United States
Department of
Agriculture

Forest
Service

**Southwestern
Region**

Soils Specialist Report

Forest Plan Revision EIS

Submitted by: __/s/ ___________________________

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May 29, 2014

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Introduction

This report evaluates and discloses the potential environmental consequences on soil condition that may result with the adoption of a revised land management plan. It examines, in detail, four different alternatives for revising the 1987 Apache-Sitgreaves NFs land management plan (1987 forest plan).

Relevant Laws, Regulations, and Policy that Apply

Forest and Rangeland Renewable Resources Planning Act of August 17, 1974 - Directs the Secretary of Agriculture to prepare a Renewable Resource Assessment every ten years; to transmit a recommended Renewable Resources Program to the President every five years; to develop, maintain, and, as appropriate, revise land and resource management plans for units of the National Forest System; and to ensure that the development and administration of the resources of the National Forest System are in full accord with the concepts of multiple use and sustained yield. Organic Administration Act of June 4, 1897

Authorizes the President to modify or revoke any instrument creating a national forest; states that no national forest may be established except to improve and protect the forest within its boundaries, 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. It authorizes the Secretary of Agriculture to promulgate rules and regulations to regulate the use and occupancy of the national forests.

National Forest Management Act of October 22, 1976 - The National Forest Management Act reorganized, expanded, and otherwise amended the Forest and Rangeland Renewable Resources Planning Act of 1974, which called for the management of renewable resources on National Forest System lands. The National Forest Management Act requires the Secretary of Agriculture to assess forest lands, develop a management program based on multiple-use, sustained-yield principles, and implement a resource management plan for each unit of the National Forest System. It is the primary statute governing the administration of National Forests.

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The Multiple-Use Sustained-Yield Act of 1960 - This act established that the sustained yield of goods and services must be conducted without resulting in permanent impairment of the productivity of the land.

The National Environmental Policy Act of 1969 - This act declares a national policy that encourages productive and enjoyable harmony between people and their environment, promotes efforts that will prevent or eliminate damage to the environment and biosphere, and enriches the understanding of the ecological systems and natural resources important to the nation.

Travel Management Rule - On December 9, 2005, the Forest Service published the TMR. The agency rewrote direction for motor vehicle use on National Forest Service (NFS) lands under 36 CFR, Parts 212, 251, and 261, and eliminated 36 CFR 295. The rule was written to address at least in part the issue of unmanaged recreation. The rule provides guidance to the Forest Service on how to designate and manage motorized recreation on the Forests. The rule requires each National Forest and Grassland to designate those roads, motorized trails, and Areas that are open to motor vehicle use.

Road System: 36 CFR 212.5 (b) - ...the responsible official must identify the minimum road system needed for safe and efficient travel and for administration, utilization, and protection of National Forest System lands. ... The minimum system is the road system determined to be needed to meet resource and other management objectives adopted in the relevant land and resource management plan (36 CFR 219), to meet applicable statutory and regulatory requirements, to reflect long-term funding expectations, to ensure that the identified system minimizes adverse environmental impacts associated with road construction, reconstruction, decommissioning, and maintenance.

Identification of unneeded roads. Responsible officials must review the road system on each National Forest and Grassland and identify the roads on lands under Forest Service jurisdiction that are no longer needed to meet forest resource management objectives and that, therefore, should be decommissioned or considered for other uses, such as for motorized routes.

Regional Forester's direction: Roads analysis process (RAP) for all other existing roads should be completed in conjunction with implementation of the off-highway vehicle (OHV) Record of Decision, watershed analyses, other project-level activities or Forest Plan revisions.

Methodology and Analysis Process

This section describes the methodology and analysis processes used to determine the environmental consequences on soil condition from implementing the alternatives. Environmental consequences are not site-specific at the broad forest planning level and will be described with qualitative descriptions supported by past studies and observations. Much of the background information is found in the Ecological Sustainability Report (Forest Service 2008) and the supporting specialist reports.

This qualitative analysis describes the current soil condition and projected trends in soil condition by alternative. It also describes the potential effects associated with management activities that could affect soil condition. The alternatives are compared using the average treatment level (midpoint of low and high for each alternative except A, which is described as an average).

Soil condition is based on the primary soil functions of soil hydrology, soil stability, and nutrient cycling as described by R3 Supplement FSH 2509.18 and interim direction (FS 2013). The current soil condition rating is described in the Ecological Sustainability Report (Forest Service 2008) and was based on how departed soils are from the historic range of natural variability. The projected trends in soil condition were based on estimates of vegetative ground cover, soil productivity, and organic matter. Each vegetation type (PNVT[1]) was examined to see whether soil conditions would generally trend towards, away or remain static with the implementation of treatments by alternative. The analysis is based on the Vegetative Dynamic Digital Tracking (VDDT) modeling results for each vegetation type using the range of acres proposed to be treated by alternative (low, midpoint, high) and estimates of soil cover and organic matter retention. Appendix B documents the detailed analysis used to project future soil condition trend.

[1] PNVT - Potential Natural Vegetation Type

Macrobiotic (biological) soil crusts have not been quantified in any detail. However, a qualitative summary may be useful in describing existing conditions and the ecological role of crusts in disturbed ecosystems. Since current composition and density of crusts have not be inventoried, we can only infer trends based on current and projected management impacts that have been shown in research to alter populations of crusts.

