# A Tale of Two Slopes: Topographic and Ecosystem Controls on Soil Properties in the Cascade-Siskiyou National Monument

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## 1. Introduction

The Cascade-Siskiyou National monument is famous for its biodiversity. Lush forests, wide-open meadows, and steep mountain slopes are home to dynamic biological systems. Beneath the complex plant and animal diversity is an even more heterogenous foundation: the soils of the Cascade-Siskiyou National Monument boast seven orders, and even more suborders. Even on a smaller level, across slopes and aspects, soil properties are highly dynamic.

This project evaluated pedogenic processes along hillslope transects at two sites: a Douglas fir forest and an oak savannah. Both ecosystems are significant portions of the monument. The goals of the project are as follows:

1. Develop two catenas to understand the soil forming processes that drive the unique ecology of the monument.
2. Calculate Soil Organic Carbon stock along the catena to understand how ecology and hillslope dominate soil carbon dynamics.
3. Use the opportunity as an educational experience for the OSU Soil Judging Team to describe pits and familiarize themselves with the soils of Southern Oregon.
4. Generate figures and data suitable for the interactive mapping platform hosted by the Friends of the Cascade-Sisikyou National Monument

### 1.1 Predicted Research Outcome

Oregon White Oak historically prefers soils that are highly exposed and more susceptible to drought than other tree species for at least part of the year, typically with a more xeric association, but it can also be found on soils with heavy clay and shallow water tables[1]. Meanwhile, Douglas Fir prefers soils with better drainage[2]. It was hypothesized that the soils in the Oak Savannah were somehow challenging for the Douglas Fir, whether it be drainage or something else related to soil hydrology.

The litter from Douglas Fir was estimated to create higher stocks of surficial C, while it was estimated that annual root die off from the roots in the Oak-Savannah would lead to deeper stores of Carbon.

### 1.2 Predicted Undergraduate Outcome

An additional aim of this project was to generate a positive field experience for undergraduate students at Oregon State University. Students at Oregon State are highly passionate about soil science. However, due to administrative changes, many courses related to soils have been moved online, taking away vital field experiences necessary to understand soils in context. Students participate in extracurricular soil judging, an activity where they travel around the state and country to examine soil morphology. Students do this activity on their own time, receiving no course credit. They learn to understand soil morphological features, classification, and interpretation. The interpretations including agricultural and land use evaluations, as well as evaluating suitability for engineering projects like septic systems and road construction. The students were be exposed to ten soil pits in soils dissimilar from those in the Willamette Valley and would learn about how to take part in comprehensive soil research.

**2.Funding Breakdown**

| Transportation | Cost/Mile | Total Miles | Daily Cost | # of Days | Total Flat Cost | Per Mile Cost for Motorpool | Total Cost | Total Cost for FRF fund |
|---|---|---|---|---|---|---|---|---|
| OSU Van Rental (For undergraduates) | $0.36 | 456 | $45 | 2 | 90 | $912 | $1002 | $0 |
| Personal Vehicles for Alex | $0.67 | 480 | NA | NA | NA | NA | $321.60 | $321.60 |

*A 12 passenger van was rented from OSU Motorpool using other ARF funding.*

Instead of paying a commercial lab, we decided that it would be a better use of funds to pay an undergraduate student to learn how to do the tests under my tutelage. The student, Max Kuempel, also collected additional vegetation data for the project. FRF funds were used until depleted, then funding for Max came out of broader ARF funds. All equipment and chemicals were already in the lab.

Funds initially for my stipend and lab testing were allocated to Max, and I worked for free. Max was paid via OSU student employee system as an hourly employee under our department.

| Hours Worked under FRF funding | Pay/Hour | Total |
|---|---|---|
| 165.3 | 16.0 | $2644.84 |

**3.Methods**

**3.1: Site Selection**

Sites were selected with the help of Bureau of Land Management Soil Scientist, Matthew McClintock. Locations were selected because of their relative similarity in elevation, climate, and relief.

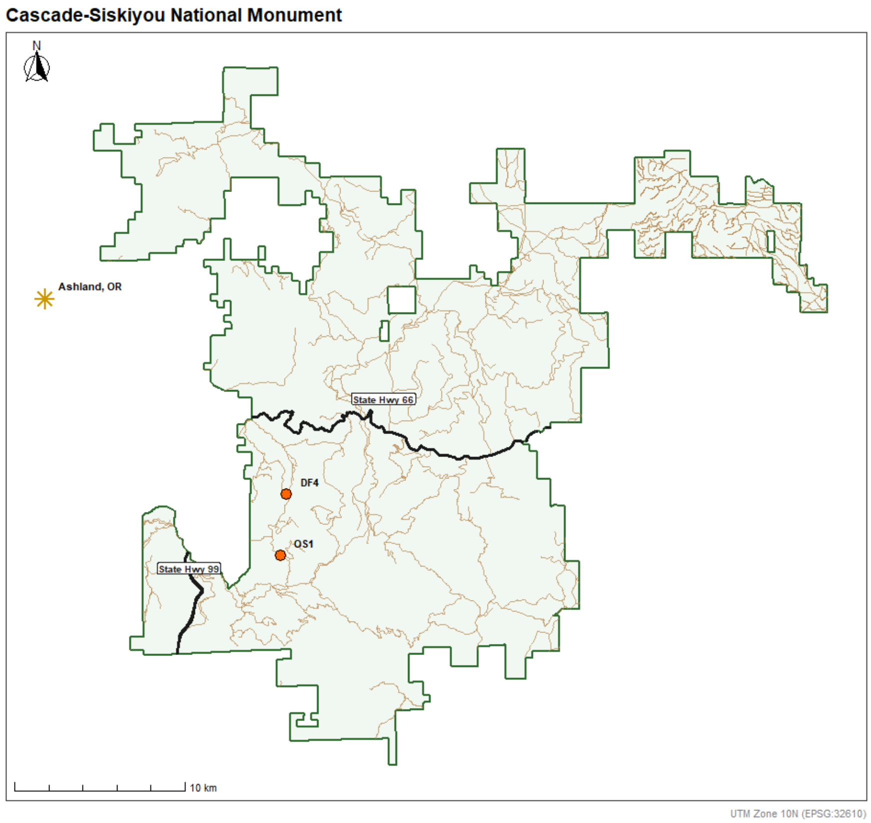



**Figure 1***: Map of sites relative to major roads at the monument.*

**Figure 2:** *Vegetation at Oak Savannah Site. Dominate tree species is young, shrubby Oregon white oak while the understory is mostly grass.*

**Figure 3***: Vegetation at Douglas Fir Site. Understory is dominated by moss, small shrubs, and downed logs. Middle aged and young Douglas Fir is the primary species of tree.*

### 3.2: Pedon Description

Pedons were described following standard methods from USDA NRCS[3]. Soil pits were dug as deep as possible, with a maximum depth of 100 centimeters. Horizons were then identified by differences in soil morphology, such as color, texture, and structure. Samples were taken from each horizon, both traditionally, and with two-inch bulk density rings. The morphological features, including redoximorphic features, moist color, texture, structure, root density, and moisture consistence, were collected. Slope was measured with a clinometer.

**Figure 4:** *OSU students observing field technique of pH in NaF, an indicator of poorly crystalline or short-ranged order minerals in soils. This test was not necessary for the completion of the project, as these soils were dominated by phyllosilicates, but it was a simple test to demonstrate soil chemistry in the field for student understanding.*


**Figure 5:** *Example soil profile, dug only to 40 centimeters due to hitting bedrock.*

**3.2.1: Environmental Description**

Ground cover was assessed using four 1 $m^2$ quadrats per soil pit, constructed from PVC pipe. Quadrats were tossed toward suitable, undisturbed areas adjacent to each pit to introduce randomization while avoiding areas directly impacted by excavation or trampling. Quadrats were also tossed to avoid single-cover situations (e.g., a quadrat falling entirely on a boulder) in order to ensure representativeness of the surrounding vegetation community. Within each quadrat, percent cover was visually estimated for all plant species, litter, bare ground, large wood, rock, moss, and lichen, with values summed and averaged across the four quadrats per pit. Tree and sapling composition was assessed using a 15 m × 15 m plot centered on each soil pit. All woody-stemmed plants with a stem diameter greater than 2 cm were counted by species, and individuals under 2 m tall were recorded separately as saplings. Species identifications were made in the field and flagged for verification where confidence was low, using the iNaturalist app to verify.

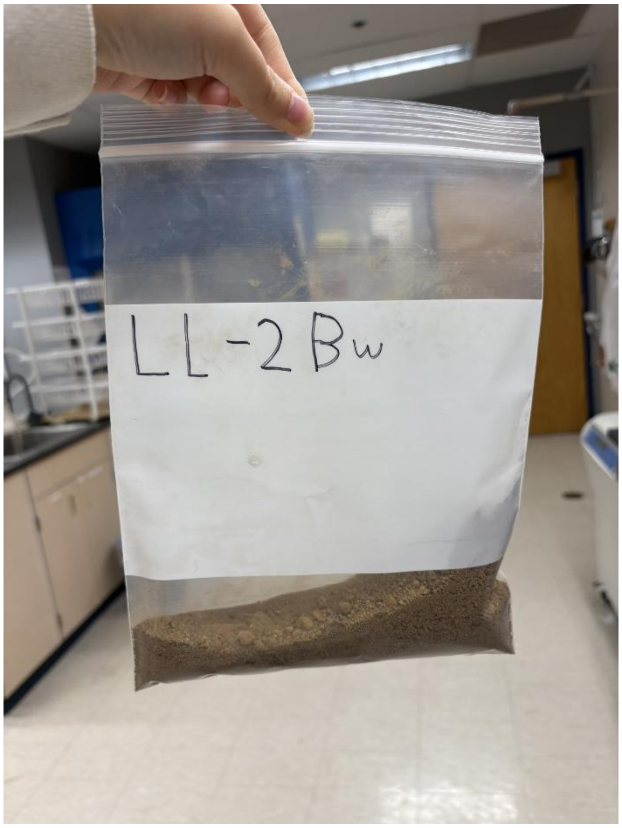
### 3.3: Lab Analysis

Tests performed were: mid-infrared spectral analysis, bulk density, X-ray fluorescence, pH, electrical conductivity, texture via hydrometer method, and organic matter content was estimated with mid-infrared spectroscopy.

#### 3.3.1. Mid-infrared spectroscopy

Soil spectroscopy is a technique based on quantitative relationships between lab-measured soil properties and the absorbance of visible to infrared light by covalent bonds. Because of this, spectroscopy offers insight into the mineralogical and organic chemical properties of soil. Mid-infrared spectroscopy has succeeded in rapidly and accurately estimating multiple soil properties and facilitating soil survey activities. Compared to wet chemical analysis, it is highly cost effective and allows for insights into properties that would be otherwise unattainable under tightly constrained budgets.

The original plan was for samples to be processed at Oregon State University using the Bruker INVENIO-R mid-infrared spectrometer, which can process all three replicates of 20 samples at once. However, due to technical issues with the equipment at Oregon State, samples were shipped to the University of Wisconsin - Madison, where the analysis was performed on a Bruker Alpha II mid-infrared spectrometer, which processes one replicate of one sample at a time.




Processing followed standard Kellogg Soil Survey Lab Methods[4], including air drying, grinding, and sieving to <2 mm and then fine grinding to <180 µm. The samples were processed by Max Kuempel and I at Oregon State University, then transported to UW Madison, dried out again, and ran in the machine by me.

