Valuing Select Tree Species for Stormwater Benefits in the South Puget Sound

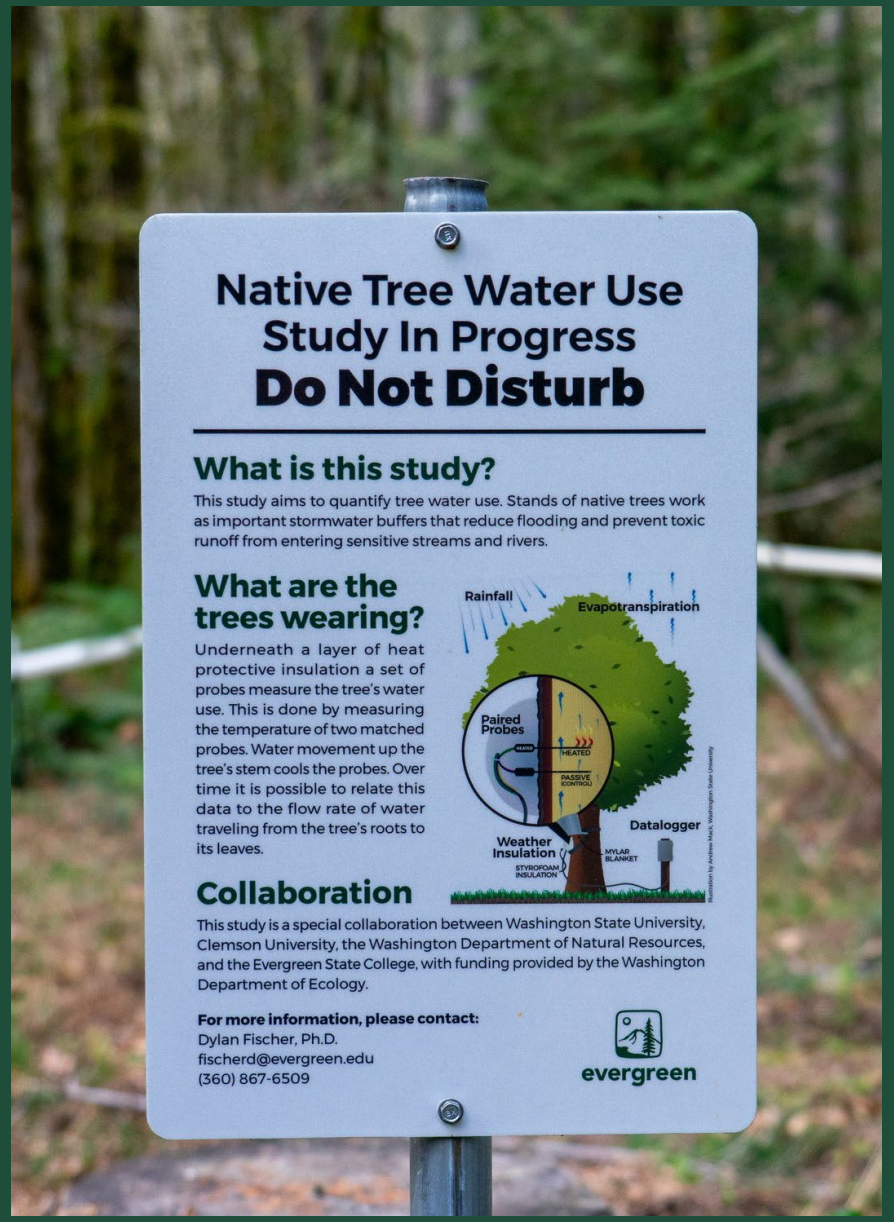
Quantifying canopy interception and transpiration over two years in the Puget Sound lowland

Douglas-fir **western redcedar** **bigleaf maple** **red alder**

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RESEARCH CONTEXT

What we know — and the gap this study fills

Most prior work

- Young street trees or non-native cultivars
- Engineered settings (rain gardens, planters)
- Single mechanism — interception or transpiration
- Short records; few native-forest measurements

This study

- Mature native trees in real forest stands
- Rural–urban interface of the Puget lowland
- Both mechanisms measured on the same trees
- Two full years spanning ~30% difference in rainfall

The gap: the stormwater value of mature native conifers and broadleaf trees — the stands most often cleared during development — has never been quantified together in this region.

OBJECTIVES

What we set out to answer

01

Does species matter?

How do transpiration and interception differ among Douglas-fir, western redcedar, bigleaf maple, and red alder?

02

Does season matter?

How does canopy phenology (leaf-on vs. leaf-off) reshape each species' water use across the year?

03

What drives it?

Which environmental factors — VPD, rainfall, soil moisture — control water use, and what does that mean for stormwater?