Assumptions

- For estimating the effects of alternatives at the programmatic forest plan level, the assumption has been made that the kinds of resource management activities allowed under the prescriptions will occur to the extent necessary to achieve the goals and objectives of each alternative. The actual location, design, and extent are not known at this time and will be a site specific (project by project) decision. Therefore this analysis refers to potential of the effect to occur, realizing that in many cases, these are only estimates. The effects analysis is useful in comparing and evaluating alternatives on a forestwide basis but is not to be applied to specific locations on the forests. Some resources are not within the Agency's ability to control; these will be noted.
- The kinds of analysis completed at the project-level would compare existing condition to desired condition to determine the site specific need for change. This analysis contains a description of how certain types of management activities affect soil function, estimates of the degree of those effects, and the mitigation used to protect or improve soil function. As an example, erosion, compaction and displacement are common impacts to soil function as a result of mechanical treatments. Soil quality standards (R-3 Supplement FSM 2509.18) provide thresholds of management concern based on soil hydrology, soil stability, and nutrient cycling. Soil condition is an evaluation of soil quality.
- Data used in this analysis represents forestwide conditions and may not represent soil condition at any given point on the landscape. It is important to realize that many differences in soils and related disturbances can occur within short distances. Overall accuracy of mapping and information provided by the TES (Terrestrial Ecosystem Survey) and soil condition protocol is considered reliable at the ecological unit or landscape level. However, on-site inspection should be conducted for site-specific project assessments. A more detailed description of existing soil condition can be found in the Soil Specialist's Report for the Ecological Sustainability Report for the Apache-Sitgreaves NFs (Forest Service 2008).On the Apache-Sitgreaves National Forests, there has been no forestwide survey of soil condition, however, there have been localized studies completed for grazing and forest health projects that can be used to infer general conditions and trends. Examples of studies can be found in the Soil Resource Specialist Report for the Ecological Sustainability Report (Forest Service 2008). These studies show the majority of areas within the piñon-juniper and Madrean pine-oak woodlands, semi-desert and Great Basin grassland vegetative types, especially areas with heavy canopy cover (generally with canopy cover greater than 40 percent), are estimated to be impaired or in some cases in unsatisfactory condition due to lack of or poor distribution of vegetative ground cover (plant basal area and litter), and reduced soil productivity. Very little range condition data is available before 1935 (USDA Forest Service 1991). However the General Terrestrial Ecosystem Survey shows that from 1902 to 1987 that as more livestock numbers and acres were grazed, range condition (and soil condition) declined, and as fewer number and acres were grazed, range condition and trend improved. One can surmise that domestic livestock grazing was not present historically (before European settlement) and therefore did not cause accelerated erosion. One report described that most of the forest lands in the arid regions had been heavily overgrazed when

the national forests were established (Box, 1979. According to Gori et al. (2007) livestock and large wildlife grazing removes fine fuels needed to carry surface and mixed-severity fires that likely maintained the more open structure and composition of piñon-juniper savannas and shrub woodlands historically. Fire history reconstructions collected at a limited number of sites (representing these piñon-juniper types) show the virtual elimination of surface and/or mixed severity fire as a disturbance agent after 1880 when livestock numbers increased over most of Arizona and New Mexico. Merriam elk did exist but are believed to occur in relatively low populations and therefore did not appreciably affect soil loss. North American bison were known to graze and were reported to denude grass in some areas, however, grasslands in Arizona are not considered to have been developed with bison as a factor in maintenance of the grasslands (Truett, 1996).

- There are a few important considerations to put the environmental effects of implementing the alternatives into context with regard to ecological restoration. Each alternative is described as having a range of treatment objectives, from low to high[2]. Each alternative has a different treatment emphasis by vegetation type. The benefits and effects to forest resources at a low objective level may be quite similar to each other in some alternatives on a forest scale and quite different at a high objective level. The benefits and effects to forest resources within each particular vegetation type may be similar or different as well. As an example, Alternative C proposes high emphasis for treatment in the ponderosa pine vegetation type, where alternatives B and D treatment emphasis are geared more towards restoration of all vegetation types that are currently departed from desired condition. At the low level treatment objectives, the resulting improvement in vegetative condition for Alternative B and D are very similar, and somewhat lower than C as modeled by the VDDT. At the high level of treatment objectives there are greater differences noted between the alternatives. In all cases with regard to Alternative A, which does not emphasize restoration treatments but fuel treatment around communities, there is little improvement towards desired conditions for vegetation condition, even with similar treatment levels.
- The 2011 Wallow Fire had dramatic effects on soil conditions, including an estimated 29 percent increase in impaired and unsatisfactory conditions. Estimated time for recovery to satisfactory conditions within the burned area depends on many factors including pre-burn conditions, burn severity, post-fire treatments, and management and weather patterns. Ground cover is expected to increase enough in high and moderate burn severity areas to bring erosion rates to a level where long-term soil productivity is no longer at risk within five years where soils are capable (Forest Service, 2008; Forest Service, 2010; Elliot, 2000). Many areas treated with mulch and seeding have already stabilized.

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[2] The low treatment objective level is based on a minimum program of work to treat areas of highest priority (prioritized areas vary by alternative) and the forests capacity based on past 5-year budget trends. The high treatment objective level is an estimate of the forests' highest capability to accomplish treatments using the current workforce and assuming funding is not a limiting factor.

Revision Topics Addressed in this Analysis

Soil Resources

Soil Condition

- Soil Condition is an evaluation of soil quality based on an interpretation of factors which affect vital soil functions
  - Indicator – Projected trend of Soil Condition as measured by a change in soil function (Qualitative)

Summary of Alternatives

A summary of alternatives, including the key differences among alternatives, is outlined in the Draft Environmental Impact Statement.

Description of Affected Environment (Existing Condition)

Soils of the Apache-Sitgreaves NFs

Soils are a physical element of the environment made up of mineral particles (e.g., sand, silt, and clay), air, water, and organic matter. Soils form by the interaction between climate, organisms, topography, parent material, and time. Soils store water, supply nutrients for plants, and provide a medium for plant growth. Soils also provide habitat for a diverse number of below-ground organisms. Due to their slow rate of formation, soils are essentially a non-renewable resource.

The forests soils are described in the Terrestrial Ecosystem Survey of the Apache-Sitgreaves NFs (TES) (Laing L., et.al. 1987). The TES is the result of the systematic analysis, mapping, classification and interpretation of terrestrial ecosystems, also known as ecological types, delineated in ecological units. It is the only seamless mapping of vegetation and soils available across the forests that includes field visited, validated and correlated sites with regional and national protocol stemming from decades of work. Major fieldwork for the TES was completed during the period of 1983 through 1986. Soil names and descriptions were approved in 1986. The TES was developed using local, regional, and southwestern U.S. research data collected prior to its publication in 1987. The forests use ground cover and vegetation canopy cover provided for each mapping unit to establish resource value ratings for soil and plant health for many management activities, particularly in the analysis and monitoring of restoration treatments and for grazing allotment management. The TES will be updated as new information is available and will occur within the planning period.