**Figure 6**. *Sample at OSU after air-drying and sieving*.

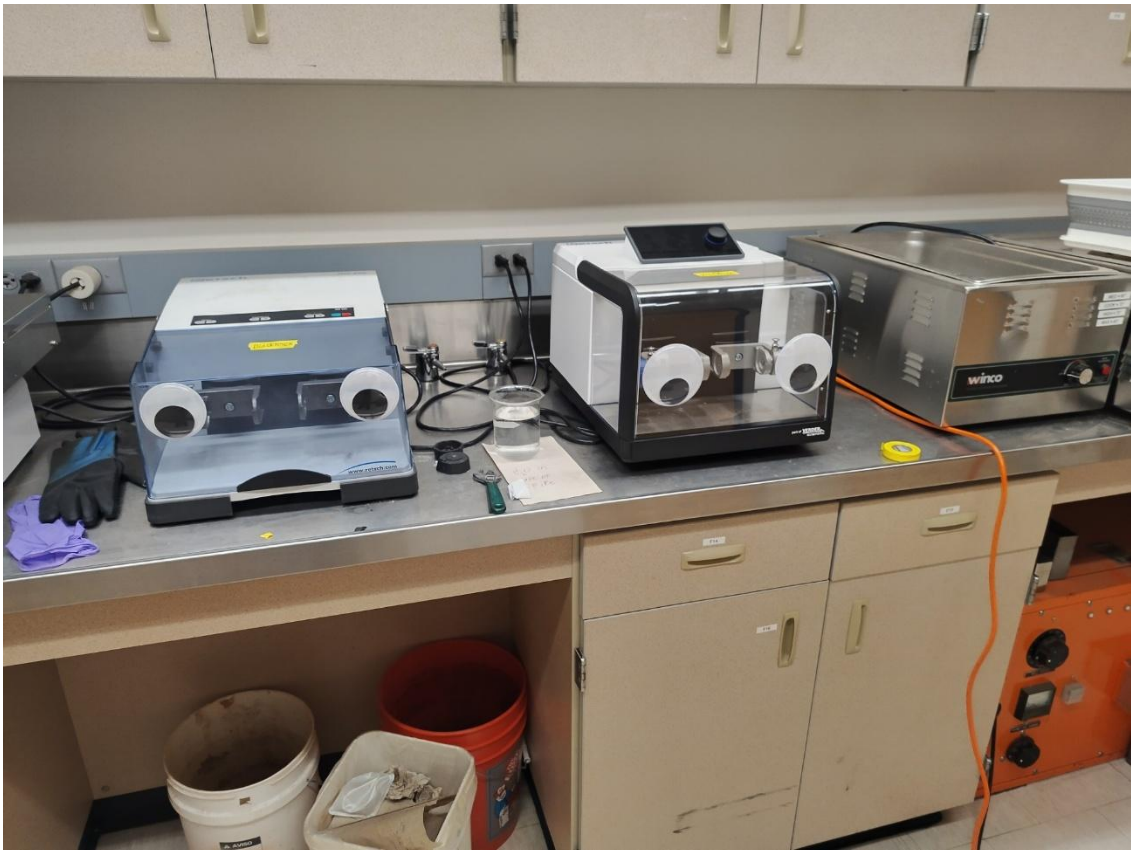



**Figure 7**: *Retsch mm 400 Mixer Mill used to fine grind soil samples at OSU.*

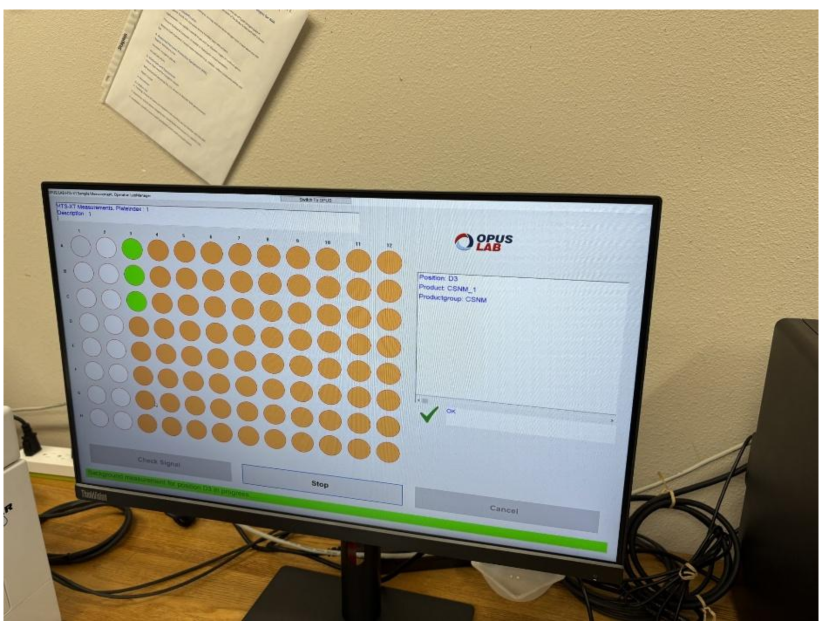



**Figure 8:** *Attempted sample scan on Bruker INVENIO-R.*

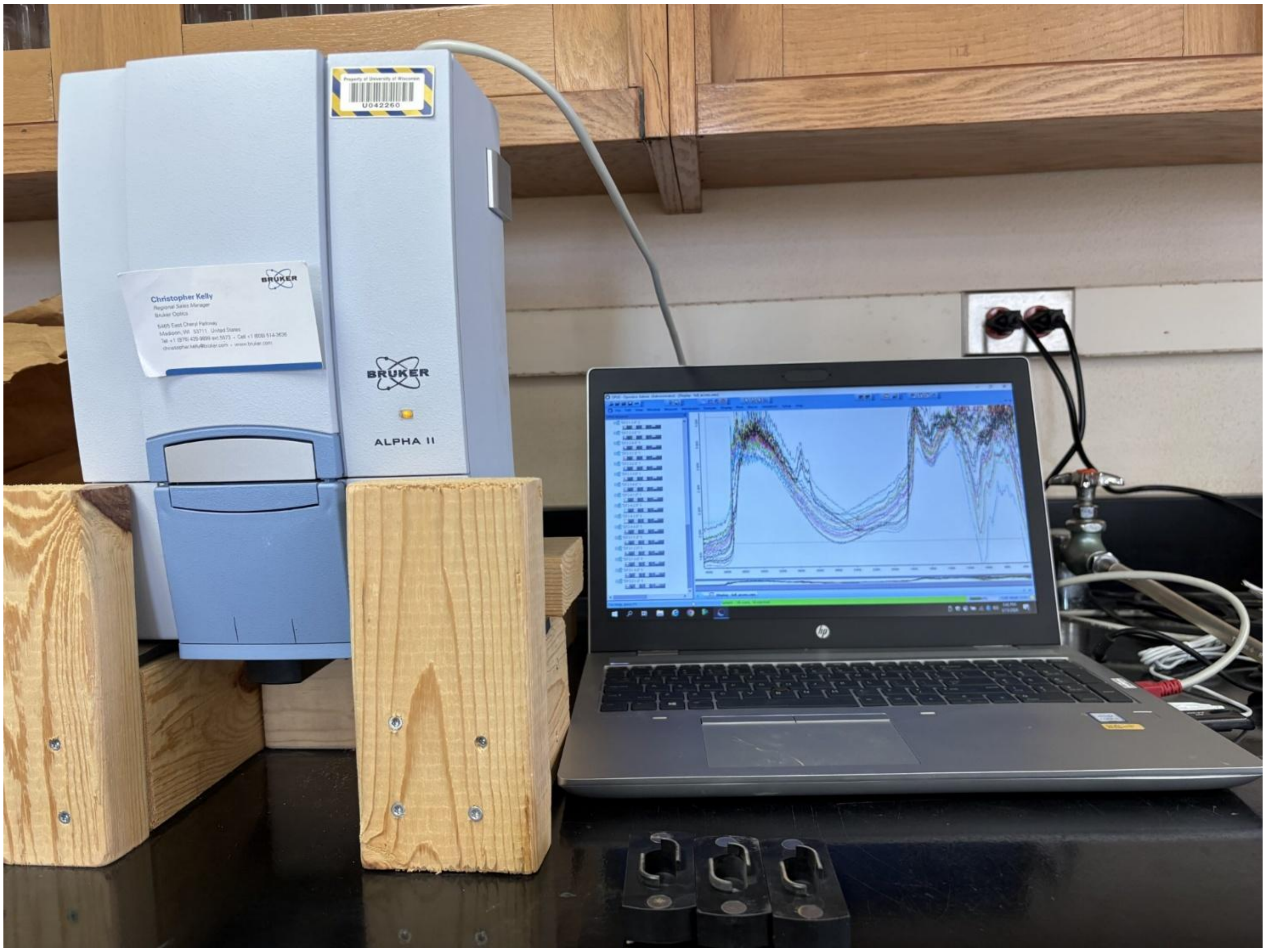



**Figure 9:** *Bruker Alpha II used for scanning of soil samples at the monument.*

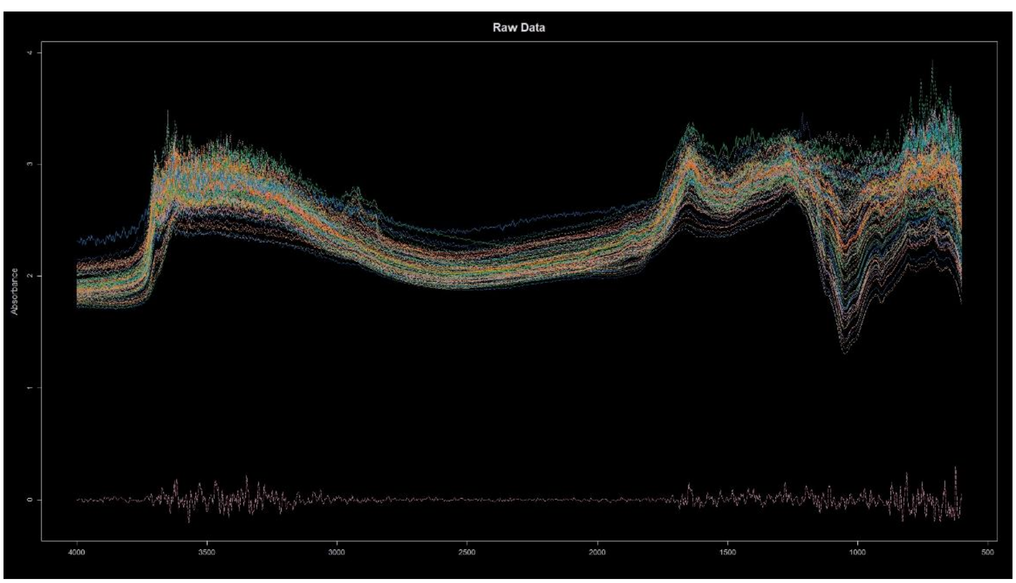



**Figure 10:** *Raw data output of MIR samples from the CSNM.*

### 3.3.2 Bulk Density

Bulk density was carried out following the ring method, where a metal cylinder of known volume is driven into the ground (2-inch rings) and an undisturbed soil sample is removed. It is then weighed wet and dry. Density can then be calculated because the mass and volume are known.

### 3.3.3 X-Ray Fluorescence

X-Ray-Fluorescence, or XRF, is a form of soil spectroscopy used to identify the presence of certain elements in soils. Within a lead cage, X-rays are shot at a flattened tray of ground soil sample. The sample emits secondary fluorescent X-rays which provide a unique signature of elements. The samples were analyzed on a Geochem 3-Beam analyzer.


