Soil Resources

Introduction

Soil is a fundamental component of the environment. It is the growing medium for most plants. Soil absorbs and stores water, releasing it slowly over time. It supplies nutrients for vegetation, which in turn supplies habitat for wildlife and other resources. All renewable resources of the Bighorn National Forest are dependent upon soil. Soil is considered a nonrenewable resource because of the time required for its formation.

Conceptually, the quality or health of a soil can be viewed as "its capacity to function." More explicitly, the Soil Science Society of America defines soil quality as, "The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance soil quality, everyone must recognize that the soil resource affects the health, functioning, and total productivity of all ecosystems."

The Forest recognizes the importance of soils information as an integral part of land management planning and began soil resource inventory efforts in the 1980s. Since then, a soil resource inventory, also know as a soil survey, has been completed on the entire Forest. A goal is to utilize soils data as much as possible in the revision process so management activities may be blended with the ecological capabilities and potentials of the land.

The primary goal of soil management is to maintain or enhance long-term site productivity. There are five categories of physical soil disturbances that have been found to affect soil productivity. The categories include: compaction, displacement, erosion, puddling, and severely burned.

Soils information is both used and analyzed at the forest planning level. This section of FEIS Chapter 3 presents an overview of alternatives and general effects on the soil resource. When projects are proposed, more site-specific soil analysis occurs, and mitigation is based on the potential, capability, and limitation of the soils at the site.

Legal and Administrative Framework

The Organic Administration Act of 1897 – the goal of this act is "to improve and protect the forest within the boundaries …"

The Multiple-Use Sustained-Yield Act – this act sets forth the secondary purpose of the establishment "for outdoor recreation, range, timber, watershed, and wildlife and fish purposes."

The Forest and Rangeland Renewable Resources Planning Act (RPA) – this act requires an assessment of the present and potential productivity of the land. Regulations

are to specify guidelines for land management plans developed to achieve the goals of the program that … ensure that timber will be harvested from NFS lands only where soil, slope, or other watershed conditions will not be irreversibly damaged.

The National Forest Management Act – this act was amended with the addition of a section that stressed the maintenance of productivity and need to protect and improve the soil and water resources and avoid permanent impairment of land productivity.

Resource Protection Measures

In order to maintain long-term soil productivity, soil disturbance should be kept to a minimum, and adequate measures need to be implemented to protect the soil resource. Mitigation measures have been developed to protect the soil resource and can be found in the forest-wide standards and guidelines, timber sale contract, and best management practices (BMPs). Resource protection measures apply to all alternatives.

Monitoring is a part of project planning and implementation. A key part of monitoring is to determine if the mitigations are working and protecting the intended resources.

Affected Environment

Soils are an ecologically rich and active zone at the interface between the atmosphere and geologic materials. Soils form as a result of complex interactions between the geologic parent material, climate, relief, organisms, and time. The diverse geology and climate of the Forest, in conjunction with natural and human disturbances, have resulted in a spatially complex pattern of soils that differ in structure and function, and response to management activities.

For the purposes of this document, the Bighorn National Forest has been divided into six physiographic units, which are areas that contain similar soils, relief, and drainage (Nesser 1982). Each unit is a unique natural landscape. Typically, within each physiographic unit, there are one or more major soils and some minor soils or miscellaneous areas. Each physiographic unit is named for the major soils or miscellaneous areas that occur there. The descriptions for each unit can be used to compare the suitability of large areas for general land uses. Because of its scale, geographic units are not suitable for use as a site level analysis tool. The soils in any one unit may vary from place to place in respect so slope, depth, drainage, and other characteristics that can affect management.

Soil Productivity

Soil productivity varies widely due to varying characteristics such as soil depth, available water holding capacity, nutrient status, and site characteristics, including elevation, slope, and aspect. The most productive soils are found in valley bottoms, toe slopes and benches.

