The influence of climate-induced drought on eight parks in North Saanich: An analysis of soils at permanent wilting point

Carmen Harrold
Sasha Plotnikoff, BSc.

Prepared for the Friends of North Saanich Parks
August 2026

Table of Contents

---

1. Acknowledgements

We respectfully acknowledge that this research project was conducted on the ancestral lands of the W̱SÁNEĆ Peoples, more specifically the BOḰEĆEN (Pauquachin) and W̱SÍḴEM (Tseycum) First Nations of the W̱SÁNEĆ Peoples. Nearby Nations include the W̱JOȽEȽP (Tsartlip), SȾÁUTW̱ (Tsawout), and MÁLEXEȽ (Malahat) Nations. We want to acknowledge that we are settlers on these lands that we spend time on, learn from, and enjoy.

We want to thank Sharon Hope, Anne Zerrath, Tim Hatfield, and Mark Brownlie, along with other members of FNSP, for guiding this research project. Additionally, we want to thank Nancy Shackelford for allowing us to use the Restoration Futures Laboratory at the University of Victoria. Without this broad support, this research project and its findings would not have been possible.

2. Abstract

This study was a continuation of previous studies conducted under FNSP to examine the gravimetric water content (GWC) and volumetric water content (VWC) in soils across eight parks in North Saanich. Soil samples were collected in May and August of 2026. Samples were weighed and dried to determine bulk density, GWC, and VWC. VWC was used to determine which soil horizons reached the permanent wilting point (PWP) by mid-May and mid-August using predetermined VWC thresholds. All Ah, Bm, and C layers of Denham Till, Green Park, and Nymph Point were already at or below PWP by mid-May. Gulf View, Quarry Park, and R.O. Bull partially hit PWP by mid-May. Finally, Lillian Hoffar and Prentice Pond were completely above PWP in mid-May. Site conditions and soil characteristics likely influenced which parks were above or below PWP in May. Out of the seven parks that were sampled in mid-August, all were below PWP. These findings align with the previous studies conducted by FNSP in the same parks. This indicates parks in North Saanich are experiencing prolonged drought conditions that will only worsen with climate change. Recommendations for climate-change mitigation in North Saanich parks are provided in Section 7.

3. Introduction

North Saanich is located in the Coastal Douglas-fir moist maritime (CDFmm) biogeoclimatic subzone of British Columbia, in accordance with the Biogeoclimatic Ecosystem Classification (BEC) system. The CDFmm is located in the rain shadow of the Olympic and Vancouver Island Mountains, occupying southeastern Vancouver Island, several islands in the Gulf of Georgia, and a narrow strip along the Sunshine Coast. This subzone is characterized by its mild, wet winters followed by warm, dry summers, hosting a rich assemblage of species including Douglas-fir (*Pseudotsuga menziesii*), the most common tree species of the CDFmm. (Fairbarns, 2004; Nuzdorfer et al., 1991; Madrone Environmental Services LTD., 2008).

Because the CDFmm is located in a rain shadow, it is much drier than other regions found along British Columbia's west coast and often experiences a pronounced summer drought (Fairbarns, 2004). As a result of climate change, the intensity and frequency of drought have increased (Mukherjee et al., 2018; Zhang & Hebda, 2005; Coulthard et al., 2016), along with shifts in temperature and precipitation patterns (Berg & Sheffield, 2018; Zuo et al., 2024). Ultimately, this has led to prolonged periods of low moisture availability in the soil (Hoover et al., 2021). Adequate soil moisture is essential for the health of forests, as this influences nutrient availability in the soil and uptake through the roots (Querejeta et al., 2021; Kreuzwieser & Gessler, 2010). In response to low water availability, forests may become increasingly vulnerable to tree mortality and dieback, ultimately impacting forest structure and essential ecosystem services such as carbon sequestration (Allen et al., 2010).

Douglas-fir-dominated and co-dominated forests, as found in the CDFmm, are particularly sensitive to climate change because their radial growth is correlated with moisture availability in the soil. Due to increasing drought conditions, Douglas-fir populations have been declining over recent decades. However, despite these large-scale trends, recent studies show that the response of Douglas-fir trees to moisture availability is relatively site-specific and can vary depending on factors such as seasonal climate and topographic features (Lewis et al., 2025; Griesbauer et al., 2019).

According to the Canadian System of Soil Classification (Soil Classification Working Group, 1998), soils in the CDFmm are predominantly Brunisolic. Brunisols range from gravel to clay textures and from imperfectly to rapidly drained soils (Smith et al., 2011). Different soil textures vary in the amount of water they can hold because of the differences in particle size and surface area. Smaller particles, such as clay, have a larger surface area and have microscopic pores that retain water to a high degree. Loamy soils are able to balance drainage and retention due to their medium particle size and surface area. Larger particles like sand have a reduced surface area and provide large gaps for water to drain through. The water retention capabilities of sand are reduced compared to clay and loam soils (Hilliard & Reedyk, 2020; Irshad et al., 2024; Rai et al., 2017).

The PWP is an important soil hydraulic characteristic that describes the point at which the moisture content in the soil is no longer sufficient to support the plants growing within it, leading to irreversible wilting and eventual plant death. This phenomenon is a result of the water within the soil matrix becoming unextractable to plants growing within the matrix because the water is held so tightly. Because of this, the PWP is often used as an indicator of plant resistance to drought stress (Garg et al., 2020). The PWP typically occurs at around -1.5 MPa. However, this value is dynamic and can vary depending on factors such as the soil profile and temperature (Tolk, 2007; Ghanbarian-Alavijeh & Millán, 2009; Kirkham, 2014). Because of this, a PWP percentage has been assigned to each unique soil texture. The threshold for PWP is approximately 4% for sand, 7% for loamy sand, 9% for sandy loam, 12% for loam, 15% for silt loam, 16% for sandy clay loam, 18% for sandy clay, 18% for clay loam, 15% for silty clay loam, 20% for silty clay, and 22% for clay (Datta et al., 2018).

Volumetric water content (VWC), which is a ratio of the amount of water to the amount of soil (Novák & Hlaváčiková, 2018), can be used as a comparison against PWP (Wiecheteck et al., 2020). One method of obtaining the VWC of soil samples is by measuring their wet and dry weights, and then calculating bulk density and gravimetric water content (GWC) (Novák & Hlaváčiková, 2018). Bulk density is the mass of dry soil divided by its total volume (Little et al., 1998; Gardner, 1986), whereas GWC is the mass of water in a sample divided by the mass of dry soil. VWC can be calculated directly from GWC (Novák & Hlaváčiková, 2018). For the purpose of this study, we used these VWC thresholds to determine which parks were at PWP. Due to increasing drought conditions, it is important to evaluate soil moisture trends over time and their potential impacts on Douglas-fir forests.

Members of FNSP have observed that the health of Douglas-fir trees in several North Saanich parks has begun to decline. To examine the impacts of climate change on Douglas-fir mortality, this study was conducted in eight North Saanich parks over the summer of 2026. The objective of this study was to determine which soils reached PWP between May and August as a potential cause of tree decline. This is an extension of two studies that took place two years ago (Hope, 2024) and four years ago (Hope and Bonsdorf, 2022), respectively. Four years ago, PWP was reached in all eight sampled parks, whereas two years ago, PWP was reached in all three sampled parks. We hypothesize that if the soils in all eight parks reach PWP by August 2026, then soil moisture deficit is likely the cause of potential Douglas-fir decline in North Saanich parks.

4. Methods

4.1 Study Site

This research study focused on eight parks in North Saanich: Denham Till, Green, Gulf View, Lillian Hoffar, Nymph Point, Prentice Pond, Quarry, and R.O. Bull (Figure 1). In order to describe and sample from the major soil horizons, one soil pit was established in each park. Soil pits had previously been dug in Denham Till, Gulf View, and Nymph Point as a result of a prior research study (Bonsdorf and Hope, 2022). In May 2026, soil pits were dug in the remaining five parks. Following the methodology outlined in Bonsdorf and Hope (2022), the location of each soil pit was chosen based on which areas were most representative of each park in terms of vegetation, topography, slope, and aspect.

