic soil properties under two types of wetland restoration. They determined that they needed to conduct a DSP soil change study that included a baseline or reference state (in this case an undisturbed reference wetland) and alternative land use conditions with a multi-scale sampling scheme to capture variability within individual wetlands and across the project area.

Determining the Target Soils and Conditions

Studies can be designed to target soils, ecological sites, or land management conditions.

Soils or ecological sites.—Targeting a specific soil(s) or ecological site(s) will determine the extent of the DSP project, where samples and observations might be collected, and where the results should be applied. Approaches for targeting soils include single soil unit, soil system, and ecological site.

Single soil unit.—The smallest unit of the study interest is a map unit component represented by a soil series. Benchmark soils that are representative of other soils in the area and/or represent important resource concerns and ecological processes are selected.

> Example: In an area of Michigan, the organic wetland soil Houghton is the most common soil in restored wetlands. The Adrian soil is very similar taxonomically and occurs in the same landscape positions. Both soils were therefore considered target soils for sampling and comparisons.

Soil system.—A study of a soil system segments the landscape and evaluates appropriate hierarchies in a soil system or catena. Soil components that represent similar portions of the landscape and/or respond similarly to land use and management conditions can be combined for sampling purposes.

> Example: In Renville County, Minnesota, the soil landscape was segmented into three parts based on topography, hydrology, and the reflected taxonomic classes (fig. 9-2). One individual soil component was chosen to represent each of the three groups.

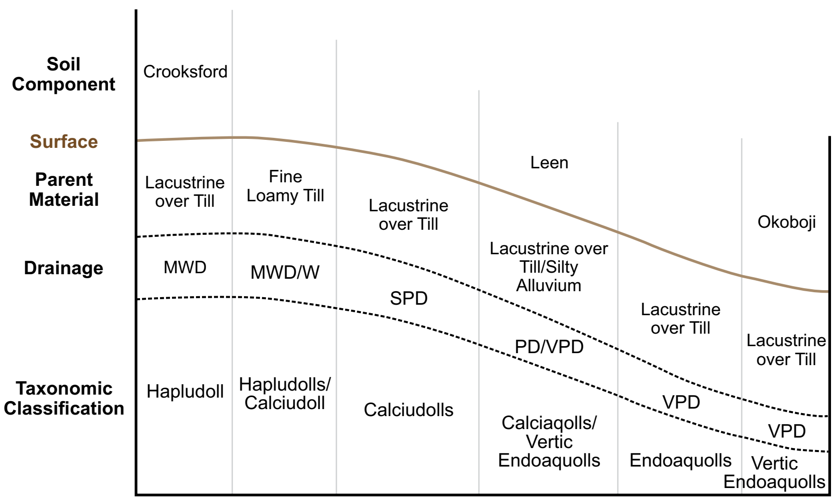
Ecological site.—The study of an ecological site groups soil components into units that are meaningful for ecological processes and land management.

Land management conditions (for reference, baseline, or comparison).—The land management conditions are selected according to the soil and type of project and can include general land cover classes (e.g., rangeland or cropland) or specific management systems (e.g., 3-year burn cycle with moderate grazing or no-till corn with cover crops). For each project, a similar level of variability within the specified land management conditions needs to be maintained. For example, comparing forested conditions within a reference state to a specific cropland management system may be more appropriate than comparing all forested conditions under a specific management system. When trying to document soil change, the chosen conceptual model should partition soil change into discrete frames of reference, conditions that can be put into separate categories (Starfield et al., 1993) and that can be sampled at separate physical locations (using the space-for-time technique). The *Soil Change Guide* (Tugel et al., 2008) recommends using common models of soil disturbance and erosion, such as STIR, RUSLE2, and SCI (Foster, 2005; Hubbs et al., 2002; USDA-NRCS, 2003, 2006). Wills et al. (2016) outlined a potential framework for grouping management systems by primary production groups and types and amount of disturbance.

Example: A DSP planning team in Michigan determined that in order to meet their goals a baseline reference wetland needed to be sampled and documented in addition to two general types of wetland restoration and typical agricultural production.