Framed formally as six hypotheses on species, seasonal, and environmental controls of the tree water budget.

TREES AS GREEN INFRASTRUCTURE

Two canopy processes move rainfall back to the atmosphere

DURING STORMS

Interception

The canopy traps and evaporates rainfall back to the atmosphere. Bark channels the remainder down the stem as stemflow.

BETWEEN STORMS

Transpiration

Trees draw soil water up through the xylem and release it as vapor, drying the soil so it can absorb and store the next storm.

Together, these two fluxes are the water a tree removes from the stormwater balance — the two processes this study set out to measure.

PART II

Methods

Measuring the tree water budget — sap flux, throughfall, and stemflow on 64 trees at two forested sites.



METHODS · STUDY DESIGN

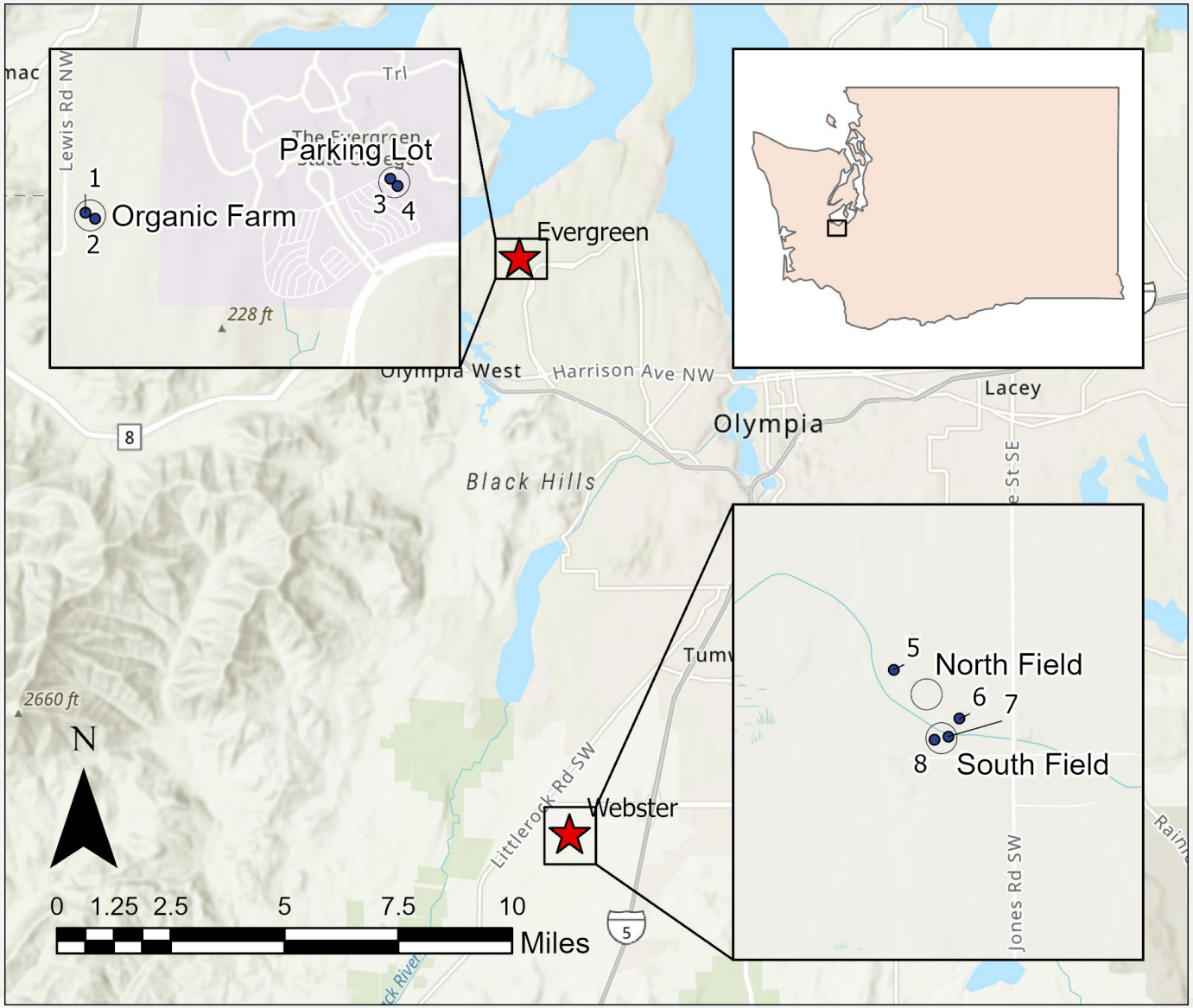
The study at a glance

64	4	2	8	2 yr	3
mature trees (DBH > 30 cm)	**native** species	**forested** sites	**plots** (4 per site)	**continuous** record	**water fluxes** measured

Sap flux (**64 trees**); throughfall (**38**) & stemflow (**24**) Plot-scale weather, soil moisture, & canopy-VPD sensors.