Soils of the Apache-Sitgreaves NFs have developed primarily from sedimentary and volcanic origins. Soils range from very shallow to deep, old and well-developed to recent and less-developed, and occur on all slope ranges from nearly level to very steep. The soil orders of Alfisols and Mollisols, as classified in Soil Taxonomy (USDA 1999), are common on the highly productive forest, woodland and grassland vegetation types. Inceptisols are commonly found in the highly eroded, thin soils associated with sandstone tuff of Datil Volcanic and Gila Conglomerate formations. Aquatic subgroups are found in wetlands and riparian areas. Elevations on the forests range from almost 11,000 feet in the Mount Baldy Wilderness Area to 3500 feet near Clifton, Arizona, which provides soil climate in upland soils ranging from cryic (cold) to thermic (hot) soil temperature regimes, and from udic (moist) to aridic (dry) soil moisture regimes. Herbage productivity ranges from near 5,000 pounds per acre in the wettest areas, to less than 100 pounds per acre in the driest, thinnest soils.

Soil Condition

Soil condition is a descriptive indicator of general soil health. Soil condition is primarily determined by evaluating surface soil properties. This is the critical area where plant and animal organic matter accumulate, begin to decompose and eventually become incorporated into soil. It is also the zone of maximum biological activity and nutrient release. The physical condition of this zone plays a significant role in soil stability, nutrient cycling, water infiltration and energy flows. The presence and distribution of the surface soil is critically important to productivity.

Soil condition is based on an interpretation of factors which affect three primary soil functions. The primary soil functions evaluated are: soil hydrology, soil stability and nutrient cycling, all of which are interrelated.

Soil condition is categorized by four classes: satisfactory, impaired, unsatisfactory and inherently unstable. The following definitions describe each class (R-3 Supplement FSM 2509.18, and FS 2013):

- Satisfactory: Indicators signify that soil function is being sustained and soil is functioning properly and normally. The ability of the soil to maintain resource values and sustain outputs is high.
- Impaired: Indicators signify a reduction in soil function. The ability of the soil to function properly and normally has been reduced and/or there exists an increased vulnerability to degradation. An impaired category indicates there is a need to investigate the ecosystem to determine the cause and degree of decline in soil functions. Changes in land management practices or other preventative measures may be appropriate.
- Unsatisfactory: Indicators signify that a loss of soil function has occurred. Degradation of vital soil functions result in the inability of the soil to maintain resource values, sustain outputs or recover from impacts. Unsatisfactory soils are candidates for improved management practices or restoration designed to recover soil functions.
- Inherently Unstable[3]: These soils have natural erosion exceeding tolerable limits. Based on the Universal Soil Loss Equation[4] (USLE) these soils are eroding faster than they are renewing themselves but are functioning properly and normally.

Current soil condition was developed for the forests during this analysis, using ASTES ecological map units as a basis. It is summarized by vegetation type (PNVT) to help describe conditions where past management activities and proposed treatments may be similar. Table 1 displays the percent of

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[3] This class is not described within FSM 2509.18. This is a category where long term soil productivity and management are not primary objectives, and management activities are avoided due to expected risk of irreprable loss of soil productivity.

[4] Universal Soil Loss Equation - an empirical mathematical model used to describe soil erosion processes. USLE has been modified from its original form to predict soil loss in forestlands and rangelands (Renard K et.al., 1997)

each soil condition class (with the desired soil condition percentage in parenthesis) for each vegetation type.

Around half of the vegetation types have a majority of satisfactory soil conditions (6 out of 14 PNVTs). Impaired soils are dominant on most of the remaining types (5 out of 14 PNVTs). There are three PNVTs with large extents of unsatisfactory or inherently unstable soil conditions: Madrean pine-oak woodland, interior chaparral, and semi-desert grassland.

Vegetation types with satisfactory soil condition have natural overstory canopy cover levels to allow for the desired amount of plant and litter ground cover. They have unaltered or natural levels of soil hydrologic function, such as high infiltration rates, high capacity for soil moisture storage, strong structure and soil pores to aid transmission of water deeper into the soil profile. They are stable and readily cycle nutrients for improved plant growth.

Woodland and grassland vegetation types with soil condition less than satisfactory tend to have well above natural overstory canopy cover levels (reduced levels of vegetative ground cover, poor distribution of vegetative ground cover (plant basal area and litter), and reduced soil hydrologic function. They are generally not stable, and may have reduced levels of nutrient availability. They also can be in areas where uncharacteristic wildfire may have altered canopy and ground cover levels, altered infiltration rates, and high levels of soil erosion.

Management activities create various degrees of soil disturbance, but *ecologically* sustainable land stewardship can minimize adverse impacts on soils. Attributes of soil condition provide threshold values that indicate when changes in soil properties would result in significant change or impairment of soil condition. Soil condition ratings apply to all lands where long-term soil productivity and satisfactory watershed condition are desired.

Table 1. Current and desired soil condition class as a percent of each vegetation type. ( ) indicates desired. Condition estimates are for Pre-Wallow fire conditions.

Vegetation Type (PNVT)	Satisfactory	Impaired	Unsatisfactory	Inherently Unstable
Ponderosa Pine Forest	94 (95-100)	0 (0-5)	6 (0)	0
Dry Mixed Conifer Forest	76 (95-100)	0 (0-5)	24 (0)	0
Wet Mixed Conifer Forest	100 (95-100)	0 (0-5)	0 (0)	0
Spruce-Fir Forest	100 (95-100)	0 (0-5)	0 (0)	0
Madrean Pine-Oak Woodland	4 (37-42)	9 (0-5)	29 (0)	58
Piñon-Juniper Woodland	16 (85-90)	74 (0-5)	0 (0)	10
Interior Chaparral	0 (14-19)	0 (0-5)	19 (0)	81
Great Basin Grassland	5 (95-100)	92 (0-5)	3 (0)	0
Semi-desert Grassland	7 (42-47)	26 (0-5)	15 (0)	53
Montane/Subalpine Grasslands	92 (95-100)	8 (0-5)	0 (0)	0
Cottonwood-Willow Riparian Forest	25 (95-100)	57 (0-5)	8(0)	0
Mixed Broadleaf Deciduous Riparian Forest	28 (95-100)	64 (0-5)	8 (0)	0
Montane Willow Riparian Forest	28 (95-100)	68 (0-5)	4 (0)	0
Wetland/Cienega Riparian Areas	100 (95-100)	0 (0-5)	0 (0)	0

Effects of the Wallow Fire on Soil Condition

The Wallow Fire had some dramatic effects on soil conditions. Soil burn severity for each PNVT is summarized in table 2. Estimated time for recovery to satisfactory conditions depends on many factors including pre-burn conditions, soil burn severity, post-fire treatments and management and weather patterns. Ground cover is expected to increase enough in high and moderate burn severity areas to bring erosion rates to a level where long term soil productivity is no longer at risk within 5 years (ASNF 2008, 2010, Elliott 2000). Many areas treated with mulch and seeding have already stabilized.

