

2025 Forest Carbon Inventory on the Evergreen State College Forest Reserves

Authors¹: Arantxa Barcenas, Maura Blair, Eva Capetti-Lefebvre, Maddie DelaCruz, Dylan Fischer, Jansan Helligso, Frankie Henrickson, Liam Kaperick, Bemsha King, Gates Marshall, Christopher Maxwell, Maddie Morgan, Aspen Overstreet, Jenna Shellman, Bradley Smith, Danny Tayrien

Summary:

In 2024/25 we completed a plot-based inventory of carbon (C) pools in the Evergreen State College Forest Reserve using a permanent plot network (The Evergreen Ecological Observation Network; EEON). In each of ten 0.0314 ha plots, we assessed C pools in aboveground vegetation using manual measurements combined with biomass estimation equations for trees, snags, large woody debris, and understory vegetation. Additionally, we measured carbon in fine woody debris and soils using gravimetric methods followed by combustion and elemental analysis for determination of organic matter and %C, respectively. We combined these estimates of C pools (vegetation, woody debris, and soils) with estimates of leaf decomposition based on a two-year decomposition experiment in a subset of plots, and estimates of soil respiration based on a single fall sample of CO₂ fluxes using the soda lime technique. Finally, all data were compared with estimates of net aboveground C change in live tree and understory biomass from permanent plot inventories in 2008-2021 in a total of 40 plots. Our data suggest an average standing C pool in the Evergreen Forest reserves of approximately 484.2 Mg C ha⁻¹, with 356.6 Mg C ha⁻¹ in aboveground trees, 49.7 Mg C ha⁻¹ in snags and large woody debris, 0.7 Mg C ha⁻¹ in understory, 43.3 Mg C ha⁻¹ in soils down to a depth of 1m, and the remainder in roots, fine woody debris and organic soil horizons. Comparison with previous data suggests an increase of 3.4 Mg C ha⁻¹ yr⁻¹ in aboveground storage from 2008-2024, an increase of 4.9 Mg C ha⁻¹ yr⁻¹ in live tree biomass between 2008 and 2021, and 3.5 Mg C ha⁻¹ yr⁻¹ per year since 2021 (based on six plots only). Over-all, these forests store large amounts of C, and rates of annual sequestration represent the upper end of C sequestration rates in temperate forests. Our data help constrain estimates and show consistent and realistic values for mature forest C storage and change through time that can help refine regional estimates.

Author correspondence: fischerd@evergreen.edu

¹ Authors appear alphabetically by last name

Introduction:

Forest carbon (C) represents a critical source of carbon storage and flux globally (Pan et al. 2024). Understanding C cycles in specific ecosystems requires an understanding of carbon as active in flux and held in pools (Harmon and Hua 1991, Pan et al. 2024). In the Pacific Northwest (USA), mature forests can represent the most C-dense ecosystems on the planet. Accordingly, measuring changes to pools and fluxes in these forests over time is essential for monitoring biome alteration (Barron-Gafford et al. 2011, Fischer et al. 2024), and such measurements represent the upper end of potential carbon sequestration in forests. Local ecosystem monitoring also promotes better understanding of global climate change dynamics and informs management toward mitigating their impact (Gray and Whittier 2014, Pan et al. 2024).

Discrete measurements of aboveground biomass, large woody debris, understory biomass and soil carbon can be used to generate estimates of total C within forest plots (Clark et al. 2001, Gray and Whittier 2014, Kirsch et al. 2012). Long term data collection in static plots allows for comparative analysis of plot carbon over time. Additionally, careful quantification of C in different terrestrial pools is necessary since different forest C pools have different rates of storage and release (Harmon and Hua 1991, Pan et al. 2024). The Evergreen Ecological Observation Network (EEON) is a system of long-term research plots within a 1000-acre lowland second-growth forest where repeated measurements of forest C in distinct pools has taken place over a 20-year period (Kirsch et al. 2012). Here, we look at aboveground tree biomass pools in 2008-2024, and average soil C in 2008 through 2025. Next, we use plot detailed surveys and lab analyses in just 6 of the 44 total EEON to better quantify C distribution among forest pools and complete a more comprehensive inventory of forest C in 2024/2025.

Methods:

Study Location:

The study takes place within a network of permanent plots (Evergreen Ecological Observation Network; EEON) in the 380 ha Evergreen State College Forest Reserve (47.073573, -122.975017). The site is situated in the Puget Sound lowlands in Olympia, Washington. The forest is a second-growth temperate rainforest with mixed hardwood and conifer dominant species. The forest type is characteristic of ~100+ year-old lowland *Tsuga heterophylla* climax-zone forests (Franklin and Dyrness 1973), and these forests are dominated by a mix of *Pseudotsuga menziesii* (Mirbel) Franco, *Alnus rubra* Bong., *Acer macrophyllum* Pursh, and *Thuja plicata* Donn ex D. Don trees, with scattered *Tsuga heterophylla* (Raf.) Sarg. and *Abies grandis* (Douglas ex D. Don) Lindley. This study summarizes carbon flux in six of the 44 EEON plots: B4, B9, C6, C11, D2, and D3 (Figure 1).