The concept of productivity includes both the ability to grow vegetation as well as the maintenance of slope stability. In some areas, past practices have slightly reduced growth

potential from compaction, nutrient loss from fires, and loss of large woody material. Soil productivity is the principle area of concern on the Forest, because it can be affected by management activities.

The effects of management practices will influence the future of soil productivity. The demand for many forest resources, which are dependent on soil productivity, is expected in the future. Soil erosion, soil compaction, and organic matter content all determine the productivity of Forest soils. The following section describes these processes/factors and their influence on productivity.

Soil Erosion is the origin of most of the sediment delivered to streams. This sediment can have adverse effects on water quality and fish habitat. The primary cause of soil erosion is overland flow from spring runoff or high intensity storms. Without overland flow, there is very little erosion. Wind erosion may occur on some exposed wind scour ridges, if the soil surface is exposed and unprotected.

Timber harvesting, site preparation, fuels treatment, and road construction remove or rearrange organic matter, which changes erosion rates. Surface erosion rates depend on such factors as soil erodibility, steepness of slope, slope length, and amount of bare ground. Erosion rates may be calculated at project levels, but not at the forest scale.

Mass movement of soil (geologic hazards) include slumping, slope failure, and earthflow. The geologic hazards with highest probability of mass movement potential have special management implications. Descriptions of the slope stability, or potential of mass movement have been, and will continue to be, used to indicate the types of management practices and mitigation measures which are appropriate for the site.

Most Forest soils are stable, thus no special measures are needed. Lands with moderately stable soils require more work in layout and design of roads and increased road construction cost. Areas with unstable soils should generally be avoided because the risk of resource damage is higher than the benefit of wood fiber production. Approximately 15% of forested lands on the Forest were removed from the tentatively suited timber base, because of the irreversible damage constraint applied during the analysis process.

Vegetation plays a major role in the complex interactions of slope stability, as well as erosion. It acts to intercept and store significant amounts of precipitation, thereby buffering the effects of storm events. The roots of vegetation physically bind soil particles together; the strength of roots adds strength to the soil; and the roots may grow to bedrock, forming an effective anchor system. Once precipitation enters the soil, it becomes available for the vegetation to remove it through evapotranspiration, which decreases the amount of destabilizing groundwater (Swanson, et al. 1989).

Soil Compaction can significantly reduce long-term soil productivity; therefore it is important to prevent unnecessary compaction. Compaction often occurs as a result of management activities, thus it is important to stay within acceptable standards in order to minimize the overall effect. The Soil Management Handbook (FSH 2509.18 R2) defines detrimental compaction as a greater than 15% increase in the average undisturbed soil bulk

density. It is believed that an increase of 15% or more would represent a significant loss in soil productivity.

Some soils are more easily compacted than others, and most soils are more easily compacted by the use of ground skidding equipment or equipment used to pile the residue after timber harvest. Each trip across the same location with a piece of machinery or a log or logs will cause some compaction. The effects are cumulative, with each succeeding trip increasing the compaction. Because it reduces soil productivity in terms of the amount of timber and forage that land can produce, compaction is not desirable for the Forest in general.

Organic Matter content and related nutrient availability is an important component of soil productivity. Soil organic matter affects both water- and nutrient-holding capacity and reduces the erosion hazard. Organic matter holds many times its weight in water and has a high cation exchange capacity that increases the soil's ability to retain nutrients for plants. As soil organic matter (leaves, needles, and twigs) decomposes, it releases nutrients, in soils. Nutrient losses are of concern because if nutrient levels are allowed to decline, the productivity of the site is reduced. These losses most often occur as a result of erosion of the surface horizon, volatilization by fire, or whole-tree harvesting.

