FOREST SERVICE HANDBOOK
MISSOULA, MONTANA

FSH 2509.18 - Soil Management Handbook

R-1 Supplement No. 2509.18-94-1

Effective 5/4/94

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The last R1 supplement issued was No. 1 (4/89) for chapter 2.

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Digest:

These directions apply to this transmittal only. Entire supplement text is replaced. New text corresponds with parent text located in the National Information Center. The electronic document names are shown above for ease in accessing them from the Information Center. Supplement numbers and dates noted above are listed for historical purposes only. All subsequent supplements will be issued by document.

Digest:

2509.18 - Defines soil quality standards, guidelines, and detrimental changes in soil properties. Provides soil quality monitoring guidance.

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FSH 2509.18 - SOIL MANAGEMENT HANDBOOK
R-1 SUPPLEMENT 2509.18-94-1
EFFECTIVE

CHAPTER 2 - SOIL QUALITY MONITORING

2.04 - RESPONSIBILITY

2.04b - Forest Supervisors.

1. Assess the extent to which soil quality standards are being met.
2. Provide training in the application of soil quality standards .
3. Evaluate the effectiveness of soil quality standards and recommend adjustments to the Regional Forester.
4. Report monitoring results to the Regional Forester.

2.04c - District Rangers.

1. Ensure that land management prescriptions are consistent with soil quality standards. Identify measures necessary to meet soil quality standards in environmental documents.
2. Conduct post activity implementation monitoring to determine if soil quality standards have been met. Consult with soil scientists to evaluate needs to adjust management practices or apply rehabilitation measures.

2.05 - DEFINITIONS

Activity Area. A land area impacted by a management activity to which soil quality standards are applied. Activity areas include harvest units within timber sale areas, prescribed burn areas, and grazing areas or pastures within range allotments. Inclusion of system roads within the activity area is dependent on analysis objectives. System roads are often evaluated separately, however, temporary roads, landings, and skid trails are included within an activity area. Riparian and other environmentally sensitive areas may be monitored and evaluated as individual activity areas within larger management areas.

Bulk Density. Soil bulk density is the mass (oven dry weight) of a unit volume of soil.

Detrimental Compaction. Soil compaction that adversely affects hydrologic function and site productivity is detrimental.

Detrimental Puddling. Soil puddling that adversely affects hydrologic function and site productivity is detrimental. Vehicle ruts or hoof prints in mineral soil, or in an Oa horizon of an organic soil, are indicators of detrimental puddling.

Detrimental Displacement. Displacement is detrimental if it adversely affects hydrologic function or site productivity.

Detrimentally disturbed soil. Detrimentally disturbed soil is soil that has been detrimentally displaced, compacted, or puddled.

Erosion. Management practices increase the susceptibility of soils to erosion when they remove ground cover, detach soil particles, and/or concentrate the overland flow of water.

Ground cover. Ground cover consists of vegetation, litter, wood residue, and rock fragments larger than three-fourths inch in diameter in contact with the soil. Minimum amounts of properly distributed ground cover necessary to protect the soil from erosion are a function of soil properties, slope gradient and length, and precipitation and must be determined locally.

Hydrologic Function. Soil hydrologic function is the ability of the soil to absorb, store and transmit water, both vertically and horizontally. Changes in soil bulk density and/or structure can alter the hydrologic function of the soil.

Large Woody Debris. Organic materials such as plant stems and branches with diameter > 3 inches. Included are woody materials from natural sources such as wildfire and blowdown, and logging slash.

Litter. The surface layer (O-horizon) of fresh and decomposed plant parts, mainly leaves and twigs (branches < 3 inches thick).

Severely Burned Soil. Soils are severely burned if all surface litter is consumed and the mineral soil has been blackened more than 1 inch deep. Oxidized soil (reddish color) is also indicative of severely burned soil.

Soil Conservation Practices. Soil conservation practices are the mechanisms used to protect soil quality while managing for other resource goals and objectives. They can be administrative, preventive or corrective measures. They are identified during project planning and design. The Soil and Water Conservation Practices Handbook (FSH 2509.22) contains a process for developing specific conservation practices for use on National Forests.

Soil Organic Matter. Soil organic matter is the organic fraction of the soil within the soil profile. It includes plant, animal, and microbial residues, both fresh and at various stages of decomposition, and the relatively resistant soil humus.

Soil Productivity. Soil productivity is the inherent capacity of a soil to support the growth of specified plants, plant communities, and soil biota. It is often expressed by some measure of biomass accumulation.

2.1 - TYPES OF SOIL QUALITY MONITORING

2.11 - Implementation Monitoring. Implementation monitoring is a part of regular management procedures on nearly all projects. It is conducted mainly by personnel responsible for project administration. Implementation monitoring evaluates whether soil conservation practices were implemented as planned and identifies needed changes in the Forest Plan implementation process. The results of implementation monitoring will be included with project documents.