The EEON represents a permanent plot network designed in 2006 for repeated measurements of forest carbon pools (EEON; <http://sites.evergreen.edu/eeon>). Briefly, The network consists of 44 circular 0.0314 ha plots in a systematic 250 m grid with a random start, designed for long term research. All live trees have been measured in these plots repeatedly since 2008, and snags, and down woody debris were also permanently tagged and measured in 2008, but less frequently since establishment. In the most-recent complete assessments of live trees (2021) tree density averaged 369 stems ha⁻¹, (26 SE), while median/mean tree diameters were 34.5 and 41.3 (1.3 SE) respectively.

Kirch et al. (2012) reported net increases in aboveground biomass C of ~1.95 Mg C ha⁻¹ year⁻¹.

Measurements of litterfall from 2007/2008 and 2014/2015 suggested annual litterfall ranges between 1.225 and 1.43 Mg C ha⁻¹ yr⁻¹ (also see Fischer et al. 2024).

Mean site temperature is ~10°C and an average annual rainfall of 127 cm with high precipitation from October to March and low precipitation from April to September (cooperative climatological data summaries, Western Regional Climate Center; <https://wrcc.dri.edu>)

The soils are characterized largely as Alderwood Gravelly Sandy Loams and Giles Silt Loams, with parent material of volcanic ash and glacial outwash (USDA web soil survey; <https://websoilsurvey.sc.egov.usda.gov>). These soils have thick O horizons, thin A horizons, and thick B horizon development, with the majority of the soil C located in the upper 30 cm (Fischer et al. 2024).

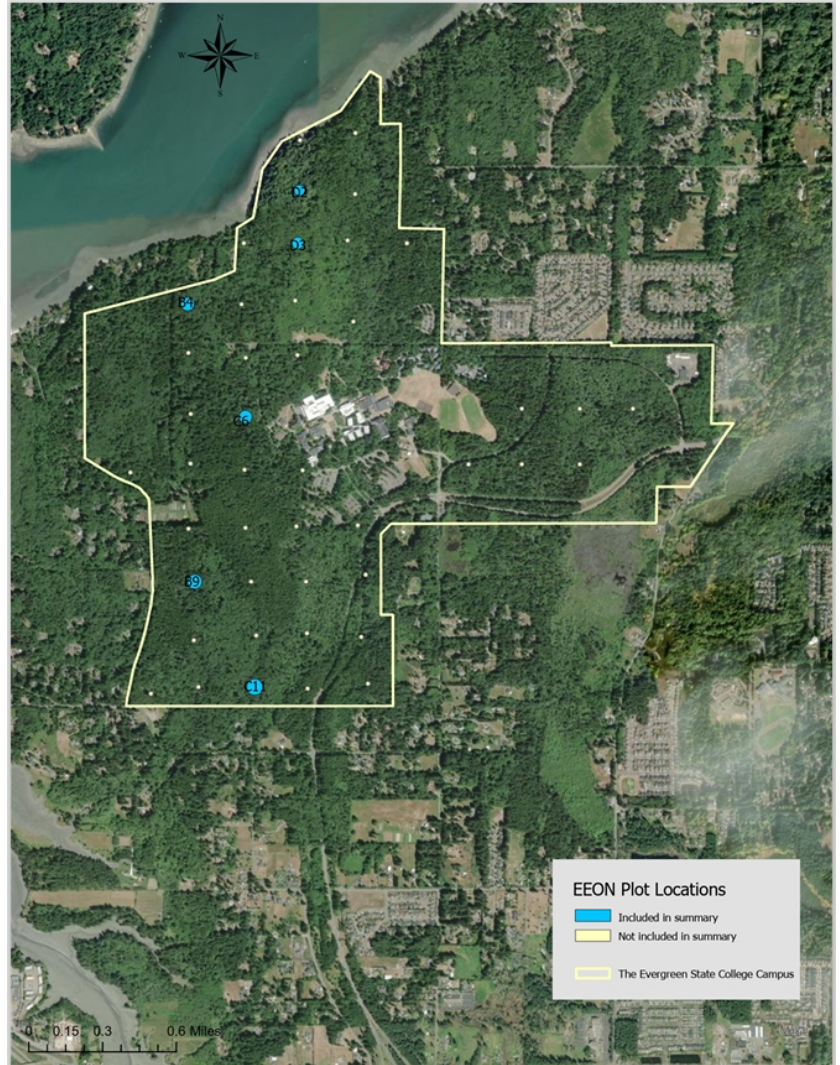


Figure 1. Map of the EEON sampling network in the Evergreen State College Forest Reserve. Yellow points represent plot locations. Blue points represent locations chosen for intensive C inventory in this report.

