On the relevance of stemflow: An argument against funneling ratios and for a return to scaled flux-per-unit-area metrics.

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November 21, 2022

Abstract

From inside the stemflow research community, the past decade's progress might look great: 1) the number of papers published on stemflow per year has doubled; 2) citations of stemflow publications have more than doubled; and 3) the number of research sites monitoring stemflow is on the rise. However, from a broader perspective, a brief Web of Science bibliometric analysis of the past decade reveals issues with these trends: 1) annual publication numbers have increased year-to-year for most topics in natural science, but stemflow publication trends are lower than related and broader disciplines; 2) self-citation is significantly higher for stemflow research than other disciplines (e.g., 26% compared to 2% for all hydrology); and, most importantly, 3) we may have more stemflow data, but we still lack a clear understanding of stemflow's mechanistic importance. This creates ambiguities as to whether and how stemflow processes can be incorporated into hydrological models and concepts. In this presentation, I argue that we should progress from using metrics that are exclusively used by those who work on stemflow (e.g., unitless metrics such as funneling and enrichment ratios) towards using scaled flux-per-unit-area metrics that may support better integration into hydrological and ecological models (e.g., water or chemical yield per unit canopy area). While the magnitudes of funneling and enrichment ratios from individual plants have effectively conveyed to broader audiences the possibility for stemflow to play important roles in ecosystem functioning, I argue that we need to now move onto mechanistic investigations of stemflow's impact on specific processes at ecohydrologically relevant scales. Dimensionless (often individual plant-scale) funneling-type metrics may not be useful in this regard, as they tell us nothing about where stemflow goes or what roles stemflow may play in the ecosystem. They also rely on an estimate of infiltration area, which has rarely been observed to date. Their use is further limited to falling liquid-phase rain, which prevents comparison of stemflow observations/processes under occult precipitation (fog, condensation) or mixed and solid-phase precipitation (snow, rime, etc). Please view the "Make Stemflow Unit-ed Again" companion video on YouTube: https://youtu.be/4vPk9m45V0c

On the relevance of stemflow:

An argument against funneling ratios & for a return to scaled flux-per-unit-area metrics.

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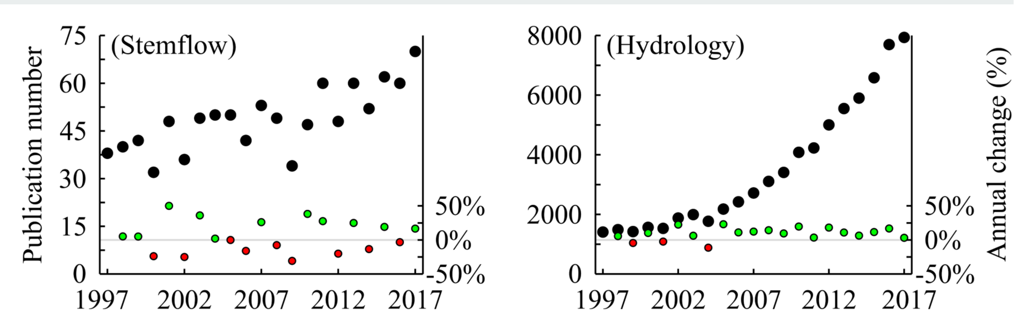
What is stemflow?

During precipitation and condensation events, a portion of water drains down plants' leaves, branches and stem to the ground as stemflow. This can result in a concentrated input of water at the surface, depending on canopy, meteorological, and surface conditions. (see central figure)

How impactful is stemflow research currently?

- Stemflow is absent from major dynamic global vegetation models (Murray et al. 2013, 10.1177/0309133312460072) and from major global hydrologic/climate models (Gutmann, 2019, 10.1007/978-3-030-29702-2_7)
- For 20 years, stemflow has been a shrinking subfield of hydrology, per trends from Web of Science (WOS):



- WOS also shows that stemflow research publications heavily self-cite (26% of citations over the past 2 decades) compared to the overall field of hydrology (only ~2%).
- So, why is the impact of stemflow research so limited? Here, I argue that the field's reliance on non-standard metrics (funneling ratios) has limited stemflow's integration into/impact on broader theory.

What is a funneling ratio (F)?

