Scale

Forest Boundary and LTA's

Indicators

Table 1. Soil Indicators

Soil Indicator	Soil Function	Description
Soil Productivity and Soil Quality	Soil Biology	Soil biology is the ability to provide habitat for a wide variety of organisms including plants, fungi, microorganisms and macro-organisms in the upper sections of the soil in order to promote root growth, control moisture and temperature within the soil profile and provide for nutrients available to plants.
	Soil Hydrology	Soil hydrology is the ability of the soil to absorb, store, and transmit water, both vertically and horizontally. Soil hydrology is extremely important on the Forest, because the ecosystem productivity is typically limited by water. Soil can regulate the drainage, flow, and storage of water and solutes, including nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water. With proper functioning, soil partitions water for groundwater recharge and use by plants and animals. Soil optimizes infiltration, reducing Surface runoff, thereby reducing erosion and sedimentation to streams and waterways.
	Nutrient Cycling	Nutrient cycling is the movement and exchange of organic and inorganic matter back into the production of living matter. Soil stores, moderates the release of, and cycles nutrients and other elements. In contrast to the annual harvests associated with agriculture, forest harvest— and hence nutrient removal— typically occurs only once per rotation or every 40 to 120 years. This not only reduces the rate of removal, but the long-time interval makes natural additions of nutrients by atmospheric deposition and by weathering of soil minerals very important in maintaining nutrient status. Soil organic matter and carbón storageare extremely important for maintaining nutrient cycling especially on sensitive soils with coarse textures that contain low amounts of inherent nutrients.
	carbon storage	Carbon storage is the ability of the soil to store carbon. The carbon cycle illustrates the role of soil in cycling nutrients through the environment. More carbon is stored in soil than in the atmosphere and above-ground biomass combined. Compaction and loss of organic matter and topsoil can be assumed to affect carbon storage. . Both the soil cation exchange capacity and soil aggregate stability are directly dependent on soil carbon storage.
Soil Stability	soil stability and support	Soil stability and support is necessary to anchor plants and buildings. Inherent soil properties, like soil texture and particle size distribution, play a major role in physical stability. The main forest impacts to structure and stability are mass wasting, erosion, and loss of organic matter.
	Filtering and buffering	In filtering and buffering, soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals. Microorganisms in the soil degrade some of these compounds; others are held safely in place in the soil, preventing contamination of air and water. Wetlands soils especially function as nature's filters. Main impacts to the filtering and buffering function include those impacts to soil hydrology and biology.

Existing Condition (Including Trends of the last 30 years)

Physiography and Soils

The diverse soils of the Manti La Sal National Forest are described, characterized and classified in seven different soil surveys.

- UT-608 (NRCS SSURGO soil database) covers most of the San Pitch Mountains (Gunnison Plateau).
- UT-627 (NRCS SSURGO soil database) covers the very southeastern portion of the San Pitch Mountains (Gunnison Plateau)

- UT-633 (NRCS SSURGO soil database) covers most of the La Sal Mountains
- CO-675 and CO-680 (NRCS SSURGO soil databases) cover the far eastern portion of the La Sal Mountains
- UT-645 (Manti La Sal National Forest Soil Survey, completed by Daniel Larsen, Forest Soil Scientist) covers the Wasatch Plateau and the Abajo Mountains/Elk Ridge

Soils on the Manti-LaSal National Forest vary considerably in relationship to the geologic, climatic, and topographic characteristics for the area. Most of the soils have formed from sedimentary rocks including sandstone, shale, and limestone. In the South Zone (La Sal Mountains and the Abajo Mtns/Elk Ridge), quartz diorite porphyry is also a major rock type from which the soils have formed. Most of the soils are well drained. The texture may range from loamy sand to clay. However, sandy loam to clay loam is the most common textural range. Soil depths are typically shallow to moderately deep (12 to 40 inches) with the exception of those soils developed on transported materials such as alluvium, colluvium, and glacial deposits. Stony or cobbly soils are common on most of the steep mountain slopes. Most of the soils, except for those on some pinyon-juniper and spruce-fir sites, have dark colored surface horizons of eight inches or more in thickness (Mollisols). In addition to the good topsoil development, there is commonly an increase in clay content in the subsoil compared to the surface texture (Argillic horizon). The soils are moderately productive, but are being limited by short growing seasons due to cold temperatures at the high elevations and limited available moisture at the lower elevations. Between these extremes is a zone typified by the aspen vegetative type, which generally has the most productive soils. High elevation rangelands have experienced significant losses of soil by erosion (Dulfon 2016).