Example: In Dodge County, Nebraska, two agricultural management systems were chosen as the target conditions. The reference condition was the highest functioning agricultural land use.

Figure 9-2



A generalized cross-section of a soil landscape near Olivia, Minnesota. A DSP project was designed to capture the effect of land use change on the soil system. Crooksford components represented relatively well drained Hapludolls, Leen components represented Calciudolls and Calciaquolls on depression rims, and Okoboji components represented Endoaquolls in depressions and lake plains. (Drainage class abbreviations: MDW—moderately well drained, W—well drained, SPD—somewhat poorly drained, PD—poorly drained, and VPD—very poorly drained.)

Data Collection Plan

A written plan serves as both a tool for organizing work and a record of how the project was conducted for future data use.

Formalizing Project Objectives

Planning decisions are recorded. The project goals and the geographic and conditional constraints are clearly defined. This information includes identification of which soils and land management conditions will or will not be acceptable for sampling.

Gathering Existing Data

Relevant data in soil survey and laboratory databases can be located by querying for the target soil taxa or spatial joins or by other means. Relevant information may also be located in journal publications, extension publications, or graduate student work through nearby universities, colleges, or other groups.

Additional Data Collection

All DSP projects need to include a protocol for data collection across multiple scales. Sites (independent locations commonly sampled as plots) should capture the full range of soils and land management conditions of interest. Within each site, a minimum of three pedons should be located in a standard layout or in a random fashion. Methods, field forms, and equipment for field data collection are discussed in appendix 3 of the *Soil Change Guide* (Tugel et al., 2008). All information should be provided as general metadata about how the project was designed and executed.

Determining Sources, Types, and Amount of Variability

Expert knowledge of the system and existing data are used to identify sources of variability. Tools such as the Multi-Scale Sampling Requirement Evaluation Tool (Tugel et al., 2008) can be used, or estimates can be made for the number of sites (independent location) and pedons per site needed to meet project objectives.

Designing a Sampling Scheme

The best arrangement of pedons within sites can be determined using the information about expected variability. The sampling scheme should include multiple sites or locations across the spatial extent of the study. The design should not under- or over-represent landscapes (e.g., hummocks or depressions) or microfeatures (e.g., trails or tree-throw) within a site. Figure 9-3 shows a sampling scheme.

Locating Sites for Data Collection

Field sites should represent both the central concept and the typical range of properties for the target soil and land management conditions. Care is needed to avoid bias in location selection. GIS techniques, such as conditioned Latin hypercube sampling, or other statistical sampling techniques can be used. Alternate locations should be chosen in case a site cannot be accessed or must be rejected. Brungard and Johanson (2015) describe a rigorous plan for substitution.

Developing data collection and sampling plan.—The protocols and procedures for DSP project sampling need to be planned. The data elements and terminology used must be compatible with the soil system. The top image in figure 9-3 shows how sites can be distributed across a region. Figure 9-4 shows pedon distribution within a paired site in Dodge County, Nebraska. In this project, sites were located as pairs (with both target land management conditions present) to limit soil variability and improve condition comparisons.

Guidelines for accepting or rejecting a site for sampling.—For most soil survey applications, soils and conditions should be verified in the field to ensure that sampling will meet project objectives. Guidelines should outline the ranges of soils, features, and land management conditions that are acceptable for inclusion in the project.

