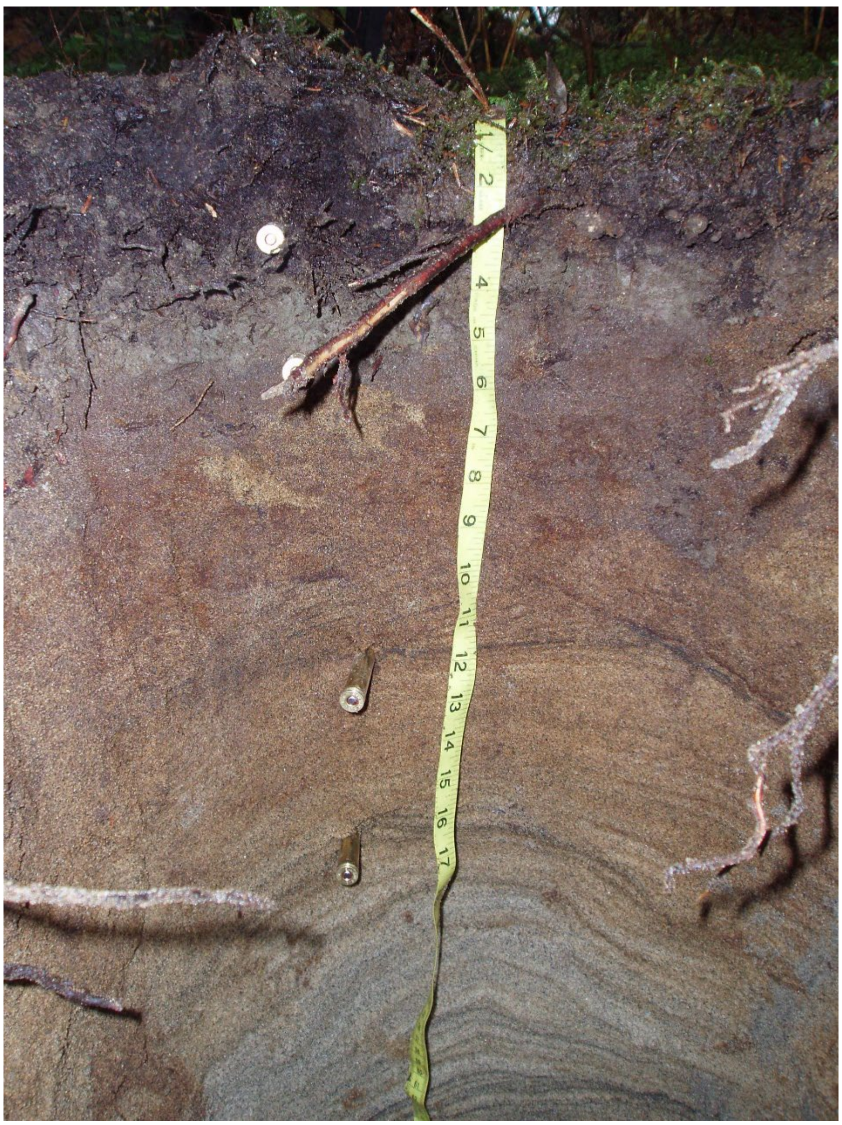
United States Department of Agriculture

Draft Soil Resources Assessment

Tongass National Forest Plan Revision



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Cover Photo: Soil layers showing in a soil pit dug on the Tongass National Forest along the Stikine River. This photo shows a soil type called a sandy Spodosol. Spodosols are soil types that often occur in cool, humid climates, where organic matter and aluminum have accumulated. Markers denote soil horizons. Photo by Dennis Landwehr.

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Forest Service, Alaska Region

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Introduction

Soil resource information is a core component of national forest planning, as this resource supports other ecological conditions key to sustaining ecosystem characteristics and function. Soil productivity is the inherent capacity of a soil to support the growth of specified plants, plant communities, or a sequence of plant communities. Soil productivity may be expressed in terms of volume or weight of vegetative growth per unit area per year, percent plant cover, or other measures of biomass accumulation. Maintaining soil productivity and minimizing soil erosion are primary objectives when managing soil resources on National Forest System (NFS) lands. Understanding the inherent soil capabilities and limitations of the landscape assures that planned activities are both obtainable and sustainable over time.

Resource Importance

Understanding the inherent soil capabilities and limitations of the landscape also assures that planned activities are both obtainable and sustainable over time. Soil quality and inherent productivity is foundational in ecosystem function. Soils are an integral part of ecosystems, their function, and the above and below ground interaction of organisms. These functions contribute to ecological resilience. Soil conservation and protections is needed to effectively maintain soil quality and productivity and improve or protect watershed conditions.

Current Management Direction

Regulatory Framework

Land potential is generally referred to as productivity of the land or soil. National environmental regulations, including the National Environmental Policy Act (NEPA) and the National Forest Management Act (NMFA), mandate that productivity of the land (and soil) should not be permanently degraded due to Forest Service management activities. Thus, understanding the variability of soil productivity when planning different management activities becomes an important consideration for sustainable natural resource management and ensuring compliance with national environmental laws.