Two second-growth stands near Olympia, Washington



Evergreen (The Evergreen State College) and **Webster** (DNR Forest Nursery) 8.7 miles apart.

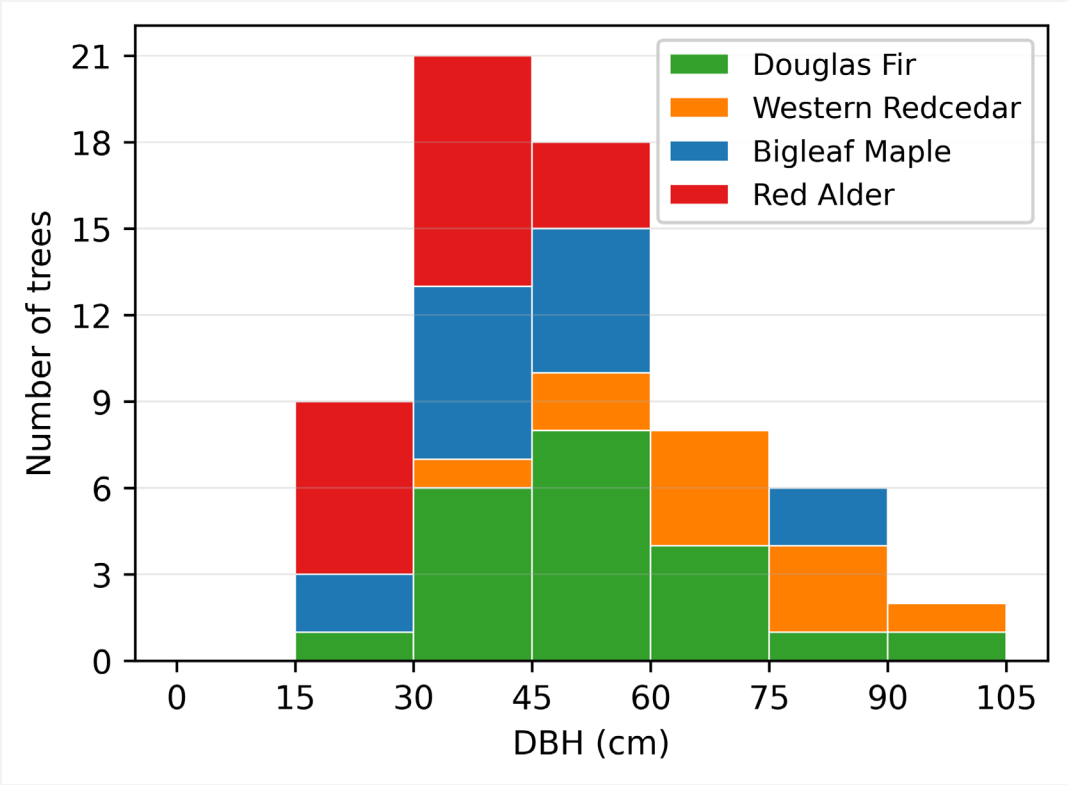
- Closed-canopy stands, ~50–90 yr old
- Mediterranean climate: wet winters, dry summers
- Glacial soils; floodplain and upland plots

METHODS · SPECIES

Four species that define the lowland forest



Douglas-fir	western redcedar	bigleaf maple	red alder
21 trees	11 trees	15 trees	17 trees



Mature size class: most trees 30–75 cm DBH, consistent with second-growth stands.

METHODS · TRANSPIRATION

Sap flux — measuring how much water each tree moves

- **Thermal-dissipation probes** 64 trees every 15 minutes.
- **Radial sampling** multiple probe depths, scaled by tree diameter.
- **Sapwood area** dye tests and species allometry.
- **Canopy area** drone imagery -> water use per unit canopy.
- **Environmental covariates** — VPD, radiation, soil moisture.



Paired thermal-dissipation probes set into the outer sapwood.

Two probe deployments (2019–2021) provided a continuous, quality-controlled transpiration record

METHODS · INTERCEPTION

Throughfall and stemflow — tracking the rain the canopy holds



Throughfall troughs



Stemflow collars

- **Throughfall** beneath 38 trees — paired PVC troughs (and profile gauges) draining to tipping-bucket rain gauges.
- **Stemflow** on 24 trees — sealed foam collars routing bole flow into collection vessels.
- **Storm events** delineated from on-site weather stations (6-hr inter-event, ≥5 mm).
- **All gauges** calibrated and normalized to open-canopy rainfall before analysis.

