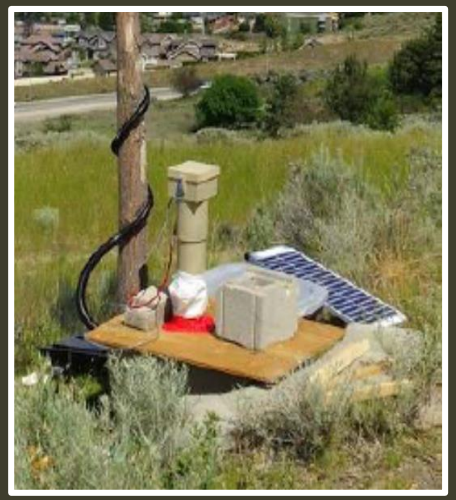
RAINFALL PARTITIONING BY TREE CANOPIES:

THROUGHFALL, STEMFLOW AND CANOPY INTERCEPTION LOSS



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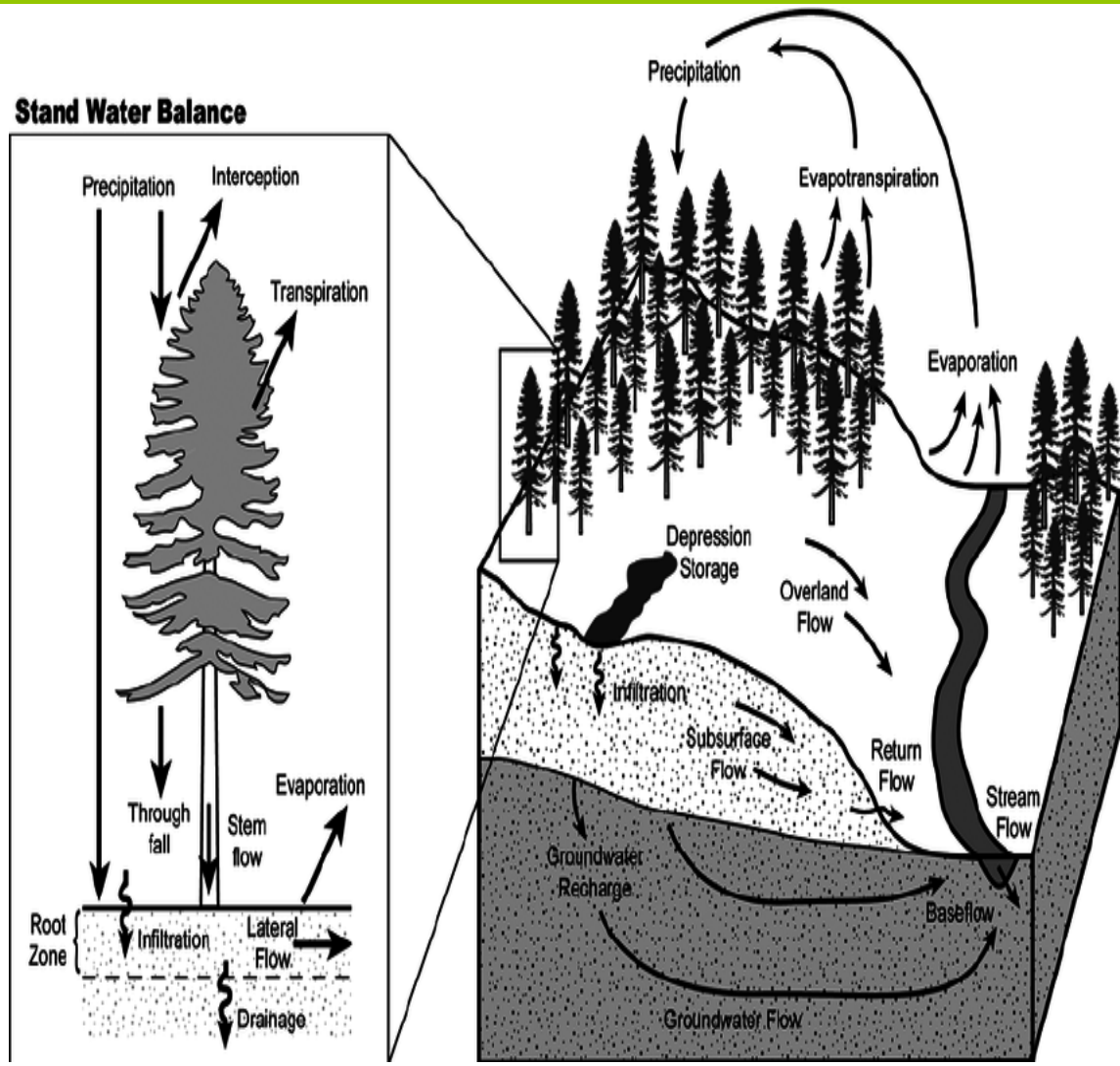
Canopy Water Balance

$$I_c = P_g - (TF + SF)$$

- **Interception loss:** evaporation of rainfall stored on a vegetation surface.
- **Throughfall:** Rain that passes directly through canopy gaps (*free throughfall*) or drips from that canopy (*release throughfall*)
- **Stemflow:** Precipitation that flows along branches and down the boles of trees to the ground.