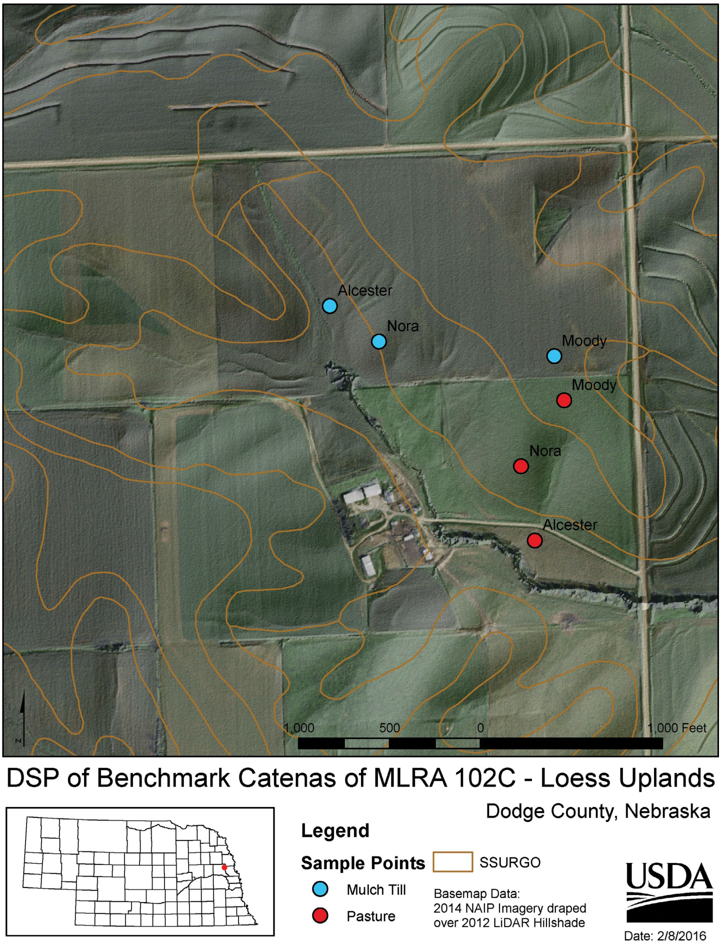
List of data elements for site information.—Management and vegetation data are typically collected at the site scale. All data elements to be measured or recorded at each site (location or plot) should be identified. They may include vegetative cover, residue, site index, or other metrics of vegetation or management. Common collection schemes for ecological site data in the project area can be used as a starting point. Table 9-1 is an example of elements that might be collected at each site, location, or plot.

Instructions for locating individual pedons and measurements.—A clear plan is needed to explain how pedons will be located within each site as well as where and how any associated surface properties will be measured. It may include a standard plot layout (fig. 9-5), randomly positioned pedons within a plot area, or transects (fig. 9-4) with pedons positioned at regular intervals along a catena contour. A plan for measuring infiltration, hydraulic conductivity, and surface features (such as residue, pattern class, and soil crust) before pedons are disturbed improves data integrity.

Figure 9-3

Documentation from the Georgia Longleaf Pine Dynamic Soil Property project (unpublished data). Care was taken to include both target land use conditions across the study area. Top: Distribution of plots across the major land resource area (MLRA) 133A. Plots were labeled to designate them as being on the A (Atlantic) or G (Gulf) side of the region and as P (pasture) or L (longleaf pine). Bottom left: A longleaf pine plot. Bottom right: A pasture plot with a transect tape (for vegetative cover measures). County names and boundaries are shown on the map. (Photo courtesy of Dan Wallace)

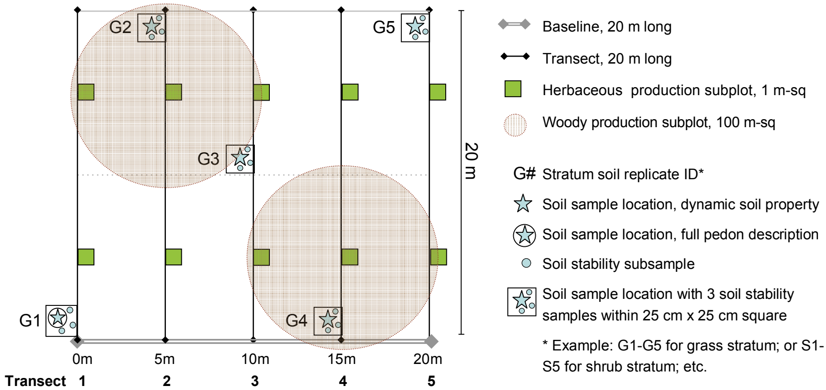
Figure 9-4



Example of pedon placement for a paired site in Dodge County, Nebraska. Each site has both target land management conditions (pasture and corn-soybeans with mulch tillage). The soil system was captured with three target soils. The central pedon location is represented on the map and labeled with the soil name. Two additional satellite pedons located along the contour are not shown on the map.