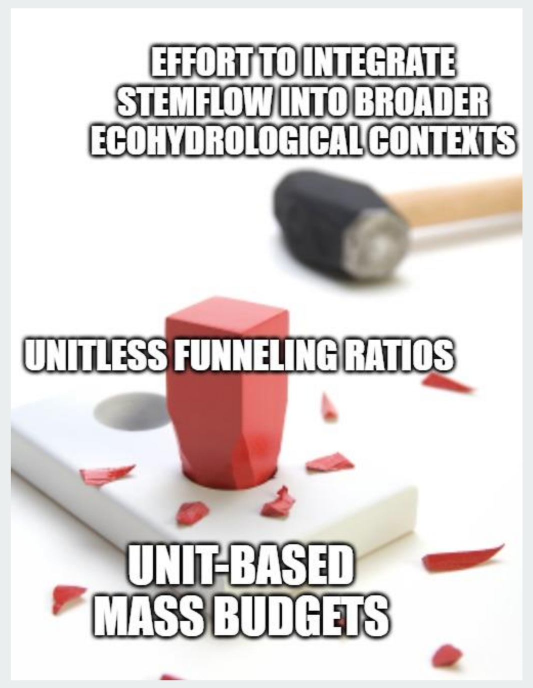
Fundamentally, F is a dimensionless ratio that compares stemflow input [L m^{-2} of infiltration area] to open/above-canopy precipitation [mm], originally computed as:

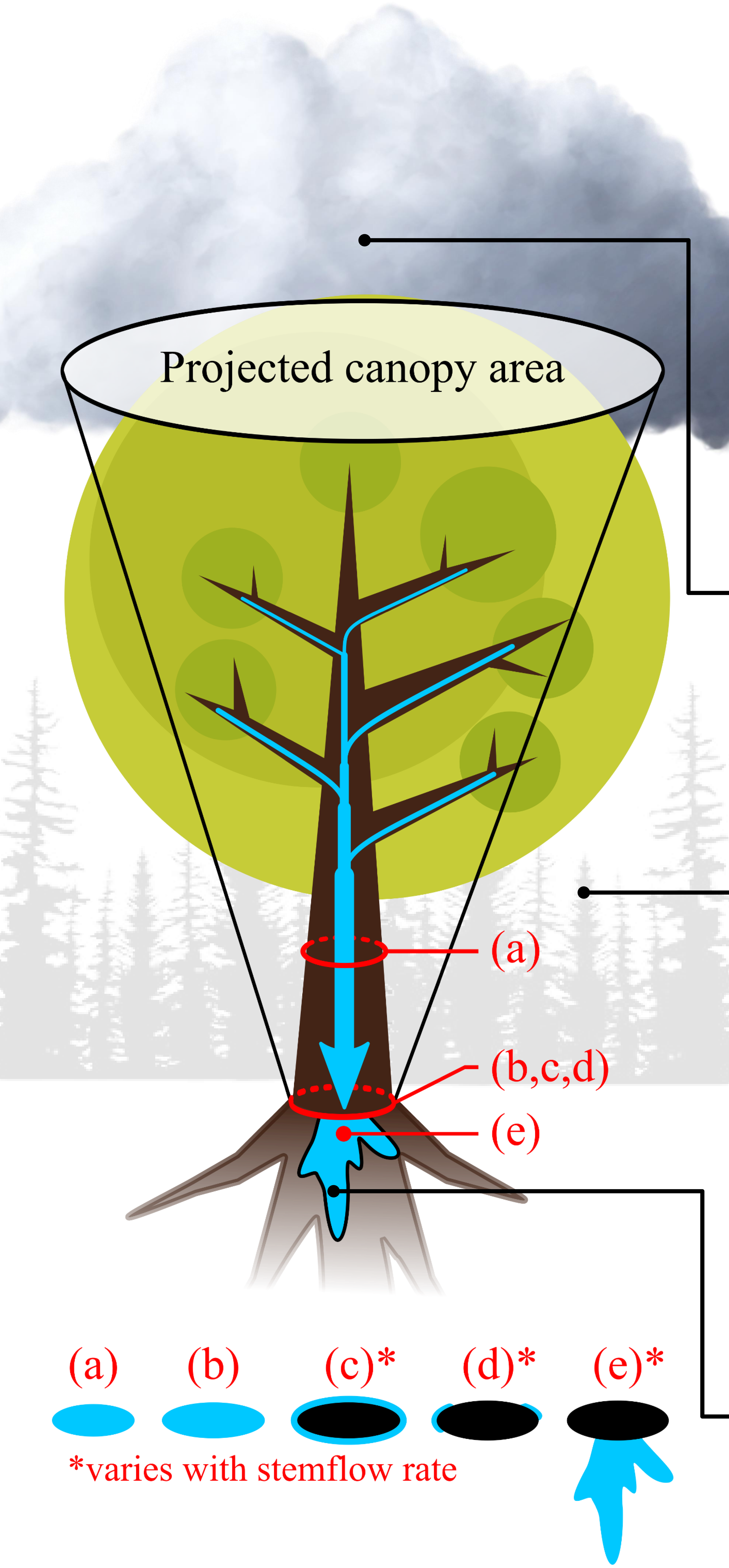
$$F = \frac{\text{Stemflow volume [mL]}}{\text{Precipitation [cm]} \times \text{Basal area [cm}^2\text{]}}$$