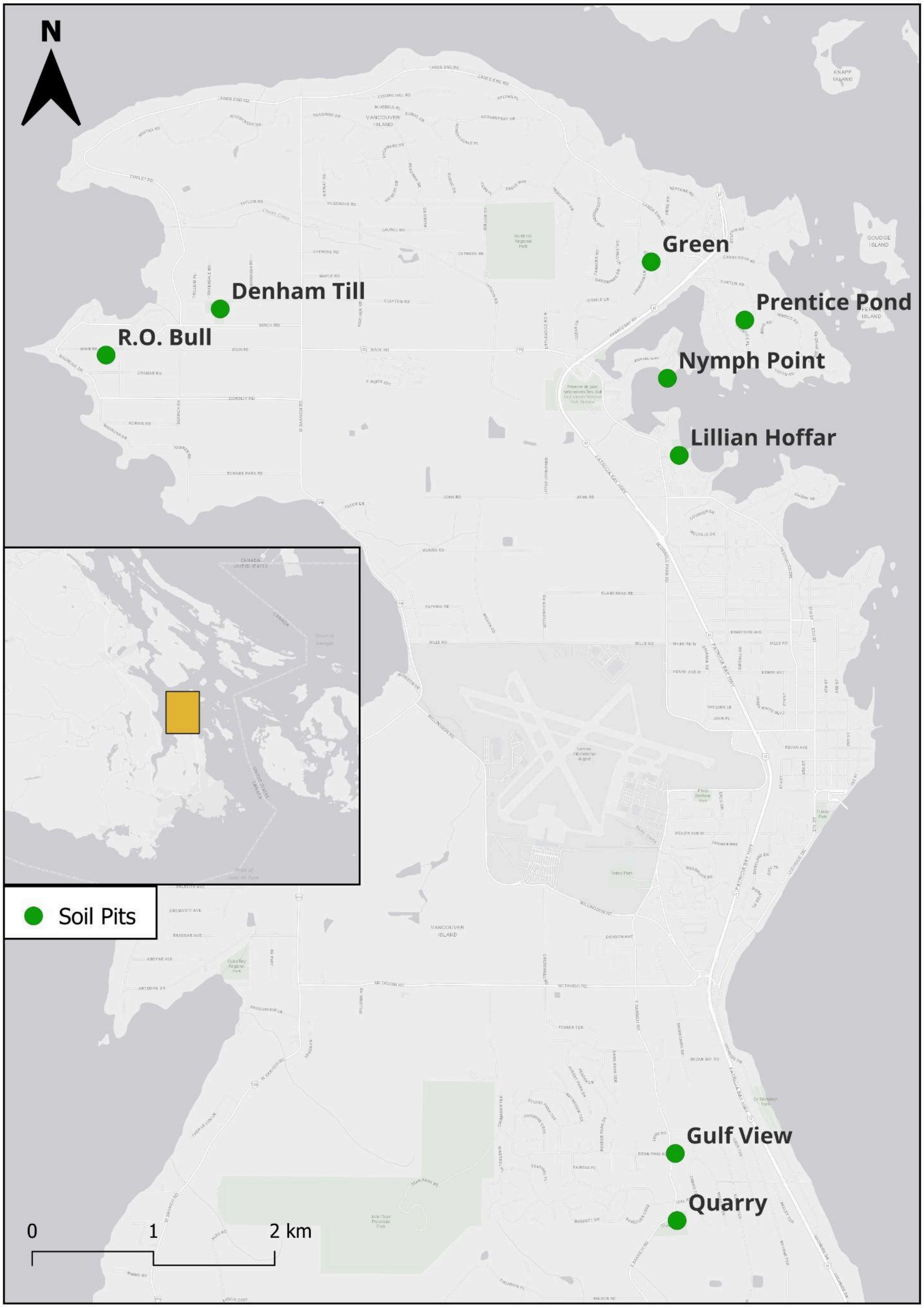

Figure 1. QGIS map showing all eight North Saanich parks where major soil horizons were described and sampled.

4.2 Soil Horizon Descriptions

Field assessments were conducted using the soil description forms provided in *Describing Terrestrial Ecosystems in the Field, 2nd Edition* (Ministry of Forests and Range & Ministry of Environment, 2010). The major soil horizons in each park were thoroughly described in Bonsdorf and Hope (2022). Using these previous descriptions for guidance and as a baseline, updated field assessments (see Appendix C) were completed in each park throughout May and June 2026.

4.3 Soil Sampling

Using the methodology outlined in Hope and Bonsdorf (2022), soil sampling was conducted on May 15th and August 14th, 2026. New side-wall faces were created in the pits during each sampling period to ensure similar sampling conditions existed in all park soil pits. Soil samples were collected in 88 mL tin cans from the Ah, Bm, and C soil horizons of all eight parks. Soil pits with multiple Bm layers were sampled from the middle, treating the Bm layers as a single layer for soil moisture sampling. The samples were then brought to the University of Victoria (Restoration Futures Laboratory) for weighing and drying (70° C). Both wet and dry weight measurements were collected from each sample.

4.4 Determining VWC

VWC was determined from GWC and therefore bulk density. Bulk density (g/mL) was determined from the dry weight of each layer divided by the total volume:

$$\rho_b = \frac{W_{dry}}{V_t}$$

Where ρ_b represents bulk density, W_{dry} is the dry weight of the soil, and V_t is the total volume. Bulk density was used to calculate GWC (g/g):

$$\theta_g = \left(\frac{W_{wet} - W_{dry}}{W_{dry}}\right)$$

θ_g represents GWC, W_{wet} represents the wet weight of the soil, and W_{dry} represents the dry weight of the soil. From here, VWC (mL/mL) was calculated:

$$\theta_v = \theta_g * \left(\frac{\rho_b}{\rho_w}\right)$$

θ_v represents VWC, θ_g represents GWC, ρ_b is the bulk density of the soil, and ρ_w is the bulk density of water, which is presumed to be 1.0 g/mL. For the purpose of comparing our results to previous studies, GWC and VWC were converted to percentages (%) in-text. Raw data for GWC and VWC are found in Appendix A. Sample calculations can be found in Appendix B.

5. Results

VWC was calculated based on wet and dry weight soil measurements taken from eight North Saanich Parks on May 15th and August 14th, 2026. According to Table 1, VWC declined from May to August in the Ah, Bm, and C layers of all parks. This excludes R.O. Bull, where soil sampling could not be completed in August (see Table 1). Each soil horizon for each respective park was compared with the VWC thresholds at PWP from Datta et al. (2018) to determine if the soil horizon was above or below PWP in May and August.

Table 1. VWC (%) of soil samples collected from eight parks in North Saanich. Sample collection took place on May 15th and August 14th. A VWC percentage at PWP has been assigned to each unique soil texture, according to Datta et al. (2018).

Park Name	Soil Horizon	Soil Texture	VWC at PWP Threshold (%)	May 2026 VWC (%)	August 2026 VWC (%)
Denham Till	Ah	SiC	20	11.6	4.5
	Bm	SiC	20	12.6	9.4
	C	HC	22	19.1	15.0
Green	Ah	SiL	15	13.7	4.6

Park Name	Soil Horizon	Soil Texture	VWC at PWP Threshold (%)	May 2026 VWC (%)	August 2026 VWC (%)
	Bm	SiCL	15	10.7	5.3
	C	SiCL	15	13.2	7.2
Gulf View	Ah	SiL	15	9.1	3.6
	Bm	SiL	15	8.9	3.0
	C	LS	7	9.2[a]	6.1
Lillian Hoffar	Ah	SiL	15	20.0[a]	5.0
	Bm	SiCL	15	20.7[a]	6.8
	C	SiCL	15	17.1[a]	9.3
Nymph Point	Ah	SiC	20	5.9	2.5
	Bm	HC	22	12.7	5.1
	C	HC	22	12.8	7.5
Prentice Pond	Ah	CL	18	26.6[a]	17.5
	Bm	CL	18	20.2[a]	13.3
	C	SC	18	33.1[a]	12.1
Quarry	Ah	SiL	15	21.5[a]	5.5
	Bm	SiL	15	12.9	3.9
	C	SiL	15	9.3	4.9
R.O. Bull[b]	Ah	SiL	15	17.7[a]	N/A
	Bm	LS	7	8.3[a]	N/A
	C	LS	7	5.6	N/A

[a]Layer was above the VWC threshold for PWP and therefore had not reached PWP at the time of sampling.
[b]The second set of soil sampling could not be completed because the soil pit was anonymously filled in.

