Soil Quality Standards Monitoring Program Administration and Implementation

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Abstract—Forest managers and resource scientists and specialists are engaged in a partnership to sustain the natural resource value of our national forests. Managers are faced with deciding which activities provide the best resource benefits with the least resource damage. Many, but not all, aspects of the decision process must be based on the science supporting our current understanding of natural resources. Scientists are charged with continuing to build these understandings and interpreting their effects in an applications setting. The roles of land managers, subject matter experts (field soil scientists), and research soil scientists are distinctly different. Each brings unique skills to the resource management problem. Together they form a powerful team that can sustain forest and rangeland ecosystems and enhance resource values.

Organizational Structure

Organizationally, the USDA Forest Service (USDA FS) soil management program is divided between the National Forest System (NFS) division and the Research and Development (R&D) division. NFS is charged with managing lands and their respective resources while R&D provides the scientific foundations to improve land and resource management decisions on NFS lands.

NFS has three levels of administration: national, regional, and national forests or grasslands. There are nine regions and 175 national forests and grasslands. R&D has three levels of administration: national headquarters, experimental forests and grasslands, and research stations.

The Forest Service manages in excess of 193 million acres of federal forest and range land. The general requirements under which this land is managed are set forth in enabling legislation. Four legislative acts are of particular importance to the issue of resource sustainability and the soil resource in particular.

Laws

The Organic Administration Act of 1897 (USDA Forest Service 1993) created the National Forests and specified that "No national forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber for the use and necessities of citizens of the United States…" The Multiple-Use Sustained-Yield Act of 1961 directs management to consider resource values but "not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output…without impairment of the productivity of the land." The Forest and Rangeland Renewable Resources Planning Act of 1974 and its amendment, the National Forest Management Act of 1976 (NFMA), set forth four important points that pertain to the need for continuous monitoring. The guidelines in land management plans are required to:

- "insure research on and (based on continuous monitoring and assessment in the field) evaluation of the effects of each management system to the end that it will not produce substantial and permanent impairment of the productivity of the land" (Section 6(g)(3)(C));

- "insure that timber will be harvested from National Forest System lands only where soil, slope, or other watershed conditions will not be irreversibly damaged" (Section 6(g)(3)(E)(i)); and
- "insure that clearcutting, seed tree cutting, and other cuts…are carried out in a manner consistent with the protection of soil, watershed, fish, wildlife, recreation and esthetic resources, and the regeneration of the timber resource." (Section 6(g)(3)(F)(v)).

In addition, Section 13 of the NFMA specifies that the "Secretary of Agriculture shall limit the sale of timber from each national forest to a quantity equal to or less than a quantity which can be removed from such forest annually in perpetuity on a sustained-yield basis."

The essence of these legislative mandates is that the USDA FS is required to conduct research, monitoring, and assessments to evaluate management effects and to manage for sustained yield in perpetuity and in a manner that assures protection of all resources and values. This is a tall order; it demands from Forest Service managers a level of resource background and knowledge that does not reside in any single individual. In fact, the NFMA requires that NFS land management plans be developed by interdisciplinary teams and with public participation. This requirement makes research, monitoring, and assessment critical for both preparing plans and assuring that they can stand up under public review.

These laws are the foundation of the USDA FS soil management program. These and other laws have been used to develop the Agency's soil management policy housed in the Forest Service Manual 2550. The manual outlines objectives and policy and assigns decisionmaker responsibility for its implementation. Technical aspects of soil management, including inventory and monitoring, are addressed in the Forest Service Handbook 2509.

The need to standardize field procedures for soil monitoring has been recognized for quite some time. The urgency to move forward with a standardization grew out of several recent court rulings that resulted in two major National Environmental Policy Act (NEPA) projects being overturned, i.e., Iron Honey (Lands Council v. Powell 2004) and Lolo Post-Burn (Ecology Center v. Austin 2005).

Lawsuits

In the Iron Honey lawsuit, the USDA FS used a "spreadsheet model" to estimate soil quality based on aerial photos and samples from throughout the Forest. The court ruled that soils analysis and effects should have been tested on the ground, not estimated from a spreadsheet model. The USDA FS did not walk, much less test, the land in the activity area. The Agency conceded that it did not test the activity area but argued that because it tested similar soils within the national forest, the methodology was sound. However, the court questioned whether the USDA FS internal conclusions of the reliability of the spreadsheet model should be trusted, since the model had not been independently validated. The court went on to say that in order to be reliable, the hypothesis and prediction of the model should be verified with observation. The predictions of the model, which may be reliable across the entire National Forest, were not verified with on-the-ground analysis. The USDA FS failed because it based the soils analysis entirely on the model, with no on-site inspection or verification, which violated NFMA (Smith 2007).