Interception = Rainfall − (Throughfall + Stemflow)

Interception estimated by difference for every tree and qualifying storm.

PART III

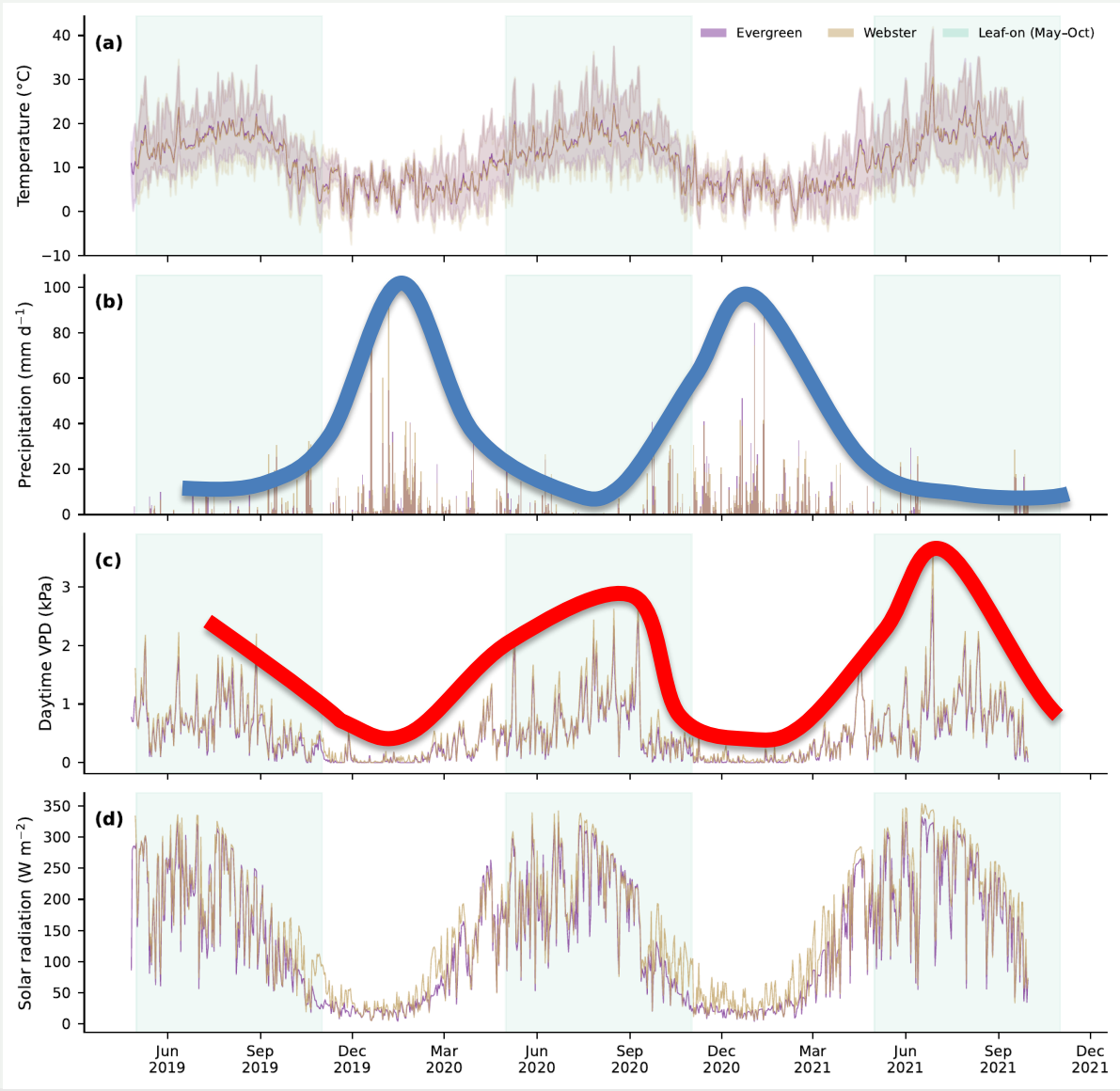
Results

What the four species revealed about the canopy water budget — and where it defied expectations.