GWC was also calculated based on wet and dry weight soil measurements taken from eight North Saanich Parks on May 15th and August 14th, 2026 (Table 2). These measurements were then compared to those taken from Denham Till, Gulf View, and Nymph Point over similar sampling periods in 2022 (Hope & Bonsdorf, 2022) and 2024 (Hope, 2024). Generally, GWC measurements from May have declined from 2022 to 2026 in all three parks. The most noticeable decline was in Gulf View, which declined from 48% to 12% in the Ah horizon, 28% to 9% in the Bm horizon, and 23% to 13% in the C horizon.

Table 2. Comparison of GWC (%) of the three soil pits maintained in Denham Till, Gulf View, and Nymph Point since 2022 across three sampling periods of 2022, 2024, and 2026. GWC is presented as whole percent values to align with previous studies (refer to Hope & Bonsdorf, 2022 and Hope, 2024).

Park Name	Soil Horizon	May 2022 GWC (%)	August 2022 GWC (%)	May 2024 GWC (%)	August 2024 GWC (%)	May 2026 GWC (%)	August 2026 GWC (%)
Denham Till	Ah	25	7	20	8	21	8
	Bm	28	7	18	10	14	13
	C	37	21	20	10	29	21
Gulf View	Ah	48	6	17	6	12	5
	Bm	28	5	13	6	9	4
	C	23	5	19	8	13	7
Nymph Point	Ah	24	6	14	2	8	3
	Bm	23	7	18	4	16	6
	C	22	5	10	3	18	10

6. Discussion

Because VWC and PWP are dependent on site-specific conditions and soil texture, direct comparisons between parks cannot be made. However, general trends from previous years can be examined to see a decline in VWC within each respective park. Following the trends of Hope (2024) and Hope and Bonsdorf (2022), VWC declined across the seven parks sampled by mid-August (Table 1). Hope and Bonsdorf (2022) found that seven of eight parks had reached PWP by mid-August, while Hope (2024) found that all three sampled parks had reached PWP by the same time period. Our results indicate that all seven sampled parks in August were below PWP according to VWC thresholds. Following trends of previous soil moisture studies in these parks (Hope, 2024; Hope & Bonsdorf, 2022), it can be inferred that all soil horizons of R.O. Bull were at or below PWP by mid-August.

When examining the VWC values in May, all soil layers of Denham Till, Green, and Nymph Point parks were at or below PWP when compared to the VWC thresholds for PWP. Other parks that were at or below PWP in May include the Bm and C layers of Quarry, the C layer of R.O. Bull, and the Ah and Bm layers of Gulf View. Their remaining layers, however, had adequate VWC to be above PWP. All layers in Lillian Hoffar and Prentice Pond were above PWP in May.

The soils in Lillian Hoffar, Prentice Pond, the Ah layer in Quarry, the Ah and Bm layers of R.O. Bull, and the C layer in Gulf View may have been above PWP in May due to site conditions and/or the nature of their soils (Hilliard & Reedyk, 2020; Irshad et al., 2024; Rai et al., 2017). Lillian Hoffar and Prentice Pond both have significant water sources in the vicinity of the soil pits; Lillian Hoffar contains an ephemeral water source (S. Hope, personal communication, May 7, 2026), and the pond within Prentice Pond Park contributes to the moisture found within the soil. Both parks have moderate to significant amounts of clay within their soils, allowing for water retention for longer periods of time due to the smaller clay particles holding onto water tightly (Hilliard & Reedyk, 2020; Irshad et al., 2024). This phenomenon can cause waterlogging and produce mottling (Soil Classification Working Group, 1998), which was found in the lower soil horizons in both Lillian Hoffar and Prentice Pond (Appendix C). The site conditions and loamy nature of the soils in Quarry, R.O. Bull, and Gulf View may contribute to certain soil horizons retaining more moisture and being above PWP in

May, as medium-sized particles provide balanced drainage and storage of water, but more research is needed to confirm possible factors at play (Hilliard & Reedyk, 2020; Irshad et al., 2024).

Comparing the soil pits in Denham Till, Gulf View, and Nymph Point that were sampled in 2022, 2024, and now in 2026, there are dramatic reductions in GWC (Table 2). The greatest reduction from 2022 to 2026 was in Gulf View. These reductions may be related to changing temperatures and precipitation as a result of climate change (Berg & Sheffield, 2018; Zuo et al., 2024). The temperature and precipitation in the months prior to sampling may give insight into differences across sampling years. Average daily temperatures in April rose across years, from 7.24°C in 2022, 8.76°C in 2024, and 10.11°C in 2026. July temperatures fluctuated: 17.99°C in 2022, 18.20°C in 2024, and 17.43°C in 2026. April precipitation was much higher in 2022 (91.6 mm) than in 2024 (29.2 mm) and 2026 (29.8 mm). July precipitation also dropped after 2022: 27.2 mm in 2022, 16.6 mm in 2024, and 14.0 mm in 2026 (Environment and Climate Change Canada, n.d.). Figure 2 summarizes these values. The increase in April temperatures and the reduction of precipitation in April and July across the three sampling periods likely influenced the amount of soil moisture in the previously established soil pits, as well as in the parks that had soil pits dug within the year of study (Berg & Sheffield, 2018; Zuo et al., 2024). This also may explain why PWP is being reached in more of the sampled parks earlier in the year (Garg et al., 2020; Hope, 2024; Hope & Bonsdorf, 2022). As climate change continues to alter temperature and precipitation patterns, GWC in the sampled parks will likely continue to decline.