In the Lolo Post-Burn lawsuit, the USDA FS looked at maps of past activities on associated soils. Data was input from the National Forest Land Systems Inventory and Burned Area Emergency Response (BAER) report into models to generate estimates of the project's possible effects. The BAER report was based on field reviews and helicopter flyovers as well as transects. Because the project was developed after the BAER transect surveys were conducted, the transect surveys did not cover the vast majority of the activity areas; only a few were crossed by coincidence. Soil sampling did not cover the vast majority of 128 sale units in BAER transects. At the time, the Northern Regional Soil Scientist, John Nesser, questioned the project soil analysis because it had failed to assess soil conditions by field testing the actual activity areas. The Draft Environmental Impact Statement states that not all proposed harvest units were visited with line transects and that much of the soil quality determination was based on information from the USDA FS Northern Region transportation and timber units with respect to past activities and regeneration level of jammer roads. The court ruled that the project was similar to that in the Lands Council v. Powell case where much of activity area was not tested; therefore, the analysis was inadequate under NEPA and NFMA (Smith 2007).

NEPA requires federal agencies to consider the environmental impacts of their proposed actions and reasonable alternatives to those actions as a means of integrating environmental values into their decisionmaking plans. National Forest land management plans typically outline, in general terms, monitoring protocols. Because there are no nationally recognized soil quality monitoring protocols, field personnel typically use the best available methodologies. Unfortunately, some of these methodologies are incompletely documented and thus subject to scientific and legal challenges when follow-up re-sampling is requested or when trend monitoring is conducted. Comparing data sets is also difficult, if not impossible, when different methodologies are used. Finally, database design and population is also complicated when similar data is collected using both well-documented and poorly documented methods.

Monitoring Methodologies

In general, there are at least three intensity levels of monitoring and assessment projects: national, regional, and project. National monitoring is generally conducted using high elevation aerial photography with statewide field sampling procedures with a data resolution to the state datasets. The best example of this protocol is the Forest Information and Analysis (FIA) project. Regional monitoring and assessment are usually conducted using National Forest and Rangeland administrative units, and use a variety of methodologies depending on the subject matter being assessed or monitored. Confidence-level for these types of efforts is generally limited to National Forest, Rangeland, or Grassland datasets but can also include associated state data. Examples of these regional types of monitoring and/or assessments include the Interior Columbia Basin Ecosystem Management Project: Scientific Assessment (Quigley and others 1999) and the Southern Forest Resource Assessment (Wear and Greis 2002).

Project level monitoring and assessments are conducted on areas within a national forest or grassland where some type of land management prescription is proposed or has been implemented (i.e., timber sales, fuel treatments, or rangeland improvements). There are three types of monitoring conducted at the project level: implementation, effectiveness, and validation. Implementation monitoring is intended to evaluate whether a particular land management prescription was conducted as directed by the NEPA decision memo and/or as directed by a project contract. Effectiveness monitoring evaluates the ability of project mitigation practices to prevent resource damage either within the project area or on adjacent resources. Validation monitoring is intended to address resource management assumptions commonly used to narrow the scope of the environmental assessment. Validation monitoring is often conducted by R&D scientists and requires a longer commitment of time to gather and analyze data. The overall protocol is intended to be used on project level monitoring efforts. As the reader might imagine, national and regional monitoring and assessments use more generalized datasets than those at the project level.

Standardization

Standardization of data collection protocols is essential at any of the levels of monitoring and assessment. Increasingly, datasets are needed and used beyond their initial purpose. All too often, inadequate documentation of how a particular dataset was obtained results in duplicated efforts or incomplete analysis of existing data because the protocol was either not well documented or unacceptable. Monitoring without adequate documentation or the use of an inappropriate protocol has resulted in the loss of project data. This type of data often cannot be used with other datasets for other levels of monitoring or analysis and consequently results in increased costs for land management projects in both time and salary. Data collection using standardized peer reviewed protocols offers at least two advantages to land management: the collected data is repeatable and will hold up to scientific and legal scrutiny. Standardized data is essential to resource condition trend analysis and to the successful defense of the data to scientific and legal challenges. Incorporating a standard statistical design of the monitoring effort is essential to assuring that the results of the collected field data provide an accurate picture of what is occurring on the project area. Understanding the reliability and the confidence of the soil data being collected is important in helping land mangers decide their level of comfort in moving forward with a particular resource management prescription. An unbiased statistical analysis will also determine the number of observations needed to accomplish a defensible on-site evaluation of potential resource impacts.