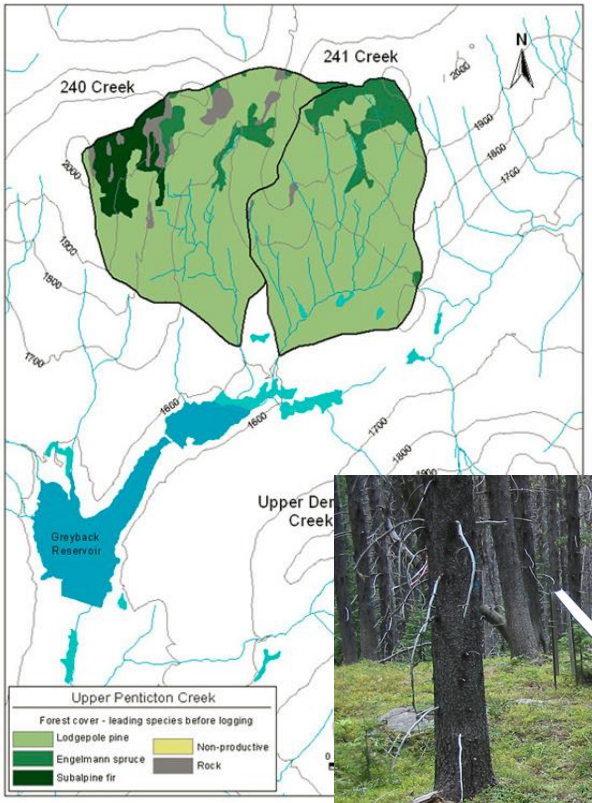


Typical Values for Mature Forests

Percentage of Growing-Season Rainfall

	Deciduous	Coniferous
Interception Loss	13 (10 – 20)	26 (15 – 30)
Throughfall	82 (78 – 85)	73 (70 – 85)
Stemflow	5 (3 – 9)	1 (0 – 2)

