Soil parent material: The role of earth's skin on forest health

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11 December 2024

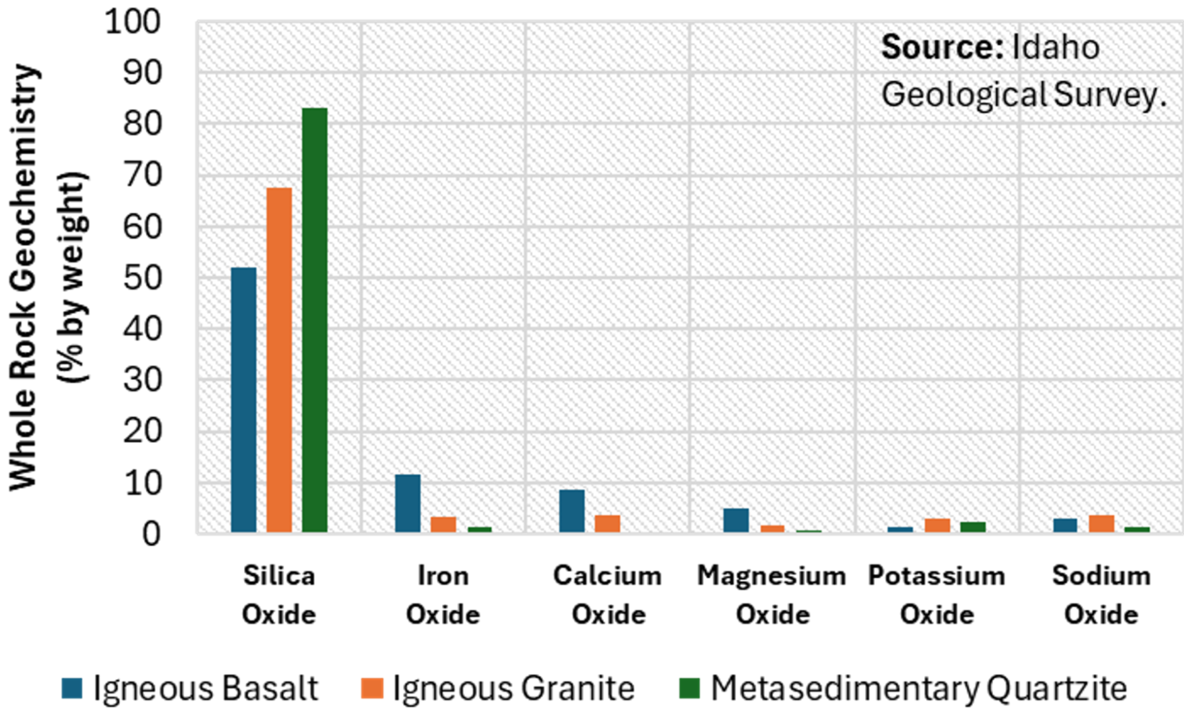

Figure 1: Average whole rock geochemistry for select rock types in northern Idaho, US.

Soil is complex, posing challenges for measurement and management at scale. Mark Kimsey from the University of Idaho highlights the importance of monitoring soil properties in forest management. This has resulted in digital tools that help align management practices with the characteristics of soil parent material and climatic conditions

Lately, much of our research and regulatory focus in managing forested natural resources has centered on climate and its long-term variability. While this focus is justified, we often overlook the foundational world beneath our feet—the Earth's skin, known as soil. Soil is inherently complex, both literally and metaphorically, presenting challenges in measurement, modeling, and management at scale. Despite these challenges, soil is fundamentally responsible for a forest's health, productivity, and resilience to both natural and human-induced stressors.