Project administration personnel need to be adequately trained in applying and monitoring the effectiveness of soil conservation practices. They should understand the purpose of soil conservation practices used and how they help meet standards. Timber Sale Administrators and Range Conservationists will receive frequent training in monitoring the effects of timber and range management practices on soil properties. Engineers will receive training related to the effects of construction practices on soil quality. Soil productivity workshops conducted for district personnel on a regular basis by soil scientists, logging engineers, and silviculturists are effective. Local researchers should be involved in these workshops whenever possible.

2.12 - Effectiveness Monitoring. Effectiveness monitoring measures how effectively soil conservation practices have limited detrimental changes in soil properties. Effectiveness monitoring can be designed to evaluate the beneficial effects of management activities, as well as detrimental changes. It is not possible to monitor effectiveness on all projects. Therefore, projects that are representative of a large number of projects will be monitored and results extrapolated to similar projects. Reliable, high quality data from a few projects is better than poor quality data from a larger number of projects.

The most important criteria for selecting representative projects are issues and concerns, such as unknown or questionable effectiveness of practices applied to sensitive areas. An example might be the use of a previously untried machine to move logs on a soil sensitive to compaction.

Soil scientists will work with specialists in timber, range, and recreation to develop practices which minimize the areal extent of detrimental soil compaction and displacement resulting from management activities. Effectiveness monitoring will be conducted to demonstrate the effectiveness of management practices.

Effectiveness monitoring of soil conservation practices requires measuring the areal extent of detrimental changes in soil properties (2.4, Monitoring Methods).

Forests should share monitoring data and experiences with the Regional Range, Air, Watershed and Ecology staff, adjacent Forests, and research personnel. Effectiveness monitoring reports will include a summary of results; a comparison of the years results with those of previous years; an evaluation of the effectiveness of soil conservation practices used; an evaluation of needed changes in the Forest Plan implementation process; and recommendations for revisions of guidelines and monitoring techniques. Monitoring results will also be reviewed on-site with key district people.

2.13 - Validation Monitoring. Validation monitoring answers the question "Are standards and guidelines appropriate for meeting Forest Plan objectives?" For soil productivity, the question is "Did compliance with standards and guidelines provide enough soil protection to assure the maintenance of soil productivity?" The relationships between management-induced changes in soil properties and productivity are not well documented or understood. Improving our understanding of these relationships will require data-intensive sampling designs, such as permanent growth and yield plots. These kinds of studies are a function of Research. The contribution of the National Forest System to validation monitoring of soil productivity will be in support of Research projects.

Soil quality research results are distributed to National Forest System personnel mostly by publication. Research-sponsored workshops and field days for National Forest System personnel will be held to ensure that research results are incorporated into management prescriptions.

2.2 - SOIL QUALITY STANDARDS

The National Forest Management Act requires that lands are to be managed to ensure the maintenance of long-term soil productivity, soil hydrologic function, and ecosystem health. Soil resource management will be consistent with these goals.

Soils can be impacted by compaction, puddling, displacement, burning, erosion, and mass movement during or following management activities. Impacts and above-ground organic matter losses that adversely affect hydrologic function or cause losses in site productivity are detrimental.

Soil quality standards, or goals, are the management of soil properties and site characteristics in a manner consistent with the maintenance of long-term soil productivity, hydrologic function, and ecosystem health. The ultimate objective is to maintain natural soil structure and fertility. Because soil structure and fertility are difficult to quantify, surrogate soil parameters are often monitored. These parameters include soil disturbance, severely burned soil, ground cover, and above-ground organic matter (litter and woody debris).

Soil quality guidelines are estimates, based on available research and local experience, of the levels of disturbance that are likely to impair long-term soil productivity and hydrologic function. Guidelines are established to provide the means to evaluate soil and site conditions following management activities and to compare those conditions to soil quality standards. Guidelines do not represent the minimum soil disturbance that will reduce inherent productivity, instead they indicate the maximum tolerable disturbance, i.e., disturbance that will result in a detectable loss of productivity. Management goals should strive to create as little detrimental disturbance as possible, not just to keep from exceeding guidelines.

Compaction, puddling, and displacement are effects of management practices and may be cumulative over time. If a guideline or combination of guidelines are exceeded in an initial entry, then future entries must have no additional effect unless natural recovery has taken place or mitigative measures have been applied between entries.

Soil quality guidelines will be evaluated and updated based on research and local experience. Local values may be developed and, if appropriate, submitted to the Regional Forester for standardization among Forests. The ultimate goal of soil resource management is to translate soil management guidelines into applicable soil conservation practices.

Guidelines used as indicators of soil quality, and as measures of conformance to soil quality standards, are presented below.

1. Soil Disturbance. If system roads are evaluated as part of an activity area, at least 80% of the area must have soil that is in satisfactory condition; that is, no more than 20% of the area may have detrimentally disturbed soil. If system roads are evaluated separately and are discounted as part of the activity area, at least 85% of the area must have soil that is in satisfactory condition. Examples of management options limiting the effects of soil disturbance, along with appropriate mitigation measures, are listed in Exhibit 1.

a. Soil Displacement. Soil displacement will be evaluated along line transects. Detrimental displacement is displacement that results in the loss of either 1 inch or one-half of the humus-enriched surface layer (A-horizon), whichever is less. The loss of the litter layer alone could be detrimental on some marginal sites.

b. Soil Compaction. Bulk density is used as an indicator of soil compaction. An increase in bulk density correlates to decreases in soil porosity, air exchange, root penetration, infiltration, and permeability.