Examples from British Columbia

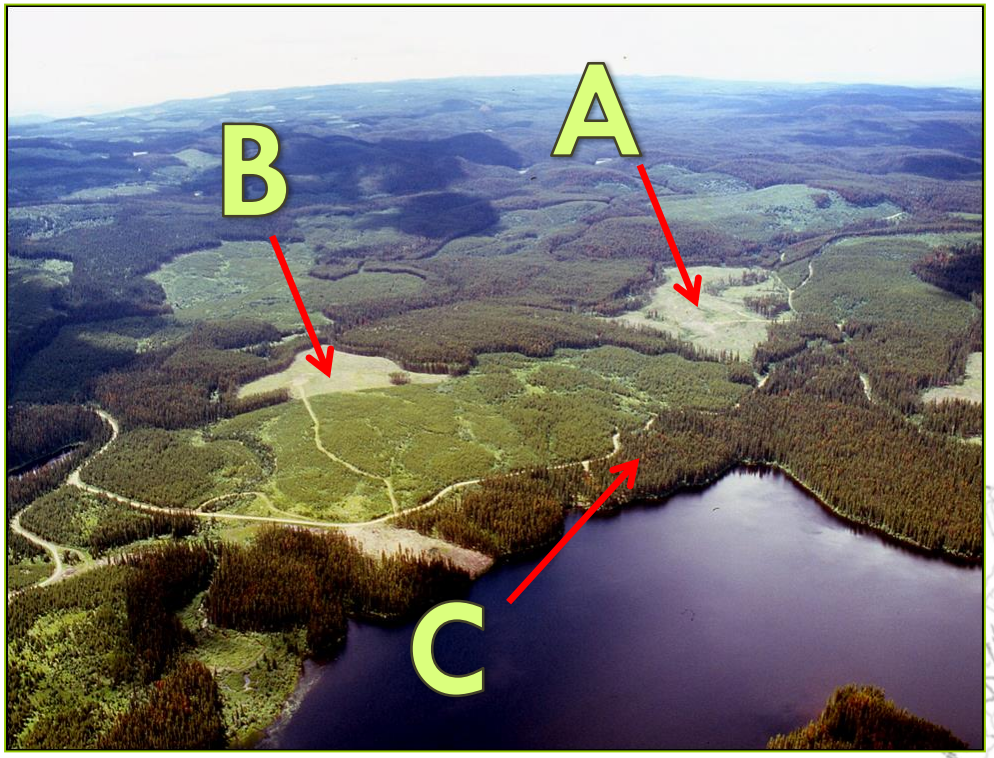


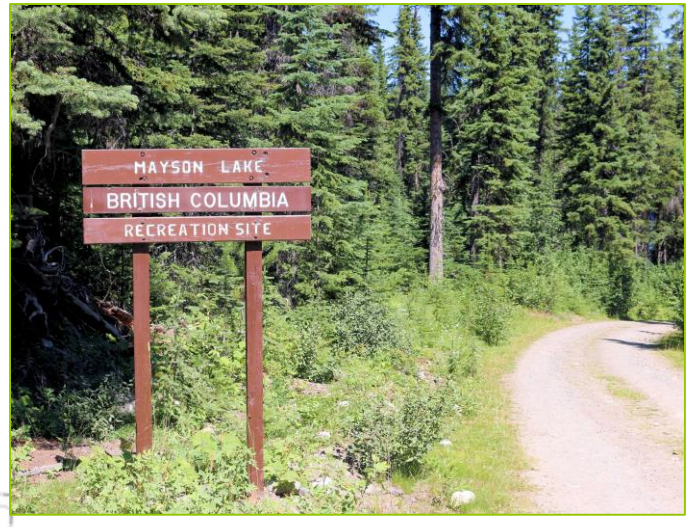
Forest	Height m	Density stems ha^{-1}	Cover %
Hemlock	30 to 40	480	85
Spruce	6 to 10	1500	75
D.-Fir #1	14 to 16	1050	85
D.-Fir #2	12 to 15	1090	70
Pine	22 to 26	720	40
Spruce/fir	20 to 24	1470	45

Forest	% of Rainfall Stem	Thru	Intc
Hemlock	1	69	30
D.-Fir #1	9	70	21
Sitka Spruce	9	77	14
D.-Fir #2	4	85	11
Pine/spruce/fir	<0.5	76	24

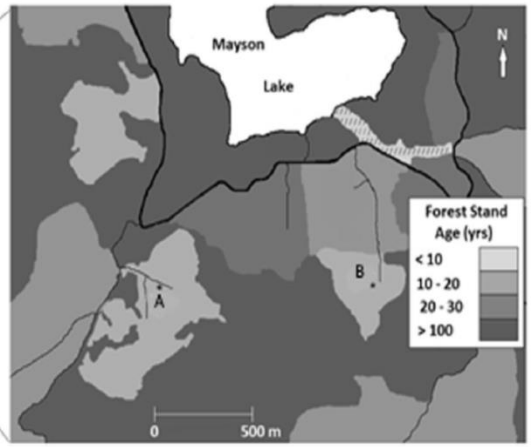
Source: Spittlehouse 1998.