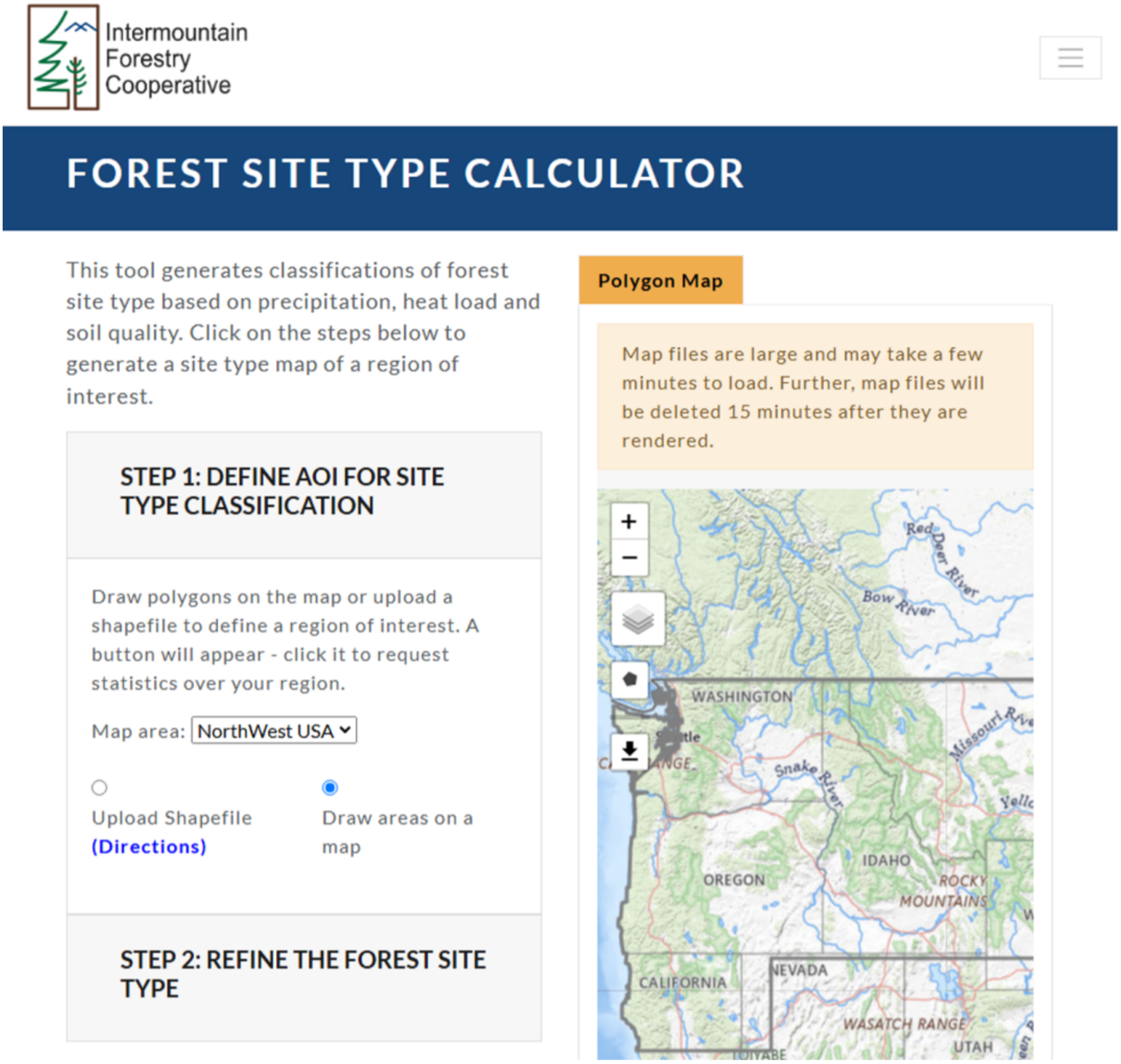

Figure 2: Intermountain Forestry Cooperative Forest Site Type Calculator.