Coarse/large Woody Material (greater than 3 inch diameter) supports the life cycle of symbiotic soil fungi (ecto-mycorrhizae), which attach to conifer roots, and greatly increase the tree's ability to take up nutrients and water. Duff and litter on the soil's surface also act as mulch and reduce soil erosion due to rainfall impact. Fine root mats in the surface soil bind the soil together, reducing down slope soil creep and washing. Some forest soils have accumulated very little organic matter and are considered sensitive to any organic matter removal by management. These soils generally occur in higher elevations where the colder climate and short growing season do not generate large amount of annual vegetative growth.

Environmental Consequences

General Effects

Litter, humus, soil wood, and certain key properties of the surface mineral layers of forest soils are usually most critical when developing silvicultural systems. These are the soil layers most easily and commonly disturbed by silvicultural activities, yet they are the most crucial to forest productivity (Graham, et al. 1991).

Coarse (i.e., large) woody debris physically protects the soil from erosion, displacement, and compaction. In addition, it can protect a regenerating forest from both abiotic and biotic elements. Coarse woody debris provides shade and protection from wind and snow and can be a critical factor in protecting newly established seedlings from livestock and other large animals.

The silvicultural methods available to manage the forest need to be assembled into complete silvicultural systems—planned programs of treatments to be applied throughout the life of a forest stand. This is important in ecosystem management. Soils are critical to the regeneration, productivity, nutrient values, and moisture-retention abilities of all forest sites.

The choice of regeneration methods is, in many ways, the most critical decision regarding the entire system. It should be selected by considering all abiotic and biotic elements that might influence forest regeneration and development, but soil properties are especially important. Physical properties of the mineral soil, especially water-holding capacity, can be used to help determine which regeneration methods would be appropriate. For example, stands located on soils with high amounts of available water would be most suited to the clear-cut methods, and stands on droughty soils with little available water would be more appropriate for selection or shelterwood methods. This is not to say that soil is the only fact that should be considered when selecting a harvest method, but soils should be used as input in the decisions. Silvicultural prescription in some cases may depend more on the shade tolerance of the tree species.

Many public forestry agencies have shifted from even-aged to uneven-aged management, primarily because of the public perception that uneven-aged management is less damaging to the environment, better for wildlife, and will result in a more aesthetically pleasing landscape.

Harvey, et al. (1994) stated that with uneven-aged management, the potential for soil damage increases because, with fewer trees removed over larger areas, ground-based extraction is mandatory to avoid excessive cost. With this forest management approach, potential soil damage threatens long-term wood production. Short- and long-term growth reductions from traffic-induced soil compaction and soil displacement can be expected. The use of mitigation such as designated skid trails will keep the disturbance to an acceptable level.

Tractor piling of logging debris and machine site preparation is used throughout the West. Similar to tractor yarding, tractor piling can detrimentally impact the soil. The greater the disturbance, the greater the potential loss of the surface organic layers. A balance is needed to achieve the level of disturbance required for site regeneration while minimizing adverse impacts from that disturbance.

After the site preparation and hazard reduction treatments are completed, it is imperative to leave sufficient large woody material on the site. As mentioned earlier, residue has several properties important for maintaining forest productivity. Graham, et al. (1991) recommend leaving a minimum of 5 to 15 tons per acre of large woody material after timber harvesting and other site treatments. These recommendations are general and will be refined as more research makes them more site-specific (Graham, et al. 1994).

Direct and Indirect Effects

Effects from Fire and Fuels Management: Wildfire is a natural process, which can cause many impacts to the soil resource, including erosion and severely burned soil (DeBano 1991).

Wildfire can have serious short-term implications for watershed protection. Severe wildfires not only destroy vegetation but also can detrimentally burn soils. Soils are considered detrimentally burned when most woody debris, litter, duff, and humus are consumed down to bare mineral soil (USDA Forest Service 1992). Detrimental burning reduces soil productivity. Gully formation, shallow slumping, and decreased microbial activity may result.