Aboveground Biomass:

Aboveground biomass was estimated using the diameter at breast height (DBH) of all living trees with a DBH greater than ten centimeters inside the plot boundary of each EEON plot and then applying standard national scale biomass estimation equations. The biomass equations were taken from the national-scale equations developed by Jenkins et al. (2003), and in this schema individual species (e.g., *Pseudotsuga menziesii*) or groups of similar species (e.g., the soft maples including *Acer macrophyllum*) are each given unique equations that are applied to each tree and used to estimate each tree's biomass. It is important to assign each unique species its specific equation because species of trees have different wood densities, which could lead to a significant difference between actual biomass in a forest and the biomass of a forest if a single equation was used for all trees. These equations provide a value for tree biomass (kg) which were then converted into megagrams (Mg), and the plot area was converted from square meters to hectares giving a biomass unit of Mg ha⁻¹. Biomass values were halved to approximate a carbon (C) value for the plot, as is typically done in many aboveground C studies, because carbon typically constitutes ~50% of total plant biomass (Clark et al. 2001).

Snags and Large Woody Debris:

Snags were counted in each plot and defined as dead trees that were still standing, with stumps included. Large woody debris (LWD) was defined as logs or large fallen branches with a DBH of at least 10 cm at the largest end.

For large woody debris, each instance had its length measured and recorded, along with the diameter at the center and both ends. These measurements were taken with a meter tape and a DBH tape. If LWD was too entrenched in the ground to wrap the DBH tape all the way around, then the tape was wrapped halfway around it and the resulting length was doubled. If a log fell and broke into multiple pieces, it was counted as one piece of LWD with total length estimated by subtracting the length of the spaces in-between, and a note made of how many pieces it was in. If a piece of LWD was partially inside and partially outside the plot, it was measured to the edge of the plot, not the end of the debris; effectively, any part of the LWD that was outside plot boundaries does not exist for the purpose of measurements in this report.

For both snags and large woody debris, the species was estimated and recorded, as well as the decay stage for the snags and decay class for logs and LWD.

Understory:

Understory measurements were taken for both saplings and forest floor species *sensu* Rex et al. (2023). Briefly, we used point-line-intercept transects to assess forest floor vegetation

community composition, abundance, and richness. In each plot, four 10 m transects were laid out in the cardinal directions from the center to the plot edges. Intercept points were marked every 10 cm, recording each vascular plant species between 0 and 3 m in height once per point. Data from the transects were averaged to estimate percent cover and total understory cover was calculated as the sum of all species cover percentage.

Saplings were counted as trees measuring less than 5 cm DBH, but greater than 2 m tall. Each sapling had its plot location recorded by quadrant (NW, NE, SW, SE) and a raw count of each species of saplings was taken and converted to biomass based on average estimates from destructively sampled samplings in 2008.

Soil OM Layer:

Organic matter and Fine woody debris (FWD) were sampled from the floor of each EEON plot to assess the magnitude and composition of the soil organic layer. Approximately 25cm by 25cm PVC quadrats were used to define the collection zones, which were placed 10 meters from plot center in each of the four cardinal directions. The exact dimensions of each quadrat were recorded so they could later be used in calculations. A knife or trowel was used to cut through the organic material along the inner edges of the quadrat to limit debris quantified to the discrete sub-sampled area. The organic layer was defined as materials whose original form (example: leaf, twig, seed) was still discernible. Mineral soil, roots, and matter decomposed beyond recognition were left in place.

After collection, the organic layer samples were transported to the lab for processing. Samples were oven-dried at 70°C for a minimum of 72 hours. Either before or after drying, material was sorted into four categories: needles, leaves, cones, and twigs/sticks/branches. Dry weights for each FWD category were recorded and used to interpolate FWD biomass.

Additional testing was performed to determine the percentages of organic matter, C, and nitrogen (N) in the samples. Subsamples were weighed, processed in a muffle furnace at 500°C for 5 hours, then weighed again. The percentage of organic matter was calculated based on subtraction of post-combustion ash mass from dry pre-combustion subsample mass. Samples were also tested with a Perkin Elmer CHNS/O 2400 elemental analyzer (PerkinElmer, Inc., Waltham, MA USA) to determine their C and N content.