Rain and evaporative demand are out of phase

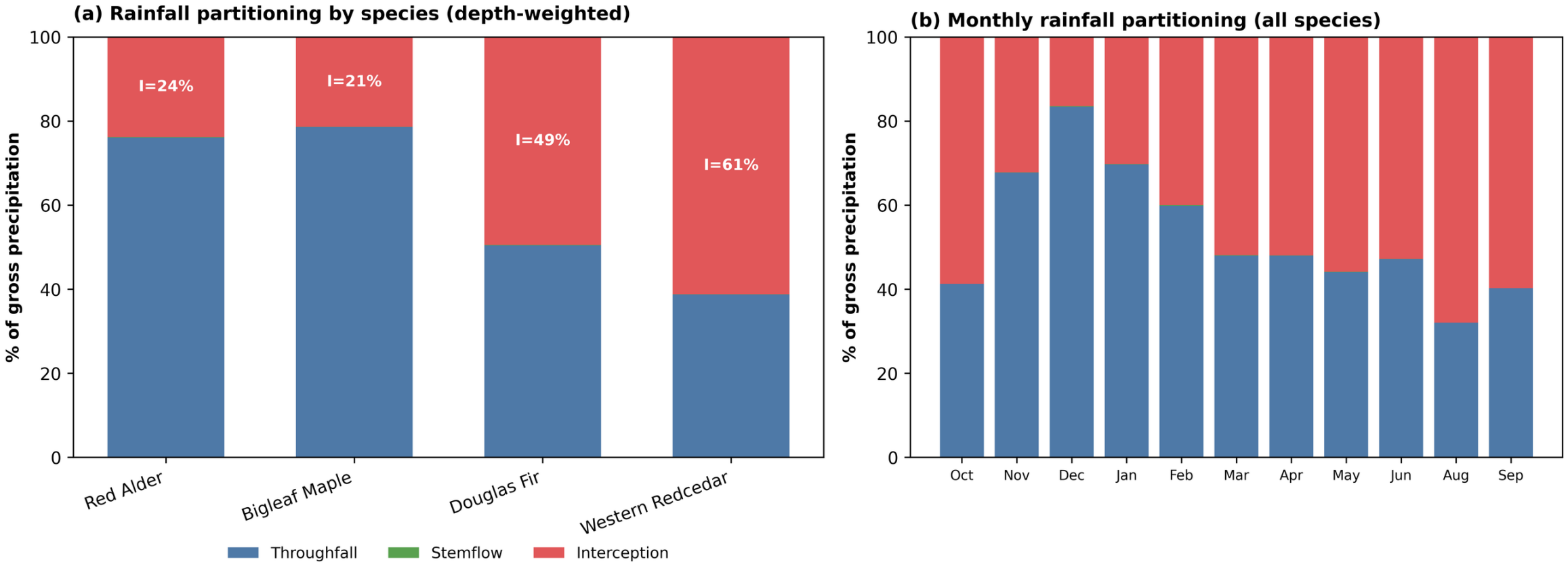
- **Rain** Both years were wet (**2,855–3,402** mm)
- **Rain** fell mostly October - May.
- **VPD and solar radiation** peaked May–September.
- **Soils** dried through summer, recharged each fall.



Why it matters for stormwater

Interception carries the wet season — big storms, most runoff, too cold to transpire. Summer transpiration then empties the soil reservoir to absorb the next storms. And through the spring and fall **shoulders — scattered storms after dry spells, the heaviest first-flush loads, peak salmon migration —** the conifers keep working.