Mayson Lake


A
B
C

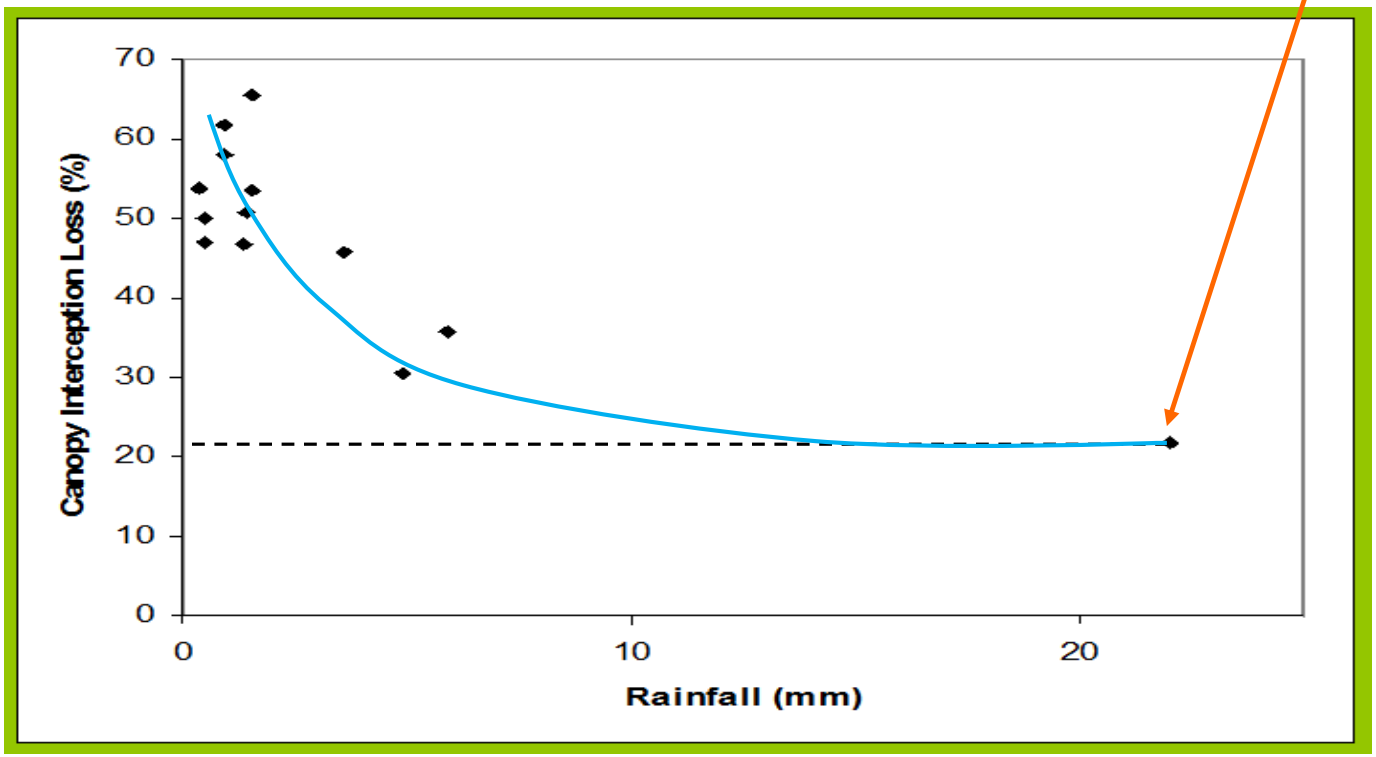

MAYSON LAKE
BRITISH COLUMBIA
RECREATION SITE


N
Kamloops
0
200 km


Mayson
Lake
N
Forest Stand
Age (yrs)
< 10
10 - 20
20 - 30
> 100
A
B
0
500 m

- Mature Pine-Spruce-Fir Stand:
  - Interception Loss…….. 26 – 30 %
  - Throughfall……70 – 73 %
  - Stemflow ……..< 0.1%

S_c = 0.9 mm
S = 0.5 mm
I = 5.3 mm

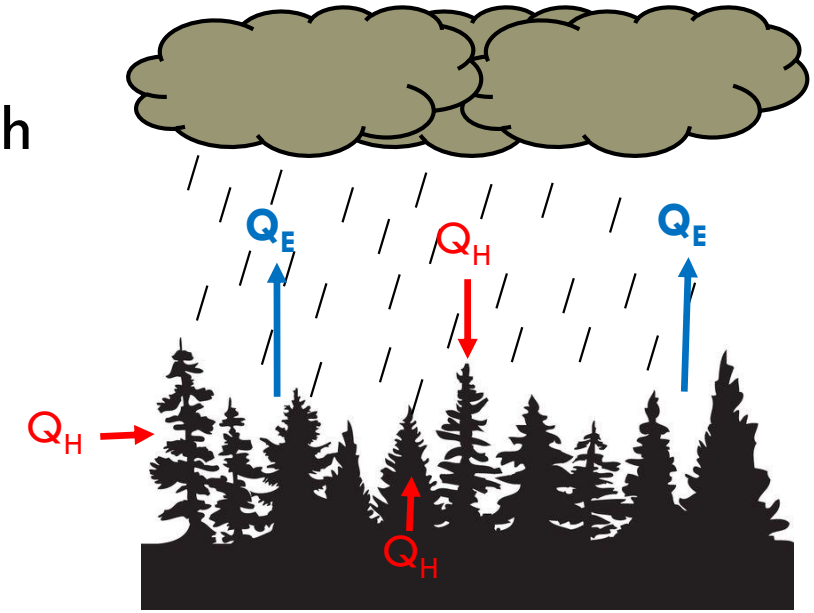


Components of Interception Loss

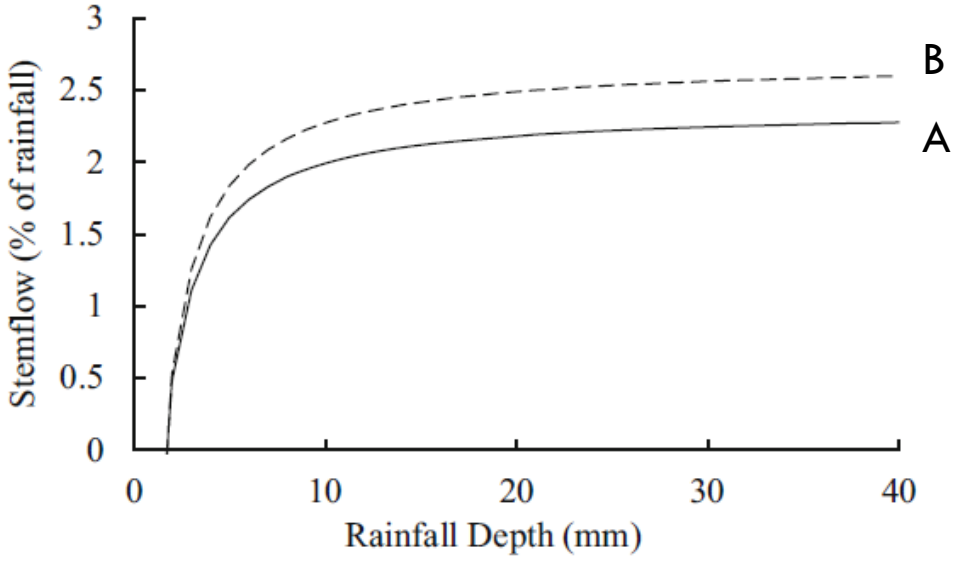
- Storage = 0.5 mm; total evaporation = 5.3 mm.
- Storage = evaporation AFTER THE EVENT
  - So when is the other 4.8 mm evaporating?