Instructions for pedon sampling and description.—Descriptions of pedons to a predetermined depth should follow standard procedures (see page 8-2 of Schoeneberger et al., 2012). It is suggested that one pedon per site be observed, one pedon per condition be sampled to a depth necessary for soil series confirmation, and detailed high-quality information, such as bulk density and water retention analysis, be collected for those pedons (table 9-2).

Figure 9-5



Instructions: The baseline should be positioned obliquely to the slope and 5 transects should be positioned at approximately 90º from the baseline parallel to one another. The individual placing the flags will fill out the "Sample Locations and ID" portion of the "Plot Master" field form while identifying and flagging the soil sample locations. The flags will be pre-labeled with the Stratum-soil replicate ID (e.g., G1-G5). At each soil sample location, stability samples, penetrometer readings, bulk density samples, and soil samples for laboratory analysis will be collected. Line-point intercept and GAP will be completed along each transect. Place herbaceous subplots at meter marks 5 and 15 on each transect. Woody subplots are centered at transect 2, meter mark 15 and transect 4, meter mark 5. Complete 1 Pedoderm and Pattern Classes form for each plot (Tugel et al., 2008).

Example of detailed plot sampling instructions for a rangeland DSP project in Utah. Because the project involved both soil scientists and range scientists, a highly detailed plan was developed for sampling. From the Soil Change Guide *(Tugel et al., 2008).*

Table 9-1

DSP Project Data Elements Collected at Site (Across Plot) Scales

Type of data	Property/measurement
Management information	Crop rotation
	Tillage system
	General description
	Tillage operations (frequency and timing)
	Applications and other operations and treatments
	Grazing management
	Forestry management

Table 9-1.—continued

Type of data	Property/measurement
Vegetation information (as appropriate)	Plant biomass or production
	Composition
	Understory
	Overstory
	Line-point intercept
	Canopy and basal gap
	Site index
Forest floor (when present in any part of study)	Woody debris
	Visual disturbance classes*
	Soil surface displacement, compaction, litter thickness, crust cover, etc.
Surface properties	Residue cover/bare soil
	Pedoderm and pattern class+

* Page-Dumroese et al., 2012
+ Burkett et al., 2011

Table 9-2

DSP Project Data Elements Collected at Pedons; Multiple Locations per Site/Plot

Type of data	Property/measurement
Surface properties	Aggregate or soil stability
	Infiltration
	Single ring
	Double ring
	Crust description (when present)
	Pedoderm and pattern class
	Relevant microtopography
	Soil surface temperature
	Cover/bare soil
Pedon properties	Pedon description
	Horizon depths, colors, textures, fragment estimates

Table 9-2.—continued	
Type of data	**Property/measurement**
Pedon properties	Agronomic feature (furrow, wheel-track, etc. at pedon location)
	Soil horizon/depth increment
	Temperature
	Cover/bare soil
	Saturated hydraulic conductivity

Instructions for sample collection.—Collecting a sample from a predetermined depth (e.g., 0–5 cm) near the surface helps in making comparisons between conditions. The kind of near surface horizon of the sample should be noted (see chapter 3). This sample can be treated as a subsample of the first horizon or described as a separate horizon. All other samples should be collected by genetic horizon to capture the most variability within the profile and allow comparisons between horizons. Because many DSPs are sensitive to disturbance, walking or using heavy equipment on sampling areas should be avoided. A plan for labeling samples is needed to keep track of soil, condition, site, and pedon replication as well as information on horizons and layers.