Soil Burn severity indicators are classified and defined as follows (Parsons et al. 2010),

- Low Soil Burn Severity - Surface organic layers are not completely consumed and are still recognizable. Structural aggregate stability is not changed from its unburned condition, and roots are generally unchanged because the heat pulse below the soil surface was not great enough to consume or char any underlying organics. The ground surface, including any exposed mineral soil, may appear brown or black (lightly charred), and the canopy and understory vegetation will likely appear "green."
- Moderate Soil Burn Severity - Up to 80 percent of the pre-fire ground cover (litter and ground fuels) may be consumed but generally not all of it. Fine roots (~3/32 inch diameter) may be scorched but are rarely completely consumed over much of the area. The color of the ash on the surface is generally blackened with possible gray patches. There may be potential for recruitment of effective ground cover from scorched needles or leaves remaining in the canopy that will soon fall to the ground. The prevailing color of the site is often "brown" due to canopy needle and other vegetation scorch. Soil structure is generally unchanged.
- High Soil Burn Severity - All or nearly all of the pre-fire ground cover and surface organic matter (litter, duff, and fine roots) is generally consumed and charring may be visible on larger roots. The prevailing color of the site is often "black" due to extensive charring. Bare soil or ash is exposed and susceptible to erosion, and aggregate structure may be less stable. White or gray ash (up to several centimeters in depth) indicates that considerable ground cover or fuels were consumed. Sometimes very large tree roots (> 3 inch diameter) are entirely burned extending from a charred stump hole. Soil is often gray, orange, or reddish at the ground surface where large fuels were concentrated and consumed.

Table 2. Soil Burn Severity acres by PNVT for the Wallow Fire.

PNVT	Soil Burn Severity Class				Total
	High	Moderate	Low	Unburned	
Ponderosa Pine Forest	11,809	22,734	79,821	14,488	128,852
Dry Mixed Conifer Forest	19,412	12,253	31,462	14,813	77,940
Wet Mixed Conifer Forest	47,409	19,835	43,494	23,702	134,440
Spruce-Fir Forest	3,874	2,462	3,897	2,423	12,656
Madrean Pine-Oak Woodland	1,246	4,767	20,396	26,679	53,088
Piñon-Juniper Woodland	583	2,225	5,587	9,389	17,784

Interior Chaparral	357	2,426	3,266	3,900	9,949
Great Basin Grassland	88	325	3,311	2,854	6,579
Semi-desert Grassland	35	251	606	624	1,517
Montane/Subalpine Grasslands	176	1,679	27,422	7,159	36,436
Cottonwood-Willow Riparian Forest	72	176	731	759	1,738
Mixed Broadleaf Deciduous Riparian Forest	0	27	212	251	491
Montane Willow Riparian Forest	196	424	1,674	1,041	3,336
Wetland/Cienega Riparian Areas	441	759	7,406	3,212	11,818
Totals	85,698	70,343	229,285	111,294	496,624

Represents only the portion of Wallow fire on the Apache-Sitgreaves NFs land.

An estimate of immediate change in soil condition is shown below by PNVT within the Wallow Fire Area. The estimate is based on pre-fire soil conditions, soil burn severity class and post fire treatment types.

Table 3. Estimated percent of Soil Condition change from Pre to Post Wallow by PNVT within the fire perimeter.

Vegetation Type (PNVT)	Satisfactory		Impaired		Unsatisfactory		Inherently Unstable	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Ponderosa Pine Forest	90%	66%	0%	19%	10%	15%	0%	0%
Dry Mixed Conifer Forest	91%	49%	0%	23%	9%	28%	0%	0%
Wet Mixed Conifer Forest	100%	52%	0%	22%	0%	27%	0%	0%
Spruce-Fir Forest	100%	50%	0%	27%	0%	23%	0%	0%
Madrean Pine-Oak Woodland	6%	4%	3%	5%	16%	16%	75%	75%
Piñon-Juniper Woodland	31%	20%	28%	37%	0%	1%	42%	42%
Interior Chaparral	0%	0%	0%	0%	0%	0%	100%	100%
Great Basin Grassland	15%	15%	85%	84%	0%	1%	0%	0%
Semi-desert Grassland	0%	0%	100%	98%	0%	2%	0%	0%
Montane/Subalpine Grasslands	100%	95%	0%	5%	0%	0%	0%	0%
Totals	78%	50%	3%	20%	7%	19%	12%	12%

Could not estimate effects to riparian areas.

Soil Crusts

An important component that affects soil condition is the condition of soil crusts. Macrobiotic crusts are the community of organisms living at the surface of soils. Major component are cyanobacteria, green algae, microfungi, mosses, liverworts and lichens (www.soilcrust.org). Biological soil crusts are commonly found in semiarid and arid environments and have been observed in coarse textured soils predominantly in piñon-juniper woodlands, semi-desert grasslands and desert communities on the forests and to a limited extent in other vegetation types dryer than piñon-juniper woodlands. Of most importance is the role crusts play in maintaining productivity of the semi-desert and Great Basin grasslands and woodland ecosystems. Mosses and other crust forming organisms are found in wetter environments, but are less important to overall soil productivity.

Crusts are well adapted to severe growing conditions, but poorly adapted to compressional disturbances. Domestic livestock and elk grazing and recreational activities (hiking, biking cross country, and off-road driving) place a heavy toll on the integrity of the crusts. Disruption of the crusts decreases organism diversity, soil nutrients, stability (and increased soil loss), and organic matter and soil productivity. Studies of trampling disturbance have noted that losses of moss cover, lichen cover, and cyanobacterial presence can be severe (1/10, 1/3, and 1/2 respectively), runoff can increase by half, and the rate of soil loss can increase six times without apparent damage to vegetation. Ungulate grazing in PNVTs where crusts are present, poses an unquantifiable risk to soil productivity and ecosystem diversity and those species that depend on its habitat for their survival (Johnston, R. 1997).