**Figure 11:** *Geochem 3-Beam analyzer testing the samples in the lead cage at OSU.*

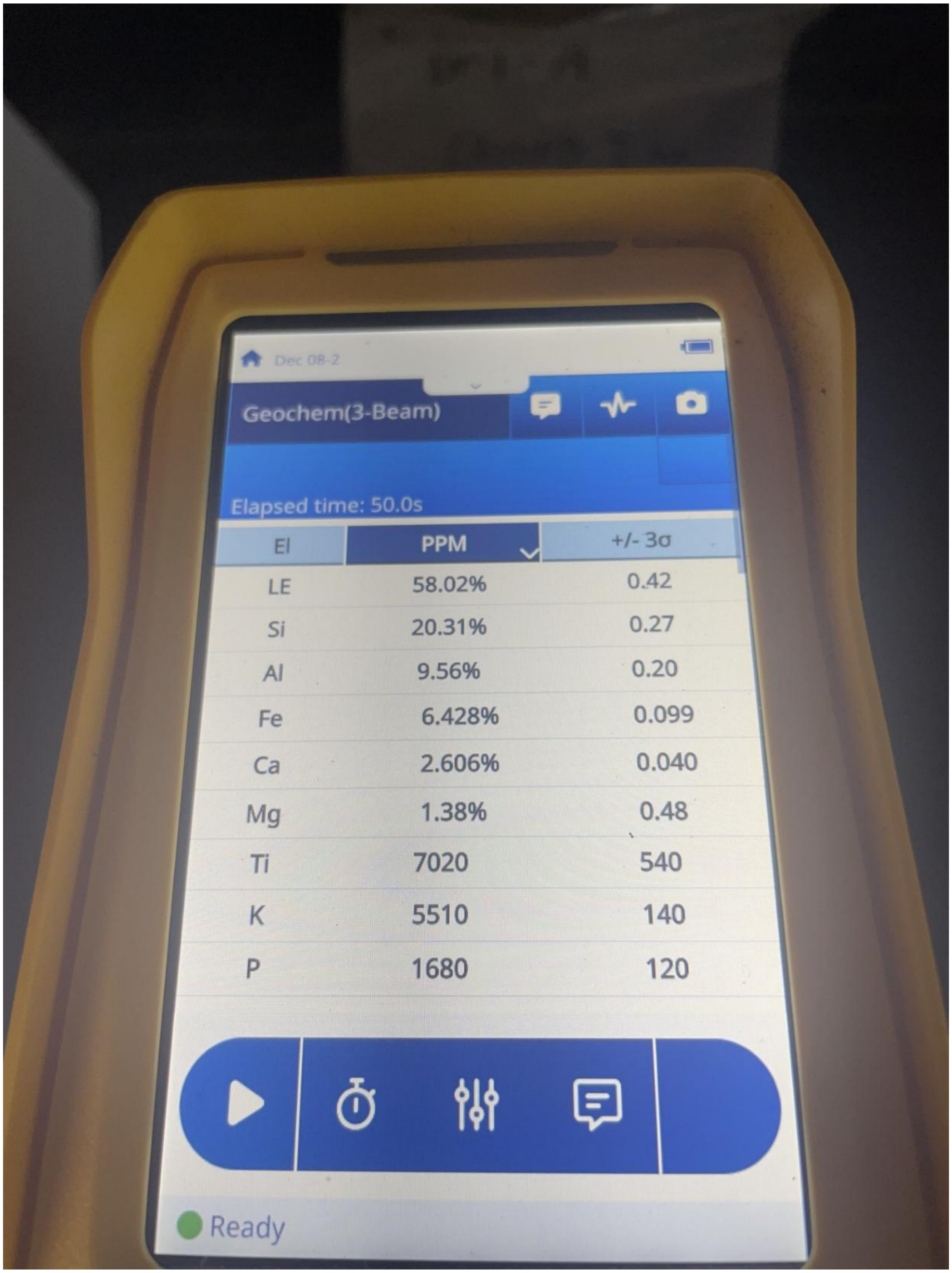



***Figure 12**: Elemental composition of sample following X-ray test as showcased on machine.*

### 3.3.4 pH and Electrical Conductivity

Soil pH is a test of the potential of hydrogen, or the alkalinity or acidity of soil. Samples were tested in a 1:1 water to soil solution on a Themo Scientific Fe150 pH benchtop meter. The meter also measures electrical conductivity of the soils, which is indicative of the ability of soil to carry a current, which is used to understand the presence of salts in soils.

### 3.3.5 Texture

Soil texture is the ratio of sand, silt, and clay. It was estimated in the field by ribbon and wire method, by both OSU scientists and undergraduate students. It was then tested via hydrometer method by undergraduate soil judger Max Kuempel at Oregon State.

The hydrometer method works by following Stoke's Law, the settling velocity of a particle is dependent on size, weight, and shape. Larger particles like sand sink to the bottom faster than smaller, finer particles.

Samples are dispersed via sodium hexametaphosphate, then a cylinder is filled with distilled water and measurements are taken at specified time intervals to estimate texture.

### 3.3.6 Organic Carbon Content

Organic carbon content was estimated via MIR spectroscopy using a model developed by Malithi Weerasekara at the Zhang Lab at Oregon State and the University of Wisconsin – Madison. The model was created using thousands of soil samples from the Kellogg Soil Survey laboratory that were tested for both MIR and organic carbon.

Descriptive Statistics

See all data?

| Category | UOM | Count | Min | Max | Mean | SD | Median | 25% | 75% | Skewness |
|---|---|---|---|---|---|---|---|---|---|---|
| Global | % | 52877 | 0.02 | 65.6 | 4.3 | 10.1 | 1 | 0.3 | 2.6 | 3.6 |

**Figure 13:** *Model descriptive statistics.*

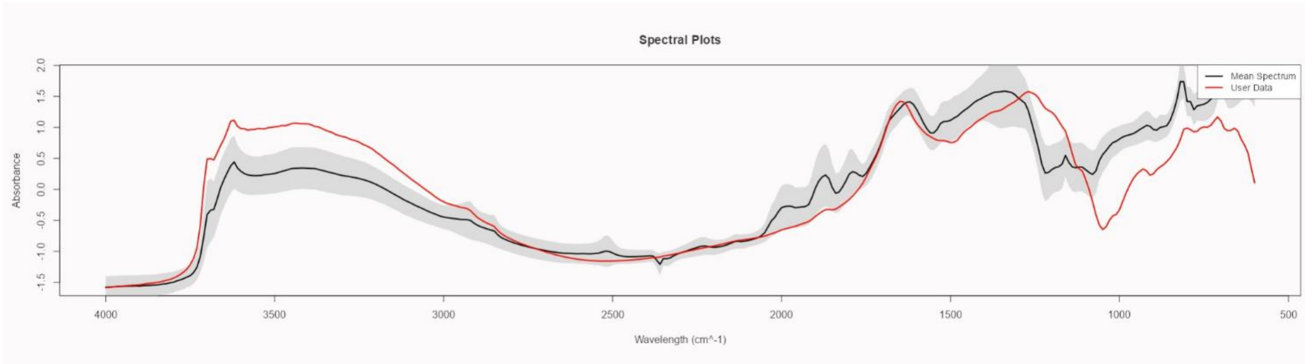



**Figure 14:** *Mean global spectra for model (Mean Spectrum), versus CSNM spectra (User data).*

**Preprocessing Information for MIR Spectral Data**

| | |
|---|---|
| Resolution | Resolution 10 cm^-1 |
| Spectral Range | 4000-600 cm^-1 |
| Noise Reduction | Savitsky-Golay |
| Normalization | Standard Normal Variate |

*Figure 15:* **Table outlines all preprocessing information for mid-infrared spectral data.**

Following standard methods[4], the Cascade-Siskiyou spectral data is preprocessed by first removing outliers via a calculated spectral similarity. The zero files produced by the Bruker Alpha II are converted into csv strings of numbers. Then, the data is normalized and resampled to clean up errors and smooth the data. After insertion into the model, results are generated.

### 3.4: Data Analysis and Calculations

The primary calculation used was carbon stock. Carbon stock is a measure of how carbon is "stored" in soils, measured in mass per unit area. While soil carbon dynamics are complex, and there is no permanent state of soil organic carbon, SOC stock is a highly valuable commodity and is significant for understanding carbon dynamics in the earth-ocean-atmosphere continuum.

$$Stock_C = OC \; x \; \rho_b \; x \; (1 - CF) \; x \; W \; x \; 0.1$$

| Soil Carbon Stock | Organic C (Estimated from MIR) | Bulk Density (Mass/Volume) | % of Soil Occupied by Rocks | Thickness of horizon | Conversion factor |
|---|---|---|---|---|---|
| $Mg_c \, ha^{-1}$ | $Mg_c \, g^{-1}$ | $gcm^{-3}$ | No units | cm | No units |

**Figure 16:** *Calculation of SOC Stock via standard equation for horizon method of SOC stock analysis.*

## 4.Results and Discussion

It was found that the soils at the Oak Savannah site were shallower than those at the Douglas Fir site, likely duo to mass wasting or long-term erosion. Soils at both sites were dark, rocky, and varied significantly across slopes.

### 4.1.2 Douglas Fir Transect

Four soil pits were dug at the Douglas Fir site with a maximum depth of 100 centimeters. The soils were dark, on an andesitic bedrock, with few rock fragments scattered throughout. The pits were aligned on the summit, upper backslope, lower backslope, and footslope.

The soils were all characterized as mollisols or inceptisols, each with cambic diagnostic subsurface horizons. All four soils had an Oi horizon, which is a horizon with “fibric” or slightly decomposed, fibrous organic matter at the surface (figure 17).

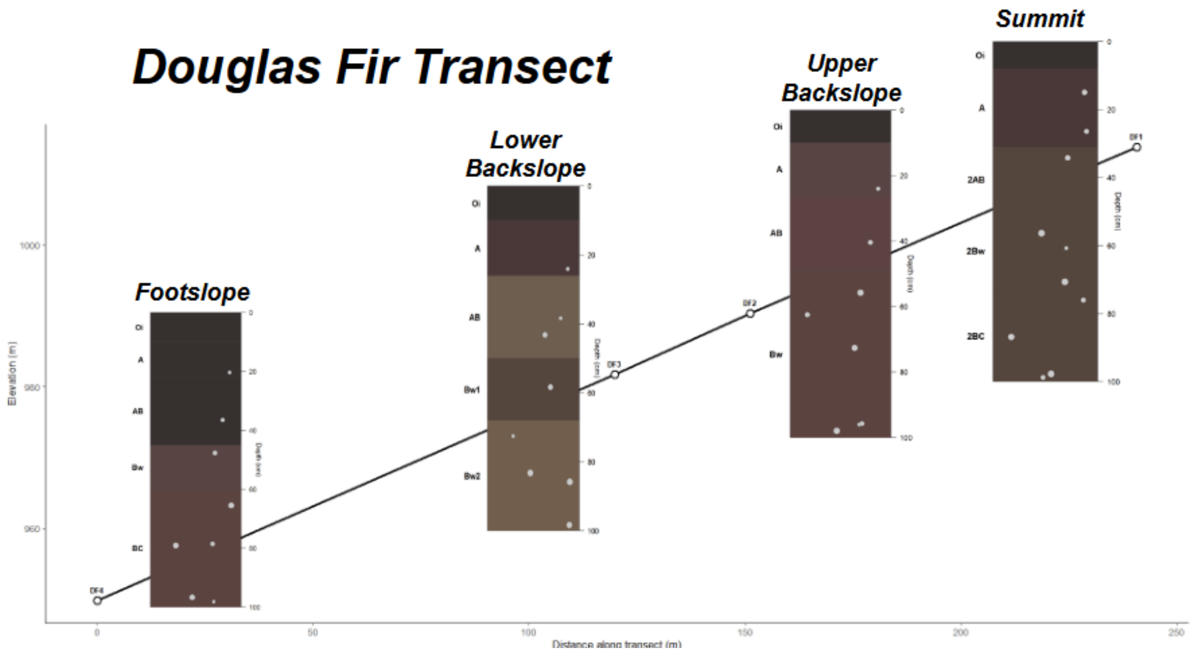



**Figure 17:** *Douglas Fir soils compared to relative position on hillslope, where the x-axis represents distance along the transect, and the y-axis represents elevation. The soil horizon descriptions and colors were identified in the field, as well as the estimate of coarse fragments, as illustrated by the grey circles. The colors were taken in the field with a Munsell book, then converted to RGB and illustrated onto the profiles using the SoilDB function in R.*

### 4.1.3 Oak Savannah Transect

Four pits were also dug at the Oak Savannah site, with a maximum depth at 100 centimeters and a minimum at 40 centimeters, due to hitting bedrock (andesite). These soils were rockier, with a shallower depth to bedrock, and evidence of clay accumulation throughout the profile.