Standardization is not intended to stifle or limit data collection but rather to maximize data utilization. There are several factors of standardization to consider: (1) identification of the question(s) to be answered, (2) size of the treatment area, (3) available staff resources, and (4) the amount of risk land managers are willing to tolerate in their decisionmaking on a proposed land management project. Depending on the outcome of the problem analysis using these factors, a monitoring project can be designed using this protocol as its foundation. One example of an experiment utilizing these important monitoring considerations is the Long-Term Soil Productivity (LTSP) experiment.

North American Long-Term Soil Productivity Experiment

To properly evaluate forest management impacts on soil quality, evidence of long-term impacts is needed. Considerable information can be found in the literature on the long-term impacts of soil disturbance. However, most of this information is from isolated experiments that often were not designed for long-term scrutiny and are too site specific to be broadly useful. An exception to this is the Long-term Soil Productivity (LTSP) experiment, which was specifically designed, among other things, to develop baseline indicators of soil quality and validate these indicators over multiple installations covering a broad range of soil classifications, ecosystems, and climates. The LTSP experiment began as a cooperative between scientists in USDA FS NFS and R&D to address legislative mandates, particularly the NFMA, which require that the management of federal lands be conducted in a manner that maintains site productivity. The cooperative grew with the inclusion of partners in the private and public sectors of the United States and Canada. Currently the cooperative includes well over 100 LTSP installations and affiliated sites, comprising the world's largest coordinated network investigating the long-term impacts of forest management on sustainable site productivity. Excellent descriptions of the genesis and development of the LTSP cooperative are provided by Powers (2006) and Cline and others (2006).

The LTSP experiment specifically examines the impacts of changes in soil porosity and surface organic matter on sustainable soil productivity. These variables were selected after considerable examination of the literature elucidated that these variables are (1) directly affected by forest management, (2) can be readily monitored, and (3) regulate soil properties and processes that, in turn, directly impact site productivity. The LTSP experiment was designed to cover the entire range of soil compaction and site organic matter levels possible resulting from a harvest operation. Consequently, the LTSP experiment presents the unique opportunity to "tease out" the relative contribution of the different soil compaction and surface organic matter combinations on site productivity across a range of installations. The experiment is intended to be long-term in nature extending, at least, to the culmination of mean annual volume increment.

At a minimum, all LTSP installations collect eight core measurements, including five soil measures, at reoccurring intervals. The five soil measures are (1) moisture and temperature (collected monthly), (2) bulk density (collected every 5 years), (3) soil strength (collected seasonally every 5 years), (4) organic matter content and chemical composition (collected every 5 years) and (5) water infiltration and saturated hydraulic conductivity (collected every 5 years). These soil measures provide a template for the current discussion on soil quality metrics.

Findings

The first LTSP installation was established in 1990 on the Palustris Experimental Forest on the Coastal Plain of Louisiana and was rapidly followed by installations in California, Minnesota, and North Carolina. Additional installations were established in subsequent years, providing the LTSP cooperative with data from installations approaching 20 years in age. To date, the LTSP cooperative has produced over 300 scientific publications on various subjects including soil properties and processes and site productivity. The majority of these publications describe information obtained from a single or a few installations; however, results that integrate the observations of several installations have also been published. Fifth-year results from a combination of several installations were presented in 2000 at the Conference on Long-Term Productivity of Forest Soils in Alexandria, Louisiana, near the site of the first LTSP installation. The papers presented were published in 2006 in the Canadian Journal of Forest Research (CJFR) as a special issue on long-term soil productivity (CJFR vol. 36). In 2003, tenth-year results from installations ≥10 years old were presented at the 10^{th} North American Forest Soils Conference in Sault Ste. Marie, Ontario, and were published by Powers and others (2005). The general findings of the conference were that organic matter removal (1) decreased soil carbon (C) concentration but not soil C content, (2) decreased soil nitrogen (N) and phosphorus (P), (3) decreased foliar N and P, but (4) did not affect productivity. Other findings showed (1) small differences between moderate and severe soil compaction, (2) bulk density increases varied with initial bulk density, (3) most sites did not exhibit bulk density recovery, and (4) the affect on productivity varied with soil texture and presence of understory.

Since that time, several other installations have reached the 10-year benchmark and will be incorporated into a presentation in 2008 at the 11^{th} North American Forest Soils Conference in Blacksburg, Virginia.

The early results from the LTSP installations speak volumes about the resiliency of the soil to disturbance. It might be tempting to conclude from this information that forest management does not impact soil productivity in the long-term. However, caution must be taken, since the information to date describes soil conditions early in the stand rotation and may not be indicative of conditions later in the rotation or into the next rotation. The general decrease in soil and foliar N and P with increasing organic matter removal may result in some sites becoming nutrient deficient, which might translate to lower productivity in subsequent rotations. Also, Ludovici (2008) found that soil compaction decreased loblolly pine (*Pinus taeda* L.) root production, thus resulting in C allocation patterns favoring aboveground productivity. Although soil compaction did not significantly affect aboveground productivity, the decrease in belowground C and nutrient stores from fewer roots may lead to lower productivity in future rotations.