Soils:

Soil C content was measured by coring each notable soil horizon in six soil 1 m deep pits in the west portion of the forest reserve. The pits were labeled according to dominant tree species in the surrounding flora as “conifer” or “alder” pits. The soil cores were 10 cm long, cores were inserted horizontally in each pit, and core volumes were ~237 cm³.

The cores were then transferred to the lab in plastic bags. In the lab, soil cores were dried in an oven and sieved. Some cores were dried first and then sieved, and others were sieved first. The drying process took place over the course of >4 days at 75°C until constant weight was achieved. The sieves have two mesh sizes, separating the soil by three particle sizes: the top sieve had a mesh size of 2.0 mm, the second sieve mesh size was 0.5 mm, and a bottom tray collected particles smaller than 0.5 mm. The fine fraction mass was comprised of particle sizes < 2.0 mm (contained in the second sieve and bottom tray).

Following the sieving, some (approx. 5-10 g) of the fine fraction was placed into a pre-weighed crucible and dried in an oven until there was no change in mass. The crucibles were then placed in a muffle furnace at a temperature of 500 °C which was maintained for five hours, bookended with a one-hour ramp-up and one-hour ramp-down period. Post muffle furnace combustion, the crucibles were stored in a desiccator to prevent absorbing moisture. Once cooled, the crucibles were weighed. The resulting weight was non-organic ash, which was subtracted from the original dry weight to determine ash-free dry mass (organic material), which is approx. 50% C.

Soil Respiration:

Soil respiration was measured using a soda lime method adapted from Keith and Wong (2006). Approximately 50g of soda lime granules (a mixture of NaOH and CaOH₂) were placed in each glass jar, oven-dried, reweighed, and sealed. In each EEON plot, four prepared jars were opened and placed under plastic chambers located along the four cardinal directions from plot center (separated by approximately 10 m). After 24-48 hours the jars were collected, then dried and weighed again. In each location, a sealed control jar was also deployed to account for non-soil-related ambient CO₂ present within the jars prior to and during deployment. The CO₂ adsorbed due to carbon efflux of the soil area within the chamber was then calculated using the following equation:

Soil CO₂ Efflux (F) (mmol C m⁻² day⁻¹) =

$$\left[\frac{\Delta mass_{sample}(g) - \Delta mass_{control}(g)}{chamber\ area\ (m^2)} \right] \times 1.69^* \times \left[\frac{exposure\ duration\ (hr)}{24\ (hr)} \right] \\ \times \left[\frac{12\ (g)\ carbon}{44\ (g)CO_2} \right] \times \left[\frac{1000\ mmol\ carbon}{12.0107\ g\ carbon} \right]$$

**note: 1.69 is the stoichiometric conversion factor to account for water generated by the carbon adsorption reaction, then lost during drying. (Grogan, 1998)*

Decomposition:

Leaf decomposition rates were measured by deploying bags of leaf litter to each plot. *Acer macrophyllum* leaves were used in experiments spanning 2022-2024, and *Alnus rubra* and *Populus trichocarpa* leaves were deployed in December 2024 to be collected in 2025. In the *A. macrophyllum* trials, approximately 1.0 g of dried leaves was added to each bag, whereas approximately 2.0 g per bag was used in the *A. rubra* and *P. trichocarpa* trials. Regardless of species and mass, leaves were placed into plastic mesh bags along with a metal tag for later identification. Bags were sealed, then placed in paper bags so that any litter lost during transport and handling could be quantified.

A series of bags was installed in contact with the forest floor at each plot. Bags were collected periodically, dried and reweighed so that mass lost due to decomposition over time could be quantified. The percent of mass remaining for each harvest date was calculated by dividing the final weight by the difference between the initial weight and the handling loss. Leaf decomposition over time typically follows an exponential decay curve, with labile sugars breaking down first and more recalcitrant forms of organic C like lignin and cellulose following later (Minderman, 1968). For each plot, the decay constant (**k**) was found by plotting the natural logarithm of the percent mass remaining versus time, then finding the linear best fit curve for the data set; The slope of this line is the decay constant (e.g., as in Keuskamp et al, 2013, LeRoy and Fischer 2019) This relationship can be summarized by the equation below,

$$\ln(\text{percent mass remaining}) = kt + b$$

where **t** = time(years) and **b** = y-intercept. Note that **b** will typically equal approximately $\ln(100)$, because at **t** = 0, the mass remaining will be close to 100%.

Results and Discussion:

Aboveground Biomass:

Carbon in aboveground biomass averaged 205.60 Mg C ha⁻¹ in 2008, and increased to 258.83 Mg C ha⁻¹ in 2021, and again to an average of 356.647 Mg C ha⁻¹ in 2024 (based on 6 plots only; Table 1). The average percent change from 2021 to 2024 was 37.79% and the average percent change from 2008 to 2024 was 73.47%.