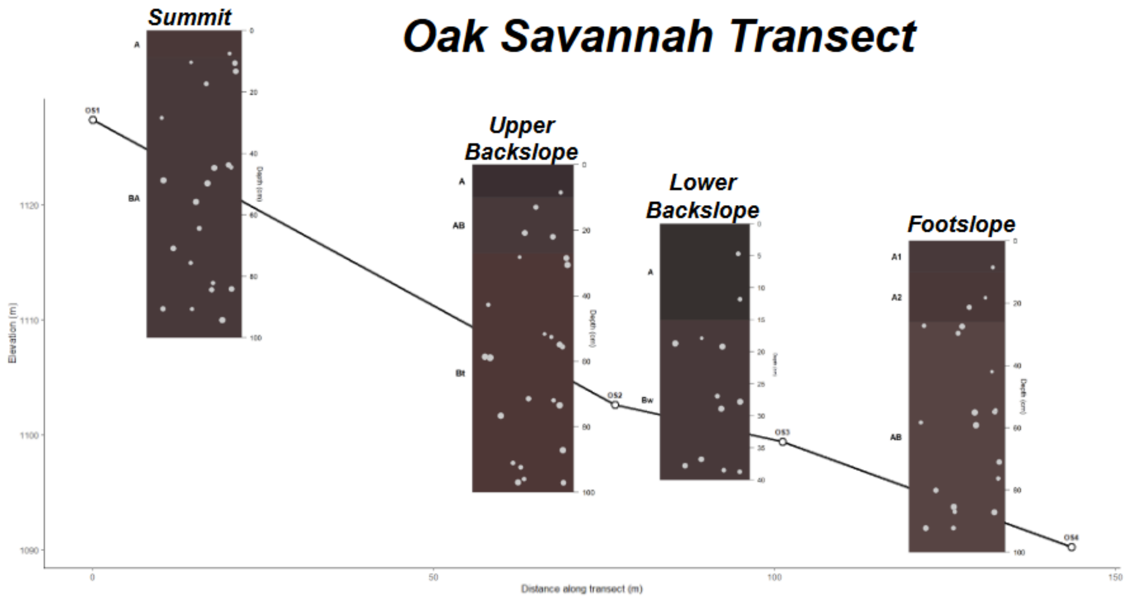



**Figure 18:** *Oak-Savannah soils compared to relative position on hillslope, where the x-axis represents distance along the transect, and the y-axis represents elevation. The soil horizon descriptions and colors were identified in the field, as well as the estimate of coarse fragments, as illustrated by the grey circles. The colors were taken in the field with a Munsell book, then converted to RGB and illustrated onto the profiles using the SoilDB function in R.*

**4.1.4 Transect Vegetation**

The Doug Fir catena sites are characterized by a dense, multi-layered understory dominated by forb and shrub species, with trailing blackberry, wood vetch, creeping snowberry, and Cascade Oregon grape collectively accounting for the majority of living cover across all four pits. Litter makes up a substantial portion of ground cover at every DF site, reflecting the high productivity and canopy closure typical of mixed conifer forest. Bare ground is minimal throughout the catena, consistent with a well-developed duff layer and dense understory vegetation. The overstory is dominated by Douglas fir, which is present at all four pits, with California incense-cedar and grand fir becoming more prominent at DF3 and DF4, suggesting a slight shift in composition moving up the catena. DF2 stands out for its exceptionally high Douglas fir sapling density, with 24 saplings recorded in the 15 m × 15 m plot, possibly indicating a recent disturbance or gap opening that has allowed for a regeneration pulse.

The Oak Savannah catena presents a strikingly different vegetation community, reflecting the drier, more open conditions characteristic of the Cascade-Siskiyou transition zone. Ground cover is dominated by grasses, particularly dogtail grass and fescue, with substantially more bare ground across all four OS pits compared to the DF sites, most notably at OS3, where bare ground exceeds 40% in several quadrats. Litter is present but less continuous than in the DF catena, and the shrub layer is nearly absent. Oregon white oak overwhelmingly dominates the overstory at OS1 through OS3, with counts ranging from 20 to 25 stems per plot, while OS4 begins to show conifer encroachment in the form of Douglas fir, grand fir, and incense-cedar saplings. This pattern at OS4 is ecologically significant for the monument, as conifer encroachment into oak savannah is a well-documented management concern at Cascade-Siskiyou and many other Pacific Northwest oak habitats, where fire suppression has allowed conifers to establish and gradually displace the open oak woodland structure.

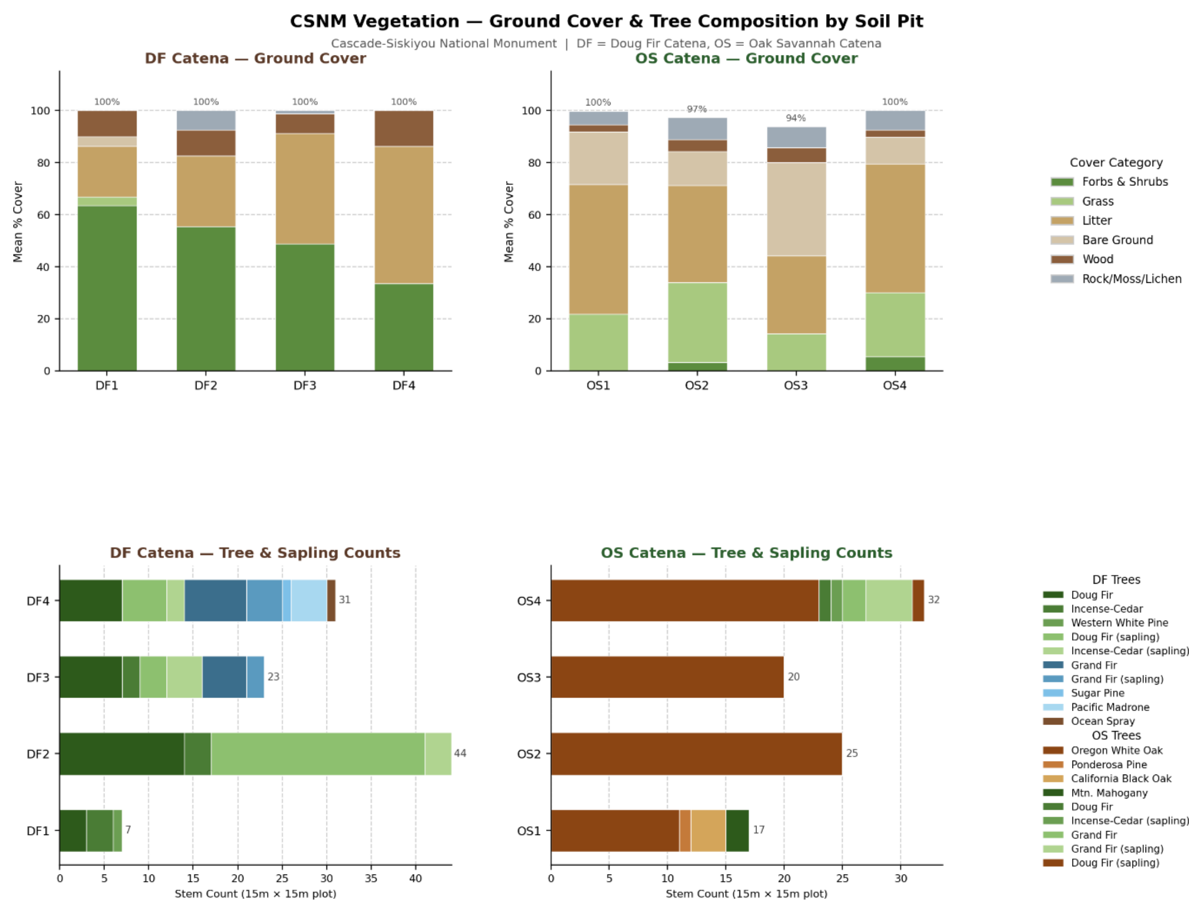



**Figure 19:** *Ground cover composition and tree and sapling stem counts across the Doug Fir (DF) and Oak Savannah (OS) catenas at the Cascade-Siskiyou National Monument. Top panels show mean percent cover averaged across four 1 m² PVC quadrats per soil pit, grouped by cover category. Bottom panels show total stem counts by species recorded within a 15 m × 15 m plot centered on each pit, with saplings (individuals < 2 m tall)*

*distinguished from mature trees. Species flagged for field verification are included in totals where cover or count was recorded.*

#### 4.1.5 Transect Discussion

A morphological difference between the two catenas is the presence of O-horizons in the Douglas Fir soils. O-horizons are organic horizons, made up of partially decomposed litter. Roots in a Savannah are primarily from grasses, which go deeper and die off annually. Meanwhile, most of the organic matter in the Douglas Fir system comes from the surficial deposition of litter, creating the dense O horizons.

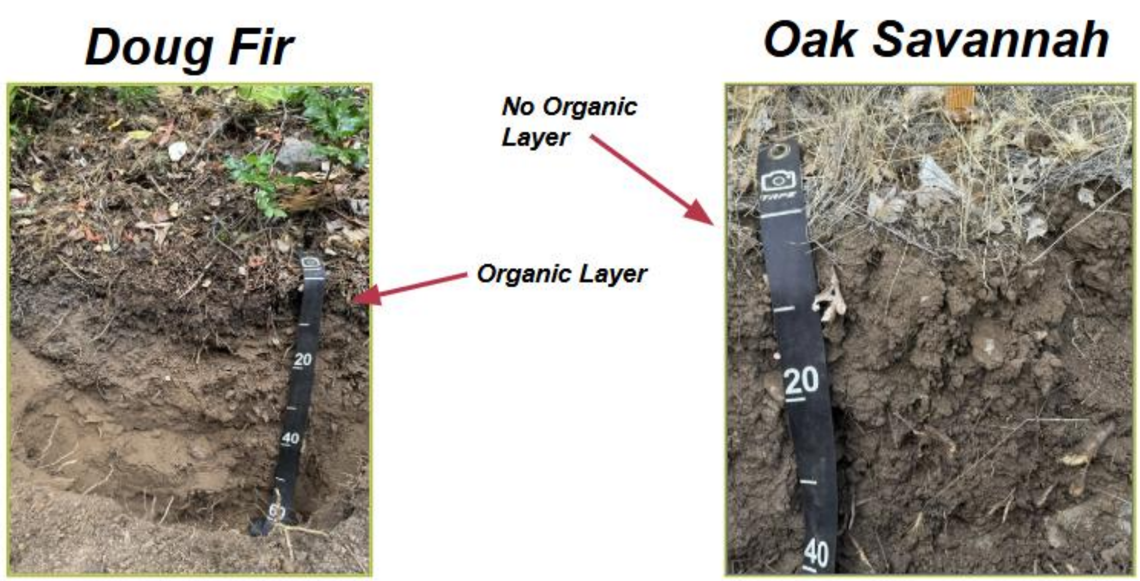



***Figure 20:*** *Side-by-side comparison of the two pedons. Note the color difference. Darker colors in soils are indicative of more broken down organic material. So while there may be a dense presence of organic material at the surface of the Douglas fir, the organic material is more dispersed throughout the profile in the Oak Savannah.*

There is also a clear difference in the shape of the landscape (figure 21). The “hump” shape in the catena for the Oak Savannah is at the lower backslope, where material seems to have accumulated from some sort of erosional event. The Oak Savannah site was also the only site to have evidence of clay films (Bt horizon) which is the process by which illuvial clay accumulates in soil over long periods of time.