Forest Service Soils Manual 2550 and Region 10 Soil Quality Standards provide guidelines and methods to comply with the Natural Forest Management Act. The Forest Service Manual, FSM 2550, has an objective to "[m]anage resource uses and soil resources on National Forest System lands to sustain ecological processes and function so that desired ecosystem services are provided in perpetuity." Policies regarding soil resources recommends the use of "soil properties to assess the condition and potential effects on soils, when planning and implementing project activities" and include an assessment of soil function and processes (FSM 2250). The manual also identifies Forest Service Disturbance Monitoring Protocol (Page-Dumroese et al. 2009) as a recommended method for assessing soil disturbance in forested landscapes.

Current Management Direction

The Forest Plan for the Tongass National Forest (2016) provides limited direction with respect to the management of soil resources. The direction can be paraphrased as follows:

1. Manage forest lands to maintain or enhance soil and land productivity,
2. Maintain or improve soil productivity,

3. Project design criteria will be applied,
4. Monitor effects of activities and long-term changes to soil productivity, and
5. The forest soil survey will be incorporated into resource analysis.

As a result of limited guidance at the Forest Plan level, Tongass National Forest project soil protection requirements have relied primarily on national and regional guidance, the professional expertise of forest soil scientists, and application of best available science information to determine how to best maintain the productivity of soil and land resources.

Soil Survey Data and Terrestrial Ecology Unit Inventories

A summary of general soil types of the Tongass can be found in the land type associations (LTAs) description (USDA Forest Service 2016b), Tongass Soil Management Unit GIS layers, and Web Soil Survey. LTAs are differentiated based on vegetation zones, geology groups, and landforms. There are 578 LTAs in the Tongass. Detailed, site-specific soil information is located within the Tongass GIS soil resource inventory, including parent material, depths, soil climate, hydrologic and sedimentation properties and responses, productivity, vegetation recovery, limitations for roads and heavy machinery operability, timber and range suitability, and other characteristics. The Tongass National Forest also has complete Terrestrial Ecological Unit Inventory (TEUI) coverage, which is used for inventory, monitoring and evaluation of soil condition and in making management predictions and interpretations.

Scope and Scale of Assessment

Spatial bounds for the assessment are the Tongass National Forest boundaries. The assessment includes a discussion of current soil conditions, which are a result of impacts since the time management activities began. Small soil disturbances typically do not have negative effects on soil productivity at the site, stand, or harvest unit scale. Larger, severe soil disturbances (where the topsoil is effectively displaced) can negatively affect soil productivity for decades or longer. Soil quality monitoring data is beginning to identify the recovery rates for soils from some levels of disturbance.

It is important to note that the scale of soil monitoring and detrimental soil disturbance is very different than the scale of a Forest Plan. National Soil Quality Standards established definitions and some minimum size requirements for detrimental soil conditions, which are based on activity areas, also referred to as a project area. Region 10 standards (USDA 2023) state that 85 percent of an activity area should be maintained in a condition of acceptable productivity potential for trees and other managed vegetation. The threshold value of 15 percent is established for assessing pre and post detrimental soil conditions at the stand or harvest unit scale. If detrimental soil conditions approach or exceed 15 percent of an activity area, soil restoration practices should be considered.

Methodology

Soil quality monitoring data collected over the last 35 years will be used to estimate effects to soils. For purposes of this analysis, the existing available soil quality monitoring data summarized in Landwehr (2018a) is the best available data for estimating detrimental soil impacts from the various activities.

Forest facilities including NFS roads (including cut, fill roadbed and landings and log transfer facilities) trails, recreation sites, hydropower facilities, powerline corridors, rights-of-way and developed mines are considered part of the Forest’s infrastructure, and because they are not meant for growing vegetation, are not subject to soil quality standards. Activities within the productive land base are subject to soil quality standards and include timber harvest, stream or vegetation restoration, temporary roads and associated landings and rock quarries, and wildlife enhancement projects. This assessment therefore focuses on the productive land base, where soil quality standards apply.

Data Limitations

There is an extensive body of soil disturbance and soil quality monitoring data available for the Tongass. However, the lack of precise soil and vegetation monitoring response to soil disturbances is a data limitation. In the absence of precise response information, the analysis takes a conservative approach using the best available data summarized in Landwehr (2018a).

Existing Soil Environment

Soil Development on the Tongass National Forest

Soil development is dominated by five major soil formation factors: climate, biota, geomorphology, parent material, and time. The three greatest influences on the development of the soils on the Tongass National Forest are a maritime climate, geomorphology, and parent material.

On a regional scale, precipitation has historically averaged 106-170 inches, depending on subregion (Littell and Johnson, DRAFT). However, there is wide localized variation, with some sites receiving less than 20 inches, and others receiving and average of over 350 inches of precipitation per year (Alaska Center for Climate Assessment and Policy 2023). The cool maritime climate causes slow organic matter decomposition and organic duff layers (5 to over 20 centimeters thick) cover most mineral soils. Displacement of the duff layer leads to soil erosion in most circumstances and that erosion can remain active until revegetation occurs.

Since the formation of the Alexander Archipelago, glacial activity has dominated the shaping of landscapes across southeast Alaska. The glacial carving of the landscape created U-shaped valleys with steep mountain slopes and fjords. The overriding ice left behind dense glacial till deposits along the steep mountain slopes and throughout valleys across the landscape. Valley deposits include well-developed end moraines, drumlins, and extensive ground moraines (Swanston 1969). Glacial till is generally found below 2,000 ft, with maximum thicknesses around that altitude, and decreased thicknesses with lower elevation, though there are exceptions. Glacial till deposits vary in depth from several feet on bedrock slopes to greater than 30 feet deep in sidevalleys and valley floors. Basal and lateral tills in many locations are often very dense due to compaction from the weight of glacial ice.