A 15% increase (20% in volcanic ash soils) in natural bulk density or a 50% reduction in infiltration rate is considered to be detrimental. Bulk density measurements are generally taken 1 inch below the mineral soil surface using a coring tool, or other appropriate method. Measuring soil infiltration rates may be appropriate when monitoring rangelands since the compacted layer is often too thin to measure using core sampling techniques.

Changes in the natural soil structure are also good indicators of soil compaction if a more qualitative method is desirable.

c. Soil Puddling. The deformation of saturated soil results in puddling. Puddling cannot result directly in compaction since there is no air-filled pore space in saturated soil. Puddling can, however, indirectly result in increased bulk density when the soil dries and reduces the soil's ability to transmit water. Any evidence of soil puddling is considered to be detrimental.

2. Severely Burned Soil. Organic matter and nutrient losses are the main effect of burning. Ground cover and above-ground organic matter requirements set limits on these losses. Soil humus losses, structural

changes, and soil sterilization are additional detrimental effects of burning. Any severely burned soil is considered to be detrimental.

3. Ground Cover. The minimum cover, following the cessation of disturbance in an activity area, should be sufficient to prevent accelerated runoff and prevent erosion from exceeding the rates of natural soil formation. Erosion rates are dependent on soil erodibility (k-factor), erosivity (rainfall factor), and slope gradient and length. Local adjustment of these factors by geographic area or potential natural plant community types may be required. On grasslands, at least 80% of the A or surface mineral horizon should contain abundant roots.

4. Above-Ground Organic Matter. Litter and large woody debris are required to retain nutrients and micro-organisms necessary to supply and cycle nutrients needed to maintain site productivity.

a. Litter. Suggested litter retention is 30% (Dumroese, 1993).

b. Large Woody Debris. The minimum amounts of large woody debris required to maintain adequate nutrient supplies to sustain site productivity will vary by habitat type and fire history. These values are being supplied by research studies (Harvey, 1987).

2.4 - MONITORING METHODS. Activity areas may be sampled by one or both of the following strategies:

1) an entire activity area may be sampled at grid points or along line transects, or

2) activity areas, or soil delineations within activity areas, may be stratified by management impact and sampled to determine differences among impacted areas. Disturbance can simply be categorized as either within or exceeding guidelines, or it can be quantified by classes or continuous variables.

2.41 - Areal Extent Sampling. Unstratified sampling (strategy 1) is most appropriate for sampling soil displacement, puddled soil, and qualitative estimation of soil compaction where the record for each point or line segment is simply whether the impact is or is not detrimental (according to the severity guidelines).

Stratified sampling (strategy 2) has the advantage that disturbance within each of the strata can be characterized more efficiently, with less sampling than would be necessary without stratification. It is most appropriate for sampling bulk density and is measured as a continuous variable. The significance of differences between strata can be determined by Student's t-test where there are only two strata (disturbed and undisturbed), or by analysis of variance where there are more than two strata.

1. Determine Sample Size. The number of samples required depends on the desired precision. Where the precision is crucial, preliminary sampling will allow computation of the required number of samples utilizing Student's t distribution, which is given in any basic text on statistics.

2. Sample Design. Monitoring data are obtained either by sampling at points, or by measuring lengths of disturbance or impact along randomly-selected lines or on grids. Step-point sampling is generally adequate. Soil type and land use or disturbance strata may be sampled independently to improve precision.

2.42 - Soil Sampling Techniques. Soil displacement, puddling, severely burned soil, ground cover, and above-ground organic matter can be determined visually and measured.

Soil compaction can be measured semiquantitatively with a spade or quantitatively with a cone penetrometer or by collecting, drying, and weighing samples of known or determined volume (core sampling). Visual and tactile (spade) estimations of soil compaction are very effective and can be calibrated with soil strength (Clayton, 1987).

Another suggested method, combining semiquantitative (eg., none, low, moderate, high) with quantitative techniques, is to establish classes of compaction using a spade. Representative soil bulk density core samples are then collected from each compaction class, and bulk density is determined. (It is important to adjust bulk density samples to account for coarse fragments).

SOME OPTIONS FOR MEETING SOIL QUALITY STANDARDS

Soil Property or Condition	To Avoid/Reduce Effects	To Mitigate Effects
Ground cover	Limit cover removal.	Import cover, mulch, redistribute cover.
Displacement	Specify and/or limit ground operations, use aerial equipment, train equipment operators.	Redistribute soil.
Compaction, hydrologic function	Operate over frozen ground or deep snow, avoid operations on moist or wet soils, operate over slash, restrict equipment to dedicated roads and trails, restrict or specify type of equipment.	Surface tillage, subsoiling.
Organic matter	Use methods that do not move topsoil and that minimize soil displacement.	Respread topsoil, fertilization.
Large woody debris	Retain cull logs on site.	Import organic material, including cull logs.

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