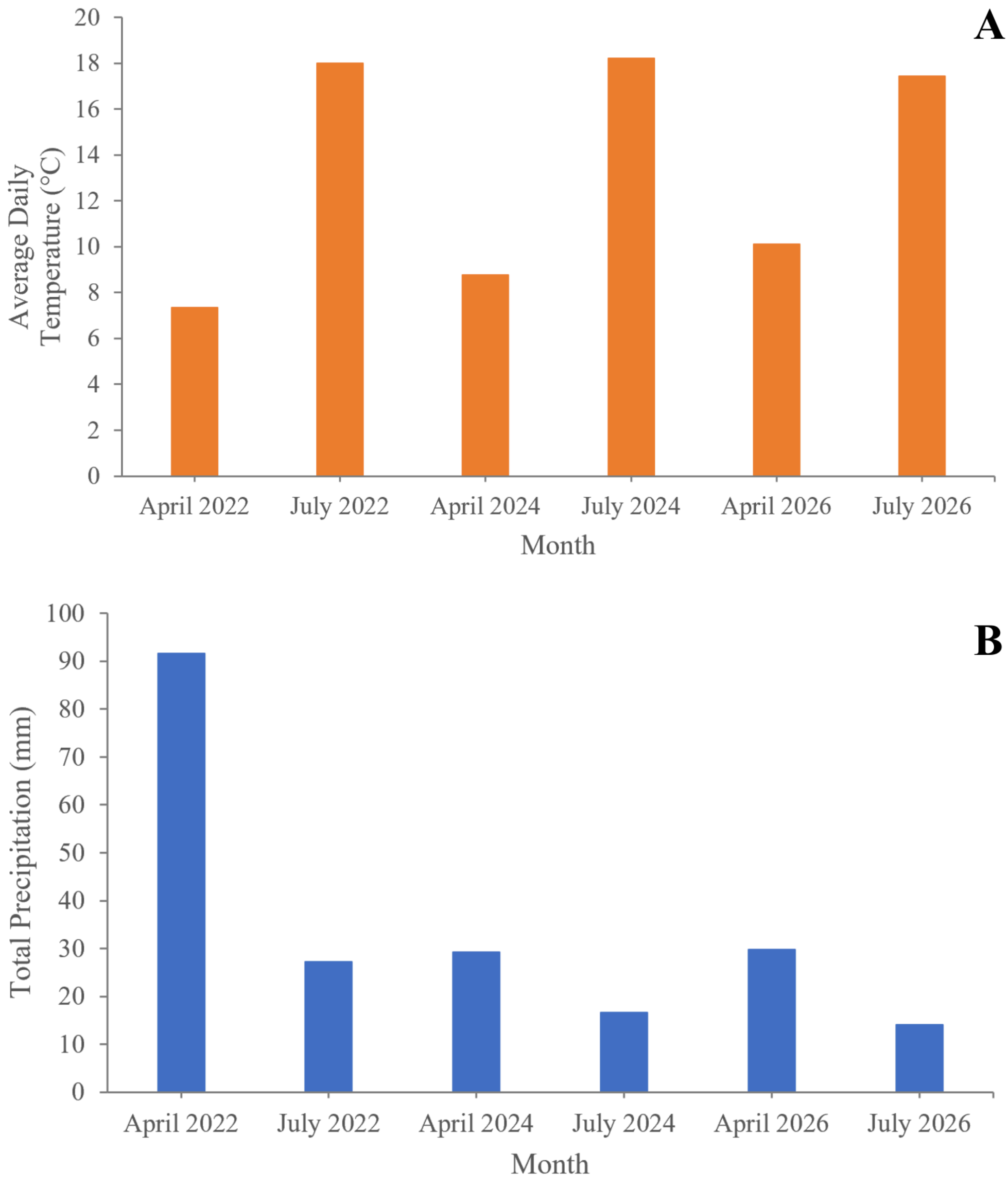

Figure 2. Average daily temperatures for each month prior to sampling in 2022, 2024, and 2026 (A) and total precipitation for each month prior to sampling in 2022, 2024, and 2026 (B). Data was retrieved from Environment and Climate Change Canada (n.d.).

The increase in parks that reached PWP in May indicates that these parks are experiencing prolonged drought stress compared to 2022 and 2024 (Garg et al., 2020; Hope, 2024; Hope & Bonsdorf, 2022). The advancement in the timing of parks reaching PWP may have serious implications for the health and longevity of Douglas-fir dominated and co-dominated forests (Griesbauer et al., 2019; Spittlehouse, 2008), including those found in many North Saanich parks. Trees are unable to extract water from the soil earlier in the year, leading to greater chances of crown dieback (Sergent et al., 2012), xylem cavitation (Rennenberg et al., 2006; Zweifel & Zeugin, 2008), and even plant death (Allen et al., 2010; Chauvin et al., 2019; van Mantgem et al., 2009). Lack of water availability in the soil earlier in the year also makes it increasingly difficult for Douglas-fir trees to take up nutrients (Querejeta et al., 2021; Kreuzwieser & Gessler, 2010) and maintain resiliency against diseases (Lee et al., 2022), pests (Freeman et al., 2019; Raffa et al., 2008), and abiotic events such as wildfires (Stevens‑Rumann et al., 2018).

Not only does prolonged drought put the health of Douglas-fir forests at risk, but it also has serious implications for ecosystem services to humans. A key concern is the loss of sequestered carbon (Allen et al., 2010), a vital strategy for climate change mitigation (Psistaki et al., 2024). In tandem with increased temperatures, drought causes a decline in a plant's ability to take up carbon via a reduction in photosynthesis and plant growth (Martínez‑Sancho et al., 2022; Pan et al., 2011; Schlesinger & Jasechko, 2014). Forests, such as the Douglas-fir forests found in the sampled parks, are one of the main terrestrial vectors for sequestration of atmospheric carbon. As climate change progresses and the intensity of drought worsens, the ability of forests to perform the essential ecosystem service of sequestering increased anthropogenic carbon emissions will continue to decline (Martínez‑Sancho et al., 2022; Roach et al., 2021).

Future research should investigate which soil types reach PWP sooner than others, specifically in North Saanich. Sampling more frequently, via a soil probe, and with a larger sample size to assess soil moisture may aid in more accurate results of when soils pass under PWP. This may assist with potential discrepancies from pre-dug soil pits compared to soil pits that were dug at the beginning of the sampling period. Future research may also benefit from using a water potential curve to make direct comparisons to PWP, rather than using VWC percentages, due to the lack of VWC and PWP literature for British Columbia. If VWC is used, it would be beneficial to determine VWC thresholds for PWP of different soil textures specific to North Saanich, as this would allow more accurate conclusions to be drawn in this region.

7. Recommendations

One way to adapt to climate change is by improving the resilience of Douglas-fir forests in North Saanich to ongoing drought. Improving forest resilience is underscored by continual research on Douglas-fir mortality in response to changing soil moisture conditions, and includes such actions as planting drought-tolerant species, reducing soil compaction, and creating management plans that centre Traditional Ecological Knowledge (TEK) alongside Western science. These values align with those outlined in the CRD's 2022-2032 Regional Parks and Trails Strategic Plan and the District of North Saanich's 2023-2026 Strategic Plan.

A study by Chagas Torres et al. (2021) showed that the physiological wilting point depends on both soil conditions and plant species. Building on recommendations outlined by Adams (2021), we suggest future planting in North Saanich parks focus on drought-tolerant species. This would help to slow declining forest health in this region, as these species wilt at lower water potentials (McGregor et al., 2020) and have greater stomatal regulation and osmotic adjustment (Ilyas et al., 2021).

Another method for adapting to the impacts of climate change on the forests in North Saanich parks is low-density planting. Douglas-fir trees growing in close proximity to one another compete for water that is available in the soil, particularly when growing in low-moisture conditions (Ares et al., 2007). Because of this, soil moisture is significantly lower in high-density stands compared to low-density stands (Lukose et al., 2025). We recommend low-density planting in North Saanich parks, as this planting technique increases forest resilience to drought (Damen et al., 2025). Additionally, the continual removal of invasive plant species from these parks, as led by FNSP, will contribute significantly to reducing competition.

We also recommend strategies to minimize foot traffic and soil compaction outside designated paths in North Saanich parks. The impact on soil compaction and soil moisture content in Douglas-fir forests is currently unknown. However, it is important to take precautionary measures until there is scientific evidence proving no effect. We recommend implementing more signage in North Saanich parks to ensure visitors and pets stay on designated trails and minimize disturbance.

Most importantly, future land management plans aiming to minimize further soil moisture loss in North Saanich parks should be created in full collaboration with local First Nations. This includes the BOḰEĆEN (Pauquachin), W̱SÍḴEM (Tseycum), W̱JOȽEȽP (Tsartlip), SȾÁUTW̱ (Tsawout), and MÁLEXEȽ (Malahat) Nations. Finally, a collaborative relationship with local First Nations would allow for TEK to be centred in management plans to reach collective goals and foster genuine relationships.

8. References

Adams, K. (2021). *The assessment and restoration of seven parks in North Saanich, B.C.* Friends of North Saanich Parks. https://www.fnsp.ca/wp-content/uploads/2023/09/FNSP_Project_KatrinaAdams2021.pdf

Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D. D., Hogg, E. H. (Ted), Gonzalez, P., Fensham, R., Zhang, Z., Castro, J., Demidova, N., Lim, J.-H., Allard, G., Running, S. W., Semerci, A., & Cobb, N. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management*, *259*(4), 660–684. https://doi.org/10.1016/j.foreco.2009.09.001

Ares, A., Terry, T., Harrington, C., Devine, W., Peter, D., & Bailey, J. (2007). Biomass removal, soil compaction, and vegetation control effects on five-year growth of Douglas-fir in coastal Washington. *Forest Science*, *53*(5), 600–610. https://doi.org/10.1093/forestscience/53.5.600

B.C. Ministry of Forests and Range, & B.C. Ministry of Environment. (2010). *Field manual for describing terrestrial ecosystems* (2nd ed.). Land Management Handbook No. 25. Research Branch, B.C. Ministry of Forests and Range.