According to Belnap, eg.al. (2001), biological crusts are generally killed by hot ground fires, resulting in loss of biomass and visible cover (Johansen et al. 1993). Frequent burning prevents recovery of lichens and mosses, leaving only a few species of cyanobacteria (Whisenant 1990). Damage and recovery of biological crusts depends on pre-fire conditions as well as characteristics of the fire. Historic burning left small patches of unburned areas between bunchgrasses or at larger scales, left patches of unburned shrubs across the landscape. This left a mosaic of successional stages and provided regeneration material for fire damaged areas (Whisenant 1990; Peters and Bunting 1994).

Most areas where crusts have been observed currently cover less than 5 percent of the soil surface. There are areas within the Rodeo-Chediski fire within the ponderosa pine and piñon-juniper vegetation types that have low levels of macrobiotic crusts (up to 10 percent ground cover) (personal observation, 2002-2007) (unpublished data for Heber Wild Horse Territory Analysis, 2007).

Past Management Impacts on Soil Condition

Historically (pre-European settlement) and without anthropogenic (man-caused) disturbances, soil loss, soil compaction and nutrient cycling would probably have been within functional limits to sustain soil function and maintain soil productivity for most soils. The exception to this could be relatively short term effects of wildfire during times of drought. Since there were no political boundaries historically, soil condition would have been similar on similar soils throughout the range of the vegetation types both within and outside of the forests.

Much of the current soil condition is related to past management on the forests. Soil condition is affected by activities that occur or re-occur at the same place over time. Permanent loss of soil productivity has and could affect the level of future goods and beneficial use of the forests in the future. Management activities that have affected soil condition include timber harvesting, prescribed fires, road construction and use, recreation facility construction and use, grazing, and special uses. Some examples of impacts that have affected current soil condition include the following:

- Heavily compacted soils from forest restoration treatments, grazing and recreation activities have caused or may cause reduced productivity for decades (Burger et.al 1998).
- Land disturbing activities caused erosion of topsoil at rates greater than the soils natural ability to replace it, commonly referred to as soil loss tolerance rate, resulted in permanent loss of soil productivity, as soils are considered a non-renewable resource (Renard, et al 1997).
- From 1902 to 1987 as more livestock numbers and acres were grazed, range condition (and soil condition) declined, and as fewer number and acres were grazed, range condition improved.
- According to Gori et al. (2007) livestock and large wildlife grazing removed fine fuels needed to carry surface and mixed-severity fires that likely maintained the more open structure and composition of piñon-juniper savannas and shrub woodlands historically.
- Road corridors that make up the forests' road system resulted in loss of soil productivity.
- Mineral extraction pits and mines resulted in permanent loss or reduction in soil productivity.
- Uncharacteristic wildfire resulted in erosion rates well beyond tolerance erosion rates.
- Footprints of administration and recreation sites have reduced soil productivity.
- Permanent special use sites, such as communication towers and buildings eliminated soil productivity.

There are activities that have improved soil condition, as well as removing risk to soil productivity such as:

- Prescribed fire has removed fuels and undesirable plant material which impede vegetation growth and condition
- Dense forest, woodland and invaded grassland canopy treatments have reduce light and water competition for desired understory grasses and shrubs.
- Channel restoration projects have restored bank and vertical stream bed stability to and have re-established ground water table levels that result in increased vegetation/soil productivity.
- Closure of maintenance level 1 roads and decommissioning or removal of unneeded roads has resulted in revegetation of old roadbeds.

Environmental Consequences

The land management plan provides a programmatic framework that guides site-specific actions but does not authorize, fund, or carryout any project or activity. Because the land management plan does not authorize or mandate any site-specific projects or activities (including ground-disturbing actions) there can be no direct effects. However, there may be implications, or longer term environmental consequences, of managing the forests under this programmatic framework.

The forests use soil condition as a descriptive indicator of general soil health. In this analysis, the expected trends in soil condition are described for each alternative for comparison. The general effects to soil function of common management activities follow, such as: forest restoration activities (mechanical and wildland fire treatments), roads, recreation, grazing, and special uses.

Soil Condition Trends

Table 4 displays the projected trends in soil condition based on estimates of vegetative ground cover, soil loss, and organic matter. Soil condition was estimated for each vegetation type was examined to see whether conditions would generally trend towards, away or remain static with the implementation of objectives of each alternative. Departure is the relative difference between satisfactory and either impaired or unsatisfactory condition. The estimated trends do not take into consideration of the effects to soil condition from the Wallow fire. The effects of the Wallow Fire were not included in this determination as conditions are quite variable by PNVT within the fire perimeter of the fire. The general trend would be that the area is improving at natural recovery rates. Current management within the Wallow Fire burned area ranges from complete avoidance to active management. Plans are not currently in place to determine where future activities would occur.

Generally, Alternative A would trend away from desired conditions, and alternatives B, C and D trend towards or are static in most cases. The following table describes the results of the analysis.

Table 4. Estimated trends in soil condition for each vegetation type by alternative for the 1st planning period of 15 years.

Vegetation Type (PNVT)	Alternative A	Alternative B	Alternative C	Alternative D	Current Departure From DC*
Ponderosa Pine	Toward	Toward	Toward	Toward	Slight
Dry Mixed Conifer Forest	Toward	Toward	Toward	Toward	Slight
Wet Mixed Conifer Forest	Static	Static	Static	Static	None
Spruce-Fir Forest	Static	Static	Static	Static	None
Madrean Pine-Oak Woodland	Static	Toward	Toward	Toward	Moderate
Piñon-Juniper Woodland	Toward	Toward	Toward	Toward	High
Interior Chaparral	Static	Static	Static	Static	Slight
Great Basin Grassland	Away	Toward	Away	Toward	Very High
Semi-desert Grassland	Away	Toward	Away	Toward	Moderate
Montane/Subalpine Grassland	Away	Away	Static	Away	None
Cottonwood-Willow Riparian Forest	Away	Toward	Away	Toward	High
Mixed Broadleaf Deciduous Forest	Away	Static	Away	Static	High
Montane Willow Riparian Forest	Away	Toward	Static	Toward	High
Wetland Cienega	Away	Static	Static	Static	None

Alternative A is based on the past 25-year average of vegetation treatments. Alternative B, C, and D are based on midpoint of the objective level of treatments.
*Current departure estimates (Forest Service 2008)