  - $E_c = a \cdot R$
  - $E_c = 0.26R = 0.3 \text{ mm / h}$

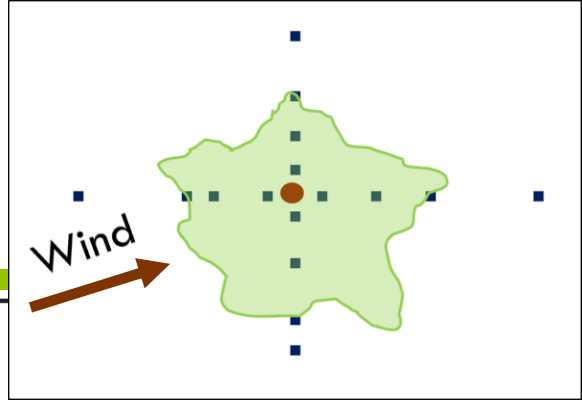
$$I_C = 0.260 P_g + 0.542, \; r^2 = 0.57$$



- Juvenile Pine-Fir Stand:
  - Interception Loss.. 10 – 11 %
  - Throughfall……87– 88 %
  - Stemflow…….. 2 %



Throughfall Spatial Variability in Juvenile Pine

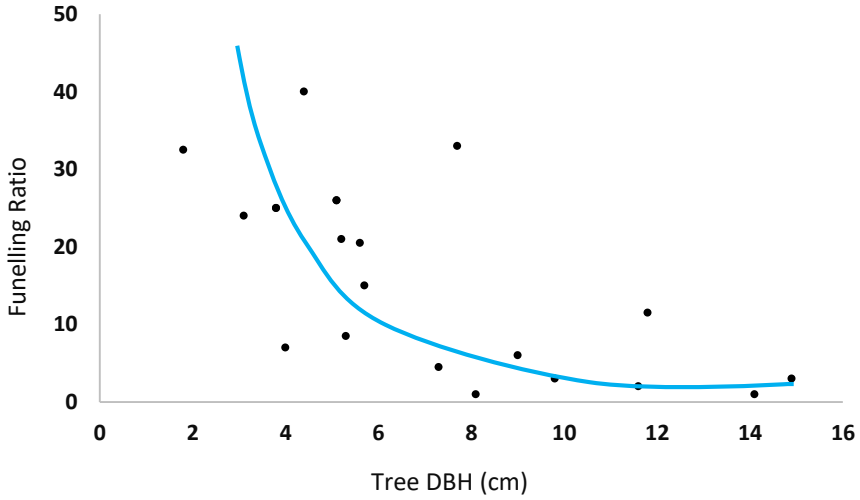


Position	Rain depth class				
	<2 mm	2 to <5 mm	5 to <10 mm	≥10 mm	Season
Inner canopy					
North	28.6	33.3	49.2	53.2	47.5
South	29.4	**37.5**^{E*}	**56.0**^{E*}	58.5	44.8
East	**25.0**^{W*}	**22.9**^{S*}	**43.8**^{W**,S*}	55.1	37.5
West	**40.0**^{E*}	49.4	**63.3**^{E**}	49.0	53.8
Mid canopy					
North	**38.5**^{W*}	**46.4**^{W*}	**65.7**^{W**}	85.1	62.7
South	42.9	**60.3**^{E*}	76.3	72.5	66.7
East	**28.6**^{W***}	**44.8**^{W***,S*}	**59.3**^{W**}	70.1	55.0
West	**64.3**^{E***,N*}	**77.3**^{E***,N*}	**82.0**^{E**,N**}	91.0	80.0
Canopy Periphery					
North	69.2	83.8	83.3	90.2	82.7
South	69.2	82.5	93.2	**90.9**^{E*}	89.0
East	57.1	63.1	71.6	**78.6**^{S*}	66.1
West	68.4	75.0	85.7	83.3	83.3
Outside of canopy					
North	71.4	81.5	90.0	91.6	88.2
South	71.4	82.8	90.0	92.3	89.0
East	71.4	83.7	92.3	92.5	88.0
West	78.9	88.6	92.3	94.6	90.7

Stemflow in Juvenile Lodgepole Stands

SO WHAT?

- Only 2 %...
- Well…
  - It is a concentrated input of water.
    - Funelling Ratio:
      - Ratio of stemflow volume to rainfall volume over area equal to basal area



Max Event FR = 112

Season-Long Mean = 23

P = 130 mm ; SF = 3000 mm

…and mature coniferous stands?