Berg, A., & Sheffield, J. (2018). Climate change and drought: The soil moisture perspective. *Current Climate Change Reports*, *4*(2), 180–191. https://doi.org/10.1007/s40641-018-0095-0

Capital Regional District (2023). *Regional parks and trails strategic plan 2022-2032*. https://www.crd.ca/media/file/crd-regional-parks-and-trails-strategic-plan-2022-2032-reduced

Chagas Torres, L., Keller, T., Paiva De Lima, R., Antônio Tormena, C., Veras De Lima, H., & Fabíola Balazero Giarola, N. (2021). Impacts of soil type and crop species on permanent wilting of plants. *Geoderma*, *384*, 114798. https://doi.org/10.1016/j.geoderma.2020.114798

Chauvin, T., Cochard, H., Segura, V., & Rozenberg, P. (2019). Native-source climate determines the Douglas-fir potential of adaptation to drought. *Forest Ecology and Management*, *444*, 9–20. https://doi.org/10.1016/j.foreco.2019.03.054

Coulthard, B., Smith, D. J., & Meko, D. M. (2015). Is worst-case scenario streamflow drought underestimated in British Columbia? A multi-century perspective for the South Coast, derived from tree-rings. *Journal of Hydrology*, *534*, 205–218. https://doi.org/10.1016/j.jhydrol.2015.12.030

Damen, F., Aitken, S., Degner, J., & Montwé, D. (2025). Drought resilience of coastal Douglas-fir is influenced by competition but not genetic selection. *Forest Ecology and Management*, *578*, 122488. https://doi.org/10.1016/j.foreco.2024.122488

Datta, S., Taghvaeian, S., & Stivers, J. (2018). *Understanding soil water content and thresholds for irrigation management*. Oklahoma State University. https://extension.okstate.edu/fact-sheets/understanding-soil-water-content-and-thresholds-for-irrigation-management

District of North Saanich (2026). *2023-2026 Strategic plan*. https://northsaanich.ca/wp-content/uploads/NS-2023-2026-Strategic-Plan-Updated-Mar-2026-WEB.pdf

Environment and Climate Change Canada (n.d.). *Daily Data Report* [April 2022, April 2024, April 2026, July 2022, July 2024, and July 2026]. Retrieved August 20, 2026, from https://climate.weather.gc.ca/climate_data/daily_data_e.html?timeframe=2&hlyRange=2013-07-09%7C2026-08-19&dlyRange=2013-05-16%7C2026-08-19&mlyRange=%7C&climate_id=1018621&Prov=BC&urlExtension=_e.html&searchType=stnProv&optLimit=yearRange&StartYear=2022&EndYear=2026&selRowPerPage=25&Line=267&lstProvince=BC&Day=19&Year=2026&Month=4#

Fairbarns, M. (2004). James Island Conservation Assessment. *Islands Trust.* Prepared for The Nature Conservancy of Canada, Victoria, BC.

Freeman, M. B., Labarge, A., & Tobin, P. C. (2019). Phenology of Douglas-Fir beetle (Coleoptera: Curculionidae) and its role in Douglas-Fir mortality in western Washington. *Environmental Entomology*, *49*(1), 246–254. https://doi.org/10.1093/ee/nvz146

Gardner, W. H. (1986). Water content. *Soil Science Society of America Book Series*, 493–544. https://doi.org/10.2136/sssabookser5.1.2ed.c21

Garg, A., Bordoloi, S., Ganesan, S. P., Sekharan, S., & Sahoo, L. (2020). A relook into plant wilting: Observational evidence based on unsaturated soil–plant-photosynthesis interaction. *Scientific Reports*, *10*(1), 22064. https://doi.org/10.1038/s41598-020-78893-z

Ghanbarian-Alavijeh, B., & Millán, H. (2009). The relationship between surface fractal dimension and soil water content at permanent wilting point. *Geoderma*, *151*(3–4), 224–232. https://doi.org/10.1016/j.geoderma.2009.04.014

Griesbauer, H. P., Klassen, H., Saunders, S. C., & Spittlehouse, D. L. (2019). Variation in climate-growth relationships for Douglas-fir growth across spatial and temporal scales on southern Vancouver Island, British Columbia. *Forest Ecology and Management*, *444*, 30–41. https://doi.org/10.1016/j.foreco.2019.04.014

Hilliard, C., & Reedyk, S. (2020). *Soil texture and water quality.* Agriculture and Agri-Food Canada. https://agriculture.canada.ca/en/agricultural-production/soil-and-land/soil-and-water/soil-texture-and-water-quality

Hope, S. (2024). *Soil moisture content study in three North Saanich parks in 2024*. Friends of North Saanich Parks. https://www.fnsp.ca/wp-content/uploads/2024/11/FNSPMoisture-Content-Study-of-Three-North-Saanich-Park-Soil-Profilesdata22.pdf

Hope, S., & Bonsdorf, T. (2022). *Soil moisture content and soil C/N ratios in selected North Saanich Parks*. Friends of North Saanich Parks. https://www.fnsp.ca/wp-content/uploads/2023/09/FNSPMoistureContent2022.pdf

Hoover, D. L., Pfennigwerth, A. A., & Duniway, M. C. (2021). Drought resistance and resilience: The role of soil moisture–plant interactions and legacies in a dryland ecosystem. *Journal of Ecology*, *109*(9), 3280–3294. https://doi.org/10.1111/1365-2745.13681

Ilyas, M., Nisar, M., Khan, N., Hazrat, A., Khan, A. H., Hayat, K., Fahad, S., Khan, A., & Ullah, A. (2021). Drought tolerance strategies in plants: A mechanistic approach. *Journal of Plant Growth Regulation*, *40*(3), 926–944. https://doi.org/10.1007/s00344-020-10174-5

Irshad, A., Ahmad, H., Muhammad, I., Khan, S. U., & Raza, S. (2024). Editorial: The role of water stress and soil texture on plant roots anatomy, architecture, and senescence. *Frontiers in Plant Science*, *15*, 1490001. https://doi.org/10.3389/fpls.2024.1490001

Kirkham, M. (2014). Field capacity, wilting point, available water, and the nonlimiting water range. In *Elsevier eBooks* (pp. 153–170). https://doi.org/10.1016/b978-0-12-420022-7.00010-0

Kreuzwieser, J., & Gessler, A. (2010). Global climate change and tree nutrition: influence of water availability. *Tree Physiology*, *30*(9), 1221–1234. https://doi.org/10.1093/treephys/tpq055

Lee, E. H., Beedlow, P. A., Brooks, J. R., Tingey, D. T., Wickham, C., & Rugh, W. (2022). Physiological responses of Douglas-fir to climate and forest disturbances as detected by cellulosic carbon and oxygen isotope ratios. *Tree Physiology*, *42*(1), 5–25. https://doi.org/10.1093/treephys/tpab122

Lewis, K. J., Elkin, C., Klassen, H., Saunders, S., & Griesbauer, H. P. (2025). Soil moisture is a main driver of growth response of coastal Douglas-fir with high spatial variability. *Forest Ecology and Management*, *595*, 122993. https://doi.org/10.1016/j.foreco.2025.122993

Little, K. M., Metelerkamp, B. and Smith, C. W. (1998). A comparison of three methods of soil water content determination. *South African Journal of Plant and Soil*, *15*(2), 80-89. https://journals.co.za/doi/pdf/10.10520/AJA02571862_377

Lukose, S., Omari, K., & Pinno, B. D. (2025). Mixing tree species and density management to reduce drought susceptibility in coastal plantation forests of British Columbia. *Forest Ecology and Management*, *598*, 123235. https://doi.org/10.1016/j.foreco.2025.123235

Madrone Environmental Services Ltd. (2008). *Terrestrial Ecosystem Mapping of the Coastal Douglas-Fir Moist Maritime (CDFmm) Biogeoclimatic Subzone*. Prepared for the B.C. Ministry of Environment. Victoria, BC. Available through the B.C. Ecological Reports Catalogue (EcoCat).