Many factors are considered in the determination of soil condition trend. Ground cover type and amount play a large role in soil condition. It affects soil all 3 soil functional elements by providing resistance to soil erosion, enhancing nutrient cycling and water infiltration by decreasing overland flow rates. A major consideration in predicting groundcover conditions is to compare the current departure of existing vegetative condition (see veg specialist's report) and model predictions to see whether vegetative conditions are moving towards desired conditions (DC), are static, or moving away from them. Groundcover conditions found under vegetation at DC generally reflect satisfactory soil groundcover conditions. In open forest PNVTs, such as ponderosa pine or dry mixed conifer, the understory composition would favor a mix of grass or forb cover with litter cover verses thick litter cover found in closed forest conditions. In woodland and tree invaded grassland types, open canopy conditions would favor grass forb cover verses bare ground conditions found in closed canopy woodlands. In closed forest PNVTs such and Spruce Fir and Wet Mixed Conifer, litter is the dominant ground cover, and vegetative states other than those caused by high severity wildfire or mechanical disturbance would result in adequate cover composition and amount and generally result in static trends (ground cover percentage is generally near 100 percent).

Riparian area soil conditions are tied closely to riparian condition (PFC). Riparian areas that are functioning properly have satisfactory soil condition. These soils have adequate vegetation to withstand bank erosion from high flows and trap sediment to form stable floodplains. Riparian areas functioning at risk or not functioning generally do not have stable, productive soils. Groundcover and vegetation are generally not adequate to protect soils from high flows, and would result in impaired soil condition. Soil conditions trends in riparian areas are therefore tied directly to predicted riparian area trends (see riparian report).

Soil Crusts

Macrobiotic crusts are affected directly through physical damage and alteration of habitat. Compressional forces reduce the soils hydrologic function, which could provide less water and nutrients to biological crusts. Across all alternatives, it is estimated that on-going improved cattle management on the forests would benefit biological crusts through decreased trampling as the forests move towards aligning capacity and allowable use. Wildland fire can also kill biological crusts and can alter soil properties as well. Individual ground disturbing projects including prescribed fire would require site specific analysis to mitigate effects to biological crust, especially in the woodland and grassland vegetation types. In all action alternatives, the elimination of most off road use will benefit crusts by removing direct damage from compaction and soil displacement generated from wheeled vehicles. Alternative A does not eliminate recreational off road use.

Forest Restoration Activities

Mechanical Treatments

Mechanical harvest and restoration treatments may impact soil hydrologic function, soil stability, and nutrient cycling through soil compaction and removal of ground cover.

Soil compaction, which reduces the soils ability to intake water and nutrients, can result from timber harvesting operations. The amount of soil compaction is dependent on harvest methods, amount of slash in traffic lanes, operator technique, and soil conditions and properties (Page-Dumroese et.al. 2010).

Project-level activities would follow best management practices and develop mitigations that would result in minimal soil compaction. The following are examples of mitigations that reduce effects of mechanical treatments:

- Timing activities in the early summer and late fall (dry soil conditions) and winter (frozen soil or logging over snow conditions) to reduce soil compaction and surface rutting.
- Concentrating thinning operations on harvest traffic lanes to reduce the areal extent of soil compaction and other changes in soil physical properties throughout the stand (Curran et al. 2005, Moghaddas and Stephens 2008).
- Leaving thinning and harvest residues in place to minimize detrimental soil compaction and aid nutrient cycling. Coarse wood to support macro- and micro- fauna would be available and balanced with the need to remove fuels to reduce the risk of high intensity fire. The potential effects of whole tree removal on soil fertility would be balanced with leaving needles and branches on thin, coarse-textured soils.

Ground cover may be disturbed during mechanical treatments (including the removal of vegetation), and may, therefore, result in some exposure of mineral soil. Although direct timber harvesting operations may result in some local soil movement, soil displacement and soil erosion are expected to be minor because most harvest units are designed to have slopes that are not steep (less than 35 percent), with short slope lengths, and adequate ground cover and topsoil that would remain intact. BMPs and Soil and Water Conservation Practices (SWCP) (FSH 2509.22 R3) are effective in mitigating ground disturbance and well as intercepting sediment in runoff. Slash distribution in cut units following timber harvesting may also protect exposed mineral soils from raindrop impacts and erosion.

Alternative Comparison

Alternative C proposes the most mechanical harvest treatments and thus the most risk from soil compaction and ground cover removal, followed by B, D then A. See table 3 for treatment objective levels (acres) of mechanical harvest treatments.

Table 5. Projected mechanical treatment by objective levels low and high for each alternative.

Treatment Levels	Alternative A	Alternative B	Alternative C	Alternative D
Low	12,182*	8,852	5,342	6,465
Average		19,590	23,997	18,953
High		30,327	42,651	25,440
* Based on the past 25-year average of vegetation treatments.				

The bulk of treatments in Alternative C would be in the ponderosa pine vegetation type, on level to moderately steep landscapes. Site specific BMPs and SWCPs would be prescribed to reduce impacts of mechanized equipment in all treatment areas. Soil disturbance monitoring (Page-Dumroese, et al 2010) would provide the necessary feedback for adaptive management to protect soil productivity. An administrative study on the Apache-Sitgreaves forest (Sitko, 2010) is providing some local correlation between soil disturbance classes and detrimental compaction.

Wildland Fire Treatments

Wildland fire (both planned and unplanned ignitions) used to meet resource objectives also may also affect soil's physical, chemical, and biological characteristics negatively. The most important soil physical characteristic that affects soil hydrologic function and soil stability is soil structure, because the organic matter component, which provides for loose, granular structure, can be lost at relatively low temperatures. The loss of soil structure increases the bulk density of the soil and reduces its porosity, thereby reducing soil productivity and making the soil more vulnerable to post-fire runoff and erosion.

The most basic soil chemical properties affected by soil heating during wildland fires are also due to loss of organic matter (Neary et.al, 2005). Soil organic matter plays a key role in nutrient cycling and exchange, and water retention in soils. When organic matter is combusted, the stored nutrients are either lost to the atmosphere or are changed into highly available forms that can be taken up readily by microbial organisms and vegetation. Those available nutrients not immobilized are easily lost by leaching or surface runoff and erosion. Nitrogen is the most important nutrient affected by fire, and it is easily lost from the site at relatively low temperatures. The amount of change in organic matter and nitrogen is directly related to the magnitude of soil heating and the severity of the fire. High- and moderate- severity fires cause the greatest losses. Nitrogen loss by volatilization during fires is of particular concern on low-fertility sites because nitrogen can only be replaced by nitrogen-fixing organisms.