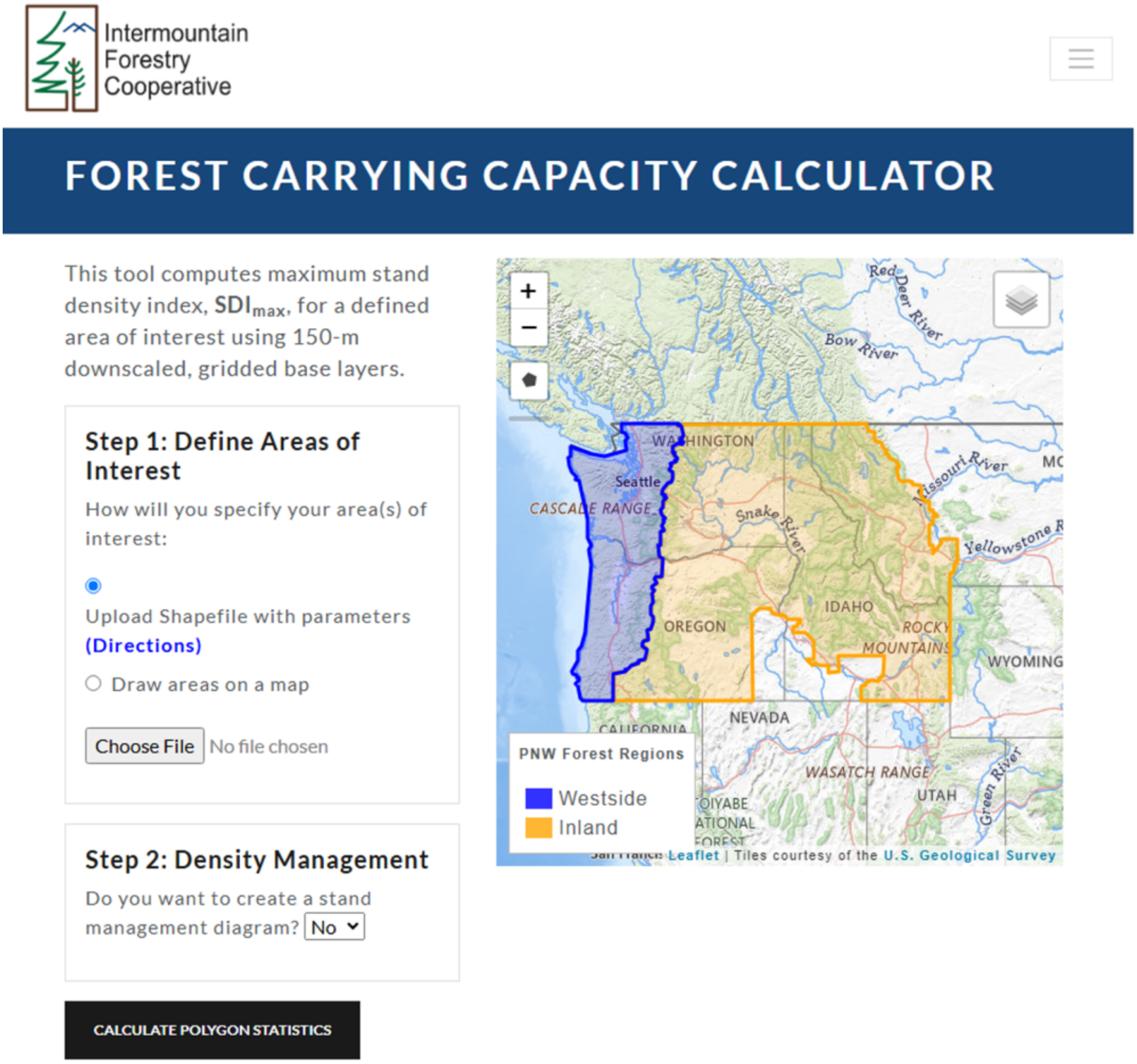

Figure 3: Intermountain Forestry Cooperative Forest Carrying Capacity Calculator.

Why should we care?

Plants, like humans, require water and nutrients to thrive, primarily sourced from the soil. Here, the rock cycle, along with other cycles like the climate, water, and nutrient cycles, plays a crucial role. Understanding geological weathering potential, such as the ratio of cations to silica and the physicochemical properties of rock minerals (e.g., grain size and oxide content), is vital for explaining variations in forest resilience and productivity. For instance, if a forester identifies soil derived from metasedimentary quartzite at one site and igneous extrusive soil at another, different management strategies should be tailored for each.

The rock cycle and soil formation

The rock cycle starts with molten magma crystallizing either within the Earth's crust (forming intrusive rocks like granite) or on the surface (forming extrusive rocks like basalt). Intrusive rocks cool slowly, resulting in larger mineral grains, while extrusive rocks cool quickly, leading to smaller grains. Soil forms over time from these rocks through processes influenced by climate, organisms, relief (topography), parent material (geology), and time, as described by Hans Jenny in 1941.