**Figure 21:** *Site of the Oak-Savannah Lower backslope, where erosion has created a kink in the landscape.*

Soils at the Oak-Savannah were also significantly rockier, likely accumulations from erosion. The lower backslope pit of the Oak Savannah sits above the kink in the landscape, where the soil depth is only 40 centimeters.

**4.2 XRF Results**

The X-ray fluorescence elemental data from the Cascade-Siskiyou National Monument mineral soils reveal a geochemical signature strongly consistent with basaltic andesite parent material derived from the older Cascade arc volcanics that underlie much of the monument. Iron is the most diagnostic indicator, ranging from approximately 60,000 to 77,000 ppm across mineral horizons, representing roughly 6-8% Fe by weight and placing these soils firmly in the category of Fe-rich volcanic soils typical of basaltic andesite weathering in the southern Cascades and Siskiyou region. Aluminum and silicon are also abundant, with Al consistently near 80,000-125,000 ppm and Si near 170,000-245,000 ppm in mineral horizons, reflecting the intermediate silica content and aluminosilicate clay mineralogy expected from basaltic andesite-derived soils. Vanadium (180-390 ppm) and cobalt (100-260 ppm) are elevated relative to average crustal abundances but are entirely expected as geochemical companions to Fe-rich basaltic andesite, as both elements substitute readily for Fe and Mg in the pyroxene and plagioclase minerals characteristic of this rock type. Chromium was detected sporadically at 60-90 ppm in select horizons, and along with the elevated Ni values observed in several profiles, is consistent with the mafic mineralogy of the basaltic andesite parent material throughout the monument. The Oi horizons in the Douglas Fir profiles stand out clearly from the mineral soil below, with dramatically lower Al and Si, elevated Ca (28,000-40,000 ppm), detectable sulfur, and higher P, all reflecting organic matter accumulation and biological nutrient cycling rather than parent material composition.

The Oak Savannah profiles are mineralogically similar to the Douglas Fir mineral horizons but show some notable differences likely tied to the monument's well-documented climatic and ecological gradients. The Cascade-Siskiyou sits at the convergence of three distinct mountain ranges and experiences strong precipitation and aspect gradients over short distances, and the differences in organic horizon development and weathering intensity between the Douglas Fir and Oak Savannah profiles probably reflect microsite moisture and vegetation conditions more than any shift in parent material. Calcium tends to be higher in Oak Savannah surface horizons, which could indicate reduced leaching under drier, more continental-influenced conditions on the eastern portion of the monument rather than any departure from the basaltic andesite parent material. Titanium is consistently elevated across both series (5,600-8,900 ppm), suggesting moderate to strong weathering that has preferentially retained Ti as more mobile elements leach out over time, a pattern consistent with progressive weathering of basaltic andesite under the monument's variable but generally seasonally dry climate. Importantly, none of the profiles show any geochemical evidence of contamination or environmental concern. Arsenic is at or below detection in nearly all samples, and where detected reaches only 5-6 ppm, well within the natural background range for soils derived from basaltic andesite. Lead ranges from below detection to 22 ppm, consistent with uncontaminated forest soils far from urban or agricultural influence. Taken together, the XRF data paint a coherent picture of clean, naturally Fe-rich soils weathered from basaltic andesite parent material at the Cascade-Siskiyou National Monument, with no anomalous trace element concentrations that would warrant further investigation.

**DF Profiles — XRF Elemental Chemistry (ppm)**

| Profile | Horizon | Depth (cm) | Mg | Al | Si | P | S | K | Ca | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | As | Pb | Ba | Sr | Zr | Rb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DF1** | | | | | | | | | | | | | | | | | | | | | | | | |
| *DF1* | *Oi* | 8 | <LOD | 17,270 | 45,378 | 1,393 | 1,766 | 2,124 | 32,942 | 1,525 | 80 | <LOD | 821 | 15,002 | 63 | <LOD | 26 | 89 | <LOD | <LOD | 90 | 155 | 18 | 6 |
| DF1 | A | 31 | 13,773 | 95,559 | 203,066 | 1,682 | <LOD | 5,506 | 26,057 | 7,020 | 268 | <LOD | 1,288 | 64,283 | 176 | 17 | 59 | 135 | <LOD | 8 | 282 | 310 | 77 | 21 |
| DF1 | 2AB | 50 | 16,243 | 104,482 | 200,916 | 972 | <LOD | 4,289 | 20,334 | 6,277 | 219 | <LOD | 1,032 | 69,032 | <LOD | 22 | 84 | 119 | 6 | 5 | 279 | 274 | 77 | 20 |
| DF1 | 2Bw | 73 | 16,094 | 105,746 | 200,696 | 709 | <LOD | 4,105 | 20,153 | 6,589 | 272 | <LOD | 1,008 | 68,742 | 136 | 14 | 90 | 117 | <LOD | 6 | 262 | 274 | 84 | 21 |
| DF1 | BC | 86 | 16,442 | 98,511 | 183,753 | 559 | <LOD | 3,349 | 19,121 | 5,606 | 221 | <LOD | 967 | 64,566 | 196 | <LOD | 81 | 100 | 5 | <LOD | 237 | 292 | 71 | 16 |
| **DF2** | | | | | | | | | | | | | | | | | | | | | | | | |
| *DF2* | *Oi* | 10 | <LOD | 26,751 | 58,896 | 1,339 | 1,089 | 3,654 | 28,902 | 2,636 | 97 | <LOD | 1,494 | 26,728 | 117 | <LOD | 38 | 98 | <LOD | 7 | 105 | 173 | 35 | 16 |
| DF2 | A | 26 | 13,127 | 97,218 | 204,796 | 1,080 | <LOD | 6,465 | 12,314 | 8,592 | 258 | 88 | 1,937 | 72,671 | 181 | 26 | 74 | 130 | 5 | 9 | 386 | 183 | 115 | 41 |
| DF2 | AB | 49 | 15,493 | 115,509 | 239,706 | 1,070 | <LOD | 6,560 | 11,748 | 8,802 | 269 | 67 | 1,613 | 76,701 | 220 | 32 | 71 | 131 | 5 | 9 | 402 | 181 | 125 | 36 |
| DF2 | Bw | 76 | 16,830 | 125,361 | 242,609 | 601 | <LOD | 6,076 | 9,970 | 8,340 | 387 | <LOD | 1,279 | 76,170 | 257 | 28 | 87 | 102 | <LOD | 10 | 351 | 165 | 119 | 30 |
| **DF3** | | | | | | | | | | | | | | | | | | | | | | | | |
| *DF3* | *Oi* | 10 | <LOD | 19,094 | 37,475 | 1,566 | 1,508 | 2,718 | 39,898 | 1,593 | <LOD | <LOD | 1,915 | 17,050 | <LOD | <LOD | 28 | 99 | <LOD | <LOD | 86 | 212 | 21 | 8 |
| DF3 | A | 26 | 13,582 | 115,247 | 218,636 | 3,320 | <LOD | 7,563 | 20,261 | 6,912 | 201 | <LOD | 2,273 | 70,337 | <LOD | 22 | 75 | 127 | 5 | 8 | 439 | 258 | 91 | 33 |
| DF3 | AB | 50 | 13,693 | 108,373 | 197,345 | 586 | <LOD | 5,233 | 12,832 | 6,659 | 202 | <LOD | 1,188 | 73,148 | 154 | 21 | 84 | 97 | 5 | <LOD | 290 | 230 | 82 | 23 |
| DF3 | Bw | 68 | 14,970 | 109,104 | 188,737 | 334 | <LOD | 4,420 | 12,642 | 6,431 | 313 | <LOD | 800 | 70,918 | 257 | 15 | 88 | 89 | <LOD | 11 | 351 | 233 | 74 | 15 |
| DF3 | BC | 85 | 16,504 | 113,309 | 199,422 | 222 | <LOD | 4,848 | 11,552 | 5,989 | 229 | <LOD | 1,169 | 66,098 | 185 | 18 | 86 | 86 | <LOD | 8 | 397 | 239 | 74 | 14 |
| **DF4 (no Oi sample)** | | | | | | | | | | | | | | | | | | | | | | | | |
| DF4 | A | 10 | <LOD | 32,489 | 66,168 | 1,472 | 1,349 | 3,553 | 28,924 | 2,703 | <LOD | <LOD | 1,970 | 31,084 | 96 | 11 | 45 | 122 | <LOD | 22 | 130 | 231 | 44 | 15 |
| DF4 | AB | 22 | 14,641 | 122,851 | 245,517 | 2,090 | <LOD | 7,251 | 20,517 | 7,027 | 234 | <LOD | 1,273 | 69,422 | 262 | 14 | 68 | 125 | <LOD | 7 | 384 | 285 | 91 | 22 |
| DF4 | Bw | 45 | 12,127 | 113,207 | 219,507 | 1,297 | <LOD | 6,549 | 19,638 | 6,315 | 180 | <LOD | 870 | 70,230 | 255 | 19 | 67 | 115 | <LOD | 7 | 367 | 301 | 92 | 21 |
| DF4 | BC | 60 | 12,087 | 101,359 | 203,464 | 926 | <LOD | 5,188 | 16,557 | 6,520 | 237 | <LOD | 806 | 67,634 | 261 | <LOD | 74 | 109 | <LOD | <LOD | 298 | 276 | 94 | 18 |
| DF4 | C | 65 | 12,281 | 123,760 | 221,282 | 917 | <LOD | 2,679 | 24,265 | 6,260 | 223 | <LOD | 651 | 66,471 | 276 | <LOD | 83 | 103 | <LOD | <LOD | 277 | 337 | 94 | 8 |