Cations[5] are not easily volatilized and usually remain on the site in a highly available form. An abundance of cations can be found in the thick ash layers (or ash-bed) remaining on the soil surface following high-severity fires. Soils that are inherently low in nutrients, and thin soils, are most impacted by high intensity wildland fires as nutrients are lost. These fragile soils would be identified at the project-level and protection measures would be prescribed.

Soil biology is also affected by wildland fire. How soil microorganisms respond to wildland fire would depend on numerous factors, including fire intensity, site characteristics, and pre-burn community composition. Some generalities can be made. First, most studies have shown strong resilience by microbial communities to wildland fire. Re-colonization to pre-burn levels is common, with the amount of time required for recovery generally varying in proportion to fire severity. Second, the effect of fire is greatest in the forest floor (litter and duff). Fires that consume major fuels but protect forest floor, humus layers, and soil humus are recommended. (Neary, et.al., 2005)

Alternative Comparison

Use of wildland fire allows the manager the opportunity to control the intensity of the fire and to avoid creating large areas treated at high soil burn severity. Each alternative proposes the use of wildland fire for fuel reduction and ecosystem restoration. Alternative D prescribes the most wildand fire for ecosystem restoration, followed by B, C, and then A. See Table 7 to compare objective treatment levels (acres) of wildland fire for each alternative.

Prescribed fire treatments range from low severity broadcast burning for ground fuel reduction, to mixed or high intensity treatments (in patches) that are designed to kill overstory vegetation to reduce the amount of canopy cover to a desired level. Alternative B and D propose the most acres of mixed severity and high severity fires. These generally may occur in focus watersheds that are away from

[5] Soil cations are ions with fewer electrons than protons, giving it a positive charge. These are generally referred to as soil nutrients. The amount of cations available for exchange between the soil and the soil solution available to plants is a measure of soil fertility. Examples of cations are ions of calcium, magnesium, phosphorous, potassium, copper, zinc and other elements.

urban interface areas. Alternative C and A have the fewest acres of mixed and high severity fires in forest types, however, mixed and high severity fires in woodland and grassland vegetation types are prescribed.

Table 6. Fire Severity Description and Projected Wildfire Treatment Acres by Fire Severity.

Wildland Fire Treatment	Low Severity Broadcast Burn	Mixed Severity	High Severity Stand Replacement
WildlandFire Characteristics	Prescribed fire reduces fuel loading either for pre- or post- restoration treatment. Removes some ladder fuels Reduces risk of crown fire.	Some moderate and high severity in patches to improve structural diversity, and open canopy. Allows for regeneration of shade-intolerant species and restores ecologic condition in most vegetation types.	Some high severity fire in small stands to improve structural diversity and open canopy. Allows for regeneration of shade-intolerant species and restores ecologic condition in selected vegetation types.
Affect to Soil Function	Little to no effect to soil functions at all scales.	Soil chemical, physical and biological function retained in more than 85 percent of the treated areas at fine and mid-scale.	Soil chemical, physical, and biological functions may be impacted and require rehabilitation treatments. Soil function retained in more than 85 % of the treated areas at the fine- and mid-scales.

Table 7. Annual Wildland Fire Treatments (acres) and estimated Fire Severity by Alternative.

Alternative	Alternative A	Alternative B		Alternative C		Alternative D	
Treatment Level	Average*	Low	High	Low	High	Low	High
Low Severity	6,844	837	5,859	566	5,566	1,748	11,653
Mixed Severity		12,035	35,181	2,426	15,737	15,800	62,905
High Severity		864	2,379	130	1284	1,080	3,765

* Based on the past 25-year average of wildland fire treatments. No breakdown of burn type available, however, the vast majority (95 percent) is estimated to be low severity. Wildland fire treatments planned in riparian areas not included.

Under all alternatives, prescribed fire is allowed to burn under strict conditions and prescriptions that should not result in large areas of high burn severity that would be detrimental to soil physical, chemical, or biological properties resulting in loss of soil productivity.

Motorized Routes

The motorized road and trail system analyzed is the same for all alternatives. The motorized route system results in a net loss of soil productivity within the road corridor, including cut and fill slopes. Roads are the dominant source of erosion and sediment in forests (Swank et. al 1989; MacDonald and Coe 2008). Some roads are located in areas that are more sensitive than others, such as along riparian areas, or in areas of inherently unstable soils. Removal of roads in riparian areas would eliminate direct deposition of sediment, allow for channel widening where needed, expansion of plants, and floodplain development. There is a large number of non-system roads (estimated to be hundreds of miles, Transportation Specialist's Report) that are contributing to loss of soil productivity as well. The following table displays objective levels for road removal by alternative.

Table 8. Road Management Treatment Objectives (miles) by Alternative.

Objective Description	Alternative A	Alternative B	Alternative C	Alternative D
Amount of NFS roads or trails removed or improved that negatively impact streams or riparian areas	Opportunity	4	Opportunity	4
Amount of unauthorized or NFS level 1 roads or trails removed or revegetated that negatively impact streams or riparian areas	Opportunity	2	3	3

New road construction is generally not required for timber harvesting within the planning area, however, the re-opening of level 1 (those roads placed in storage between intermittent uses) increases the amount of open roads and the amount of soil erosion that occurs during the life of a project. Occasionally, temporary road construction would also remove vegetation along the road corridor, expose mineral soil, and result in soil compaction along the roadbed. Typically, there is pulse of erosion from roads during the first two years following road construction or reopening (MacDonald and Coe 2008; Megahan 1974). Slope failures and mass movement of soils may occur as the result of road construction. New roads or re-opening closed roads may also provide an avenue for the invasion and establishment of invasive plant species. Temporary roads would be closed, obliterated, and revegetated following use. Road design, avoidance of problem soils, appropriate design criteria, and road closures would be implemented in order to minimize impacts to soils.

Alternative Comparison

The motorized route system (miles, management level, and location) is the same for all alternatives, however, use of roads, trails and the additional amount of level 1 roads are estimated to be higher in alternative C followed by B, D and then A because Alternative C and B have the greatest percentage of timber harvest/mechanical restoration treatments of all alternatives. Motorized recreation is also emphasized in Alternative C. Localized impairment of soil condition occurs in some locations which is currently not quantified primarily around communities from off road use and is part of Alternative A.