- "the observed high stemflow intensities combined with preferential flow of stemflow may lead to enhanced subsurface stormflow. This suggests that even though stemflow is only a very minor component of the water balance, it may still significantly affect soil moisture, recharge, and runoff generation"

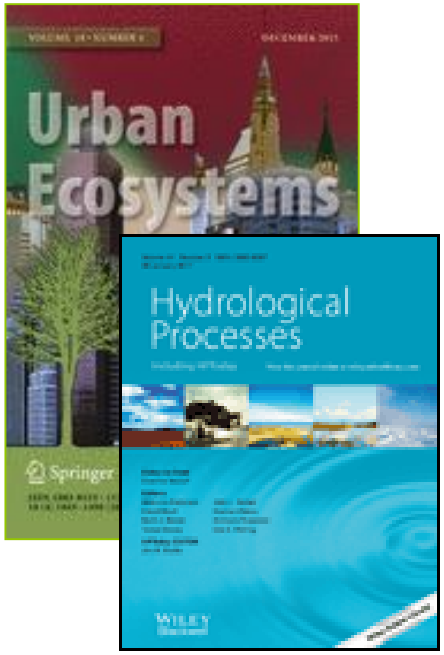
Spencer and van Meerveld *Hydrological Processes* (2016)

- "Many geoscientists now recognize stemflow as an important phenomenon which can exert considerable effects on the hydrology, biogeochemistry, and ecology of wooded ecosystems and shrublands".

Levia and Germer *Review of Geophysics* (2015)

Stemflow in Urban Environments

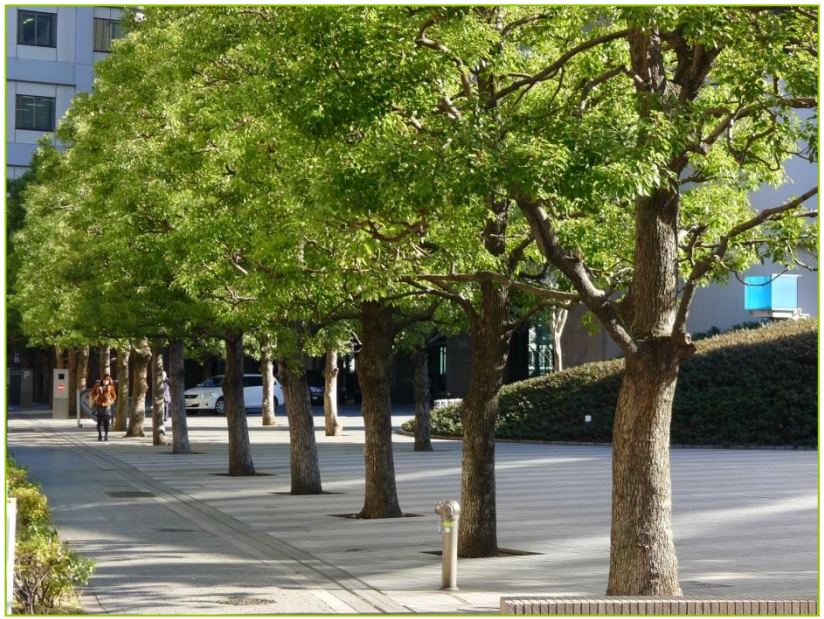
- Stemflow greater for isolated trees
- Average stemflow as high as 12%, event maximum = 23%
- Funelling Ratios for rains > 10 mm averaged 26 (max average = 86)
- Event funelling ratios as high as197

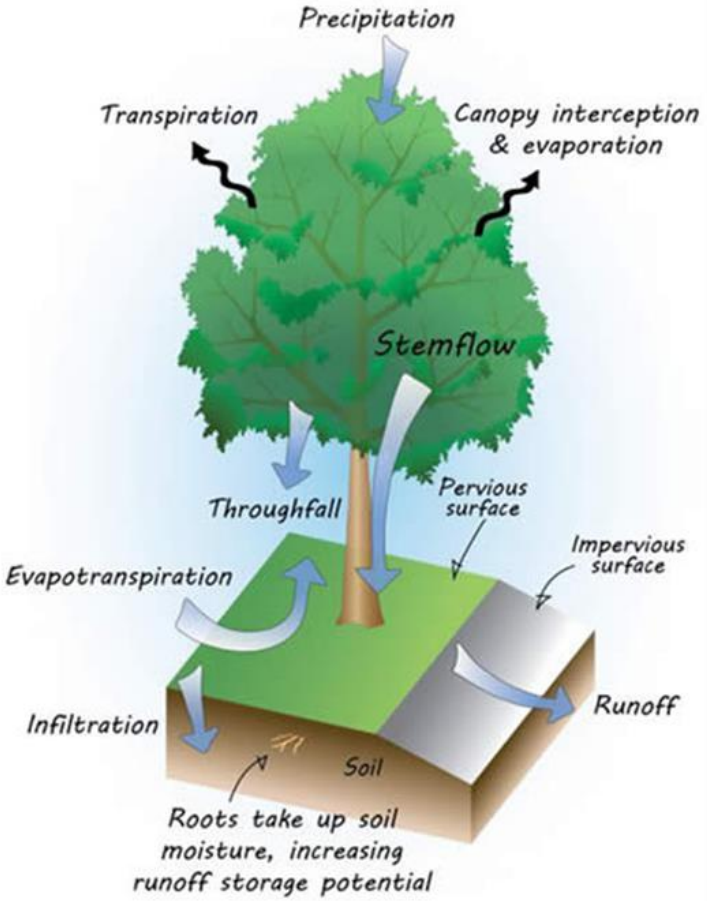


Rain = 25.6 mm

SF = 5040.6 mm

- Importance:
  - Stormwater Management
    - SF = 10 – 40 % of Interception Loss
  - Self-Irrigation





Is it Just Water that is being Concentrated?