Table 1. Carbon pools in EEON plots in 2024.

Plot (2024)	Aboveground Tree C (Mg ha ⁻¹)	Snag and LWD C (Mg ha ⁻¹)	Understory C (Mg ha ⁻¹)	Soil C (Mg ha ⁻¹)
B4	513.68	19.86	0.65	30.59
C6	253.98	9.80	0.22	Not Measured
D2	420.58	77.42	1.08	71.47
B9	269.66	7.80	0.43	38.74
D3	200.70	6.79	0.61	36.12
C11	481.28	176.43	1.25	45.01

Rates of change may have potentially shifted through time, but apparent shifts may also be due to changes in which plots were measured. From 2008 to 2021, the yearly average percent change using all plots in the EEON network (Table 2) was +12.60% yr⁻¹, but between 2021 to 2024, the yearly average percent change was 1.99% yr⁻¹. However, the 2024 data were from only six plots. Considering only the six plots measured in 2024, the average yearly increase was 4.07% between 2021 and 2024, and 2.91% between 2008 and 2024.

Table 2. Plot C change in aboveground biomass from 2008-2021

Plot	Dominant Trees	Total Aboveground C 2008 (Mg ha ⁻¹)	Total Aboveground C 2021 (Mg ha ⁻¹)	Average Net C sequestration in aboveground Biomass (Mg ha ⁻¹ yr ⁻¹)
B4	ACMA/ PSME	406.09	487.56	5.82
B9	N/A	124.92	161.0	2.58
C6	PSME	188.64	241.83	3.80
C11	PSME	387.15	490.24	7.36
D2	THPL	263.57	331.97	4.89
D3	ACMA	169.65	211.22	2.97
Average	PSME/ALRU/ACMA	205.60	258.83	3.92

Snags and Large Woody Debris (LWD):

When combining C in snags and large woody debris across measured plots in 2024, we measured an average of 49.68 Mg C ha⁻¹, although over half of this C comes from a single plot, C11. The plot C11 had 176.43 Mg C ha⁻¹, which accounts for 59.18% of the total C (298.1 Mg C ha⁻¹) contained in snags and LWD across all plots. In this plot, there is a significant amount of new woody debris as a result of wind damage. Excluding this outlier plot, the average C in this pool was 24.33 Mg C ha⁻¹.

In 2008, the average C in snags and LWD was 26.56 Mg C ha⁻¹, across the entire EEON plot network (Kirsch et al. 2012). This is very similar to the average carbon in 2024 when the outlier plot was excluded.

Understory: Understory layers typically represent a relatively small proportion of total forest carbon. In 2024, we found an average of 0.71 Mg ha⁻¹ C for the understory. This represented 0.14% of the Average Total Plot C in 2024.

Soil OM Layer:

In 2025, carbon in soil OM layers and fine woody debris averaged 8.06 Mg C ha⁻¹, which was slightly less than the average of 9.02 Mg C ha⁻¹ in 2008. Nevertheless, 95% confidence intervals around the 2025 value were approximately 1.7, suggesting that the most recent 2025 values overlap strongly with the 2008 values. In both years, OM C was less than 10 Mg ha⁻¹, or 30-50% of LWD and snag C, and 3-5% of aboveground biomass C values.

Soils:

Soils sampled within 1-m deep pits demonstrated a typical pattern of rapid reductions in soil C with depth, where highest C values were in the top 10 cm, most soil C was located between 0-30 cm, and minimal amounts were found with depth (Figure 2). Soil C in the top 10 cm represented approximately 38% of all soil carbon measured to 1m. We determined this value by fitting a third-order polynomial to a carbon (g cm⁻³) by depth scatterplot, and then using integral calculus to derive the total carbon between 0-100 m. We then divided the average C in the 0-10 cm samples by the total from 0-100 cm.