Now, several F metrics exist to compare stemflow to various rainfall and net rainfall fluxes across various scales.

How can a non-standard unitless metric become a problem?

While F magnitudes from individual plants have effectively convinced broader audiences that stemflow may play important roles in ecosystem functioning, I argue that we now need mechanistic investigations of stemflow's impact on specific processes at ecohydrologically relevant scales. Dimensionless (often individual plant-scale) F metrics may not be useful in this regard, as they tell us nothing about where stemflow goes or what ecosystem roles it may play.





MAKE STEMFLOW UNIT-ED AGAIN

Why would we use F without unit-ed metrics (like yield)? Select quotes from active proponents of dimensionless ratios yield some insights:

"Stemflow is not 'yielded' on the basis of projected crown area. This is simply a fallacy."

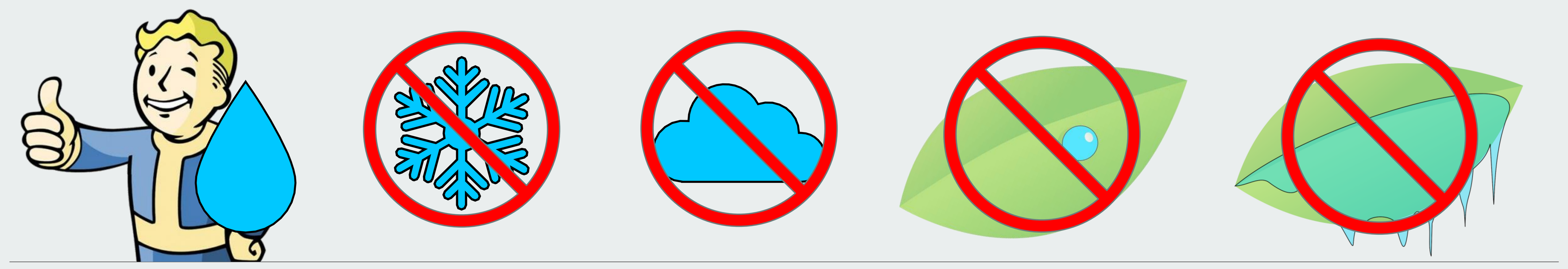
Yield is a standard hydro metric (volume running off from a drainage area). In the case of stemflow: volume draining from the projected crown area.

"Stemflow [yields] are misleading and under-represent the actual flux"

On the contrary, reporting stemflow yields may *lead* to the integration of stemflow into broader theory. These yields can also be quite impressive! DOC example (yield = g-C m^{-2} y^{-1}):

Sources of stemflow?

Stemflow is generated from various atmospheric water events/sources. Funneling ratios are only applicable for a single precipitation type: falling liquid-phase precipitation.



Missing the forest for the trees?

1st-order understanding (across ecosystems/climates) is needed. F (& enrichment ratios) are typically tree-level metrics & we lack the process-level understand to contextualize stemflow at the tree-level. Thus, we need a scaling framework that yields stand-level estimates, and account for (a) tree-size-stemflow relationships & (b) forest size-density relationships.

Stemflow comparison overload!

Options for comparison abound…

- Open rainfall?
- Throughfall? Which throughfall?

Since stemflow is spatially localized & local throughfall variability is large, do we use throughfall drip or dry points?

What is stemflow's infiltration area?

TL;DR?

GSU Forest Ecohydrological Research Lab

Take a picture/scan to view "Make Stemflow Unit-ed Again" campaign video: https://youtu.be/4vPk9m45V0c