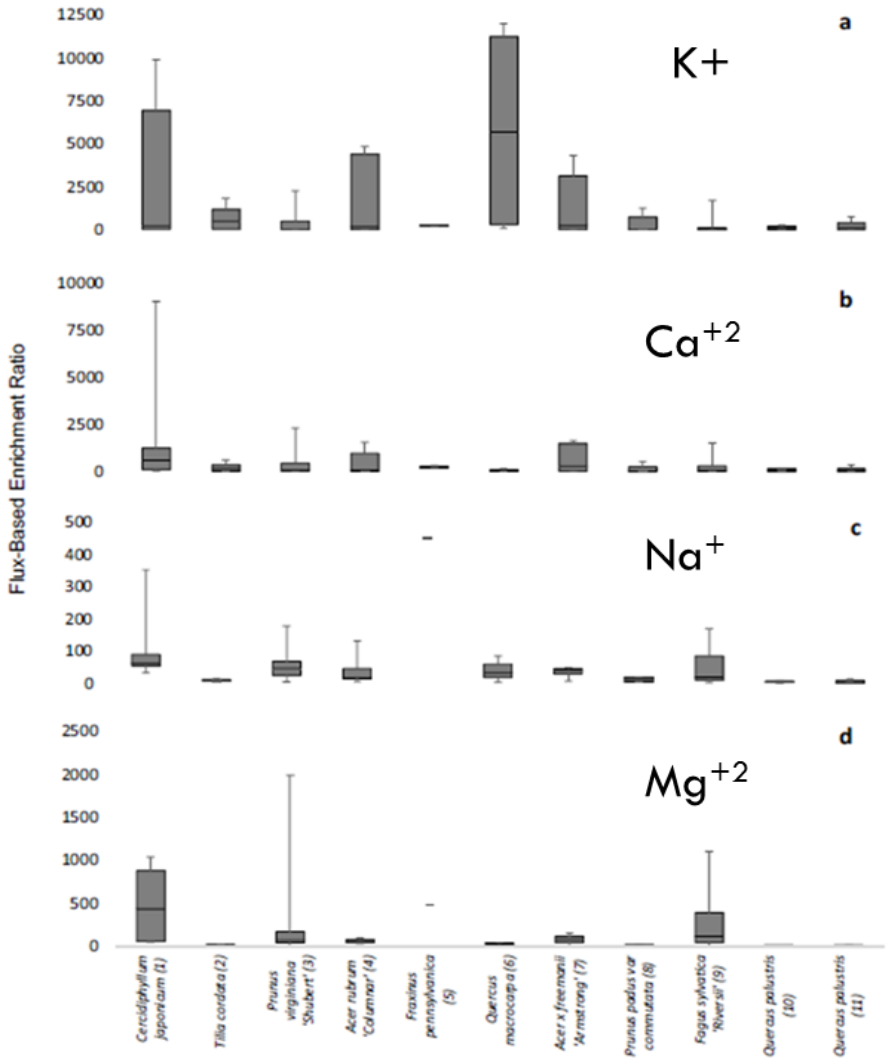


TABLE II. Effect of stemflow partitioning on dissolved organic carbon (DOC) concentration in stemflow water and as percent enrichment with respect to throughfall and rainfall DOC concentrations.

Species	Common name	SF%	SF DOC	TF DOC	RF DOC	SF:TF	SF:RF	Study
				($mg \cdot L^{-1}$)		Enrichment (%)	Enrichment (%)	
Quercus pyrenaica	Pyrenean oak	0.8	168.4	23.5	7.1	716.6	2371.8	[1]
Quercus pyrenaica	Pyrenean oak	0.61	138.4	15.7	6.3	881.5	2196.8	[1]
Larix laricina	Larch, Tamarack	1.6	129.9	nd*	nd	nd	nd	[2]
Abies balsamea	Balsam fir	3.5	90.8	nd	nd	nd	nd	[2]
Pinus resinosa	Red pine	0.7	82.1	nd	nd	nd	nd	[2]
Quercus pyrenaica	Pyrenean oak	0.64	68.2	13.9	5.9	490.6	1155.9	[1]
Picea glauca	White spruce	6.4	65.8	nd	nd	nd	nd	[2]
Quercus pyrenaica	Pyrenean oak	0.95	62.3	9.9	6.4	629.3	973.4	[1]
Picea rubens	Red spruce	2.3	60.6	nd	nd	nd	nd	[2]
Populus grandidentata	Largetooth aspen	6.1	32.3	nd	nd	nd	nd	[2]
Pinus strobus	White pine	5.3	31.6	nd	nd	nd	nd	[2]
Acer rubrum	Red maple	5.6	28.4	nd	nd	nd	nd	[2]
Fagus sylvatica	Beech	5.2	15.8	16.3	2.2	97	703.1	[3]
Betula papyrifera	White or paper birch	3.9	13.7	nd	nd	nd	nd	[2]