Southeast Alaska geology is varied with granitics, sedimentary (both carbonates and non carbonates), volcanics, and metamorphics. Soils overlying bedrock or residuum often mimic the original bedrock texture. Different bedrock types can drive soil nutrient availability such as soils over granodiorite being poorly drained, gravelly and nutrient poor, whereas soils overlain by carbonates tend to be higher in pH with more readily available nutrients.

Geomorphology is diverse in the Tongass. Active glacial terrains (icefields, recently deglaciated, mainland rivers) are typically unconsolidated rocky silty soils deposited by moraines, uplifted beaches, glacial till deposits, and loess from mainland river deltas. Inactive glacial terrains are angular mountains (angular mountains, rounded mountains, hills, lowlands, outwash plains) with U-shaped valleys with glacial till depositions often mid-slope to the valley bottoms. Post-glacial terrains such as volcanics are less common and contribute to volcanic ash and cinders.

The Tongass National Forest is shaped by how water is processed through the landscape. Windthrow, landslides, and flooding are the primary disturbance regimes since the retreat of glacial ice, with all contributing to soil formation and productivity on the Tongass National Forest. Backslopes and sideslopes typically have more well-drained mineral soils developed from residuum, colluvium, and till interspersed with wetlands, whereas in the lower topography, such as valley bottoms in glaciolacustrine/outwash deposits, thick layers of peat can form where drainage is poor. Alluvial fans and colluvial cones can often occur near the footslope landscape position.

Mineral (Spodosols, Inceptisols, and Entisols) and organic (Histosols) soils develop from colluvium, residuum, organic materials, glacial till (ablation and compact), bedrock, alluvium, volcanic ejecta, marine beach deposits, glacial outwash, glaciomarine and marine sediments, glacial drift, loess and sand dune parent materials. Soils cover roughly 70 percent of the inventoried land surface on the Tongass, the remainder consists of ice, exposed bedrock, and bodies of water. Spodosols and Histosols dominate the soil orders. Most soils display fine roots to the restrictive layer in depth, such as bedrock or compacted glacial deposits.

Poorly and very poorly drained deep organic deposits (more than a meter thick) commonly form over bedrock or dense till and support a variety of forested and non-forested wetlands. Poorly drained organic soils, less than a meter thick over bedrock, are often found on broad ridgetops and glacially scoured benches or rock knobs.

Well-drained organic soils can be subject to soil displacement from management activities or windthrow. Well-drained organic soils commonly occur on broken convex rocky terrain and are often less than 50 centimeters thick over bedrock. Areas of these soils are often small and occur in complex with mineral soils.

Soil Quality and Inherent Soil Productivity

FSM chapter 2550 (Soil Management) directs soil resource management on National Forest System lands. The objectives of the national direction are (1) to maintain and restore soil quality on National Forest System lands, and (2) to manage resource uses and soil uses on National Forest System lands to sustain ecological processes and function so that desired ecosystem services are provided in perpetuity. Region 10 Soil Management directives (FSM 2550-2023-1) support these national objectives and further direct forest plan land management components to contain measurable soil protections that can be monitored.

The main function drivers of inherent soil productivity on Tongass National Forest are soil hydrology, carbon storage, soil organic matter, nutrient cycling, and soil stability. Inherent soil productivity influences what plant communities can grow on the forest and how well they grow. Maintaining soil quality and productivity are important considerations in determining the level of natural resource extraction, like timber harvest, that the land can sustain, as well as other forest values, such as wildlife habitat and biodiversity.

Soil function is any ecological service, role, or task that soil performs. Soil quality is the capacity of a specific kind of soil to sustain productivity, maintain or enhance water and air quality, support human health and habitation, and provide for ecosystem health. Soil productivity is the inherent capacity of the soil resource to support appropriate site-specific biological resource management objectives, which include the growth of desirable plant species, plant communities, or a sequence of plant communities.

Both function and productivity can be described as the sum of the six ecological soil functions: soil biology, soil hydrology, nutrient cycling, carbon storage, soil stability and support, and filtering and buffering. These six functions are briefly described below, along with ways in which management and development can affect each soil function.

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. The major drivers of soil biological function are presence of organisms and thermodynamics. Vegetation canopy and soil cover (forest floor, fine and coarse woody debris) provide macro and microhabitat and climate conditions on-site to support soil organisms.

Soil Hydrology

Soil hydrology is the ability of the soil to absorb, store, and transmit water both vertically and horizontally. Soil can regulate the drainage, flow and storage of water and solutes, including nitrogen, phosphorous, 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.

Many soils on the Tongass National Forest are classified as hydric soils. Hydric soil forms under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions within the upper part. Anaerobic conditions exist when biologically available oxygen is absent from the soil. In hydric soils, soil organic matter accumulates because the microorganisms decompose plant and animal material more slowly than in anaerobic soils. This decrease in decomposition causes organic matter to build up at the surface. As a result, anaerobic soils usually have a dark or almost black surface.

Soil saturation can vary based on site-specific physical characteristics such as soil type, bedrock orientation, and slope gradient. The amount of soil saturation in the Tongass National Forest may be impacted by future climate change with increased storm events and seasonal rainfall.

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 management action, or every 100 to 300+ years. This not only reduces the rate of removal of soil nutrients, but also maintains nutrient content by long-time additions of nutrients by atmospheric deposition and by weathering of soil minerals.