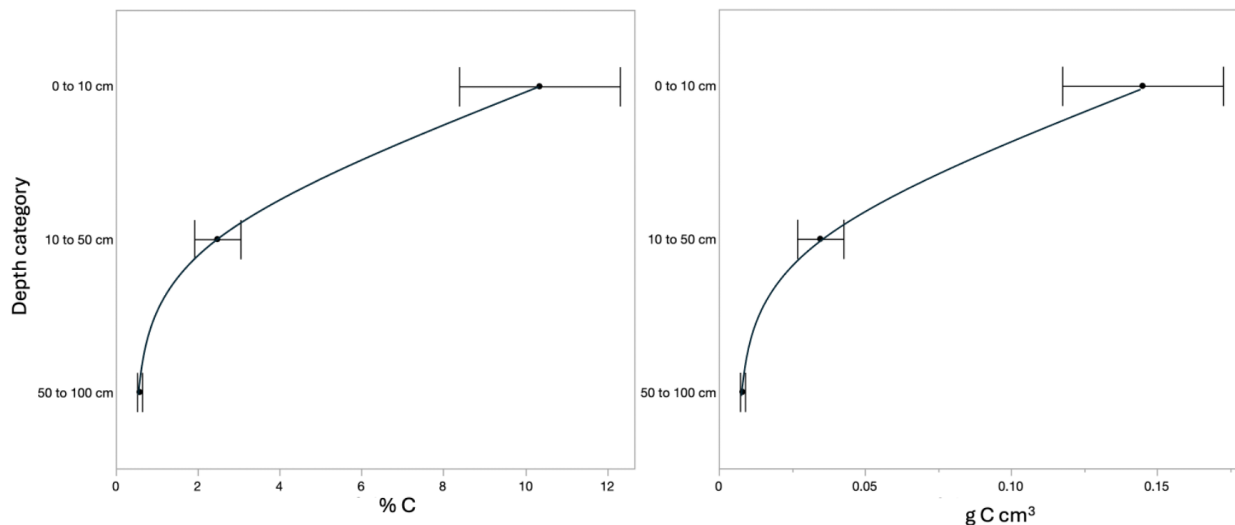


Figure 2. Soil C with depth. Left panel shows %C change with depth based on elemental analysis. The right panel shows total C per cm³ after multiplying % C by bulk density. Error bars represent 95% confidence intervals around mean values.

Accordingly, soil C content in plots represented in 1-10 cm was divided by 0.38 to estimate 0-100 cm depth C within each plot. In general, soil C within our intensively sampled plots

did not indicate a clear association with aboveground C. Soil values (Table 1) varied between 30.59 and 71.47 Mg C ha⁻¹.

Decomposition and soil respiration

Annually litter decomposition suggests consistent accretion of material in the soil O horizons annually (Table 3). Decomposition rates are < 1 y⁻¹, showing leaves do not completely decompose over the course of a year. In fact, when we collected leaves decomposing over a 2-year time frame (2022-2024), we found mass had changed very little since the end of year 1 of decomposition. Extrapolation of soil respiration rates (Table 3) over the course of a year suggests an annual loss of approximately 12.2 Mg C ha⁻¹ yr⁻¹, more than 50% of which is likely due to respiration of recently fixed C by plants belowground.

Table 3. Decomposition and soil respiration rates.

Plot	Leaf Decomposition (K, yr ⁻¹)	Soil Respiration (mmol C, m ⁻² day ⁻¹)
B4	-0.9041 (1-2 mos. harvest only)	317.46
C6		318.75
B9		284.61
D3	-0.35 (2-year harvest)	161.15
C11		343.84
D2	-0.3172 (2-year harvest)	247.13

Plot C change:

In 2008, total aboveground C stores in the six intensively monitored plots averaged 429.7 Mg ha⁻¹, and this pool increased to 484.2 by 2024 (Table 4). This change reflects an approximately 3.4 Mg ha⁻¹ yr⁻¹ flux into forest vegetation. This flux was variable by plot, however, and ranged from just 0.21 to > 9 Mg ha⁻¹ yr⁻¹. Such variability may reflect small-scale changes in individual plots where loss of single trees can significantly reduce C storage, and ingrowth of trees previously counted as saplings (or previously too small to measure) can result in dramatic increased in C.

Table 4. Total Plot C Change 2008 – 2024 (Excluding Soil)

Plot	Total Plot C 2008 (Mg C ha ⁻¹)	Total Plot C 2024 (Mg C ha ⁻¹)	Change in C (Mg ha ⁻¹ yr ⁻¹)
B4	602.89	628.8	1.62
B9	346.42	349.72	0.21
C6	278.68	323.53	2.80
C11	588.10	745.15	9.82
D2	523.44	602.57	4.95
D3	238.90	255.71	1.05

Correlations:

Carbon pools are correlated at some scales and not others. We found strong correlations between measurements of total aboveground standing mass in 2008, 2021, and 2024 (represented as aboveground tree C) (Figure 3). Net rates of C sequestration were also correlated with total aboveground mass and tree C in all years. Soil respiration was correlated with aboveground C in all years, but this correlation was relatively weak ($r = 0.53-0.59$; Figure 3). Some other interesting correlations included correlations between snag and LWD C and standing aboveground and tree C, and with Net C sequestration in aboveground C. Understory C was also positively correlated with other aboveground C pools and C sequestration rates but not soil respiration (Figure 3). Soil C was generally not well-correlated with aboveground C measures.