Instructions for sample handling.—Many of the properties measured in DSP studies are the same as those measured in standard soil survey procedures. The emphasis is on targeting, tracking, and replicating certain conditions. However, some measures are of particular interest for DSP sampling, such as bulk density, aggregate stability, and soil biology measures (e.g., enzyme activity). The samples should be handled carefully and not exposed to crushing or warming. Samples should be air dried as soon as possible if they are to be shipped and/or stored for more than 24 hours.

Desired minimal dataset for laboratory samples.—The dataset should have information on standard inherent properties to allow for correlation and comparisons between soils and sites. It may include standard pedon description information (such as horizon thickness, texture, and coarse fragments) and laboratory data (such as particle-size determination). At minimum, the DSP dataset should include carbon (organic and inorganic), pH, EC, bulk density, aggregate stability, biological enzymes (β-glucosidase is recommended), particulate organic matter, and nutrients (N, P, K, etc., as appropriate). Table 9-3 provides a potential list of properties to measure. The Kellogg Soil Survey Laboratory currently analyzes standard interpretive and dynamic properties.

Table 9-3

Measurements of Dynamic Soil Properties on Individual Samples

Type	Property/measurement
Standard interpretive	Standard laboratory characterization
	Particle-size determination
	Other properties *in lieu* of particle size
	Minerology (clay or other as appropriate)
	CEC
Standard dynamic	Organic carbon
	Derived from total and inorganic carbon
	Inorganic carbon
	Derived from calcium carbonate equivalent
	pH
	EC
	Bulk density
	Aggregate stability
	Water stable aggregates
	Total N
	P (Mehlich or other as appropriate)
	Water retention
	Extractable bases
	Extractable acidity
	ECEC
	Permanganate extractable carbon (POX-C or Active C)
	Soil enzymes
	β-glucosidase
	Particulate organic matter (POM)
Supplemental as needed and available	SAR
	Plant available P
	Dry sieve aggregates
	Potentially mineralizable N

Table 9-3.—continued

Type	Property/measurement
Field lab	pH
	Active C (kit for permanganate extractable C)
	Aggregate stability
	Advanced soil structure and pore analysis
	CO_2 burst and respiration tests

Analyzing Dynamic Soil Property Data

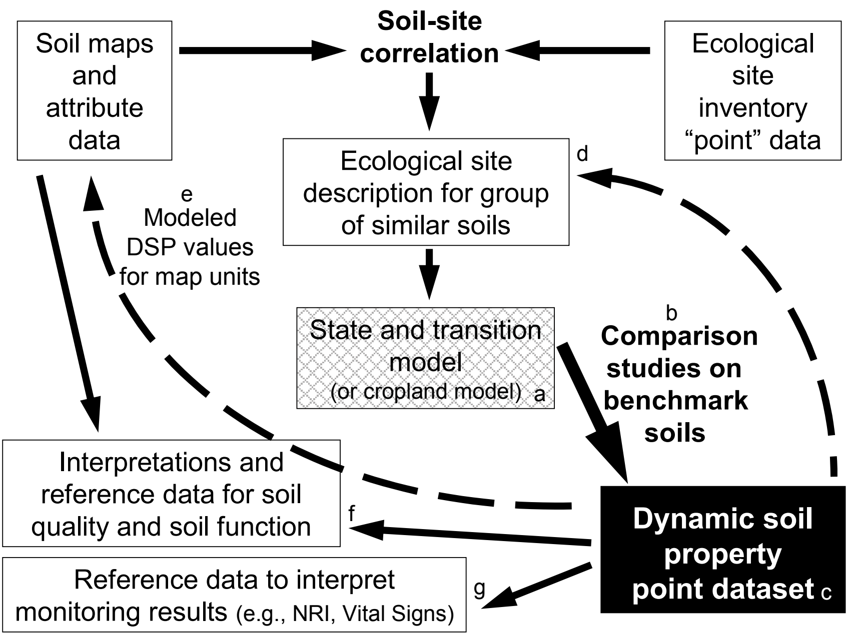
DSP data can be used for many purposes, some directly related to soil survey and many others that are indirectly related (fig. 9-6). The first and most long-lasting outcome of a DSP project is the collection and documentation of soil and vegetation data under various land use and management scenarios. This is an immediate product that can serve as input for many other products, such as conservation effects modeling and general geospatial analysis.