During these biogeochemical processes, analogous to the water cycle, nutrients can be transformed into plant-available forms, held in the soil, or even lost to atmosphere or water. Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled through soil. Decomposition by soil organisms is at the center of the transformation and cycling of nutrients through the environment. Decomposition liberates carbon and nutrients from the complex material making up life forms and puts them back into biological circulation, so they are available to plants and other organisms. Decomposition also degrades compounds in soil that would be pollutants if they entered ground or surface water. Nutrient cycling can be assessed by considering organic matter composition on a site (forest d floor, fine and coarse woody material) and the nutrient availability (topsoil horizons and nutrient deficiencies).

Nearly all the nitrogen in forest systems is bound to organic matter. Very little of the total pool of nitrogen is available to plants; only about 2.5 percent of total organic nitrogen is released annually (Grigal and Vance 2000). The rate of nitrogen release from organic matter (mineralization) is controlled by microbial decomposition, which in turn is controlled by environmental factors as well as the amount and chemical composition of organic matter (Grigal and Vance 2000). Rates of nitrogen mineralization are highly spatially variable within stands (Johnson and Curtis 2001). The availability of nitrogen from organic matter has been said to "most often limit the productivity of temperate forests" (Hassett and Zak 2005). Logging residues are a source of nitrogen during early periods of stand growth after harvest (Hyvönen et al. 2000, Mälkönen 1976). Dead woody material left after logging provides carbon-rich material for microbes to feed upon, and microbial populations typically increase after forest harvests due to the input of logging residues. Microbes immobilize nitrogen in their tissues and limit losses that could otherwise occur through leaching or volatilization. As dead woody material gradually decomposes during the 15 to 20 years following harvest, microbial populations decline and slowly release the nitrogen to growing vegetation (Wilhelm et al. 2017).

One research study in the southeastern United States found that nearly all the nitrogen and much of the phosphorous that moved down through the litter layer into mineral soil was in organic forms because of microbial transformations of organic matter in the forest floor (Qualls et al. 1991). This indicates that some nitrogen and phosphorous can be moved from the litter layer into mineral soil where it may be stable for a longer period. Phosphorus is another essential nutrient that is mainly supplied, in forms available to plants, by the microbial breakdown of organic materials. A deficiency of available phosphorus can limit plant metabolism of nitrogen, and some forests may be limited by phosphorus availability (Trettin et al. 2003). Inorganic phosphorus is often present in soil minerals, but under low-pH conditions, soluble aluminum and iron often react with inorganic phosphorus to form insoluble compounds that are unavailable to most plants (Pritchett 1979). Sulfur, like nitrogen, occurs in soil primarily as organic compounds and is made available for plant growth through oxidation by microbes to sulfate forms (Fisher and Binkley 2000).

Wood loss may alter soil processes of forest regeneration and growth to favoring species with lower soil moisture and nutrient requirements and provide for a greater potential for soil erosion. Potential loss or reduction of organic matter can lead to a decline in several key soil and foliar nutrients (Powers et al. 2005). Further effects also include a reduction of habitat for species requiring soil wood as dens or as substrate for invertebrates, bacteria, and fungi, which affect food availability for small rodents and their predators

Soil Organic Matter – Down Woody Debris

Soil organic matter and coarse and fine woody debris are good indicators of soil productivity and overall forest health. Organic matter, including the forest floor duff, litter, and large woody material, is essential for maintaining ecosystem function by moderating soil temperatures, improving soil water availability, providing an important seed source, storing nutrients and carbon, and promoting biodiversity (Powers 2006 and Page-Dumroese et al. 2010). Soil organic matter is fundamentally important to sustaining long-term soil productivity. Soil organic matter is influenced by silviculture activities, burning, as well as decomposition and accumulation rates.

The organic component of soil is a large reserve of nutrients and carbon and is the primary site for microbial activity. Forest soil organic matter influences many critical ecosystem processes, including the formation of soil structure. Soil structure influences soil gas exchange, water infiltration rates, root penetration, and water-holding capacity. Soil organic matter is also the primary location for nutrient recycling and humus formation, which enhances soil cation exchange capacity and overall fertility. Soil organic matter depends on inputs of biomass (e.g., vegetative litter, fine and coarse woody debris) to build and maintain the surface soil horizons, support soil biota, enhance moisture-holding capacity, and prevent surface erosion. Nevertheless, in natural systems organic matter fluctuates with forest growth, mortality, fire, and decay.

Based on recent research, coarse woody debris is recommended to be left after treatment to encourage biodiversity and ecological function (e.g., microbial action, mushroom production) (Page-Dumroese et. Al., 2006). The Alaska Region has an interim guideline in the R10 Soil Management directive that defines coarse woody debris as logs or other woody debris more than 10 inches in diameter and 10 feet long, provided at a minimum rate of 5 pieces distributed across 1 acre. Since these guidelines were adopted from R6, future monitoring is needed to determine if this adopted guideline is appropriate with Tongass forests and harvest methods.