Soil formed from igneous rocks can be subsequently eroded and transported by water (alluvial), wind (eolian), or gravity (colluvial). When these transported sediments are buried and subjected to heat and pressure, they can transform into sedimentary or metamorphic rocks, like metasedimentary quartzite, which, when uplifted, begin the soil formation cycle anew.

For illustrative purposes, let’s focus on two very different rock types and their soil counterparts. First, metasedimentary quartzite. Weathered metasedimentary soils reflect a variety of particle sizes ranging from clay to sand, depending on alluvial depositional speed. Low-energy deposits are dominated by silt and clay-sized particles, while high-energy deposits are dominated by sand-sized particles. Metasedimentary quartzite is derived primarily from higher energy alluvial deposits of sand-sized particles, which are rich in silica oxides and hard to weather. In fact, the silica oxide fraction in these rocks can compose up to 80% of its geochemistry (Figure 1).

Soils derived from weathered igneous extrusive basalt are quite different. Given the rapid cooling of magma on the earth’s surface, mineral grain sizes are smaller in nature and, upon weathering into the soil, contribute primarily to the clay and silt particle size fractions. Furthermore, igneous extrusive minerals have relatively higher concentrations of potassium, magnesium, calcium, and iron oxides compared to metasedimentary quartzite (Figure 1).

Thus, metasedimentary quartzite soils are dominated by coarse-textured, silica-rich soil particles, which in turn have low water holding capacity, low cation exchange capacity (derived from clay-sized particles), and fewer plant essential nutrients than their igneous basalt soil counterparts.

Forest management implications

Why is this important in forest management? Plants are essentially soil nutrient miners, distributing the nutrients obtained from the soil across differing cellular structures in roots, bole, branches, and foliage to support growth and defense chemicals. A significant portion of these soil-derived nutrients are held in the aboveground biomass fractions of fine branches and foliage, which is a fraction most affected by forest harvest activities. Often, in light of fire risk, branch, non-merchantable bole segments, and foliage are burned at a log processing area, thus concentrating nutrients mined from across a forested area into a small, confined area, if not flared into the atmosphere.

Why does this matter? Soils derived from geologies with high silica mineral fractions are at a higher risk of long- term nutrient pool loss following intensive silvicultural activities where nutrients aren’t replaced through activities such as fertilization or biomass retention.

Biomass retention of non-merchantable biomass fractions has several benefits. First, it maintains plant essential nutrients on site following harvest activities, reducing the potential need to apply expensive fertilizer treatments. Second, it aids in retaining soil moisture, which is of particular importance on coarser textured soils (e.g., metasedimentary quartzite). Harvest residue, if left on site, reflects incoming solar radiation from soil surfaces, allowing the soil to maintain fine root-friendly soil temperatures and reduce overall soil evapotranspiration of critical plant water supply. This can be particularly critical during the re-establishment of a future forest on soils with inherent low nutrient supply and water retention.

Innovative tools for forest management

To address these issues and provide management solutions, the Intermountain Forestry Cooperative at the University of Idaho has been tasked by their stakeholders to develop models and digital toolsets that integrate this knowledge into consumable products that allow forest management activities to reflect the characteristics of underlying soil parent material and their climatic regimes. These include calculators like the:

- Forest site type calculator:
  A calculator that generates a site quality index as a function of precipitation, heat load, available soil water, and depth to a soil restrictive layer (Figure 2).
- Forest carrying capacity calculator:
  A calculator that allows a user to define the maximum amount of trees of a certain size a site can carry relative to species composition, climate, topography, soil parent material, and geographic location (Figure 3).

These tools aid in developing management strategies that optimize desired silvicultural outcomes, whether economic and/or ecological in nature. Such products are outcomes reflecting decades of sponsored research by our industrial and public agency stakeholders and in collaboration with regional and national soil and geology mapping agencies such as the Idaho Geological Survey, the United States Geological Service, and the Natural Resource Conservation Service. Conceptually and practically, such toolsets can be developed for stakeholder use anywhere globally, including forest soil research and existing soil and geology mapping products.

Contributor Details

Stakeholder Details

- Article Categories
- Agribusiness

- Article Tags
- Environment
- North America Analysis
- Soil Health

- Publication Tags
- OAG 045 - January 2025

- Stakeholder Tags
- SH - Intermountain Forestry Cooperative - University of Idaho