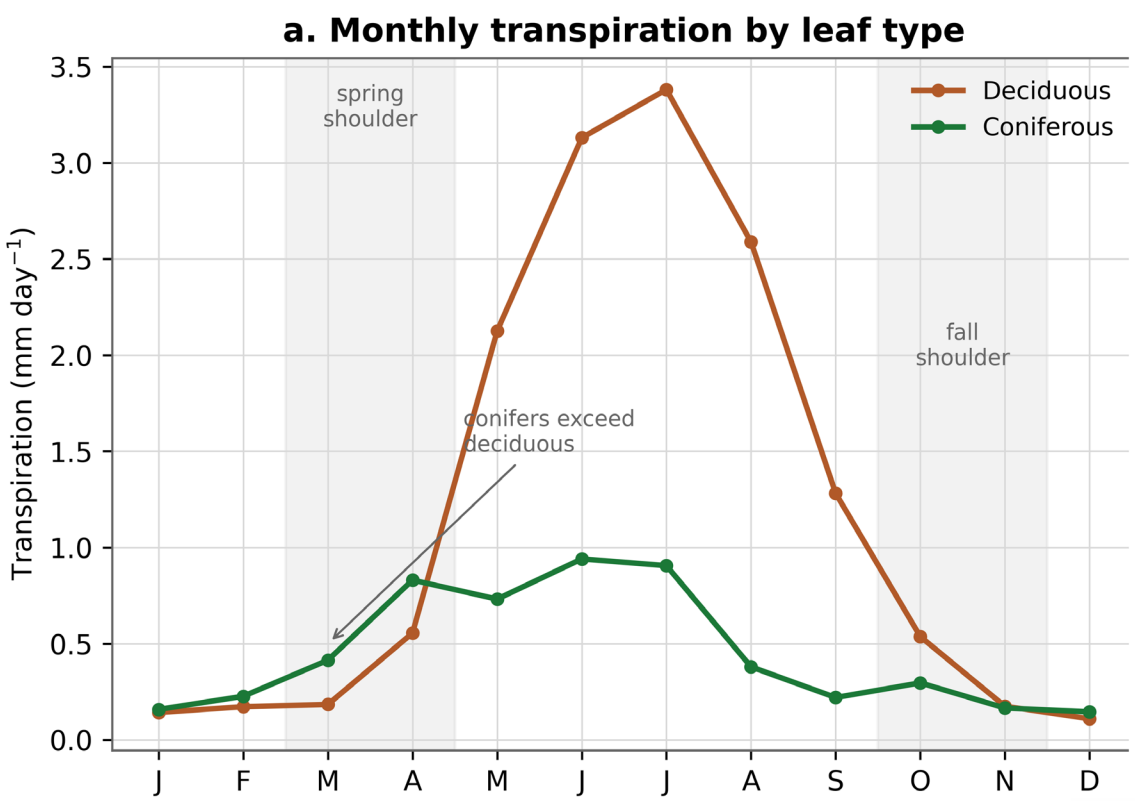
Evergreens intercepted more rainfall

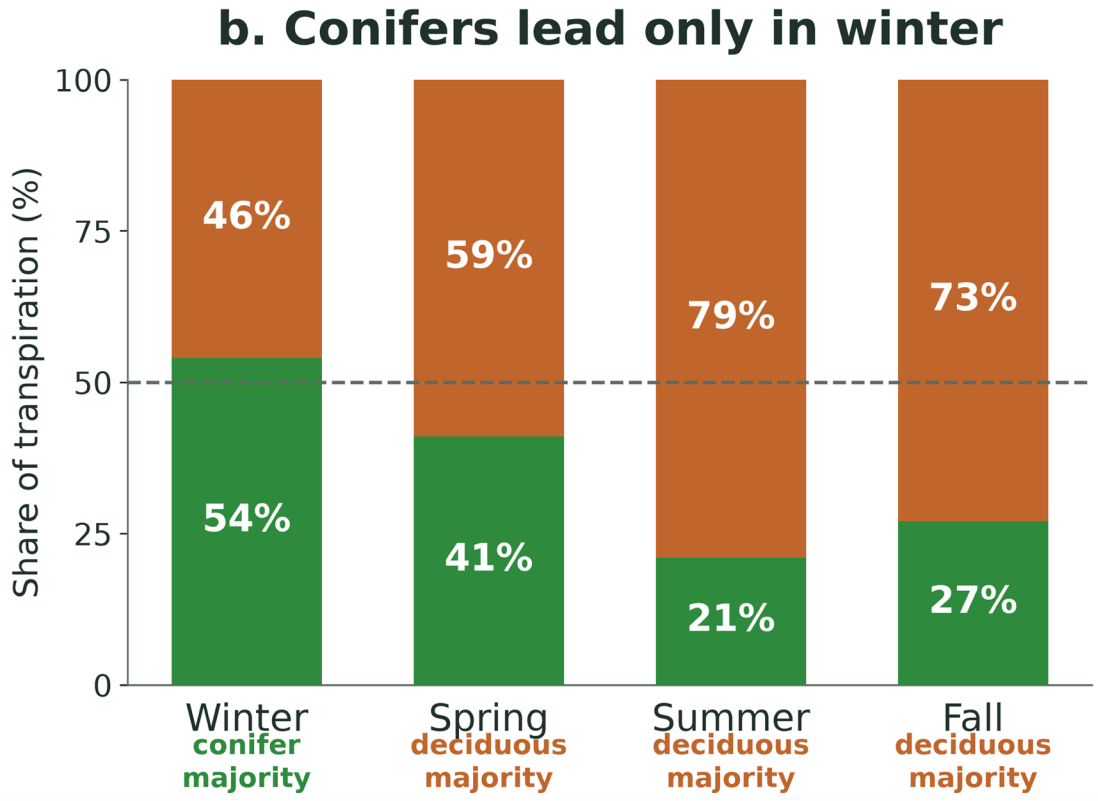


Depth-weighted canopy interception: western redcedar 61% and Douglas-fir 49% — roughly **2–3× the deciduous broadleaves** (red alder 24%, bigleaf maple 21%).

Interception was lowest during large winter storms and highest during small summer storms.