Along with the evolution in monitoring soils, organic matter rose in significance to assure soil productivity (Powers 1990, Jurgensen et al. 1997, Page-Dumroese et al. 2010). Woody debris, fungi, mycorrhizae, and associated decomposition functions all play critical roles in soil development and function, in turn contributing to soil productivity. Harvesting timber, especially whole tree harvesting reduces the above ground biomass on a site, and thus the residual vegetation has high value towards contributing to soil function as both mulch and substrate for soil nutrient cycling. Harvesting also decreases microbial biomass. Tongass forest monitoring (Landwehr et al 2012) found that soil organic duff thickness was reduced in older young-growth stands when compared to adjacent old-growth stands. Soil organic matter is also vitally important to sustaining soil productivity (Jurgensen et al. 1997). Soil biological processes and nutrient cycling are two main functions of soil organic matter. Soil provides habitat for a wide variety of organisms including plants, fungi, microorganisms and macro-organisms in the upper sections of the soil that promote root growth, control moisture and temperature within the soil profile, and provide for nutrients available to plants (Barrios 2007). These organisms, which include mycorrhizae fungi, are important for soil health and overall soil function. There has been some evidence to suggest that maintaining mycorrhizae diversity may be a factor in maintaining forest ecosystem health (Amaranthus et al. 1990, Wiensczyk et al. 2002). The presence of coarse woody debris as at least one form of habitat is an important factor in maintaining mycorrhizae diversity in forest soils (Harvey et al. 1987, Graham et al. 1994).

Typically, the forested soils in the Tongass hold most of the soil organic matter in the upper horizons of the soil profile. Coarse woody debris lines the surface but decays to soil wood and integrates deeper into the soil via bioturbation. Forest organic duff in the Tongass range from a few cm to 12 cm or more depending on the last disturbance and habitat type. Another component of coarse woody debris and organic matter in the forest floor is brown cubicle rot or soil wood. Residue left after advanced brown-rot decay is a brown, crumbly mass composed largely of lignin. In healthy forest ecosystems, especially coniferous forests, the upper-most soil horizon contains a significant portion of brown-rotted wood residues. The sponge-like properties of advanced, brown-rotted wood act as a moisture and nutrient sink and provides habitat.

Carbon Storage

The carbon cycle includes the role of soil in cycling nutrients through the environment (see Carbon Stocks Report). Limiting factors of soil-carbon storage are depth and rockiness. 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). Soil organic matter is formed by the biological, chemical, and physical decay of organic materials that enter the soil system from sources belowground (e.g., roots, soil biota) or aboveground (e.g., leaf fall, crop residues, animal wastes and remains). It then begins to be consumed by soil organisms. Thus, if no new plant residue is added to the soil, soil organic matter would gradually disappear. If plant residue is added to the soil at a faster rate than soil organisms convert it to carbon dioxide, carbon would gradually be removed from the atmosphere and stored (sequestered) in the soil. Large quantities of soil organic matter accumulate in environments such as wetlands, where the rate of decomposition is limited by a lack of oxygen, and high-altitude sites where temperatures are limiting to decomposition. Most carbon in mineral soil comes from root turnover (Schmidt et al. 2011), although some is moved from the forest floor into upper mineral soil layers (Qualls et al. 1991) or slow to decompose wood contributions (Pierson et al. 2021).

Soil carbon also plays a role in developing soil structure and soil stability. The maintenance of active soil carbon is important in maintaining soil stability, which influences water infiltration, reducing surface runoff, lowering sedimentation, and improving air infiltration into the soil to support plant root respiration and other soil biota.

Soil Support and 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. The need for structural support can conflict with other soil uses. For example, soil compaction may be desirable under roads and houses, but it can be detrimental for the plants growing in these compacted sites. Roads, skid trails, recreation trails can all increase compaction. Sensitive soils for the support and stability function are soils with high erosion hazards and soils with high mass wasting hazards.

Slope stability remains a hazard on the Tongass National Forest. Landslides (the dominant soil disturbance mechanism) are common on steep slopes, especially where shallow soils overlie dense glacial till and bedrock (Swanston 1969 and 1974; 1997 Tongass Forest Plan). See the *Geology and Geologic Hazards* Assessment for information about risk factors and occurrence. Landslides can impede soil productivity on slopes removing the top layers of nutrient rich soil down to glacial till or bedrock. It can take 50 to 100+ years for soil layers to develop on these exposed surfaces to support desired plant vegetation. Debris deposited on lower slopes and valley bottoms may improve soil productivity locally due to the incorporation of organic nutrients and improved drainage. Regeneration on lower slopes is rapid. Management induced landslides are considered detrimental soil conditions and are included in soil quality monitoring. Evaluating erosion and mass wasting risk in relation to land management ground disturbing projects is completed through slope stability assessments.

Tree removal can increase landslide potential, through increasing soil saturation and loss of root strength (Johnson et al. 2007). Current direction requires mitigations to minimize risk, as discussed in the *Geology and Geologic Hazards* Assessment.

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. The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits. Soil absorbs contaminants from both water and air. 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. Wetlands are also discussed in the *Aquatic Ecosystems* Assessment.

Soil Quality and Productivity Monitoring

Soil function is difficult to measure in the field. Consequentially, we use factors that can be readily observed and measured These factors include the degree of disturbance to surface organic matter and disturbance to topsoil. Most management activities affect surface organic matter, but it can rebound relatively quickly as surface leaf litter and roots in the soil rebuild organic matter stocks. In contrast, the mineral topsoil could be considered a summation of a site's potential to support growth based on bedrock, terrain, climate, and rate of soil development. When management activities displace or remove portions of the organic and mineral soil, this impact involves a longer-term recovery than disturbance to forest floor. These consequences last longer on thin soils with less overall nutrient capitol.