Martínez‐Sancho, E., Treydte, K., Lehmann, M. M., Rigling, A., & Fonti, P. (2022). Drought impacts on tree carbon sequestration and water use – evidence from intra‐annual tree‐ring characteristics. *New Phytologist*, *236*(1), 58–70. https://doi.org/10.1111/nph.18224

McGregor, I. R., Helcoski, R., Kunert, N., Tepley, A. J., Gonzalez‐Akre, E. B., Herrmann, V., Zailaa, J., Stovall, A. E. L., Bourg, N. A., McShea, W. J., Pederson, N., Sack, L., & Anderson‐Teixeira, K. J. (2020). Tree height and leaf drought tolerance traits shape growth responses across droughts in a temperate broadleaf forest. *New Phytologist*, *231*(2), 601–616. https://doi.org/10.1111/nph.16996

Mukherjee, S., Mishra, A., & Trenberth, K. E. (2018). Climate change and drought: A perspective on drought indices. *Current Climate Change Reports*, *4*(2), 145–163. https://doi.org/10.1007/s40641-018-0098-x

Novák, W., & Hlaváčiková, H. (2018). Soil-water content and its measurement. In *Applied soil hydrology* (pp. 49-61). Springer, Cham. https://doi.org/10.1007/978-3-030-01806-1_5

Nuzdorfer, F. C., Klinka, K., & Demarchi, D.A. (1991). Chapter 5: Coastal Douglas-fir Zone. In D. Meidinger & J. Pojar (Eds.), *Ecosystems of British Columbia* (pp. 81–95). BC Ministry of Forests.

Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., Phillips, O. L., Shvidenko, A., Lewis, S. L., Canadell, J. G., Ciais, P., Jackson, R. B., Pacala, S. W., McGuire, A. D., Piao, S., Rautiainen, A., Sitch, S., & Hayes, D. (2011). A large and persistent carbon sink in the world's forests. *Science*, *333*(6045), 988–993. https://doi.org/10.1126/science.1201609

Psistaki, K., Tsantopoulos, G., & Paschalidou, A. K. (2024). An overview of the role of forests in climate change mitigation. *Sustainability*, *16*(14), 6089. https://doi.org/10.3390/su16146089

Querejeta, J. I., Ren, W., & Prieto, I. (2021). Vertical decoupling of soil nutrients and water under climate warming reduces plant cumulative nutrient uptake, water‐use efficiency and productivity. *New Phytologist*, *230*(4), 1378–1393. https://doi.org/10.1111/nph.17258

Raffa, K. F., Aukema, B. H., Bentz, B. J., Carroll, A. L., Hicke, J. A., Turner, M. G., & Romme, W. H. (2008). Cross-scale drivers of natural disturbances prone to anthropogenic amplification: The dynamics of bark beetle eruptions. *BioScience*, *58*(6), 501–517. https://doi.org/10.1641/b580607

Rai, R. K., Singh, V. P., & Upadhyay, A. (2017). Soil analysis. In *Planning and evaluation of irrigation projects* (pp. 505-523). Academic Press. https://doi.org/10.1016/B978-0-12-811748-4.00017-0.

Rennenberg, H., Loreto, F., Polle, A., Brilli, F., Fares, S., Beniwal, R. S., & Gessler, A. (2006). Physiological responses of forest trees to heat and drought. *Plant Biology*, *8*(5), 556–571. https://doi.org/10.1055/s-2006-924084

Roach, W. J., Simard, S. W., Defrenne, C. E., Pickles, B. J., Lavkulich, L. M., & Ryan, T. L. (2021). Tree diversity, site index, and carbon storage decrease with aridity in Douglas-Fir forests in western Canada. *Frontiers in Forests and Global Change*, *4*. https://doi.org/10.3389/ffgc.2021.682076

Schlesinger, W. H., & Jasechko, S. (2014). Transpiration in the global water cycle. *Agricultural and Forest Meteorology*, *189–190*, 115–117. https://doi.org/10.1016/j.agrformet.2014.01.011

Sergent, A., Rozenberg, P., & Bréda, N. (2012). Douglas-fir is vulnerable to exceptional and recurrent drought episodes and recovers less well on less fertile sites. *Annals of Forest Science*, *71*(6), 697–708. https://doi.org/10.1007/s13595-012-0220-5

Smith, C. A. S., Webb, K. T., Kenney, E., Anderson, A., & Kroetsch, D. (2011). Brunisolic soils of Canada: Genesis, distribution, and classification. *Canadian Journal of Soil Science*, *91*(5), 695–717. https://doi.org/10.4141/cjss10058

Soil Classification Working Group, (1998). *Brunisolic order*. Government of Canada. https://sis.agr.gc.ca/cansis/taxa/cssc3/chpt04.html

Spittlehouse, D. L. (2003). Water availability, climate change and the growth of Douglas-Fir in the Georgia Basin. *Canadian Water Resources Journal/Revue Canadienne Des Ressources Hydriques*, *28*(4), 673–688. https://doi.org/10.4296/cwrj2804673

Stevens‐Rumann, C. S., Kemp, K. B., Higuera, P. E., Harvey, B. J., Rother, M. T., Donato, D. C., Morgan, P., & Veblen, T. T. (2018). Evidence for declining forest resilience to wildfires under climate change. *Ecology Letters*, *21*(2), 243–252. https://doi.org/10.1111/ele.12889

Tolk, J. A. (2007). Soils, permanent wilting points. In S. W. Trimble (Eds.), *Encyclopedia of Water Science* (2nd ed., pp. 1140-1142). CRC Press.

Twarakavi, N. K. C., Sakai, M., & Šimůnek, J. (2009). An objective analysis of the dynamic nature of field capacity. *Water Resources Research*, *45*(10). https://doi.org/10.1029/2009wr007944

van Mantgem, P. J., Stephenson, N. L., Byrne, J. C., Daniels, L. D., Franklin, J. F., Fule, P. Z., Harmon, M. E., Larson, A. J., Smith, J. M., Taylor, A. H., & Veblen, T. T. (2009). Widespread increase of tree mortality rates in the Western United States. *Science*, *323*(5913), 521–524. https://doi.org/10.1126/science.1165000

Wiecheteck, L. H., Giarola, N. F., De Lima, R. P., Tormena, C. A., Torres, L. C., & De Paula, A. L. (2019). Comparing the classical permanent wilting point concept of soil (−15,000 hPa) to biological wilting of wheat and barley plants under contrasting soil textures. *Agricultural Water Management*, *230*, 105965. https://doi.org/10.1016/j.agwat.2019.105965

Veihmeyer, F. J., & Hendrickson, A. H. (1931). The moisture equivalent as a measure of the field capacity of soils. *Soil Science*, *32*(3), 181–194. https://doi.org/10.1097/00010694-193109000-00003

Zhang, Q., & Hebda, R. J. (2005). Abrupt climate change and variability in the past four millennia of the southern Vancouver Island, Canada. *Geophysical Research Letters*, *32*(16). https://doi.org/10.1029/2005gl022913

Zuo, Z., Qiao, L., Zhang, R., Chen, D., Piao, S., Xiao, D., & Zhang, K. (2024). Importance of soil moisture conservation in mitigating climate change. *Science Bulletin*, *69*(9), 1332–1341. https://doi.org/10.1016/j.scib.2024.02.033

Zweifel, R., & Zeugin, F. (2008). Ultrasonic acoustic emissions in drought‐stressed trees – more than signals from cavitation? *New Phytologist*, *179*(4), 1070–1079. https://doi.org/10.1111/j.1469-8137.2008.02521.x

