Forest Inventory and Analysis
Soil Quality Indicator

FIA Fact Sheet Series

Soils represent the basic support system for terrestrial ecosystems because of their role in providing nutrients, water, oxygen, heat, and mechanical support to vegetation. Any environmental stressor that alters the natural function of the soil has the potential to influence the productivity, species composition, and hydrology of forest systems. In the Forest Inventory and Analysis (FIA) Program, we collect data to evaluate soil physical and chemical properties and the extent of erosion and compaction.

Why Is Soil Quality Indicator Important? Soil quality refers to the capacity of a soil to function within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin, 1994).

Information about soil chemical and physical properties can be used to answer the following types of questions about soil quality and forest health:

- Can declines in forest productivity be correlated with changes in the availability of soil nutrients and water to plants?
- What impacts are pollution (e.g., acid deposition) having on soil chemical properties?
- How much carbon is currently stored in forest soils and is this quantity changing over time?
- What percent of U.S. forestland is impacted by soil compaction and soil erosion?
- How much topsoil and forest floor material may be lost each year due to accelerated erosion?

Data from the soil quality indicator are not intended to be used alone when making statements about forest health. However, once the presence of a potential soil quality issue has been identified, these indicator data can be considered in association with other FIA measurements to assess the impact of soil quality on forest health.

Soil quality information contributes to the investigation of several key forest ecosystem concerns: (1) the productivity and sustainability of forest systems, (2) the conservation of soil and water resources, (3) the accumulation of persistent toxic substances, and (4) the contribution of forested systems to the global carbon cycle.

How are Soil Physical Properties Measured in the Field? Field measurements and observations are divided into the following three categories:

- *Soil Sampling* – samples of the forest floor and mineral soil collected from each plot and submitted to a laboratory for chemical and physical analysis.
- *Soil Compaction* – the percentage of the soil surface exhibiting evidence of soil compaction and the types of compaction observed.
- *Soil Erosion* –factors related to the accelerated loss of soil due to water erosion (e.g., bare soil, forest floor thickness, slope, soil texture).

Field personnel working in FIA receive thorough training in field procedures at the beginning of each field season. Errors are further minimized by audits of the field personnel. Potential sources of error are identified in complementary quality assurance studies.

What Types of Analyses are Done on Soil Samples in the Laboratory? Mineral soil samples collected from FIA plots are analyzed for a suite of physical and chemical properties including:

- Bulk density, water content, and coarse fragment (>2-mm) content
- pH (water and 0.01 M $CaCl_2$)
- Total carbon
- Total organic carbon
- Total inorganic carbon (carbonates) (pH>7.5 soils only)
- Total nitrogen
- Exchangeable cations (Na, K, Mg, Ca, Al, Mn)
- Extractable sulfur and trace metals (Sr, Ba, Mn, Ni, Cu, Zn, Cd, Pb).
- Extractable phosphorus (Bray 1 method for pH < 6 soils, Olsen method for pH > 6 soils)

Forest floor and litter samples are analyzed for:

- Bulk density and water content
- Total carbon
- Total nitrogen

Where and When are Soil Properties Measured? FIA field personnel collect soil data during the Phase 3 field season, which begins in early June and ends in September. Soil samples are sent to the laboratory immediately after collection wher they are stabilized by air drying. Laboratory analyses are conducted throughout the fall and winter following the field season.

Soil samples for laboratory analysis

are collected along transects that run nearly at tangents to the annular subplot (Fig.1). Volumetric forest floor samples are collected adjacent to subplots 2, 3, and 4. Mineral soil cores representing depth increments of 0-10 cm and 10-20 cm are collected from locations adjacent to subplot 2. A total of five samples are collected on each plot (three forest floor, two mineral).

Field measurements related to erosion and compaction estimates are made on all four subplots on the Phase 3 field plot.

Are There any Special Concerns When Measuring Soil Variables? Soils respond to changes over longer time scales than most other components of forest ecosystems. Diurnal and seasonal variations in soil chemistry are not a concern for the types of chemical and physical analyses conducted in this program. However, determination of soil chemical variables in the laboratory can be highly method dependent. Use of FIA laboratory data with other soil information requires careful consideration of the analytical procedures used.

Erosion and compaction measurements are based largely on the properties of the soil surface. Any site condition that obscures the forest floor can affect collection of soil data, including: (1) standing water; (2) snow; (3) recent leaf drop; (4) trampling or other disturbance by the field crews. These effects are minimized by thorough training and strict adherence to data collection procedures.

How can Soils Data be Analyzed? The primary use of the soil quality indicator is to provide baseline information about the status of forest soils so that changes in soil quality can be monitored over time. Spatial and temporal trends in the number and distribution of plots with accelerated erosion, compaction, changes in soil organic matter content, and nutrient or other chemical limitations are evaluated by region or forest type. Results from the trend analyses are then combined with other FIA indicators to evaluate site productivity and forest health.

For example, field variables related to landscape position, soil texture, and ground cover are used in conjunction with other FIA indicator data and outside information to model rates of soil erosion on FIA plots. These estimates can be used to identify regions where certain management practices may be more likely to result in accelerated soil loss.

Soil chemical and bulk density data can be combined to develop indices of plant nutrient availability in different systems. These baseline data may provide additional insight into forest health problems identified through other FIA measurements. As an example of how soil chemical data may be displayed, Figure 2 illustrates the geographic distribution of soil pH summarized by Bailey's ecoregions in the eastern U.S.