**OS Profiles — XRF Elemental Chemistry (ppm)**

| Profile | Horizon | Depth (cm) | Mg | Al | Si | P | S | K | Ca | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | As | Pb | Ba | Sr | Zr | Rb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **OS1** | | | | | | | | | | | | | | | | | | | | | | | | |
| OS1 | A | 9 | 16,901 | 87,459 | 184,600 | 891 | <LOD | 4,505 | 30,804 | 7,469 | 383 | 82 | 1,741 | 71,117 | 186 | 44 | 85 | 107 | <LOD | 13 | 212 | 319 | 68 | 14 |
| OS1 | Bw | 30 | 17,474 | 103,536 | 209,216 | 744 | <LOD | 4,380 | 32,196 | 7,559 | 319 | 71 | 1,750 | 72,347 | 173 | 59 | 81 | 97 | <LOD | <LOD | 256 | 315 | 69 | 12 |
| **OS2** | | | | | | | | | | | | | | | | | | | | | | | | |
| OS2 | A | 10 | 12,553 | 93,352 | 216,359 | 823 | <LOD | 4,877 | 19,034 | 8,882 | 366 | <LOD | 1,942 | 67,790 | 212 | 30 | 88 | 118 | <LOD | 11 | 373 | 271 | 99 | 18 |
| OS2 | AB | 27 | 9,280 | 78,185 | 173,454 | 468 | 117 | 3,983 | 12,481 | 8,059 | 230 | <LOD | 1,462 | 66,233 | 175 | 31 | 90 | 100 | <LOD | <LOD | 250 | 202 | 97 | 20 |
| OS2 | Bt | 47 | 10,700 | 96,546 | 170,166 | 188 | <LOD | 2,182 | 8,328 | 5,663 | 233 | <LOD | 1,431 | 68,105 | 202 | 27 | 85 | 82 | 5 | <LOD | 277 | 149 | 81 | 12 |
| **OS3** | | | | | | | | | | | | | | | | | | | | | | | | |
| OS3 | A | 15 | 13,916 | 81,895 | 180,920 | 752 | <LOD | 4,075 | 19,878 | 7,997 | 253 | 58 | 1,642 | 72,433 | 201 | 38 | 91 | 118 | <LOD | 8 | 248 | 295 | 84 | 19 |
| OS3 | Bw | 40 | 14,842 | 90,445 | 181,440 | 668 | <LOD | 3,516 | 15,611 | 7,495 | 235 | 62 | 1,408 | 70,373 | 163 | 36 | 90 | 109 | <LOD | 8 | 240 | 232 | 89 | 19 |
| **OS4** | | | | | | | | | | | | | | | | | | | | | | | | |
| OS4 | A | 10 | 12,101 | 93,652 | 211,074 | 904 | <LOD | 5,668 | 18,117 | 8,878 | 241 | <LOD | 1,743 | 65,821 | 181 | 25 | 82 | 106 | <LOD | 7 | 349 | 237 | 106 | 24 |
| OS4 | AB | 26 | 11,110 | 79,949 | 174,075 | 565 | <LOD | 3,922 | 13,949 | 7,324 | 222 | <LOD | 1,374 | 64,364 | 171 | 30 | 88 | 110 | <LOD | <LOD | 229 | 215 | 88 | 18 |
| OS4 | Bt | 48 | 17,525 | 90,132 | 186,914 | 229 | <LOD | 2,546 | 14,986 | 6,261 | 253 | <LOD | 1,246 | 69,430 | 225 | 22 | 83 | 99 | <LOD | 6 | 252 | 209 | 79 | 11 |

Cream rows (Oi) = organic surface horizons. <LOD = below limit of detection. All values in ppm. Method: Geochem (3-Beam) XRF, 12/8/2025.

**Figure 22:** *X-ray fluorescence (XRF) elemental chemistry (ppm) of soil horizons from eight soil pits across the CSNM study area, collected December 8, 2025. Profiles are grouped by transect: Douglas Fir profiles (DF1–DF4) and Oak Savannah profiles (OS1–OS4). Cream-shaded rows indicate organic surface horizons (Oi). Values below the*

*instrument detection limit are reported as <LOD. Major elements (Mg, Al, Si, Ca, Fe) reflect a Fe-rich, mafic-derived parent material consistent with basaltic geology of the region. Trace elements including As, Pb, Cu, and Zn are at or near background levels throughout all profiles.*

### 4.3 pH results

This data shows the CSNM mineral soils are all slightly acidic, with pH values from between 6.0 to 6.9 across all pits, regardless of position on transect. This is somewhat unusual since higher horizons tend to be more acidic. O horizons were omitted because they require separate preparation methods, and O pH is not relevant for soil classification. Still, the soils with O horizons should have had lower pH in the topsoil (A horizons) and did not. Overall, these soils are chemically favorable at near neutral pH. There is slightly more variability in the Oak Savannah soils, with the Bt horizon in OS2 having a low pH.

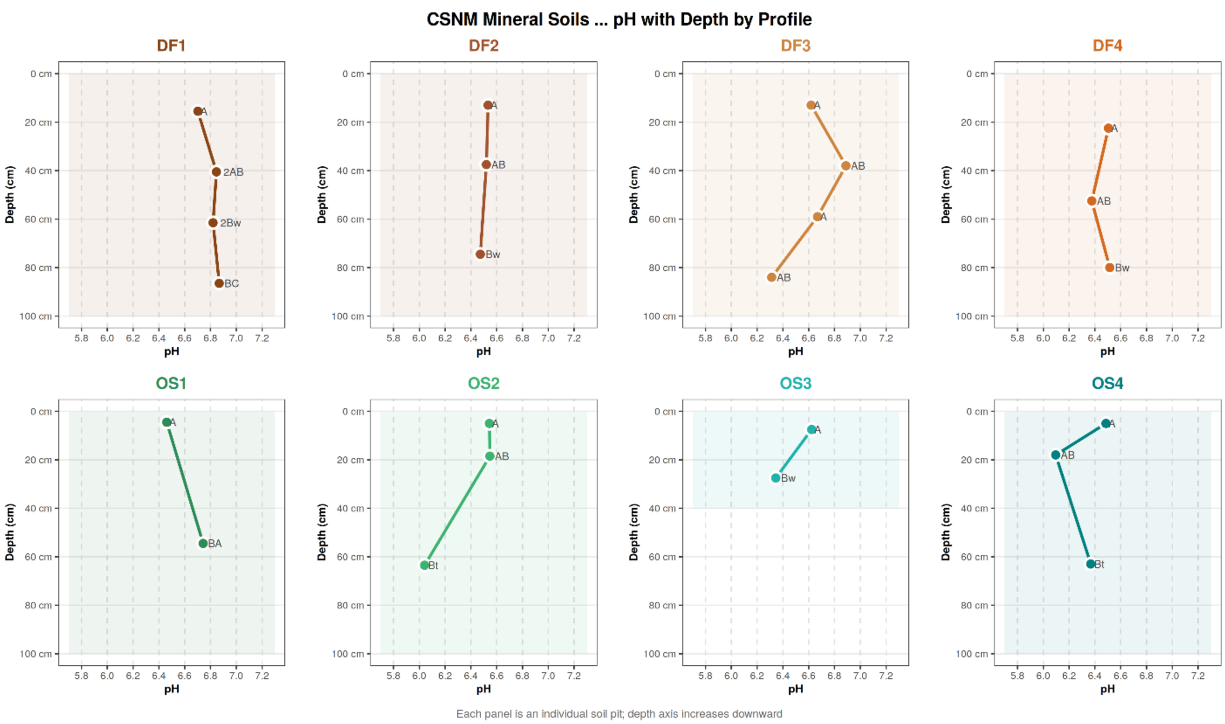



**Figure 23:** *This figure shows pH depth changes by pit along each transect, with Douglas Fir (DF) on top and Oak Savannah (OS) on bottom.*

| Profile | Horizon | Top depth (cm) | Bot depth (cm) | pH |
|---|---|---|---|---|
| DF1 | A | 0 | 31 | 6.702 |
| DF1 | 2AB | 31 | 50 | 6.846 |
| DF1 | 2Bw | 50 | 73 | 6.820 |
| DF1 | BC | 73 | 100 | 6.868 |
| DF2 | A | 0 | 26 | 6.533 |
| DF2 | AB | 26 | 49 | 6.520 |
| DF2 | Bw | 49 | 100 | 6.473 |
| DF3 | A | 0 | 26 | 6.619 |
| DF3 | AB | 26 | 50 | 6.889 |
| DF3 | A | 50 | 68 | 6.668 |
| DF3 | AB | 68 | 100 | 6.313 |
| DF4 | A | 0 | 45 | 6.505 |
| DF4 | AB | 45 | 60 | 6.376 |
| DF4 | Bw | 60 | 100 | 6.515 |
| OS1 | A | 0 | 9 | 6.461 |
| OS1 | BA | 9 | 100 | 6.743 |
| OS2 | A | 0 | 10 | 6.543 |
| OS2 | AB | 10 | 27 | 6.547 |
| OS2 | Bt | 27 | 100 | 6.041 |
| OS3 | A | 0 | 15 | 6.623 |
| OS3 | Bw | 15 | 40 | 6.345 |
| OS4 | A | 0 | 10 | 6.486 |
| OS4 | AB | 10 | 26 | 6.096 |
| OS4 | Bt | 26 | 100 | 6.368 |

**Figure 24:** *Table of soil pH values by horizon.*

### 4.4 Texture Results

Soil texture across both catenas is consistently fine-grained, reflecting the clay-rich nature of soils developed from basaltic andesite parent material under the weathering conditions of the Cascade-Siskiyou. The Doug Fir profiles show a moderate but consistent increase in clay content with depth, transitioning from silty clay loam and clay loam textures in the upper horizons to clay and silty clay in the subsoil. DF2 is the most clay-rich of the four profiles, reaching clay texture as shallow as the A horizon and maintaining it through the Bw, consistent with a wetter, more weathered position on the landscape. DF3 and DF4 show slightly sandier surface horizons before clay content increases downward, while DF1 is the most uniform in texture throughout. The organic Oi horizons in all four DF profiles are excluded from mineral texture analysis, as expected.

The Oak Savannah profiles tell a similar story of clay enrichment with depth but with more pronounced textural contrasts, particularly in the profiles containing argillic Bt horizons. OS2 and OS4 both show dramatic clay increases in the Bt horizon, jumping to clay texture with values near 57 and 60% clay respectively, which is a strong indication of illuvial clay accumulation and confirms the argillic horizon designation. OS3, with only two sampled horizons extending to 40 cm, transitions from clay in the A to silty clay in the Bw, suggesting active weathering and clay formation even in this shallower profile. OS1 is the most texturally uniform of the OS profiles, moving from silty clay at the surface to clay loam in the subsoil. Taken together, the texture data across both catenas are consistent with a landscape undergoing active pedogenesis from basaltic andesite, with clay illuviation playing an increasingly prominent role in the Oak Savannah profiles where reduced organic matter inputs and drier surface conditions promote translocation of fine particles to depth.

**OS Profiles — Particle Size Analysis**

| Profile | Horizon | Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Texture Class |
|---|---|---|---|---|---|---|
| **OS1** | | | | | | |
| OS1 | A | 0–9 | 38.8 | 40.8 | 15.1 | Silt Loam |
| OS1 | Bw | 9–100 | 37.1 | 36.6 | 20.7 | Silt Loam |
| **OS2** | | | | | | |
| OS2 | A | 0–10 | 29.2 | 41.5 | 24.1 | Silt Loam |
| OS2 | AB | 10–27 | 23.6 | 38.8 | 43.2 | Clay |
| OS2 | Bt | 27–100 | 11.4 | 19.9 | 59.9 | Clay |
| **OS3** | | | | | | |
| OS3 | A | 0–15 | 35.1 | 38.7 | 20.2 | Silt Loam |
| OS3 | Bw | 15–40 | 6.0 | 39.1 | 33.1 | Silty Clay |
| **OS4** | | | | | | |
| OS4 | A | 0–10 | 18.9 | 40.5 | 30.7 | Clay Loam |
| OS4 | AB | 10–26 | 19.3 | 35.5 | 45.0 | Clay |
| OS4 | Bt | 26–100 | 10.4 | 25.9 | 56.5 | Clay |

Sand, silt, and clay values (%) determined by hydrometer method (ASTM D7928).

Texture class assigned using USDA classification system.

Oi = organic surface horizon (no mineral texture). Re-run values used where applicable.