Most management activities and natural disturbance processes affect soil resources depending on site productivity and recovery potential. Following passage of the National Forest Management Act in 1976, regions of the U.S. Forest Service developed standards and guidelines for the protection of forest soils. Soil and Water Standards and Guidelines outlined in the 1997, 2008, and 2016 Forest Plans are important for minimizing potential soil disturbance. National Soil Quality Standards establish definitions and some minimum size requirements for detrimental soil conditions. Region 10 standards (USDA 2023) state that 85 percent of an activity area should be maintained in a condition of acceptable productivity potential for trees and other managed vegetation. The threshold value of 15 percent is established for assessing pre and post detrimental soil conditions at the stand or harvest unit scale. If detrimental soil conditions approach or exceed 15 percent of an activity area, soil restoration practices should be considered.

Status and Trends

Management activities that have affected soil condition include timber harvesting, mechanical treatments, road construction and use, recreation facility maintenance and use, mining, burning, and special uses.

Some examples of impacts that have affected current soil condition include:

- Land disturbing activities caused erosion of mineral soil at rates greater than the soils natural ability to replace it, referred to as soil loss tolerance rate. This has resulted in permanent loss of soil productivity, as soils are considered a non-renewable resource.
- Road corridors that make up Forest Road systems resulted in loss of soil productivity.
- Mineral extraction pits and mines resulted in permanent loss or reduction in soil productivity.
- Footprints of administration and recreation sites, such as developed campgrounds, have reduced soil productivity.
- Permanent special use sites, such as communication towers and buildings eliminated soil productivity.

Activities that have improved soil condition, as well as removing risk to soil productivity such as:

- Thinning dense forest has increased light through enhanced forest biodiversity thus boosting divergent organic soil nutrient inputs. (Enter in peer-reviewed citation).
- Decommissioning and road storage has removed culverts and restored terrain back to proper functioning condition resulting in improved drainage and decreasing landslide and slope stability risk.
- Invasive species treatments have targeted species that have negative soil stability, quality, and productivity impacts.
- Implementation of USDA Forest Service Best Management Practices has resulted in decreased erosion and sedimentation from roads and timber harvests.
- Revegetation efforts on exposed mineral soils on stream banks, road cuts, and landslides has decreased erosion and sedimentation and provided a source of organic inputs for nutrient cycling and biological habitat.

Vegetation management and road building are the primary stressors that have affected soil productivity on Tongass National Forest. Soil and Water Standards and Guidelines outlined in the 1997, 2008, and 2016 Forest Plans are important for minimizing potential soil disturbance. The Tongass National Forest has collected extensive soil disturbance monitoring data over 35 years. According to soil and water implementation and effectiveness monitoring, the Tongass National Forest is implementing current soil standards and guidelines successfully during timber sale activities and road and landing construction. rootwad harvest, invasive species spread, and burning have lesser impacts. The Forest now considers how these stressors may be affected by the impacts from changes in climate trends. According to soil and water implementation and effectiveness monitoring, the Tongass National Forest is implementing current soil standards and guidelines successfully during timber sale activities and road and landing construction.

Timber Harvest and Other Vegetation Management

Long-term soil productivity monitoring (Landwehr 2008) evaluated 15-year-old harvested stands with original high levels of documented soil disturbance. Results indicate soil disturbances less than 25 square feet in area were not identifiable after 15 years of recovery and not likely detrimental to woody plant growth regardless of soil type. Soil conditions in older young-growth (older than 50 years) evaluated long-term soil disturbance and results indicate soil displacements smaller than 100 square feet in area were rarely identified in highly productive stands after 50 years of recovery (Landwehr 2008). Results further indicate that nutrient rich soils may tolerate more severe and extensive soil disturbance before exhibiting a reduction in desired vegetative growth at the desired growth rates. Detrimental soil conditions within older young-growth stands were primarily soil displacements and soil erosion. Soil displacements primarily occurred from skid trails or spar tree landing and yarding corridors. Soil erosion was identified on steeper slopes in the displaced areas as evidenced by the presence of small gullies and ephemeral streams; however, soil erosion was almost entirely arrested after 50 years of recovery. Areas of soils greater than 100 square feet in area generally resulted in different vegetation communities and reduced growth rates compared with adjacent undisturbed sites (Landwehr et al. 2012).

The Tongass National Forest has collected extensive soil disturbance monitoring data over 35 years. The data collected indicate that timber harvest units, including cable helicopter, and shovel yarding systems (restricted to slopes less than 30%), are within the established Region 10 soil quality standard of less than 15 percent detrimental soil disturbance (FSM 2550-2023-1 and Landwehr et. Al 2012). Soil quality monitoring with soil disturbance transects continues on the forest. Monitoring and evaluation reports are written bi-annually in addition to periodic reports summarizing soil disturbance transect data and/or soil bulk density sampling data. The most pertinent of these reports are Landwehr and Nowacki (1999), Landwehr (2008 and 2014) and Landwehr et al. (2012).

Soil impacts from timber harvest systems can vary by harvest type and method. The past effects from timber harvest can leave displaced soils from skid trails, landings, and spar tree/cable corridors. Shifts away from skyline harvest systems creates pressures to use ground-based systems on steep slopes. This shift impacts soil productivity since cable systems disturb less soil on ground-based systems. Ground based harvest equipment has been used on the forest for over 30 years. Landwehr (2014) summarized the history of ground-based equipment timber harvest on the forest and provided the most recent soil quality monitoring data for timber harvest with ground-based equipment, especially on slopes greater than 30 percent. The report documents the increase in detrimental soil disturbance conditions with operations on steeper slopes. On slopes over 30 or 35 percent, the amount of detrimental soil conditions caused by ground-based equipment triples but was still within Region 10 Soil Quality Standards and recommends restricting equipment to slopes less than 30 to 35 percent.