Recreation Activities

Recreational uses shown to impact soils include off-road motor vehicle use, camping, hiking, mountain biking, and horseback riding. All of these activities may result in erosion and compaction. These impacts tend to be minor, and may occur on only a small percentage of the planning area.

Implementing site specific BMPs and SWCPs for recreation projects would minimize adverse soil impacts. The impacts from recreation could occur under all of the alternatives. No recreation development is specifically outlined in any alternatives. Recreation use and demand is estimated to increase proportionately for all alternatives with the increase in population growth (Recreation Specialist's Report).

Alternative A would continue to allow motorized cross-country travel. Motorized cross-country travel would increase the potential for sediment delivery to streams, reduce soil productivity due to compaction and erosion, destroy vegetative cover, and natural ground litter. Cross-county motorized travel also could destroy biological soil crusts. The action alternatives would eliminate motorized cross-country travel. Erosion and sediment transport would be reduced as disturbed areas revegetate and there would be less physical impact to biological soil crusts.

Grazing Activities

Improper grazing management has the potential to reduce soil condition directly through hoof compaction, and indirectly from the removal or protective vegetation and subsequently, ground cover. The effects to soil condition would be reduced soil hydrologic function in highly compacted cattle concentration areas, and reduce soil stability from loss of ground cover wherever over utilization of available forage exists. Grazing would not be considered detrimental where sufficient herbaceous material remains to protect the soils during periods of intense summer rains, or during spring runoff. Site specific BMPs and SWCPs provide protection from the effects of grazing and are prescribed in project-level analysis.

Differences in soil condition as related to grazing impacts between alternatives are indirectly tied to the level of restoration treatments provided for each alternative. As noted in the Vegetation Specialist Report, the overstory canopy cover prescribed in the desired conditions would provide an increase in understory vegetation as treatments are implemented and maintained. The relationship between overstory cover and herbaceous production has been validated in Arizona forests (Jameson, et.al. 1967; Thill, et.al. 1983). This increase would indirectly reduce grazing pressure as treatments progress across the forest. Increases in available forage would allow range managers flexibility in management to favor rehabilitation or rest in areas that are currently not in satisfactory soil condition, such as found in riparian, grassland and woodland vegetation. Direct impacts to soils from grazing are analyzed at the project leve, where effects are mitigated and monitored.

Alternative Comparison

Alternatives that improve forage conditions overall would mitigate impacts to soil condition from grazing cattle and wildlife. More forage in uplands provide for reduction of impacts to sensitive areas like riparian areas. Alternative B then D provide the most opportunity for soil condition improvement or protection because of predicted forage increases in all open canopy vegetation types, as well as direct improvement opportunities for riparian areas. Alternatives C provides upland improvement in open forest and woodland vegetation types, however, provides for little forage improvement in grassland or riparian vegetation types, and Alternative A would provide only improvements in soil conditions in open forest and piñon-juniper vegetation types. In all alternatives, grazing management plans would provide mitigation to protect sensitive areas from domestic use, including riparian, where often times grazing exclusion is the only option. Wildlife impacts generally would not be mitigated. Improvements in general vegetation and soil conditions provide managers the most flexibility in improving conditions.

Special Uses

Terms and conditions of special use permits would require site specific BMPs to provide for maintenance of soil productivity in all alternatives. Therefore, there are no anticipated effects to soil condition from permitted special use activities.

Climate Change

Based on current climate models, some of the climate change factors that may influence soil condition include the following:

- More extreme natural ecological disturbance events, including wildfires, intense rain, flash foods, and wind events (Swetnam et al. 1997)
- Greater vulnerability to invasive species, including insects, plants, fungi, and vertebrates (Joyce et al. 2006)
- Long-term shifts in vegetation patterns (Westerling et al. 2006; Millar et al. 2007)
- Cold-tolerant vegetation moving upslope, or disappearing in some areas; migration of some plant species to the more northern portions of their existing range (Clark 1998)
- Potential decreases in overall forest productivity due to reduced precipitation (Forest Service 2008)
- Potential lower vigor and productivity of forage plants, and thus overall soil conditions.
- Potential decreased forage production and shortened growing and grazing season,
- Potential flashfloods and increased risk of animal disease can adversely affect the livestock industry (Joyce et al. 2001) dependent upon the Apache-Sitgreaves NFs' forage resources.
- Potential decline if adjustments to numbers based on allowable forage are not made in response to productivity decreases from climate change.

In light of the changes indicated above, there is a need to reduce vulnerability by maintaining and restoring resilient native ecosystems. Restoring and maintaining resilience in forest, woodland, chaparral, grassland, chaparral and riparian ecosystems are part of the basic elements of forestwide desired conditions, and objectives and management approaches would be best provided for in order in Alternatives B, D, C then A . Restoring and maintaining resilience would likely improve the potential for ecosystems to retain or return to desired conditions after being influenced by climate change related impacts and variability. Management practices (e.g. thinning for age class diversity and structure, and reclaiming and restoring native grasslands) that sustain healthy plant and animal communities, and provide adequate nutrients, soil productivity, and hydrologic function promote resilience and reduce opportunities for disturbance and damage. See Vegetation Specialist's Report for further discussion of ecological condition trends.

Cumulative Environmental Consequences

Potential cumulative environmental consequences from other land owners, when added to the environmental consequences listed above, include the following:

- Soil loss through wind or water erosion leaving the forests or coming onto the forests would potentially reduce soil productivity due to soil deposition on the receiving lands.
- Airborne deposition of pollutants, including soil, could potentially reduce soil productivity; however, this is currently not contributing to a measureable reduction and it is not expected to in the future (see Air Quality Specialist Report). The analysis area for air quality deposition are those areas monitored by the IMPROVE site for Mount Baldy Class I airshed (see Air Quality Specialist Report).

Adaptive Management

Soil disturbance monitoring (Page-Dumroese, et al 2009) would provide the necessary feedback for adaptive management to protect soil productivity. An administrative study on the Apache-Sitgreaves forest (Sitko, 2010) is providing some local correlation between soil disturbance classes and detrimental compaction.

Other Planning Efforts

No known planning efforts are known that may address or may impact soil condition.

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