**Figure 25:** *Particle size analysis by horizon for the Oak Savannah (OS) catena profiles at the Cascade-Siskiyou National Monument. Sand, silt, and clay percentages were determined by the hydrometer method (ASTM D7928), with re-run values used where initial runs were flagged for error. Texture class was assigned using the USDA classification system. No organic surface horizons were present in the OS profiles. OS3 was sampled to 40*

*cm only; all other profiles extend to 100 cm. Depth ranges reflect the top and bottom of each sampled horizon.*

**DF Profiles — Particle Size Analysis**

| Profile | Horizon | Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Texture Class |
|---|---|---|---|---|---|---|
| **DF1** | | | | | | |
| *DF1* | *Oi* | *0–8* | — | — | — | *Organic* |
| DF1 | A | 8–31 | 41.7 | 38.6 | 17.6 | Silt Loam |
| DF1 | 2AB | 31–50 | 35.9 | 35.5 | 22.8 | Silt Loam |
| DF1 | 2Bw | 50–73 | 35.5 | 30.5 | 25.4 | Clay Loam |
| DF1 | BC | 73–100 | 35.5 | 38.4 | 26.6 | Silt Loam |
| **DF2** | | | | | | |
| *DF2* | *Oi* | *0–10* | — | — | — | *Organic* |
| DF2 | A | 10–26 | 26.4 | 39.8 | 26.9 | Clay Loam |
| DF2 | AB | 26–49 | 22.4 | 41.3 | 30.7 | Clay Loam |
| DF2 | Bw | 49–100 | 18.2 | 40.1 | 38.4 | Silty Clay Loam |
| **DF3** | | | | | | |
| *DF3* | *Oi* | *0–10* | — | — | — | *Organic* |
| DF3 | A | 10–26 | 45.0 | 38.2 | 11.6 | Silt Loam |
| DF3 | AB | 26–50 | 31.4 | 44.4 | 24.6 | Silt Loam |
| DF3 | Bw | 50–68 | 24.8 | 38.4 | 30.8 | Clay Loam |
| DF3 | BC | 68–100 | 30.5 | 37.9 | 29.9 | Clay Loam |
| **DF4** | | | | | | |
| *DF4* | *Oi* | *0–10* | — | — | — | *Organic* |
| DF4 | A | 10–22 | 44.4 | 41.7 | 11.8 | Silt Loam |
| DF4 | AB | 22–45 | 47.0 | 32.2 | 11.4 | Silt Loam |
| DF4 | BC | 45–60 | 27.4 | 36.4 | 13.8 | Silt Loam |
| DF4 | C | 60–100 | 49.9 | 40.0 | 9.4 | Silt Loam |

Sand, silt, and clay values (%) determined by hydrometer method (ASTM D7928).

Texture class assigned using USDA classification system.

Oi = organic surface horizon (no mineral texture). Re-run values used where applicable.

**Figure 26:** *Particle size analysis by horizon for the Doug Fir (DF) catena profiles at the Cascade-Siskiyou National Monument. Sand, silt, and clay percentages were determined by the hydrometer method (ASTM D7928), with re-run values used where initial runs were flagged for error. Texture class was assigned using the USDA classification system. Oi horizons are shaded and reported without mineral texture values. Depth ranges reflect the top and bottom of each sampled horizon.*

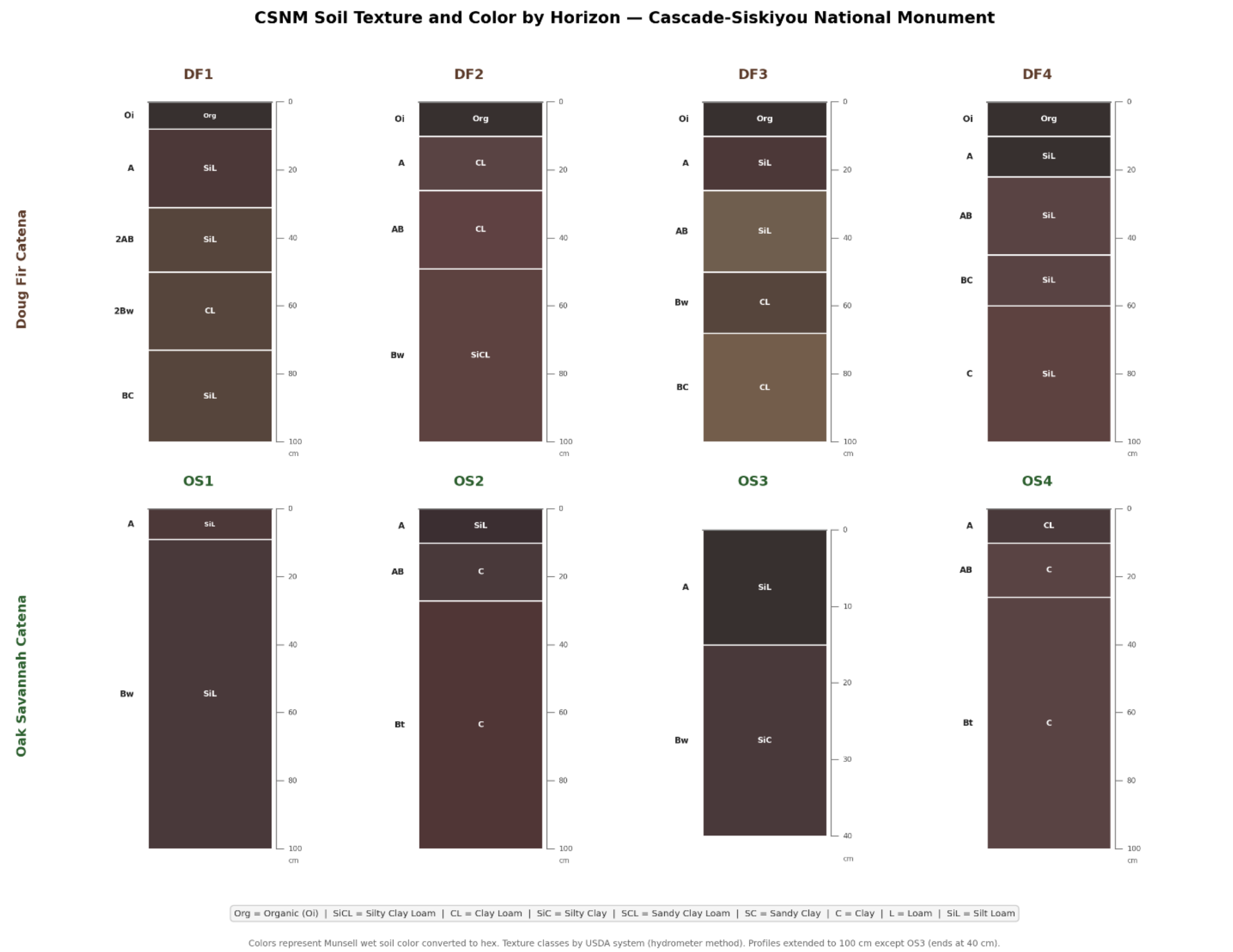



**Figure 27:** *Soil profile diagrams for the Doug Fir (top row) and Oak Savannah (bottom row) catenas at the Cascade-Siskiyou National Monument, showing horizon designations, USDA texture class abbreviations, and Munsell wet soil color converted to hex. Each profile is drawn to scale with depth increasing downward. All profiles are extended to 100 cm except OS3, which ends at 40 cm (the maximum sampled depth). Oi horizons in the DF profiles are shown but excluded from texture classification. Made using soil dB package in R. Texture class abbreviations: Org = Organic, C = Clay, SiC = Silty Clay, SC = Sandy Clay, CL = Clay Loam, SiCL = Silty Clay Loam, SCL = Sandy Clay Loam, L = Loam, SiL = Silt Loam, SL = Sandy Loam.*

### 4.5 Carbon Stock Results

The Douglas Fir catena profiles store substantially more soil organic carbon than the OS profiles, with total SOC stocks ranging from 353 to 459 Mg C/ha across the four Douglas Fir pits compared to just 68 to 252 Mg C/ha in the OS pits. The organic surface horizons (Oi) are the single largest driver of this difference, the Douglas Fir Oi horizons contain between 26 and 45% SOC by weight and contribute 200 to 311 Mg C/ha on their own, which in most cases exceeds the combined carbon stored in all underlying mineral horizons. This reflects the thick, well-developed forest floor typical of mixed conifer stands, where cool, moist conditions slow decomposition and allow organic matter to accumulate. Mineral horizon SOC declines sharply with depth in all Douglas Fir profiles, dropping from around 2 to 6% in the A horizon to well under 2% in the B and BC horizons, a pattern consistent with progressive dilution of organic inputs by mineral material as depth increases.

The Oak Savannah profiles lack organic surface horizons entirely, which accounts for much of the difference in total carbon storage relative to the DF catena. SOC concentrations in the Oak Savannah mineral A horizons are modest, ranging from about 1.9 to 2.8%, and decline gradually through the profile. OS3 stands out as notably carbon-poor, with a total stock of only 68 Mg C/ha across just two sampled horizons extending to 40 cm, the shallowest profile in the dataset and likely reflecting the thin, rocky soils characteristic of the more exposed, drier positions in the oak savannah. OS4 has the highest total carbon storage among the Oak Savannah profiles at 252 Mg C/ha, driven partly by a deep AB horizon extending to 100 cm with relatively high bulk density, suggesting that while surface carbon inputs are lower in the savannah, deeper mineral horizons can still accumulate meaningful stocks over time. Taken together, these data highlight the outsized role that forest floor organic horizons play in ecosystem carbon storage at the Cascade-Siskiyou Monument, and suggest that land cover and vegetation type are stronger controls on SOC stocks than parent material or depth alone.

**OS Profiles — Soil Organic Carbon by Horizon**

| Horizon | Lower Depth (cm) | Thickness (cm) | SOC (%) | Coarse Frag. (%) | Bulk Density (g/cm³) | SOC Stock (Mg C/ha) | Stock/cm (Mg C/ha/cm) |
|---|---|---|---|---|---|---|---|
| **OS1** | | | | | | | |
| A | 9 | 9 | 2.04 | 5 | 1.2 | 20.9 | 2.323 |
| BA | 100 | 91 | 1.64 | 15 | 1.3 | 165.2 | 1.815 |
| **OS1 Total Stock** | | | | | | **186.1** | |
| **OS2** | | | | | | | |
| A | 10 | 10 | 2.81 | 8 | 1.2 | 31.0 | 3.102 |
| AB | 27 | 17 | 1.50 | 12 | 1.2 | 26.9 | 1.584 |
| Bt | 100 | 73 | 1.47 | 18 | 1.4 | 122.9 | 1.684 |
| **OS2 Total Stock** | | | | | | **180.9** | |
| **OS3** | | | | | | | |
| A | 15 | 15 | 1.95 | 8 | 1.2 | 32.2 | 2.147 |
| Bw | 40 | 25 | 1.50 | 26 | 1.3 | 36.1 | 1.445 |
| **OS3 Total Stock** | | | | | | **68.3** | |
| **OS4** | | | | | | | |
| A1 | 10 | 10 | 2.62 | 6 | 1.2 | 29.6 | 2.955 |
| A2 | 26 | 16 | 2.08 | 10 | 1.4 | 41.9 | 2.618 |
| AB | 100 | 74 | 1.79 | 15 | 1.6 | 180.6 | 2.441 |
| **OS4 Total Stock** | | | | | | **252.1** | |

SOC = soil organic carbon. CF = coarse fragment content (%). BD = bulk density (g/cm³).
Stock (Mg C/ha) = SOC% × BD × thickness × (1 − CF/100) × 100. Cream rows = organic surface horizons (Oi).