Initial steps for DSP data analysis are the same as those for any aggregation of soil survey data. The data compilation is complicated by replication across sites and pedons. Good recordkeeping and labeling throughout the process help ensure reliable results. To allow for improvement over time, all data aggregation should be documented through written records, program scripts, and public databases. The following outline describes several important steps and considerations in analyzing DSP data.

DSP Data Handling

1. **Maintain the project's data collection plan.** The data collection plan serves as the metadata for the project and will explain to future data users how and why the data was collected.
2. **Enter and check data for errors.** Enter data into required programs and databases and examine it for errors. This data includes information about the sites, pedons, samples collected, and land management systems. Some information (such as infiltration rate) may be collected in the field and recorded later in a database or other file structure.

Figure 9-6



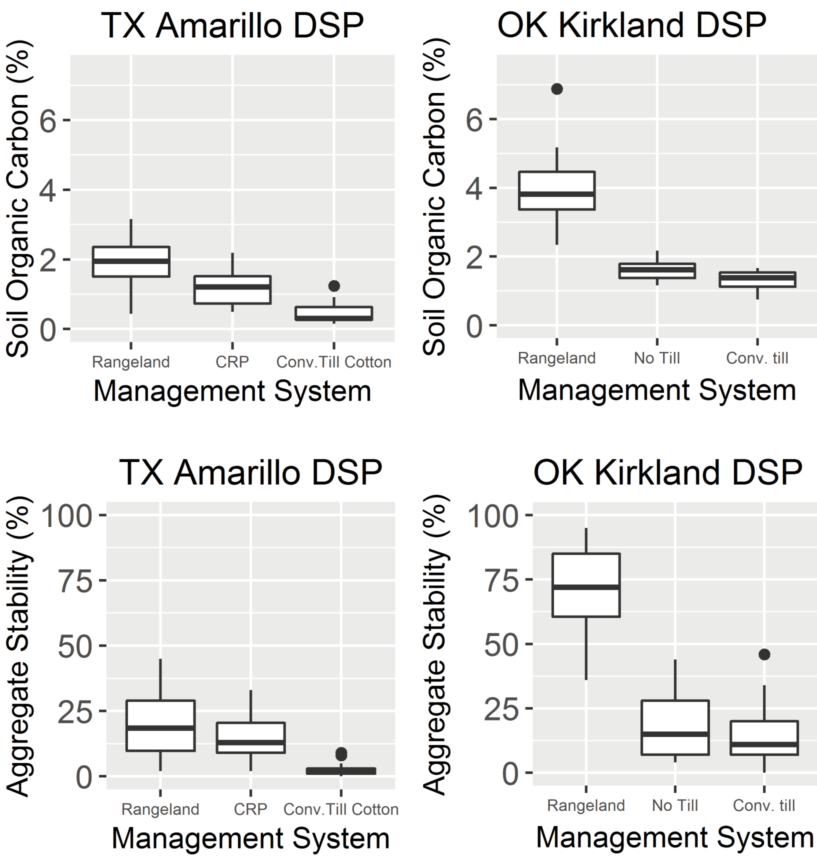
Dynamic soil property data in relation to ecological sites, soil interpretations, and monitoring data. A simple conceptual model (a) is used to design comparison studies (b). Dynamic soil property data derived from these studies are used to populate a point dataset (c). The point data are then available to include in ecological site descriptions (d), model dynamic soil property values for similar soils (e), develop interpretations (f), and interpret monitoring data collected through programs (g), such as the Natural Resources Inventory (NRI), Vital Signs, and Forest Inventory and Analysis (FIA). From Tugel et al., 2008.