The North Zone (Wasatch Plateau) is renowned for land instability and flooding. Landslides, debris avalanches, and mudflows are most prevalent on soils of the North Horn Geologic Formation, particularly where the land and bedrock slopes in the same direction. Soil erodibility is moderate to high. The soils typically have textures of very fine sandy loam to silty clay and loam at the surface. The subsoils are generally finer textured and less permeable, which contributes to soil instability and landslides on the North Horn developed soils. The abundance of steep slopes and occurrence of intense summer thunderstorms are prime factors which relate to high erosion potentials when surface cover is removed.

Soil Erosion hazard

The susceptibility of soil to erosion, or the relative loss of exposed soil to erosional forces, is expressed by soil erosion hazard ratings. These hazard ratings take into account slope, soil type and texture and is considered to be soil lost through sheet and rill erosion where 50 to 75 percent of the surface has been exposed through some type of disturbance including logging, fire, grazing or mining. A rating of “slight” indicates that erosion is not likely if soils are bared; whereas, a rating of severe or very severe, indicate a high likelihood of sheet and/or rill erosion if soils are bared and a loss of soil productivity will likely result from the loss of soil. Table 3 displays the general soil erosion hazard ratings across the forest. The abundance of steep slopes and occurrence of intense summer thunderstorms are prime factors which relate to high erosion potentials when surface cover is removed. Also large scale destructive change has occurred across the forest since the turn of the century. The normal existence of a soil mantle on practically all grazeable terrain is the basis for all indicators of range condition and trend that relate to soil. The soil mantle itself is an indicator of a long period of essential stability. In view of this stability, signs of recent disturbance such as active gullies, wind scoured depressions, and top soil remnants indicate that the slow constructive process of soil development has been superseded by rapid, destructive process of accelerated erosion (most recent example Seeley fire 50K acres, Curtis-Tollestrup et al. 2012). When vegetal control is lost and erosion sets in at a rate that is accelerated rather than normal, the principal changes are no longer evolutionary, but revolutionary in character. The constructive development of soil, vegetation and animal life that took place under prevailing topography and climate, is overwhelmed by destructive processes, and orderly succession no longer apply. Over time as grazing has decreased and restoration projects have occurred across the Forest, soil cover has increased and likely reduced the soil erosion on the Forest (Goodrich 2012), but much of the destructive change that has occurred is still evident (Dulfon 2016).

Table 2. Erosion hazard ratings across the Manti La Sal National Forest

Erosion Hazard Rating	Acres	% of Forest
Slight	61,338	4
Moderate	433,946	32
Severe	778,184	57
Very Severe	17,233	1
Not Rated	79,302	6

Landslide Hazards

Table 3. Landslide Risk within the La Sal Mtns and the Abajo Mtns

Physiographic Region	Acres			
	Extreme Risk	High Risk	Moderate to High Risk	Moderate Risk
La Sal Mountains	0	0	18,384	12,397
Abajo Mountains/Elk Ridge	650	0	52,770	29,445
Wasatch Plateau and San Pitch Mountains	32,726	169,607	173,602	190,072
Total Acres	33,376	169,607	244,756	231,914

Areas mapped with extreme landslide risk are areas with active mapped landslides. Areas mapped with high risk are located within the Wasatch Plateau and the San Pitch Mountains on slopes greater than 35 percent on the North Horn Formation. These areas do not have any active landslides currently, but this landform is known to have active landslides and has a lot of landslide activity in the past. Areas mapped with moderate to high risk are located on slopes greater than 35 percent on formations known to contain active landslides, but there are no active landslides currently mapped. Areas mapped with moderate risk are located on slopes 20-35 percent on formations know to contain active landslides with no current active landslides mapped. Maps of the landslide risk are located in the Appendix D.

Soil Quality and Soil Productivity

Soil is the foundation of the ecosystem. Soil quality is 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 water and air quality, and support human health and habitation and ecosystem health. Soil productivity is defined as the inherent capacity of a soil to support the growth of specified plants and plant communities, or sequence of plant communities. Plant growth is generally dependent on available soil moisture, nutrients, texture, structure, organic matter, and the length of the growing season.

Grazing

Currently there are 171 allotments on the Manti La Sal National Forest. Cattle, sheep and/or horse grazing covers almost the entire Forest. Soil monitoring Forest rangelands was conducted in 2015. Soil compaction was found at seven of the 45 sites surveyed with percent area of compaction ranging from 10 to 30 percent. All sites were rated as stable or very stable except one , which was rated at risk with moderate stability due to compaction, loss of organic matter at the site and reduced carbon storage (see the soils project file for site specific monitoring data).