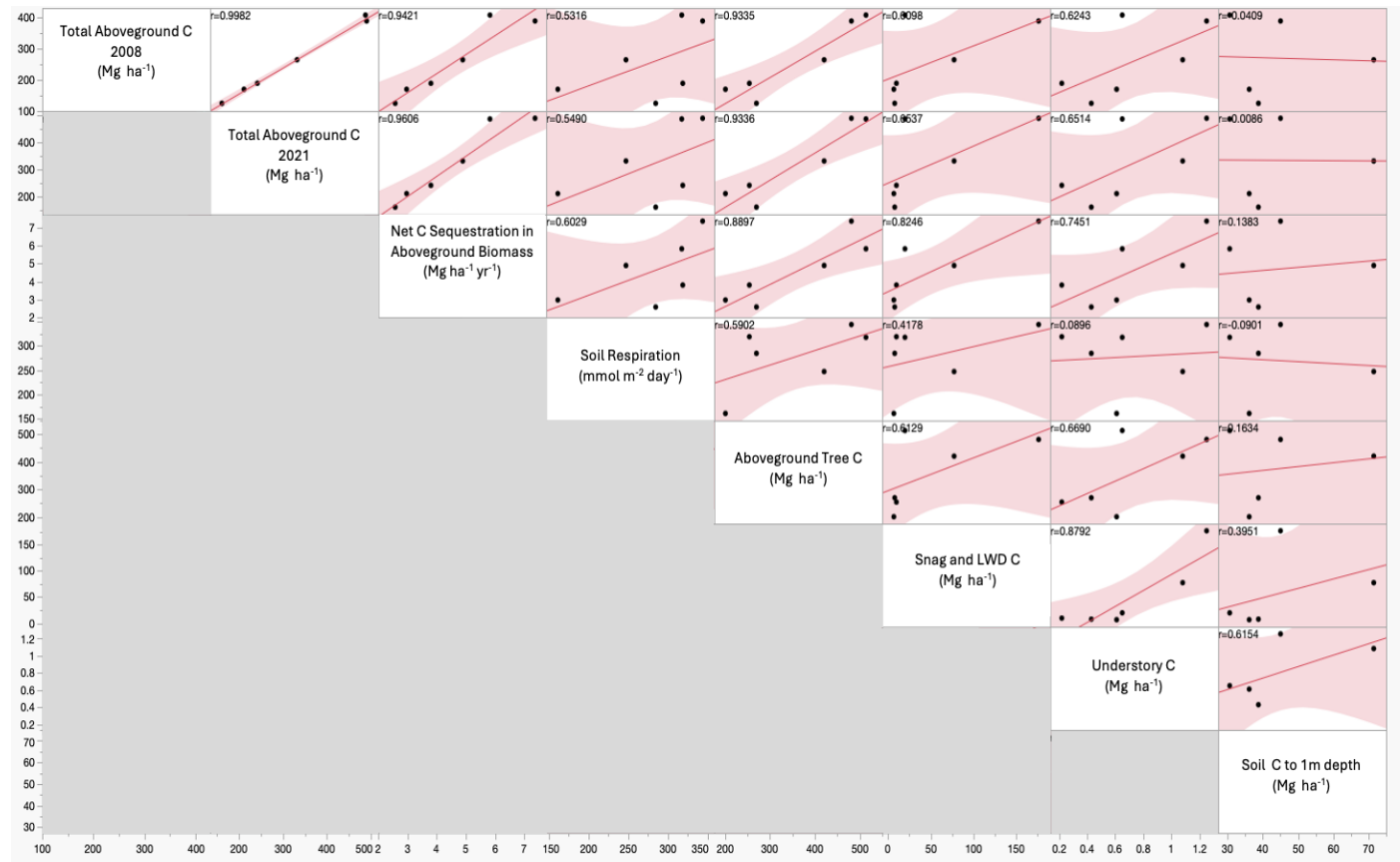


Figure 3. Correlations between C pools and fluxes. Pool and flux values are given along the x and y axes, while units are given in the central white boxes with parameter labels.

Context and Conclusions:

Over-all, these data show high values of C storage and sequestration. While these values are especially high compared to regional estimates of C density in forests (Gray and Whittier 2014, Hoover and Smith 2021), they are still low compared to the most productive forests in the PNW region. For example, young *Sequoia sempervirens* (redwood) forests may have a maximum carbon accretion rate of $>16 \text{ Mg C ha}^{-1} \text{ year}^{-1}$ (Jones and O'Hara 2012). Such forests may reach C density values of $> 1000 \text{ Mg ha}^{-1}$. Meanwhile, regional estimates of *Pseudotsuga menziesii* forest suggest an average of 143 Mg C ha^{-1} and $1.82 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$ in annual sequestration. More localized estimates of forest C pools and fluxes in national forests across the Pacific Northwest suggest our forest pool and flux estimates agree well with estimates from lower-elevation forests of the Olympic Peninsula (Gray and Whittier 2014). Afforestation and forest growth in similar low-elevation habitats in our region could have similar high C sequestration rates, and could increase regional C uptake. The forest in our study represents a case study in the potential for low-elevation forests to sequester high amounts of C in forest vegetation.