DeBano et al. (1998) in their book *Fire's Effects on Ecosystem* discussed that fire-related changes in soils produce a wide array of changes in the surrounding ecosystem because of the interdependency between the soil and other ecosystem components. Immediate short-term and long-term response to fire occurs. Immediate effects of fire arise as a result of the heat released during a fire and directly impact the soil and surrounding ecosystem. The response of biological components (soil microorganisms and vegetation) of the fire is rapid. Another immediate effect is the release of gases and other air pollutants by the combustion of soil organic matter during a fire. The long-term fire effects are usually subtler, but they can persist for years following a fire or be permanent. When the effects become long-term, they are considered an impact to the soil resource. An example of long-term fire effects is the disruption of the relationship between nutrient cycling and long-term productivity.

After a wildfire, streamflow may increase in response to soil and vegetation changes. A severe wildfire may create hydrophobic soil condition, which decreases the infiltration capacity. This decrease in the soil's ability to absorb water, combined with reduced transpiration resulting from vegetation removal, can result in significant streamflow increases. If the resulting streamflow causes streambank instability and undermines the integrity of downstream structures in the floodplain, soil erosion will occur. This is particularly important in forested areas where intense thunderstorms can create considerable overland flow if infiltration capacity is reduced.

Severely burned areas would need emergency treatments to prevent watershed and soil degradation. The Forest has a burned area emergency rehabilitation program and plan that would respond to watershed concerns after a major wildfire (USDA Forest Service 1995). This would be true for all alternatives.

For prescribed burning, similar hazards exist as described for wildfires, but conditions are expected to occur over a smaller area and have lesser impacts. The areas selected for burning are usually small enough and burn cool enough so that widespread adverse effects area minimized, and effects are not as severe as those resulting from a major stand replacement fire.

Prescribed burning can affect the physical and chemical nature of the soil. The amount of soil erosion after a prescribed burn depends on the inherent erodibility of the soil. Project analysis and monitoring would be completed for all prescribed burn proposals so that long-term soil productivity would not be impaired. Prescribed fire programs in all alternatives can be implemented in a way that prevents excessive soil impacts.

The effects of wildfire on soil resources, could potentially be greater in those alternatives, such as Alternative C, where natural processes dominate, depending on fuels loads, moisture, insect and disease activity. See the Biodiversity section for more information on natural processes. The potential for impacts from fuel treatments would be similar for the other alternatives, but may be decreased under Alternative B, due to the higher level of active vegetation management.

Effects from Rangeland Management and Big Game Use: Johnson and others (1994) stated that perhaps livestock grazing during the late 1800s has caused the greatest degree and extent of land disturbance in the western United States. The mobility and extensive use of vegetation by various ungulates across western rangeland affected virtually all segments of the landscape to some extent. The effect was greatest along watercourses, in basin meadows, and on ridgetops, where stock driveways and bedding grounds were used season after season for many years. Degradation of native vegetation in some areas has been so complete that thresholds have been passed, leaving unnatural vegetation communities. This change in vegetation type is usually less diverse biologically, than the native flora or contains invasive, less desirable plants.

Under a properly managed grazing system, livestock are well distributed, grasses are grazed to a preferred use, and trailing is minimized, leaving adequate vegetation for soil protection through surface cover. Proper utilization levels need to account for both livestock and big game needs. If grazing systems are not properly managed, riparian areas may be heavily grazed and streambanks become raw and erosive. If too much forage utilization occurs, upland soils may become compacted and the loss of vegetation can result in increased erosion. Erosion takes place on livestock trails to watering sites or favored crossings, such as over roads, ridges, and streams. In some areas, overgrazing has resulted in soil compaction. Excess trailing can also result in rilling, which reduces ecosystem integrity.

An interpretation of desired vegetation condition and soil standards on the Forest has indicated that some of the rangelands do not meet existing forest plan direction, and soils may be exceeding natural erosion rates in some locations. Changes in the amount and timing of use, pasture rotation, deferment, resting, and vacating allotments are appropriate means to reduce grazing related erosion problems. An evaluation of soil stability and watershed function, using soil surface characteristics as indicators of soil erosion and runoff, should become a fundamental component of all inventory and monitoring programs for rangelands (National Research Council 1994).