Deciduous dominate spring–fall; conifers hold the winter





By season: conifers hold the transpiration majority in winter (54%). Deciduous lead spring, summer, and fall, & overwhelmingly in summer.

Why the shoulders still matter

Conifers never fully stop. In the leafless weeks they out-transpire the dormant broadleaves, keeping the canopy active for the high-ADP shoulder storms — biggest first-flush loads, salmon season.

RESULTS · TRANSPIRATION

Bigleaf maple moved the most water

bigleaf maple

1.89

mm / day (2-yr mean)

red alder

0.94

mm / day (2-yr mean)

Douglas-fir

0.58

mm / day (2-yr mean)

western redcedar

0.32

mm / day (2-yr mean)

The deciduous broadleaves out-transpired the conifers through the growing season — **bigleaf maple's leaf-on use reached 158% of monthly rainfall.**

But this is a summer story — vapor-pressure deficit sets the timing. Bigleaf maple ramps up steeply with atmospheric demand; the conifers regulate conservatively yet stay active year-round, holding the winter and keeping the canopy working when the broadleaves are bare.

INTERPRETATION

Two benefits, two seasons —mechanisms are complementary

WET SEASON

Interception leads

- Large winter storms, greatest runoff risk
- Evergreen conifers keep 50–61% in the canopy
- Broadleaves are leafless — conifers still transpire at low rates

DRY SEASON

Transpiration leads

- Little rain to intercept
- Deciduous broadleaves lead — summer use often exceeds rainfall
- Soil water is drawn down, restoring storage for the next wet season

A mixed native canopy covers both seasons — the full year of the stormwater problem, not just the storms.

PART IV · PHASE II

From the forest to the street

A separate study that carried Phase I’s questions to young urban and street trees — with a new portable mobile sap-flux sensor.

Distinct trees, sites, and years. Phase II led by Dylan Fischer, Ani Jayakaran & Steven Quick.



PHASE II · WHAT IT ADDED

From remnant forest trees to the urban canopy

Young urban & street trees

Trees instrumented in developed settings — parking lots and street edges on the Evergreen campus.

A portable mobile sap-flux sensor

A carry-in unit measures a tree over 24–48 hours, rotating through about five trees a week — no permanent datalogger required.

Whether water-use rate scales with size

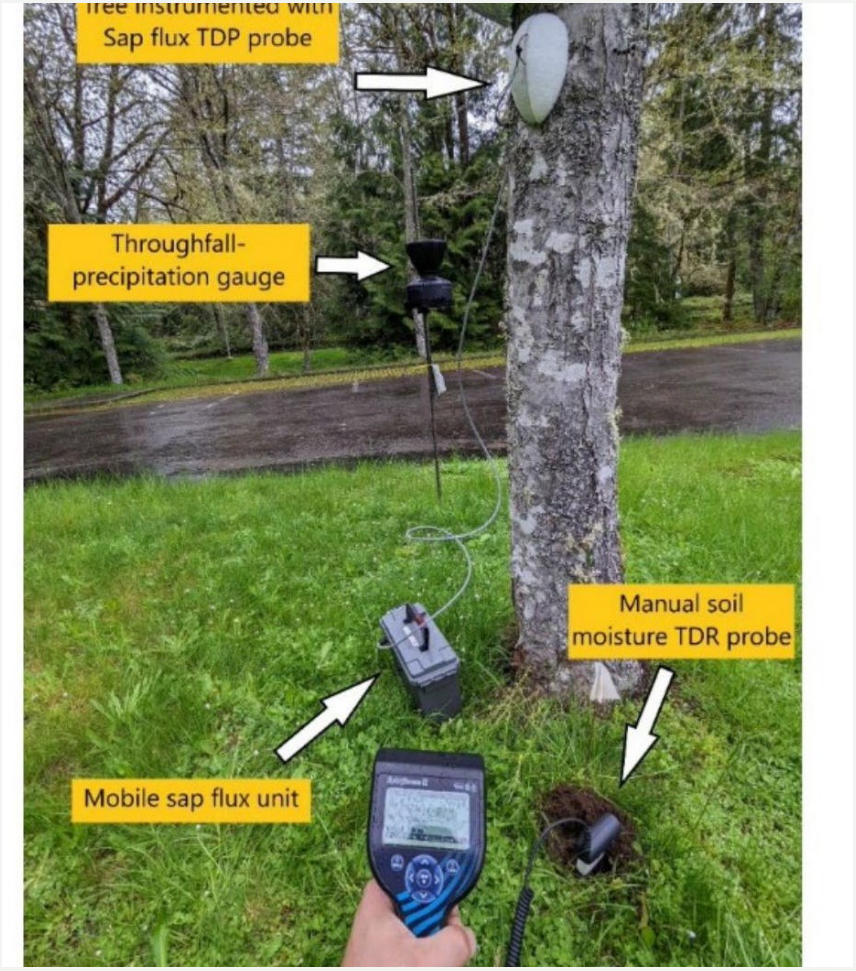
Testing the baseline sap-flux–size relationship for Douglas-fir and bigleaf maple, so Phase I can be applied across tree sizes.