9. Appendix A – Soil Moisture Raw Data

9.1 May Soil Moisture Raw Data

Park	Soil Horizon	Wet Weight (g)	Dry Weight (g)	Net Weight (g)	Tin Volume (mL)	Bulk Density (g/mL)	GWC (g/g)	VMC (mL/mL)
Denham Till	Ah	59.26	49.04	10.22	88	0.557	0.208	0.166
	Bm	87.53	76.48	11.05	88	0.869	0.144	0.126
	C	75.51	58.66	16.85	88	0.667	0.287	0.191
Green Park	Ah	64.06	52.00	12.06	88	0.591	0.232	0.137
	Bm	91.00	81.56	9.44	88	0.927	0.116	0.107
	C	103.74	92.11	11.63	88	1.047	0.126	0.132
Gulf View	Ah	74.81	66.77	8.04	88	0.759	0.120	0.091
	Bm	98.30	90.43	7.87	88	1.028	0.087	0.089
	C	71.26	63.16	8.10	88	0.718	0.128	0.092
Lillian Hoffar	Ah	66.30	48.67	17.63	88	0.553	0.362	0.200
	Bm	74.73	56.55	18.18	88	0.643	0.321	0.207
	C	87.82	72.74	15.08	88	0.827	0.207	0.171
Nymph Point	Ah	67.56	62.39	5.17	88	0.709	0.083	0.059
	Bm	79.76	68.61	11.15	88	0.780	0.163	0.127

Park	Soil Horizon	Wet Weight (g)	Dry Weight (g)	Net Weight (g)	Tin Volume (mL)	Bulk Density (g/mL)	GWC (g/g)	VMC (mL/mL)
	C	75.33	64.08	11.25	88	0.728	0.176	0.128
Prentice Pond	Ah	80.23	56.86	23.37	88	0.646	0.411	0.266
	Bm	100.04	82.27	17.77	88	0.935	0.216	0.202
	C	175.32	146.22	29.10	88	1.662	0.199	0.331
Quarry Park	Ah	55.92	36.98	18.94	88	0.420	0.512	0.215
	Bm	76.09	64.75	11.34	88	0.736	0.175	0.129
	C	70.86	62.65	8.21	88	0.712	0.131	0.093
R.O. Bull	Ah	61.76	46.16	15.60	88	0.525	0.388	0.177
	Bm	87.63	80.34	7.29	88	0.913	0.091	0.083
	C	81.91	76.99	4.92	88	0.875	0.064	0.056

9.2 August Soil Moisture Raw Data

Park	Soil Horizon	Wet Weight (g)	Dry Weight (g)	Net Weight (g)	Tin Volume (mL)	Bulk Density (g/mL)	GWC (g/g)	VWC (mL/mL)
Denham Till	Ah	51.30	47.35	3.95	88	0.538	0.083	0.045
	Bm	73.18	64.89	8.29	88	0.737	0.128	0.094
	C	74.63	61.46	13.17	88	0.698	0.214	0.150
Green Park	Ah	51.01	46.92	4.09	88	0.533	0.087	0.046
	Bm	72.96	68.30	4.66	88	0.776	0.068	0.053
	C	89.74	83.41	6.33	88	0.948	0.076	0.072
Gulf View	Ah	67.27	64.07	3.20	88	0.728	0.050	0.036
	Bm	75.48	72.86	2.62	88	0.828	0.036	0.030
	C	83.15	77.74	5.41	88	0.883	0.070	0.061
Lillian Hoffar	Ah	58.29	53.88	4.41	88	0.612	0.082	0.050
	Bm	67.32	61.34	5.98	88	0.697	0.097	0.068
	C	76.72	68.53	8.19	88	0.779	0.120	0.093
Nymph Point	Ah	67.63	65.45	2.18	88	0.744	0.033	0.025
	Bm	75.39	70.87	4.52	88	0.805	0.064	0.051
	C	71.10	64.50	6.60	88	0.733	0.102	0.075
Prentice Pond	Ah	78.41	63.03	15.38	88	0.716	0.244	0.175

Park	Soil Horizon	Wet Weight (g)	Dry Weight (g)	Net Weight (g)	Tin Volume (mL)	Bulk Density (g/mL)	GWC (g/g)	VWC (mL/mL)
	Bm	79.51	67.85	11.66	88	0.771	0.172	0.133
	C	110.33	99.67	10.66	88	1.133	0.107	0.121
Quarry Park	Ah	43.99	39.12	4.87	88	0.445	0.124	0.055
	Bm	63.58	60.11	3.47	88	0.683	0.058	0.039
	C	85.12	80.85	4.27	88	0.919	0.053	0.049
R.O. Bull[1]	Ah	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Bm	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	C	N/A	N/A	N/A	N/A	N/A	N/A	N/A

[1]Sampling could not be completed because the soil pit was anonymously filled in.

10. Appendix B – Calculations

10.1 Bulk Density Sample Calculation

$$\rho_b = \frac{W_{dry}}{V_t}$$

$$\rho_{b\ Denham\ Till\ Ah-Aug} = \frac{47.35\ g}{88\ mL}$$

$$\rho_{b\ Denham\ Till\ Ah-Aug} = 0.538\ g/mL$$

10.2 Gravimetric Moisture Content Sample Calculation

$$\theta_g = \left(\frac{W_{wet} - W_{dry}}{W_{dry}}\right)$$

$$\theta_{g\ Denham\ Till\ Ah-Aug} = \left(\frac{51.30\ g - 47.35\ g}{47.35\ g}\right)$$

$$\theta_{g\ Denham\ Till\ Ah-Aug} = 0.083\ g/g$$

10.3 Volumetric Water Content Sample Calculation

$$\theta_v = \theta_g * \left(\frac{\rho_b}{\rho_w}\right)$$

$$\theta_{v\ Denham\ Till\ Ah-Aug} = 0.083\ g/g * \left(\frac{0.045\ g/mL}{1.0\ g/mL}\right)$$

$$\theta_{v\ Denham\ Till\ Ah-Aug} = 0.045\ mL/mL$$

11. Appendix C - Soil Pit Descriptions

11.1 Denham Till Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LF	-3 to 0	Notes: Mostly Garry oak and salal leaves, small twigs and branches							
Ah	0 to 4.5	10 YR 3/2	SiC	/	Few very fine, abundant fine, plentiful medium, very few coarse	Few fine	Medium subangular blocky	Dry, loose	Irregular horizon boundaries (0 to 1.5 cm and 0 to 7 cm); broken and only appears in part of the pit
Bm1	4.5 to 48	10 YR 4/6	SiC	10% subangular gravel	Few fine, few medium, very few coarse	Plentiful fine, few medium	Medium angular	Dry, slightly hard	/
Bm2	48 to 53	10 YR 4/3	SiC	/	Few very fine, very few medium	Few fine	Medium angular	Dry, slightly hard	Mottling is frequent and small; colour 10 YR 5/8
C	53+	10 YR 5/3	HC	/	/	Few fine	Coarse angular	Dry, slightly hard	Mottling is frequent and small; colour 10 YR 5/8; dark and decaying roots

General notes: Texture was determined using crushed moist soil. Vegetation: salal type, red huckleberry, snowberry, Garry oak, bigleaf maple, western redcedar, and Oregon grape. At the edge of arbutus-Douglas-fir type. The soil pit is predetermined and contaminated.

11.2 Green Park Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LH	-2 to 0	Notes: Oregon grape							
Ah	0 to 12	10 YR 4/3	SiL	30% subangular (25% gravel, 5% cobble)	Abundant micro, abundant very fine	Plentiful fine, very few medium, very few coarse	Fine subangular blocky	Dry, loose	Irregular boundary
Bm1	12 to 27	10 YR 4/4	SiCL	25% subangular (10% gravel, 15% cobble)	Abundant fine, plentiful medium, plentiful coarse	Few fine, very few medium	Fine subangular blocky	Dry, soft	/
Bm2	27 to 38	7.5 YR 4/4	SiCL	10% subangular gravel	Few fine, few medium	Few fine	Fine subangular blocky	Dry, slightly hard	/
C	38 to 50+	10 YR 4/3	SiCL	30% subangular gravel	Few very fine	/	Fine subangular blocky	Dry, loose	/

General notes: Texture was determined using crushed moist soil. Vegetation: Oregon grape, western sword fern, western redcedar, Douglas-fir, bigleaf maple, abundant maple seedlings, daphne seedlings, June plum seedlings, and moss (species unknown) on decayed logs. Trees are fairly young. Vegetation is salal type at the bottom of the slope. The soil pit is located on the downward slope going west. Charcoal was found in the Bm1 layer.