With grazing occurring over large areas of the Forest in all alternatives, the possibility for accelerated natural erosion rates exists. These effects of livestock and wildlife grazing would be similar under all alternatives.

Effects from Recreation Management: Overuse of campsites can cause soil compaction and deterioration of the vegetation. Both the compaction and vegetation deterioration can lead to increased surface-water runoff and gully formation. This situation presently occurs in some developed recreation sites or at frequently used, dispersed recreation sites, such as campsites near streams. These effects are expected to be similar under all alternatives. Effects can be mitigated by surface treatments, such as the application of gravel or paving, for heavily used footpaths or by closing areas to dispersed camping. Mitigation would be applied under all alternatives.

Since vegetation is removed from trails and compaction occurs, either during construction or by use, trails increase the potential for erosion. Where trails descend/ascend steep slopes, gullying may occur. Proper trail reconstruction, proper cross-drainage, barriers, and interpretive signing can mitigate effects. Some indirect adverse impacts can result from trail construction. For example, as access increases, so does off-trail hiking and biking on previously undisturbed areas. This can increase soil erosion, gullying, and compaction. Interpretive signing and barriers area examples of mitigation that can help reduce the amounts of off-trail use.

Off-highway motorized recreation has the potential for heavy impacts to the soil resource. When use is heavy or concentrated along corridors, ground cover tends to be damaged without the opportunity to recover. Soils are compacted and, in some instances, the topsoil layer is lost. Heavy use on unstable soils or steep slopes has caused soil erosion, permanent loss of ground cover, and gully formation.

Dispersed motorized recreation can damage soil and water resources; however, because the areas affected are so small and scattered, the effects on soil and water are negligible at the forestwide scale. In general, the impacts occur when users do not comply with existing regulations: for example, OHV use occurring off designated travel ways. Incorporating the watershed conservation practices identified in the forestwide standards (see Revised Plan, Chapter 1) will further mitigate effects.

The effects of recreation on soil resources, could potentially be greater in those alternatives, such as Alternative E, where higher levels of motorized recreation opportunity are expected to occur.

Effects from Timber Harvesting: Timber harvesting affects the soil in many ways. Activities such as skidding, decking, site preparation, and machine piling of slash results in various degrees of soil displacement, soil compaction, and disturbance to vegetative ground cover. Within a cutting unit, regardless of silvicultural prescription, skid trails can lead to erosion and gullying if not properly located, constructed, and mitigated.

When individual projects are planned, site-specific soil characteristics are taken into consideration. Some soil characteristics will restrict where timber harvesting can be done. Soil characteristics may also require specialized harvesting methods. Where soils are highly erosive or unstable, care must be taken to keep soils in place. Slash should be lopped and scattered on some soil types to maintain nutrients and organic material.

Timber harvest can affect the soil productivity through heavy equipment compaction to the soil and through the removal of nutrients in the form of tree boles, limbs, and branches. The effects of equipment operation will result in varying degrees of disturbance or removal of the existing vegetation, litter, and humus from the surface of the soil. Heavy equipment on the forested site can result in detrimental puddling, compaction, erosion, and displacement. In addition to these direct effects, damaged soil can lead to increase runoff from the lower infiltration rates, sedimentation, lower permeability, and reduced site productivity.

The amount of soil erosion occurring within a timber sale depends on the amount of bare soil, slope steepness, slope length, inherent erodibility, and rainfall intensity. Slash and logging debris that remains after a timber sale reduces erosion because it protects the soil from raindrop impact and presents physical barriers to soil movement. If logging activities expose too much soil, then erosion becomes excessive and site productivity is reduced or impaired.