Harvesting

Since 1992, approximately 11,182 acres of the Forest have been harvested through commercial thinning and salvage treatments. These treatments likely led to local areas of compaction, soil loss and erosion especially where skid trails and temporary roads have been utilized. Practices have evolved to be more conscious of the impacts to soils; logging practices have shifted to less-impactive equipment (e.g., cable and skyline methods), and in current day forest management, soil restoration is included in the majority of projects in order to meet the desired conditions for the land.

Prescribed Fire and Wildland Fire

Over history there have been several landscape scale fires throughout the Forests on approximately 129,389 acres. Prescribed fire and wildland use fire have also occurred. Within prescribed burn areas, litter layers and organic matter was likely kept intact and nutrient losses were likely minimal due to low to moderate burn severity in a controlled environment (Certini 2005). Wildland fires; however, are more unpredictable and burn severities tend to be higher, loss of organic matter, soil cover and soil microbial changes are more likely to occur (Certini 2005) along with increased erosion (Wondzell and King 2003; Larson et al. 2009), further reducing the nutrient pool available (Megahan 1990; Certini 2005).

Soil Water Balance

The USGS has recorded at least seven multiyear droughts occurring in the State since 1896 (Wilkowuske et al. 2003) and droughts are becoming increasingly common and more severe than in the past (Littell et al. 2016; Seager et al. 2007). Trees have evolved protective mechanisms to deal with water stress, but there are many external factors that determine the effects of drought, including soil composition and topography, as well as the species mix, age and density of trees.

Carbon Storage

Soil stores carbon and globally more carbon is stored in soil than in the atmosphere and above-ground biomass combined. Limiting factors of soil carbon storage are depth and rockiness of the soil. Carbon compounds are inherently unstable and owe their abundance in soil to biological and physical environmental influences that protect carbon and limit the rate of decomposition (Schmidt et al. 2011).

On the Manti La Sal and within the Intermountain Region of the US Forest Service, most of the drier soils present contain approximately 0.5% soil organic carbon and cooler/moister soils contain approximately 8% soil organic carbon (Reeves et al. 2016; Brady 2002), and approximately 29% of the carbon stored on the Manti La Sal is soil organic carbon. The Forest Service Land within the Intermountain Region as a whole has approximately 135 Mg C/ha of which approximately 75 Mg C/ha is soil organic carbon and forest floor carbon stocks (Heath et al. 2011). On the Manti La Sal specifically, approximately 12,700,000 metric tons of carbon are stored in the soil (measured in 2014), this amount has dropped since 2008 when approximately 13,000,000 metric tons of carbon were stored in the soil on the Forest (Scottom and Anderson 2016). Soil organic carbon amounts overall have been increasing over time (USDA 2015).

Soil Stability

Soil stability and support is necessary to anchor plants and structures. Inherent soil properties, like soil texture and particle size distribution, play a major role in physical stability.

Past Flooding and Erosional Actions

Erosion and flooding have shaped much of the Manti La Sal National Forest as well. Historic catastrophic flooding occurred throughout the late 1880's and early to mid-1900's depositing material on the valley floors (Reynolds 1911; USDA 1935, 1947, 1948, 1957, 1983, 1986 and 2016a and b). This was likely partly due to overgrazing in the hillslopes leading to cover loss and exposed soil on slopes that are very prone to erosion when bared (Reynolds 1911; Stewart and Forsling 1931). Erosional events have been well documented on the Forest (USDA 1927, 1928, 1946, 1948, 1950; Ellison 1954) and in fact much of the Wasatch Plateau has formed due to erosional processes. Past erosion has been surveyed on approximately 51,431 acres across the Forest. The majority of the erosion monitored was moderate in severity with gullying, bare soil, cattle trailing and sheet erosion noted (Table 6). The severe to very severe erosion was found mostly on steeper slopes ranging from 80-100% slope in concave landscape positions. The implementation of grazing management, best management practices (BMP's) and erosion control measures has likely reduced the erosional occurrences on the Forest overall, but erosion has been noted in recent years as well following wildland fires and flooding events (Vanderbilt 2006).

Table 4. Erosion noted on the Manti La Sal National Forest

Erosion Type	Acres
Bare ground	26
barrens and trail disturbance	2,032
gulley	37,643
outcrop	389
outcrop and trail disturbance	42
sheet	12
trail disturbance	806
unspecified	10,406
(blank)	74

Restoration Efforts

Watershed restoration efforts have been ongoing since the 1950's and have included soil erosion restoration through reseeding, reduction in livestock grazing and implementation of range management. Following the flooding, erosional and landslide events of the 1980's, restoration efforts ramped up and included erosion control measures to reduce sediment production, revegetating riparian and hillslope areas, road restoration, reconstruction and decommissioning. In recent years, restoration has been more focused on prescribed burning, invasive plant control and watershed improvement projects which have occurred on approximately 29,668 acres.