The bulk of the past old growth harvest activities occurred between the 1960s and 1980's on the Tongass National Forest and it has tapered off since. Young growth harvest activities are expected to increase in the future The 1997, 2008, and 2016 Forest Plans required on-site slope stability analysis for old-growth timber harvest on slopes greater than 72 percent gradient. Application of this standard has resulted in the avoidance of hundreds of unstable areas and limited amount of timber harvest on slopes greater than 72 percent. Long-term monitoring of slopes greater than 72 percent is part of the ongoing forest-wide landslide inventory effort. Chapter 5 in the 2016 Forest Plan allows stability analysis for young growth harvest on slopes greater than 72 percent to be analyzed using historic and current air photos, and informal or formal soil disturbance field reviews depending on specific project needs. Tongass soil scientists continue to address site specific conditions to limit cumulative effects and meet the Region 10 Soil Quality Standards and Tongass National Forest Plan.

Several soil compaction studies have been completed on different timber harvest systems on the Tongass National Forest. The most recent studies have measured soil bulk density on skid trails created as part of the commercial thinning project (Landwehr and Silkworth 2011) and shovel trails used for stream restoration (Landwehr and Foss 2014). The shovel trails used for stream restoration experienced tens and in some cases hundreds of equipment passes to move wood from the roadside to the stream. The commercial thinning tractor skid trails moved cut logs to the roadside and most trails received tens and in some cases hundreds of passes of equipment. Studies before them (Landwehr and Foss 2006; Landwehr et al. 2012; Alexander 1990) found that soils at a few individual sample sites on equipment trails were compacted but overall, the equipment trails were not compacted.

There are several reasons for the lack of detrimental soil compaction in Tongass soils. First, Tongass soils are generally coarse textured with clay contents of typically less than 20 percent. Secondly, Tongass soils have high organic matter content and often have high coarse fragment content that resists compaction. Thirdly, vegetation grows rapidly in young-growth stands, and the root growth s loosens soils. Trees are subject to strong winds which cause tree rocking or windthrow that loosens upper layers of soil. Finally, on the Tongass, cull logs and slash are used to spread the weight of the equipment out over a larger surface area, thus avoiding potential compaction (Landwehr and Foss 2014). Based on soil quality monitoring data summarized in the 2016 Forest Plan FEIS (USDA Forest Service, 2016c) and summarized in Landwehr (2018a), soil scientists estimate less than 1 percent of the stands harvested prior to 1979 may not meet soil quality standards. Those areas included tractor-logged stands with high densities of primary skid trails or stands containing a high amount of temporary road, spar tree corridors, rock quarries, and/or post-harvest landslides. The monitoring data indicates stands harvested since 1979 meet soil quality standards.

Alluvial soils are generally included in riparian management areas. The current forest plan allow limited commercial timber harvest in riparian management areas outside the Tongass Timber Reform Act buffers as long as riparian management objectives (Appendix D in the 2016 Forest Plan) can be met. The need to minimize soil disturbance on alluvial soils, especially in areas of braided channels, has long been recognized (1977 Southeast Alaska Area Guide, Martin et al. 1995). Appendix D of the Forest Plan requires minimizing soil disturbance on fluvial channel process groups (alluvial fans floodplains and moderate gradient mixed control channels) to prevent the formation of new channels and to limit alder regeneration. Soil disturbance can be reduced considerably by the method of harvest and guidelines for equipment operations. For example, tractor logging commonly used in the 1950's and 1960's, typically resulted in more than triple the amount of soil disturbance as cable yarding during the same period (Landwehr et al. 2012). Monitoring of more recent ground-based yarding operations indicates that ground-based yarding on slopes up to 30 percent gradient results in soil disturbance amounts similar to cable yarding.

Road Building and Landings

Roads and landings are considered part of the permanent national forest management infrastructure and transportation system. Road building trends have decreased over time since the 1970’s to 1990’s. Building system roads and associated landings and rock quarries dedicates soils to administrative purpose and out of productive land base. Road construction is avoided on slopes >67% and deep glacial till soils over 55% due to increased high landslide potential (see the *Geology and Geologic Hazards Assessment*). Roads have been decommissioned over the past decades to limit runoff and sediment production. Suich restoration efforts may continue under the current 2016 Forest Plan and existing travel management plans. Standards and guidelines, BMPs, including those identified in the Soil and Water Conservation Handbook (USDA Forest Service 2006) and National (USDA Forest Service 2012) and other relevant mitigation measures, are applied at the project level to minimize potential adverse effects.

Landing locations are considered part of the road network based on the transportation handbook and are co-located, to the extent possible, with turnouts, borrow areas, and turnaround areas required for road construction and subsequent safe travel. Both Region 10 and National BMPs specifically consider landing location and design and re-use of existing landings while maintaining water quality protection. For young-growth management, many existing roads and landing would be reused if the roads and landings are compatible with management objectives and water quality protection. Temporary roads and associated landings with cull wood waste are included in detrimental soil condition calculations.