Are Related Data Sets Used? In addition to FIA data, information from other sources are used in the analysis of soil quality, including:

- Soil survey data from the National Resource Conservation Service.
- Erosion models developed by the USDA Agricultural Research Service and other federal agencies (e.g., Revised Universal Soil Loss Equation, Water Erosion Prediction Project).
- Climate data from regional weather stations (used in erosion models)

References

Doran, J.W. and Parkin, T.B. 1994. Defining and assessing soil quality. P. 3-21. In: J.W. Doran et al (Ed.) Defining soil quality for a sustainable environment. SSSA Spec. Pub. 35. SSSA, Madison, WI.

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- Visit our National FIA website: http://www.fia.fs.fed.us
- See our "FIA Contacts" Fact Sheet

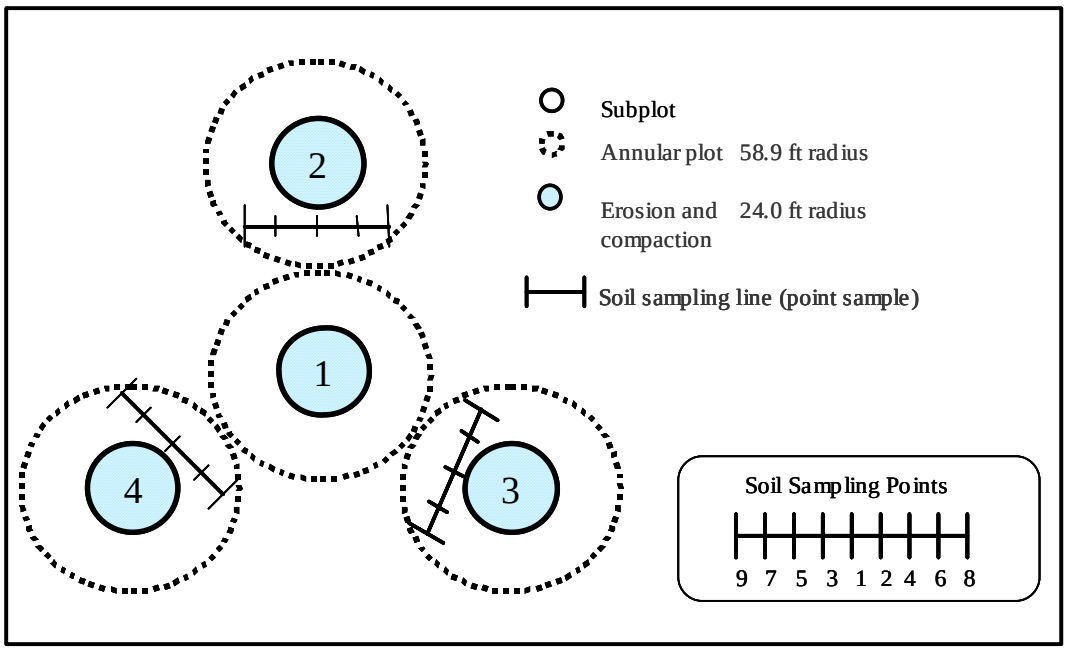

Figure 1: Diagram of FIA plot showing soil measurement locations. Soil samples are collected along transects that run nearly tangential to the subplot. During the first visit to a plot, soils are collected at point 1. Subsequent sample locations are spaced at 10 ft intervals alternating on opposite sides of sampling point 1.

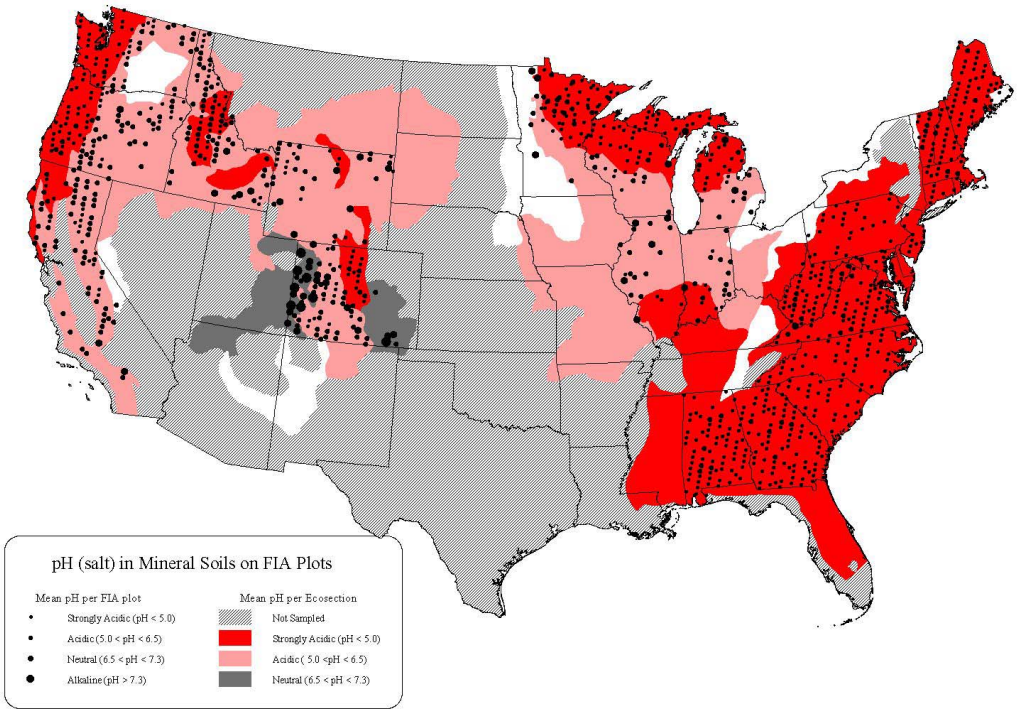

Figure 2: Mean soil pH in mineral soil samples collected on P3 plots in 1998 and 1999. Symbols represent mean soil pH on an FIA P3 plot. Shaded areas represent mean values summarized by Bailey's ecosection.