3. **Compile or link data across common scales.** Link and label DSP data, as appropriate, to include site and observation information (e.g., vegetation and individual pedons from the same site are labeled with the same plot ID). A robust database should allow for the association of data elements across conditions and locations.
4. **Generalize horizons and other units of measure.** Data collected by samples that are individually labeled, such as by genetic horizon, must be grouped into common units so that properties can be analyzed and compared. Add other data elements (such as comparable layer; Tugel et al., 2008) that

group all possible horizons in the project. Keep scripts and rules as part of the project metadata and documentation.

5. **Aggregate individual observations and measurements.** From the smallest individual data element (sample values) to the broadest level of interest (soil and land use or management system), select meaningful comparisons between conditions. Aggregate horizons, pedons, and sites to make comparisons.
    a. Create separate data elements for surface samples (0–5 cm) and comparable layers, such as all A horizons or all B horizons or other combinations outlined in the *Soil Change Guide* (Tugel et al., 2008).
    b. Use weighted averages by depth to combine horizons into pedon values.
    c. Compute statistical measures for plots or sites.
    d. Compute statistical measures for land use or management.
6. **Analyze data.**
    a. Perform data evaluation and graphical comparisons. Preliminary data is evaluated to gauge general trends, identify errors, and locate any outliers. Graphs should include box plots by comparable layers, pedons, and sites and depth functions within pedons. Figure 9-7 shows a summary of two surface layer DSPs for two separate DSP projects. Data visualization can be used to explore, examine, and share general conclusions about the project.
    b. Calculate descriptive statistics across soil groups. Initial summary statistics include central tendencies (mean, median, and mode) as well as measure of dispersion and variability (range, standard deviation, etc.).
    c. Calculate descriptive statistics for individual land management conditions (as appropriate). Calculate measures of central tendencies, dispersion, and variability. Use site averages or a mixed model to accurately reflect any autocorrelation between observations taken at the same site.
    d. Conduct statistical comparison and ascertain meaningful differences. Evaluate statistical differences between land management conditions.
        i. Use T and F tests for differences. Mixed models optimize use of fixed (condition) and random (plot replication) factors.

Figure 9-7



Dynamic soil properties of 0–2 cm samples for two DSP projects (Amarillo and Kirkland soils) for: a) soil organic carbon (%) measured as total carbon and b) water stable aggregates (%). Box plots represent the 25th and 75th percentiles. Note that rangeland was used as a reference condition for both projects but that different alternate land management systems were used for comparison. The soils also have different reference levels of these two DSPs.

ii. Examine literature to determine if described differences are meaningful to soil function.
iii. Evaluate sampling sufficiency (e.g., were enough samples collected to detect a difference if one exists?). If properties are more variable than originally anticipated, the sampling design

may not have the power to detect anything other than a very large difference. Additional sites can be chosen and samples collected so that meaningful statistical comparisons can be made to detect smaller (but important) differences in DSP values.

7. **Make inferences about soil variability, land management conditions, and soil change.** A final report should summarize the project goals, the target soils and land management conditions, the data collection process, and the methods of data aggregation and analysis. Final conclusions should include the most specific level of evaluation and the expected area of inference (i.e., other areas where the results might apply). This report serves to document the process and support any conclusions.
8. **Populate soil survey databases (such as information for soil map unit components) as appropriate.** Depending on the nature of the project, report results for the entire extent of the soil (or soil group) or report results as being limited to certain conditions.

Care should be taken when incorporating DSP project data into standard data aggregation. Consider the distribution and representativeness of data when populating general component information, such as representative values (RV). If differing management conditions have statistically different DSPs, compare the distribution of the conditions assessed to the number of pedons available for aggregating. You may need to aggregate by land management condition and then weight the conditions by spatial prevalence to arrive at an overall value.

Summary of DSPs in Soil Survey

Dynamic soil properties enhance soil survey by providing information about soil properties that change with land use and management. Information about DSPs improves the ability to document, explain, and predict the effects of land use and management on soil and ecosystem function. DSP data can be collected as general information or as projects designed to detect statistical differences between management and land use types. In both approaches, DSPs are collected in a way that documents both soil properties and classifications and land use and management information. Careful planning, sampling, and analysis ensure that DSP data enhances soil survey projects and allows for additional use of soil information.

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