Trends (Future 40 years - 2020-2060)

Climate Change

Shifts in climate could play out mostly in mid elevation forests where winter moisture comes as rain rather than snow, and where a decrease in snowpack could result in prolonged periods of soil moisture deficit.

The effects that climate change could have on soils are variable and integrated; changing one factor within the soil, (ie increasing soil temperature), can have an effect on several soil functions overall. Within in an increase in soil temperature, there is generally an increase in soil microbial activity and soil respiration, which overtime may increase nutrient cycling and decrease the amount of organic matter in the soil and at the soil surface, also releasing more carbon from the soil organic carbon pool (Brevik 2013). The interactions of increased soil temperature and changes in type and amount of precipitation will also affect the soil functions differently especially across different soil types. Finer soil textures are expected to buffer changes in climate more readily than coarse soil textures and those areas with finer soil textures will experience change more slowly (IAP 2016).

For an in-depth discussion on soils and climate change, see the IAP Physical Resources-Soils Report, Draft 2016. These soil carbon changes could lead to changes in soil structure, soil bulk density, and soil porosity (Pal Singh et al 2011; IAP 2016), potentially changing water infiltration rates and rooting depth. Warmer soil temperatures will likely lead to increased losses of soil carbon (IAP 2016).

Future Adaptations

- Manage the above ground carbon to manage below ground carbon and provide for more soil organic carbon and more carbon storage (IAP 2016). Soils with argillic horizons and higher clay content might stabilize carbon more readily, but sensitive soils in alpine locations where soil organic carbon stores are higher now, may be more susceptible to carbon loss with climate change or management (D'Amore and Kane 2016). Increasing harvest rotation lengths may also increase carbon storage in the soil, reducing erosion will decrease soil losses and soil carbon losses, so intact forest floors are important in management. Managing for effective ground cover, shrub cover and species composition within the upland range areas as outlined in the Rangeland Ecosystems Management Handbook (FSH 2209.1 Chapter 20, USDA 2005) will also contribute to above ground and below ground carbon stores on rangelands. Finally afforestation and protection of deep organic soils will help increase soil carbon storage or at least keep it at current levels (D'Amore and Kane 2016).

- Promote native plant species and plant diversity that can adapt to changes in soil condition due to changes in climate or fire regimes (Butterfield et al. 2016; IAP 2016).

- Utilize grazing systems that can respond quickly to changes in climate, especially in higher elevation rangeland where soil loss is evident in order to keep ground cover present and protecting the soil resource (IAP 2016).

- Develop soil vulnerability maps on watershed or project scale to determine how vulnerable soils are to climate change and how resilient specific soils may be to climate change or other stressors such as wildfire (IAP 2016).

- Develop robust soil quality standards utilizing soil functions so they are adaptable to changing climate and changing management goals across the Forest.

- Develop ground cover requirements based on erosion hazard ratings, slopes etc in order to ensure reduced erosion, adequate organic matter and sustained soil productivity over time. Encourage soil biological crust formation to protect the soil surface and increase organic matter.
- Utilize adaptive management strategies in order to account for changing conditions over time.
- Collaborate with other agencies to help inform how climate change may affect the soil resource and work together to come up with solutions on how protect the soil resource, keeping it resilient over time.

Data Gaps

- Landslide risk maps exist across the forest, but the layer is currently being refined
- LTA's are good, but need to develop a consistent soil survey across the Forest with interpretations and enter it in SSURGO
- No post-harvest or post prescribed burn soil monitoring data is available to inform the current condition of the soil, how much detrimental soil disturbance is on the Forest and how much detrimental soil disturbance is caused from different management activities, is there a total soil resource commitment on the Forest?
- Ecological site descriptions (ESD) are in the process of development, ESD's have not been completed across the Forest. ESD's will be very helpful in determining the health of the rangelands across the Forest in terms of soil stability, hydrologic function and biotic integrity.
- No inventory of soil restoration needs

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Appendix A. Manti La Sal National Forest Landtype Group Association Maps

Appendix B. Manti La Sal Soil Parent Material and Soil Taxonomy Summaries

Appendix C. Past Fire and Harvesting Activities with soil effects across the Manti La Sal National Forest

Appendix D. Manti La Sal National Forest Landslide Risk Assessment Maps

Appendix E. Maps and tables of mean water deficit over 16 years (2000-2015) and soil vulnerability to climate change maps across the Manti La Sal National Forest