11.3 Gulf View Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LF	-1.5 to 0	Notes: Mostly small twigs and Douglas-fir cones							
Ah	0 to 22	7.5 YR 3/2	SiL	10% subangular (5% gravel, 5% cobble)	Few fine, few medium	Few fine, very few medium	Coarse subangular blocky	Dry, loose	Plastic and sticky
Bm	22 to 56	10 YR 4/3	SiL	20% subangular (15% gravel, 5% cobble)	Few medium, few coarse	Few fine, few medium	Coarse subangular blocky	Dry, loose	Slightly sticky, non-plastic
C	56 to 75+	10 YR 5/6	LS	30% subangular gravel	/	/	Coarse subangular blocky	Dry, loose	No mottling

General notes: Colour was determined using crushed moist soil. Vegetation: trailing blackberry, snowberry, Oregon grape, and ocean spray. The soil pit is located on a gentle slope. The soil appears to be glacial till. Soil description is based on the properties presented in Bonsdorf and Hope (2022).

11.4 Lillian Hoffar Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LF	-2 to 0	Notes: Deciduous leaves, twigs, dead insects, moss, buds, and red alder catkins							
Ah	0 to 7.5	7.5 YR 3/2	SiL	5% subangular gravel	Few fine	Few fine	Fine to medium subangular blocky	Dry, loose	/
Bm	7.5 to 25	7.5 YR 3/4	SiCL	/	Few medium, few coarse	Very few fine	Medium angular blocky	Dry, soft	Frequent and fine mottling; colour 7.5 YR 5/8
C	25+	10 YR 6/1	SiCL	/	Very few fine	Few very fine, very few fine	Medium to coarse angular blocky	Dry, hard	Large mottling scattered throughout horizon; colour 7.5 YR 5/8
General notes: Irregular soil boundaries. Vegetation: snowberry, western swordfern, black cottonwood, June plum, moss (species unknown), trailing blackberry.									

11.5 Nymph Point Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LF	-1.5 to 0	Notes: Deciduous leaves and small twigs							
Ah	0 to 7	10 YR 4/3	SiC	30% subangular gravel	Plentiful very fine, few fine	Few very fine, plentiful fine	Medium subangular blocky	Dry, soft	/
Bm1	7 to 21	10 YR 5/3	C	25% subangular gravel	Few fine, plentiful medium	Few very fine, few fine	Medium subangular blocky	Dry, soft	Consistent colour
Bm2	21 to 47	10 YR 5/3	HC	35% subangular gravel	Plentiful fine, plentiful medium	Few fine	Medium subangular blocky	Dry, slightly hard	Mottling; colour 10 YR 5/8
C	47+	10 YR 4/2	HC	30% subangular gravel	Few very fine, plentiful fine, plentiful medium	Very few fine	Coarse subangular blocky	Dry, slightly hard	Mottling; colour 10 YR 5/8

General notes: Texture was determined using crushed moist soil. Vegetation: arbutus, Douglas-fir, snowberry, daphne seedlings, Garry oak, sedges, clover, Oregon grape, scotch broom, and marsh jaumea (at the bottom of slope). Vegetation above the soil pit: red clover, trailing blackberry, honeysuckle, sweet vernal grass, orchard grass, June plum, Sierra Nevada peavine, pacific sanicle, common vetch, and ribwort plantain. The soil pit is predetermined on a bank edge along a very steep slope.

11.6 Prentice Pond Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LFH	-2.5 to 0	Notes: Moss (species unknown)							
Ah	0 to 15	10 YR 3/2	CL	20% subangular (10% gravel, 10% cobble)	Plentiful very fine, plentiful fine, plentiful medium, very few coarse	Few fine, very few medium	Medium subangular blocky	Moist, firm	Dark colour indicative of humus
Bm	15 to 33	10 YR 3/3	CL	15% subangular (10% gravel, 5% cobble)	/	Few fine, plentiful medium	Medium subangular blocky	Moist, friable	Mottling; colour 7.5 YR 5/8
C	33+	10 YR 5/3	SC	40% subangular (30% gravel, 10% cobble)	/	/	Coarse subangular blocky	Moist, firm	/

General notes: Texture and colour were determined using crushed moist soil. Vegetation: Douglas-fir, salal, June plum, trailing blackberry, western sword fern, western redcedar, bigleaf maple, moss (species unknown), western skunk cabbage, snowberry, and horsetail. Lots of woody debris nearby including large logs. The site is very variable in terms of vegetation and elevation. The soil pit is in a depression, but is reflective of variable topography of the park; the site is not sloped, but there are gentle slopes nearby. There is a pond above the soil pit.

11.7 Quarry Park Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LH	-1.5 to 0	Notes: Twigs (~1 cm diameter), leaf litter, Douglas-fir cones and needles, and western redcedar needles							
Ah	0 to 9	7.5 YR 3/2	SiL	40% subangular (25% gravel, 15% cobble)	Abundant small, few medium	Plentiful fine, few medium	Very fine subangular blocky	Dry, loose	/
Bm1	9 to 35	5 YR 4/6	SiL	45% subangular (30% gravel, 15% cobble)	Plentiful medium, few coarse	Few fine, few medium	Very fine subangular blocky	Dry, loose	/
Bm2	35-65	10 YR 4/6	SiL	35% subangular (30% gravel, 5% cobble)	Few medium, few coarse	Few fine, very few coarse	Fine subangular blocky	Dry, loose	/
C	65+	10 YR 4/6	SiL	35% subangular gravel	/	/	Fine subangular blocky	Dry, loose	/

General notes: Vegetation: Oregon grape, Douglas-fir, daphne seedlings, English ivy, English holly, western starflower, bigleaf maple, and western redcedar. Some Douglas-fir trees are old growth (~175 years old), whereas others are fairly young. Light vegetation overall. There is a potential maple-Oregon grape vegetation association. The surrounding area consists of rocks and western red cedar. There is a gentle downslope with slight slippage. There is decayed wood in the upper quadrant of the profile. The soil appears to be glacial till.

11.8 R.O. Bull Soil Data

Horizon	Depth (cm)	Colour	Texture	Coarse Fragments	Roots	Root Pores	Structure	Consistence	Comments
LH	-4 to 0	Notes: Lots of twigs (<1 cm to ~1 cm), broken branches (1 to 5+ cm), Douglas-fir cones and needles, western redcedar needles							
Ah	0 to 18	7.5 YR 3/2	SiL	25% subangular (10% gravel, 15% cobble)	Abundant fine, plentiful medium		Medium granular		Irregular horizon boundary
Bm1	18 to 44	7/5 YR 4/4	LS	35% subangular (15% gravel, 20% cobble)	Plentiful fine, few medium		Medium granular		/
Bm2	44 to 65	7.5 YR 3/4	LS	15% subangular (5% gravel, 10% cobble)	Few fine, few medium, very few coarse		Medium granular		/
C	65+	7.5 YR 4/4	LS	/	Few fine, few medium		Fine granular		Distinct boundary; no peds

General notes: Vegetation: Oregon grape, western redcedar, Douglas-fir, American trailplant, western starflower, mountain sweet cicely, daphne seedlings, June plum and bigleaf maple upslope, western swordfern and bracken fern downslope. The soil pit is ~5 to 10 m away from a walking trail on a gradual west-facing downslope. There are lots of twigs and woody debris. There are pockets of fine roots that are clustered.