**Figure 28:** *Soil organic carbon (SOC) data by horizon for the Oak Savannah (OS) catena profiles at the Cascade-Siskiyou National Monument. Columns report horizon lower depth, thickness, SOC concentration, coarse fragment content, bulk density, total SOC stock, and stock per centimeter of soil depth. SOC stocks were calculated as: SOC% × bulk density × horizon thickness × (1 − coarse fragment fraction) × 100, and are reported in Mg C/ha. No organic surface horizons (Oi) were present in the OS profiles. Profile totals represent cumulative SOC stock summed across all sampled horizons. Note that sampling depths ry by profile, which should be considered when making direct comparisons of total stocks across sites.*

**DF Profiles — Soil Organic Carbon by Horizon**

| Horizon | Lower Depth (cm) | Thickness (cm) | SOC (%) | Coarse Frag. (%) | Bulk Density ($g/cm^3$) | SOC Stock (Mg C/ha) | Stock/cm (Mg C/ha/cm) |
|---|---|---|---|---|---|---|---|
| **DF1** | | | | | | | |
| *Oi* | *8* | *8* | *45.36* | *0* | *0.6* | *217.7* | *27.216* |
| A | 31 | 23 | 3.33 | 5 | 1.2 | 87.4 | 3.799 |
| 2AB | 50 | 19 | 0.90 | 5 | 1.2 | 19.4 | 1.023 |
| 2Bw | 73 | 23 | 1.00 | 8 | 1.3 | 27.4 | 1.193 |
| 2BC | 100 | 27 | 1.64 | 10 | 1.4 | 55.8 | 2.066 |
| **DF1 Total Stock** | | | | | | **407.8** | |
| **DF2** | | | | | | | |
| *Oi* | *10* | *10* | *33.93* | *0* | *0.6* | *203.6* | *20.357* |
| A | 26 | 16 | 3.42 | 4 | 1.2 | 63.0 | 3.940 |
| AB | 49 | 23 | 1.47 | 4 | 1.2 | 38.8 | 1.688 |
| Bw | 100 | 51 | 0.78 | 8 | 1.3 | 47.7 | 0.936 |
| **DF2 Total Stock** | | | | | | **353.1** | |
| **DF3** | | | | | | | |
| *Oi* | *10* | *10* | *40.00* | *0* | *0.6* | *240.0* | *23.998* |
| A | 26 | 16 | 6.38 | 4 | 1.2 | 117.6 | 7.350 |
| AB | 50 | 24 | 1.40 | 5 | 1.2 | 38.3 | 1.596 |
| Bw1 | 68 | 18 | 1.04 | 5 | 1.3 | 23.1 | 1.284 |
| Bw2 | 100 | 32 | 0.68 | 8 | 1.3 | 25.9 | 0.810 |
| **DF3 Total Stock** | | | | | | **444.9** | |
| **DF4** | | | | | | | |
| *Oi* | *10* | *10* | *25.94* | *0* | *1.2* | *311.3* | *31.132* |
| A | 22 | 12 | 2.40 | 3 | 1.2 | 33.5 | 2.791 |
| AB | 45 | 23 | 1.72 | 3 | 1.3 | 50.0 | 2.172 |
| Bw | 60 | 15 | 1.31 | 5 | 1.3 | 24.4 | 1.624 |
| BC | 100 | 40 | 0.78 | 8 | 1.4 | 40.2 | 1.005 |
| **DF4 Total Stock** | | | | | | **459.3** | |

SOC = soil organic carbon. CF = coarse fragment content (%). BD = bulk density ($g/cm^3$).
Stock (Mg C/ha) = SOC% × BD × thickness × (1 − CF/100) × 100. Cream rows = organic surface horizons (Oi).

**Figure 29:** *Soil organic carbon (SOC) data by horizon for the Doug Fir (DF) catena profiles at the Cascade-Siskiyou National Monument. Columns report horizon lower depth, thickness, SOC concentration, coarse fragment content, bulk density, total SOC stock, and stock per centimeter of soil depth. SOC stocks were calculated as: SOC% × bulk density × horizon thickness × (1 − coarse fragment fraction) × 100, and are reported in Mg C/ha. Cream-*

*shaded rows indicate organic surface horizons (Oi). Profile totals represent cumulative SOC stock summed across all sampled horizons.*

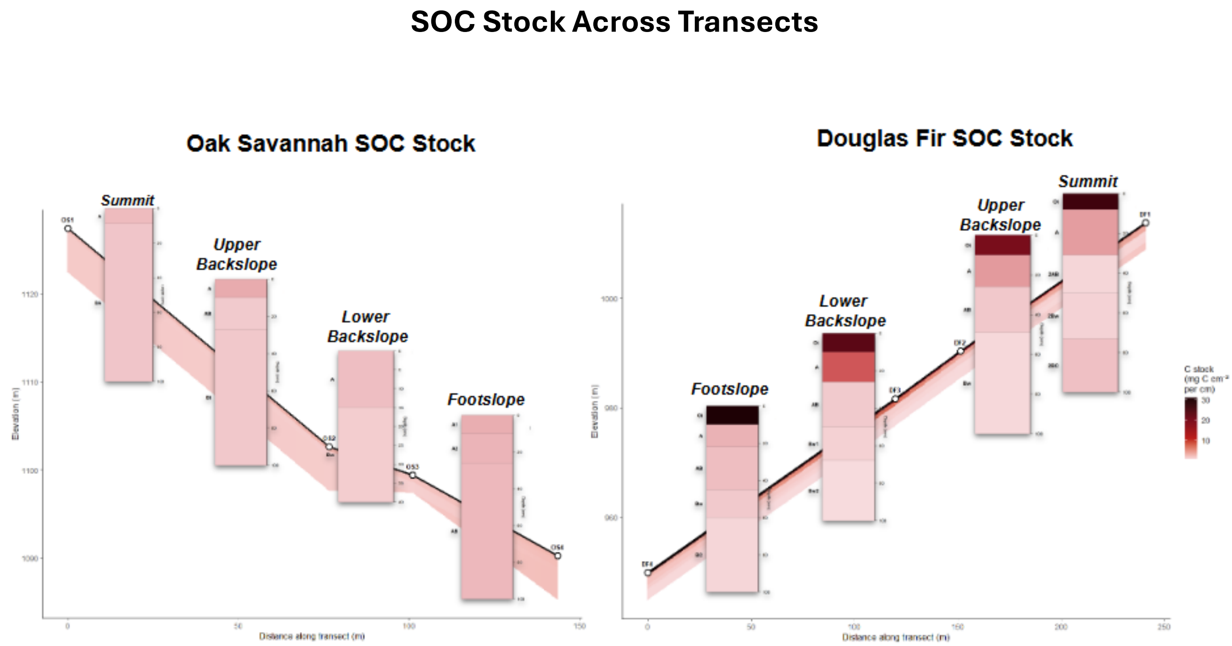



**Figure 30:** *Soil organic carbon (SOC) stock (Mg C/ha/cm) across the Oak Savannah (left) and Douglas Fir (right) catena transects at the Cascade-Siskiyou National Monument. Soil profiles are plotted at their measured positions along the slope transect and at their approximate elevations, with horizon thicknesses drawn to scale. Color intensity within each profile reflects SOC stock per centimeter depth, with darker red indicating higher carbon concentrations. Landscape positions (footslope, lower backslope, upper backslope, summit) are labeled for each pit. The shaded band along the transect line represents the slope surface. Note that transect lengths and elevation ranges differ between the two catenas.*

Figure 30 displays carbon distribution across the catena transects for both the Oak Savannah and Douglas Fir sites, with soil profiles plotted at their actual positions along the slope and colored by stock per centimeter depth. In the Oak Savannah catena, SOC stocks are relatively low and consistent across all four landscape positions, summit, upper backslope, lower backslope, and footslope, with pale pink shading throughout indicating uniformly modest carbon concentrations. There is no clear trend of carbon accumulation downslope, which might otherwise be expected if erosion and colluvial deposition were concentrating organic matter at lower slope positions. This likely reflects the limited organic matter inputs from the sparse grass and open oak canopy, combined with the drier conditions that characterize this catena.

The Douglas Fir catena tells a significantly different story. The footslope pit (DF1) stands out immediately with a deep, dark red upper horizon indicating very high SOC stock per centimeter, driven by the thick Oi organic surface horizon that contributes the majority of carbon storage at that position. Moving upslope through the lower backslope, upper backslope, and summit positions, the profiles become progressively lighter in color, suggesting declining carbon intensity with elevation despite the consistently forested canopy. This downslope enrichment pattern is consistent with the accumulation of organic matter through both in-situ production and lateral movement of organic material along the slope. Overall, the figures underscore the strong influence of vegetation type and landscape position on SOC distribution at the Cascade-Siskiyou National Monument, with the conifer-dominated DF catena storing substantially more carbon, and concentrating it most strongly at the footslope position.

**4.6 Student Success Results**

This project provided meaningful field research experience for six undergraduate members of the Oregon State University soil judging team, supporting four key student learning outcomes over the course of the fieldwork. Students gained direct exposure to the process of field-based scientific research, observing and participating in data collection from start to finish in a real research context rather than a classroom setting. Building on this, students developed practical soil description skills by working through eight soil pits across two distinct catenas, building hands-on proficiency in horizon identification, texture, structure, color, and other morphological properties central to soil science.

Equally valuable was the opportunity for students to engage with working professionals at multiple career stages. Interactions with a PhD student, a soil scientist with the Bureau of Land Management, a professor of pedometrics, and a retired soil microbiologist gave undergraduates direct exposure to the diverse career pathways available within the soil and environmental sciences, and modeled what a life in scientific research and land management can look like. Students also developed a personal connection to the Cascade-Siskiyou National Monument, a nationally significant landscape at the convergence of three mountain ranges and one of the most ecologically and geologically diverse areas in the Pacific Northwest, fostering an appreciation for public lands and the role of soil science in understanding and managing these ecosystems.

**Figure 31**: *OSU Students attempting to take a sample from a shallow soil pit while collecting data.*

**Figure 32*:*** *OSU Students exploring the Cascade-Siskiyou National Monument*.

**Figure 34:** *OSU Students practicing pit description at the Douglas Fir Site.*

## 5. Conclusion

The soils of the Cascade-Siskiyou National Monument reflect the remarkable ecological and geological complexity that defines this landscape. Across both the Doug Fir and Oak Savannah catenas, soil morphology, chemistry, and carbon storage are strongly shaped by the interplay of basaltic andesite parent material, topographic position, and vegetation type. The XRF data confirm a consistent mafic geochemical signature throughout all profiles, with elevated iron, vanadium, and cobalt reflecting the volcanic origin of the parent material and presenting no evidence of contamination or environmental concern. Soil pH is uniformly slightly acidic across all horizons, placing these soils in a chemically favorable range for nutrient availability and biological activity.

The most striking contrast between the two catenas lies in organic carbon storage and vegetation structure. The Doug Fir catena profiles store substantially more SOC, driven largely by thick organic surface horizons that can contribute more carbon than all underlying mineral horizons combined, while the Oak Savannah catena profiles store comparatively modest amounts of carbon distributed more evenly through the mineral soil. This difference mirrors the vegetation data, which show a dense, diverse understory and conifer-dominated overstory in the DF catena compared to an open, grass-dominated ground layer and oak-dominated canopy in the OS catena. The appearance of conifer saplings at OS4 is a notable finding, consistent with ongoing conifer encroachment into oak savannah that has been documented more broadly across the monument and highlights the importance of continued monitoring and management of these open woodland communities.

Taken together, these data provide a detailed baseline characterization of soil physical, chemical, and biological properties across two ecologically distinct landscape positions within the Cascade-Siskiyou National Monument. Beyond the scientific findings, the project demonstrated the value of integrating undergraduate education into field research, giving six Oregon State University soil judging team members hands-on experience in soil description, geochemical analysis, and carbon assessment alongside professional soil scientists. These outcomes underscore the potential for monument lands to serve not only as subjects of scientific inquiry but as living classrooms for the next generation of soil and environmental scientists.

## 6. Acknowledgements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- This project was completed under the supervision of Yakun Zhang.
- Special thanks to Malithi Weerasekara for allowing the use of her models pre-publication. Models will become publicly available in the future.

## 7. Works Cited


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