Mark Johnson and Johannes Lehmann 2006 *Ecoscience*

Dissolved Organic Nitrogen

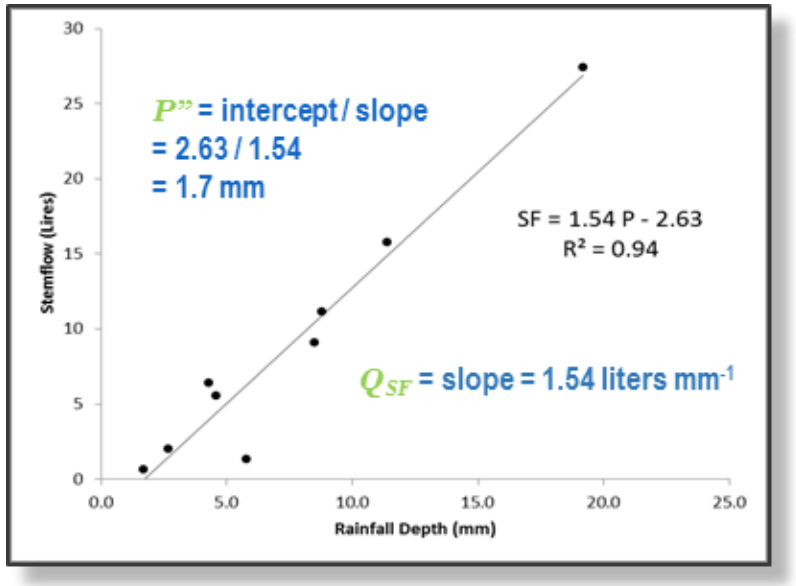
Species	Common name	SF:RF Enrichment (%)
Larix laricina	Larch, Tamarack	nd
Abies balsamea	Balsam fir	nd
Eschweilera spp.	Jarana, Kakeralli	1155.6
Picea glauca	White spruce	nd
Pinus resinosa	Red pine	nd
Fagus sylvatica	Beech	310.3
Picea rubens	Red spruce	nd
Bixa orellana	Annatto, Arnatto	888.9
Populus grandidentata	Largetooth aspen	nd
Acer rubrum	Red maple	nd
Bactris gasipaes	Peach palm (fruit)	622.2
Vismia spp.	Vismia (fallow species)	555.6
Oenocarpus bacaba	Bacaba palm, Turu palm	544.4
Bertholletia excelsa	Brazil nut	544.4
Theobroma grandiflorum	Cupuaçu	533.3
Pinus strobus	White pine	nd
Betula papyrifera	White or paper birch	nd
Bactris gasipaes	Peach palm (heart of palm)	**233.3**

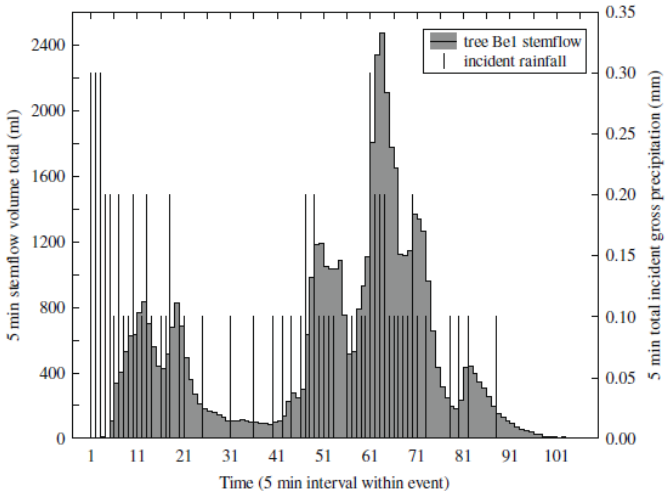
Implications

- Redistribution of rainfall by canopies can have important implications for the amount and spatial redistribution of water. These implications include:

  - - evaporation modelling (i.e. use of Penman-Monteith Model).
  - - soil moisture and biogeochemical sampling.
  - - hydrologic process understanding (e.g. groundwater recharge)

Future Work





$$SF = (P - P'')\, Q_{SF}$$

$$SF = (P - 1.7) \cdot 1.54$$

Thank You

Contact: Darryl Carlyle-Moses **dcarlyle@tru.ca**

https://www.youtube.com/watch?v=DqXwgD8u8Pg

http://www.kamloops.ca/stormwatertrees/index.shtml#.WJChs_KLVQM