Acknowledgements:

We would like to thank the science support staff and other supportive students at the Evergreen State College. We especially thank Joseph Stevic who provided field and gear support for all measurements. We also give sincere thanks to Dr. Lydia McKinstry, who co-taught the Science of Carbon Program at the Evergreen State College in 2024/2025. Finally, many thanks to the students in the Science of Carbon program who were unable to continue in winter 2025, but helped conduct these measurements in fall, 2024.

References:

- Barron-Gafford, G.A. et al. (2011). The relative controls of temperature, soil moisture, and plant functional group on soil CO₂ efflux at diel, seasonal, and annual scales. *Journal of Geophysical Research: Biogeosciences*, 116(G1). <https://doi.org/10.1029/2010JG001442>
- Clark, D.A., Brown, S., Kicklighter, D.W., Chambers, J.Q., Thominson, J.R., & Ni, J. (2001). Measuring net primary production in forests: Concepts and field methods. *Ecological Applications*, 11(2), 356–370.
- Fischer, D. G., Chamberlain, Z. R., Cook, C. E., Martin, R. A., & Mueller, L. O. (2024). Long-term patterns in forest soil CO₂ flux in a Pacific Northwest temperate rainforest. *Forests*, 15(1), 161. <https://doi.org/10.3390/f15010161>
- Franklin, J. F., & Dyrness, C. T. (1973). *Natural vegetation of Oregon and Washington* (Vol. 8). US Government Printing Office.
- Gray, A. N., & Whittier, T. R. (2014). Carbon stocks and changes on Pacific Northwest national forests and the role of disturbance, management, and growth. *Forest Ecology and management*, 328, 167-178.

Grogan, P. (1998). CO₂ flux measurement using soda lime: correction for water formed during CO₂ adsorption. *Ecology*, 79(3), 1467–1468.

Harmon, M.E. & Hua, C. (1991). Coarse woody debris dynamics in two old-growth ecosystems. *BioScience*, 41(9), 604–610. <https://doi.org/10.2307/1311697>

Hoover, C.M. and Smith, J.E., (2021). Current aboveground live tree carbon stocks and annual net change in forests of conterminous United States. *Carbon Balance and Management*, 16(1), p.17.

Jenkins, J.C. et al. (2003). National-scale biomass estimators for United States tree species. *Forest Science*, 49(1).pp. 12-35.

Jones, D.A. and O'hara, K.L., (2012). Carbon density in managed coast redwood stands: implications for forest carbon estimation. *Forestry*, 85(1), pp.99-110.

Keith, H. & Wong, S. (2006). Measurement of soil CO₂ efflux using soda lime absorption: both quantitative and reliable. *Soil Biology and Biochemistry*, 38(5), 1121–1131. <https://doi.org/10.1016/j.soilbio.2005.09.012>

Keuskamp, J.A., Dingemans, B.J.J., Lehtinen, T., Sarneel, J.M., & Heffting, M.M. (2013). Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. *Methods in Ecology and Evolution*, 4(11), 1070–1075. <https://doi.org/10.1111/2041-210X.12097>

Kirsch, J. L., Fischer, D. G., Kazakova, A. N., Biswas, A., Kelm, R. E., Carlson, D. W., & LeRoy, C. J. (2012). Diversity-carbon flux relationships in a northwest forest. *Diversity*, 4(1), 33-58.

LeRoy, C. J., & Fischer, D. G. (2019). Do genetically-specific tree canopy environments feed back to affect genetically specific leaf decomposition rates?. *Plant and Soil*, 437, 1-10.

Minderman, G. (1968). Addition, decomposition and accumulation of organic matter in forests. *Journal of Ecology*, 56(2), 355–362. <https://doi.org/10.2307/2258238>

Pan, Y., Birdsey, R.A., Phillips, O.L., Houghton, R.A., Fang, J., Kauppi, P.E., Keith, H., Kurz, W.A., Ito, A., Lewis, S.L., & Nabuurs, G.J. (2024). The enduring world forest carbon sink. *Nature*, 631(8021), 563–569.

Rex, I., Fischer, D.G., & Bartlett, R. (2023). A decade of understory community dynamics and stability in a mature second-growth forest in western Washington. *Northwest Science*, 96(3-4), 164–183.