Climate Change and Carbon

The Tongass National Forest has seen increasing temperatures and temperatures are projected to continue to increase. Precipitation patterns and timing are shifting across the forest. The projected rise in soil temperature may cause earlier growing seasons, pushing some plants into higher elevation or changing growing seasons at increasingly higher elevations. The Tongass has cold-limited conditions whereby temperatures below 10 degrees Celsius (50 Fahrenheit) limit the active growing period for plants and microbes, expressed as growing degree days. Higher temperatures at the lower elevations may increase soil deficits in soil moisture in the summer and high evapotranspiration may increase drought and affect nutrient solubility and plant uptake. These shifts affect the timing of nutrient cycling and may negatively impact soil microbial activity. Since nutrients are a biogenic process, minimum temperature and moistures are needed to advance decomposition, including storing carbon. Nutrient cycling may accelerate nitrogen mineralization in the short term but deficits in the long term. Changes in climate and soil moisture may alter the composition and activity of soil microbial communities and soil organic matter accumulation. In response to these potential changes, the Tongass National Forest has adopted practices to ensure leaving sufficient organic matter and to monitor down woody debris.

The recognition of carbon’s importance could shape future management decisions. This recognition could result in more site-specific prescriptions of treatments as we gain understanding on gains and losses of carbon from the soil. Residual soils on the Forest, though shallow, still account for 44% of carbon on the site (Heath et al. 2011). Limiting factors for soil carbon storage are soil depth and rockiness of the soil. While it also may be tied to soil wood, roots, soil organic matter, forest floor and the wood debris and leaf litter that surface soil. The amount of carbon stored or converted to carbon dioxide from decomposition of detritus depends on available material and biotic potential within soil (DeLuca et al. 2019).

Understanding how carbon is impacted by the removal of non-merchantable material will need to be considered when determining what is needed for maintaining soil function (Page-Dumroese et al. 2010). 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).

The amount of carbon stored or converted to carbon dioxide from decomposition of detritus depends on available material and biotic potential within soil (DeLuca et al. 2019).

Other Disturbances

Root-wads attached to tree boles are needed for stream restoration projects. Removing trees with the root-wad attached can cause severe soil displacements on the soil duff and topsoil. Beginning in 2009, the forest has had a need to harvest root-wads for stream restoration projects from a few acres each year. Monitoring the effects of root-wad removal on soil productivity is ongoing (Foss 2015; Landwehr 2018). To date, all root-wad harvests that have resulted in regeneration harvests have met minimum stocking guidelines, indicating that the sites have adequately regenerated. Growth of trees and natural soil recovery is being monitored with photo points (Foss 2015). Following the 2009 root-wad harvest of 6 acres, visual monitoring resulted in the development of guidelines for root-wad harvests (Landwehr 2009). The guidelines for root-wad harvest are used to minimize impacts to soils.

Invasive plants can alter soil productivity. Invasives can outcompete native species shifting plant community composition and decreasing plant community diversity. Some invasives can emerge earlier than natives, changing the timing and quality of plant-derived inputs to the soil. Plant invaders can impact soil microbial communities and nitrogen availability. In addition, differences in plant litter quality among invasive and native plant species affects the composition and activity of decomposer organisms within the soil that mediate nutrient and carbon cycling (McLeod et al. 2021).

Controlled burning has not been commonly practiced on the Tongass and only a few studies document the effects to soils. Landwehr 2018 summarized some documented findings and suggested that in light of the moderate burn intensity there is little change to soil physical properties. However, minor changes in the chemical soil properties were identified and may be beneficial. In other areas of the forest, such as near Control Lake on Prince of Wales Island, a high burn severity was shown to have negative effects on soil and site productivity. There is no soil quality monitoring on slash pile burning, however this burn method is predicted to result in detrimentally burned soil (Landwehr 2018).

Key Takeaways

- Results from monitoring of implementation of Best Management Practices on the Forest for over 30 years have shown that these practices minimize soil erosion (including landslides) associated with management activities.
- Maintaining soil productivity is as an important part of managing the forest. Over the last decades, the Tongass National Forest established soil monitoring programs. Additionally, long term research plots across the nation were installed to understand the linkage between disturbance and productivity. Past and present monitoring inform project designs to maintain soil productivity.
- Design criteria to conserve soils will continue to evolve for treating steep slopes mechanically as a transition to new ground-based systems to treat steep ground occurs. Soil monitoring of these new systems will usher in new protection measures.
- Continuation of vegetation management treatments will require balancing needs to maintain soil productivity and ecological integrity. There is a need to maintain organic matter, maintain slope stability, and minimize soil disturbances remain while balancing economic and stand objectives.
- Soil restoration activities are likely to continue increasing. The level of road decommissioning has increased over the past planning period. As travel management continues, unneeded roads may continue to be decommissioned and shift to Forest Service designated productive land base.

- Soils vary in their susceptibility to specific types of detrimental soil disturbance as well as their ability to recover from disturbance either naturally or from mitigation actions.
- Recovery timing and success also vary among different types of detrimental soil disturbance and severity of disturbance.
- Some types of detrimental soil disturbance, such as excessive soil erosion or soil displacement on soils highly susceptible to degradation will not recover unless active land reclamation actions are implemented.

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Glossary

Inherent capability. The ecological capacity or ecological potential of an area characterized by the interrelationship of its physical elements, its climatic regime, and natural disturbances. (36 CFR 219.19).

Productivity. The capacity of NFS lands and their ecological systems to provide the various renewable resources in certain amounts in perpetuity. It is an ecological term, not an economic term (36 CFR 219.19).