Road building activities associated with timber management can impact the soil resource. Road construction and reconstruction require that the soil be excavated, cut through, and reshaped by heavy equipment. When the vegetation is removed and bared soil is exposed, there is an increased chance that erosion will take place. In some cases, road reconstruction may be beneficial, particularly if it corrects drainage problems. In many cases, road reconstruction removes vegetation and reshapes the road surface. For these reasons, road reconstruction is considered a detrimental effect to soil resources even though there may be some beneficial effect to administrative uses.

The effects of timber harvest on soil resources, could potentially be greater in those alternatives, such as Alternative E, where a higher level of vegetation management and associated road construction would occur.

Effects from Travel Management: Motorized vehicle use on designated travelways and off-road uses have the potential to adversely impact soils through loss of vegetative cover, erosion, and compaction. Motorized off-road uses do not cause damage if the use is minimal and infrequent. Once vegetation has been imprinted by tires, the potential for additional use may be encouraged and the level of resource impacts increase because of the potential for erosion and compaction.

Decommissioning of a road can have a positive effect on the soil resource. Road decommissioning should re-establish proper drainage, remove structures requiring long-term maintenance, and restore vegetative cover that would stabilize soils and reduce sedimentation. Road decommissioning techniques may vary, but it is essential that soil and water objectives be met in the selected closure method.

Unclassified user created routes exist on the Forest, and are generally concentrated around areas of high use, resulting from big-game hunters, wood gathers, and other recreating public. These roads are not part of the Forest road system and have not been designed or authorized for motorized use. Decomissioning unclassified roads will have a beneficial

effect on long-term soil productivity and will reduce overall open-road density on the Forest.

For this reason, motorized use is restricted to roads and trails in all alternatives unless specifically allowed by Forest order. All alternatives propose to decommission the same amount of road per year, thus there is no difference between alternatives regarding road decommissioning.

Cumulative Effects

The effects on soils from major ground-disturbing activities expected to occur across the entire Forest under all of the alternatives, over the life of the Revised Plan, are shown in the following table. The cumulative effects table at the beginning of Chapter 3 includes the list of past, present, and reasonably foreseeable future activities that were considered with regard to cumulative effects to the soil resource on the Forest. Alternative C is expected to have the least impact to aquatic and riparian resources and Alternative E would have the most effect on those resources.

Table SR-1. Relative impact of alternatives on the soil resource.

Land Use Category	**Less Impact← Relative Impact →More Impact to soil resources**					
Effects from land authorizations	No difference between alternatives					
Effects from motorized recreation mgmt. (potential for user created roads)	C	B	D-DEIS	D-FEIS	A	E
Effects from livestock grazing	No difference between alternatives					
Effects from timber harvesting (tied to road effects)	C	B	D-DEIS	D-FEIS	A	E
Effects from timber harvesting (tied to vegetation management)	C	B	D-DEIS	D-FEIS	A	E
Lands allocated to Management Area category 5	C	B	D-DEIS	D-FEIS	A	E
Suited timber by Alternative	C	B	D-DEIS	D-FEIS	A	E
Effects from prescribed fire	C	A	E	D-DEIS	D-FEIS	B
Effects from wildland fire	B	D-DEIS	D-FEIS	E	A	C
Effects from utility corridors	No difference between alternatives					
Land available for locatable minerals and oil and gas	C	B	D-DEIS	D-FEIS	A	E

Alternatives can be evaluated on a cumulative effects basis in terms of the amount of activity in the same area. For timber harvesting, those alternatives with greatest multiple entries to the same area would potentially have the greatest cumulative effects. Each alternative differs in the relative amount of activities scheduled.

The effects above show estimated future disturbance differences between alternatives. Yet, watersheds have been impacted to some extent by past management efforts. A discussion of cumulative effects to watersheds is contained in the Aquatic section of Chapter 3. Compliance with state Best Management Practices will ensure that future management activities under any of the alternatives will continue to protect the soil resources on the Forest.