The same two-flux framework

Transpiration by sap flux plus interception by throughfall — measured independently, on the same footing as Phase I (not pooled with it).

PHASE II · METHODS

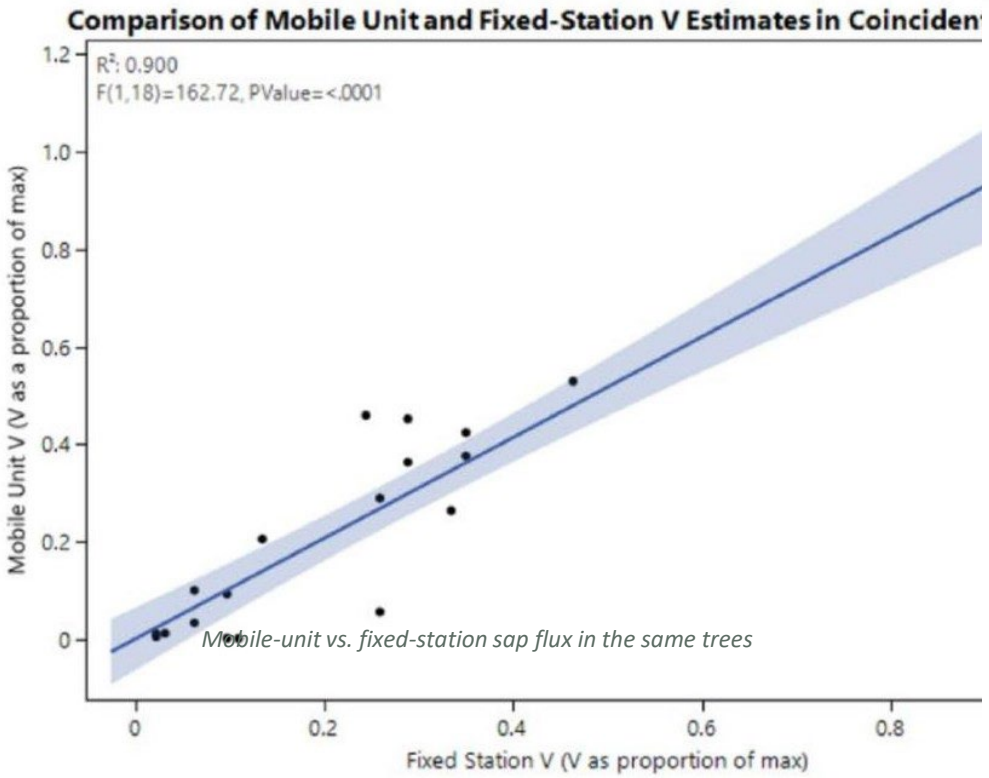
A sap-flux sensor you can carry



Mobile unit, throughfall gauge & soil probe on a street tree

The mobile unit moves from tree to tree, so a small team can measure many trees without a permanent station at each one.

Validated against fixed stations: **slope 1.01, R^2 = 0.90**



Mobile-unit vs. fixed-station sap flux in the same trees

PHASE II · TREE WATER BUDGET

Trees mitigated 42–66% of annual rainfall

*Phase II trees (2023–24). Forest and street groups are **different species** — a relative picture, not a controlled comparison.*

SPECIES	TYPE	% OF ANNUAL RAINFALL	DEPTH (cm)
Bigleaf maple	forest	52.9%	88.7
Douglas-fir	forest	42.3%	70.9
Honey locust	street	61.3%	102.7
Red maple hybrid	street	65.7%	110.1

The street trees returned the highest values per unit canopy area and a promising signal that urban street trees can meaningfully mitigate stormwater. However, survival, maintenance, and longevity of street trees are uncertain, enhancing the value of existing native older trees.

CONCLUSIONS

What native and street trees do for stormwater

1. Trees remove a large share of rainfall.
2. It is not a simple evergreen-vs-deciduous story.
3. The mechanisms are seasonally complementary.
4. Street trees count — and we can now measure them.

IMPLICATIONS FOR PRACTICE

What this means for stormwater programs

- **Retain mature trees first**
- **Count street trees in the toolkit**
- **Credit by performance, not species alone**
- **Protect the permeable root zone**

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Thank you

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Photos: Jason Berg · The Evergreen State College