Challenges

There are many challenges to maintaining a long-term study. In some cases, we have little or no control over these challenges, for example, natural disasters such as hurricanes and tornados. The LTSP installations in Mississippi and Louisiana faced a serious threat in the form of Hurricane Katrina. Although these sites survived the onslaught, they could have been wiped out. The beauty of the LTSP cooperative is that the number and variety of installations ensure that a loss of a few installations will not be fatal to the overall study. There are other situations, such as fires and insect infestations, where we have some control, but challenges can still occur despite our best planning. However, the most serious challenge facing long-term studies is the need to maintain consistent, long-term commitment to the study. This is something that can be controlled. Over the course of a long-term study, there are invariably considerable changes in the people involved and their priorities. At a study's initiation, the partners must have a long-term vision and commitment for the study, as was the situation for the LTSP cooperative. The LTSP partners recognized the need to keep the study relevant in the face of changing national priorities. This involves more than just political support but includes financial backing and, where appropriate, involvement of new partners. Recently, the NFS Southern Region and the R&D Southern Research Station renewed their Memorandum of Understanding (MOU) in support of the installations in the South. As part of this MOU, partners in the State and Private (S&P) branch of the USDA FS were included to assist in the dissemination of the LTSP findings. It is critical to periodically assess the political and scientific climate to maintain the relevancy of the LTSP experiment. Only by maintaining the long-term nature of the LTSP study will we truly be able to address the question of forest management effects on soil quality.

The Road Ahead

As previously discussed, laws and USDA FS policies are made to protect NFS lands and resources for future generations. The need to keep existing commitments to efforts like the LTSP experiment is critical. Changes in soil are complex, and it often requires several years—even decades—to fully observe the affects of a disturbance, especially when dealing with long-lived tree species. Small changes in soil properties as a result of soil disturbance that might seem scientifically insignificant at one point may become significant when the soil disturbance is repeated in multiple rotations as an acceptable management practice. As the LTSP experiment has demonstrated, measurable changes in soil conditions tend to be site and/or soil horizon specific, and the changes in the soil capability may not be observable within the current management period. With these casual generalizations in mind, we look ahead.

The USDA FS is pursuing the use of environmental management systems (EMS) to boost its resource management and monitoring endeavors. An EMS is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. An intriguing aspect to EMS implementation is in the arena of third party review and evaluation. The intent of the neutral third party review is to validate that the EMS parameters are truly being adhered to outside of the Agency's influence. The 2008 Planning Rule (revision of the Forest Service's land management planning policy) includes a provision to establish an EMS on national forests and grasslands. Although the areas the EMS would address have not been completely fleshed-out, the process offers an important opportunity to include monitoring parameters related to soil function and productivity. The hope is that with a future planning rule, land management plans will incorporate monitoring or an EMS that includes soil components such as, percentage of bare soil, soil porosity, and/or soil organic matter content, especially in light of ecosystem function and watershed condition.

On another policy front, NFS and R&D have been in continuing dialogues about the need to strengthen the collaboration in the natural resource area of soil science. These efforts were given further urgency after the USDA FS lost two lawsuits (Iron Honey and Lolo Post-Burn) in which the soil analysis was deemed to be inadequate. The National Soil Information Network (SoilNet) is the culmination of these collaborative discussions. The SoilNet charter establishes a formal process to raise soil-related land management questions to the R&D community. Once the questions have been identified, SoilNet provides a mechanism to identify and organize a network of R&D scientists and facilities across the United States to address them. SoilNet has three focus areas: (1) Science Integration and Delivery, (2) Resource Monitoring and Data Management, and (3) Research and Development. Organizationally, SoilNet is composed of a Technical Team and a Steering Team. Proposals are reviewed by the Technical Team who makes a recommendation to the Steering Team. The Steering Team then makes a recommendation to the directors of the Watershed, Fish, Wildlife, Air and Rare Plants and Environmental Sciences Research who approve the proposals for potential funding.

Collaborations and Databases

The EMS and SoilNet are conduits we can use to strengthen our understanding of soil processes and functions on NFS lands. But, as often is the case, collaborations with other land managers (i.e., private land owners, other agencies) will be essential to getting the total picture of ecological processes and watershed condition. With the challenges posed by climate change, it will be more important than ever to have accurate information on associated lands and to be able to compile data across administrative boundaries. The development of electronic data warehouses with standardized protocols and well-documented monitoring records will be in greater demand as time passes. The soil quality protocol introduced in this paper is intended to advance that journey. It will only be successful if the data that is collected in the field is corporately stored in databases that are accessible by interagency resource specialists and land managers.

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