Vertical variation in the transport and fate of radiocesium through the canopy via branchflow and stemflow

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Abstract

This study seeks to better understand the vertical variation in the transport and fate of radiocesium via branchflow and stemflow in the aftermath of the Fukushima nuclear power plant accident. Working in both a coniferous forest (Cryptomeria japonica, young Japanese cedar stands, average height is 14.0 m) and a mixed deciduous broadleaved forest (Quercus serrata, Japanese oak stands, average height is 13.3 m), we employed isotopic tracers to help determine the fate of radiocesium transported by branchflow and stemflow from the upper and lower portions of the canopy. Branchflow was harvested and examined from the upper canopy layers (including younger foliage, dead foliage, and live branches), whereas stemflow was collected in both the upper and lower portions of the canopy (with varying portions of live and dead branches). Particular attention was paid to the washoff, leaching, adsorption, transport, and storage (stem and bark) of radiocesium. The preliminary results showed radiocesium leaching (Cs-137 concentration) was greater for branchflow that received washoff and leachate from the dead foliage than the branchflow receiving radiocesium inputs from mixed and young foliage. For the tree trunk, radiocesium leached more in stemflow from the lower part of the canopy as compared to the upper canopy. We also found that the isotopic composition of branchflow was generally enriched in δ18O and δD compared to open rainfall and throughfall, however, the differences in enrichment between branchflow and stemflow remains unclear. Further work should examine the effect of tree architecture on the cycling of radiocesium both stemflow and branchflow.

Vertical variation in the transport and fate of radiocesium through the canopy via branchflow and stemflow

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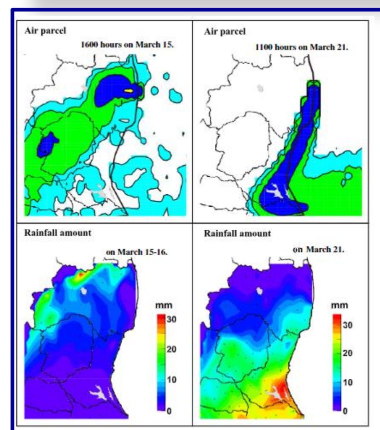
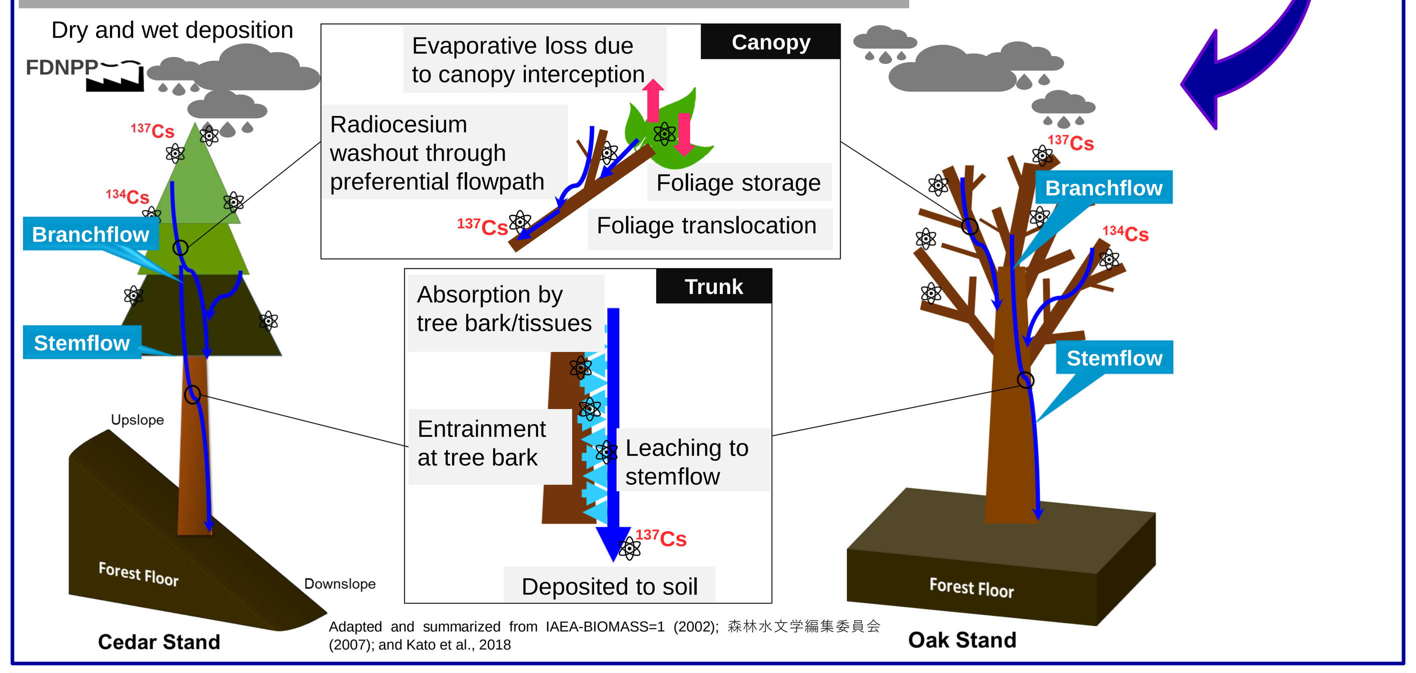
Background of research



(Kinoshita et al., 2011)

- March 12, 2011 – radionuclides released from FDNPP –> dry deposition (MEXT, 2011)
- March 15 and 16, 2011 - 2 rainfall events –> wet deposition most aerosols and water-soluble gases are washed out by a rainfall (Kinoshita et al., 2011)
- Most of the radionuclides were deposited on March 15 in Fukushima prefecture (Kinoshita et al., 2011)

Transportation and fate of radiocesium leaching via branchflow and stemflow



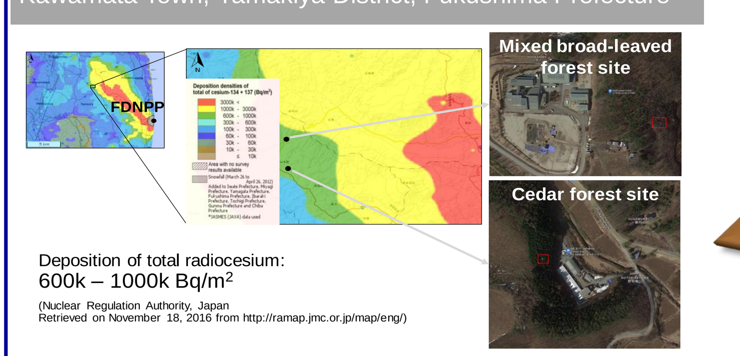
Research questions

1. Does the upper canopy or the tree trunk serve as the larger source of ^{137}Cs leachates via stemflow and branchflow?
2. Does branchflow and stemflow generation affect the ^{137}Cs leaching process?
3. Does the spatial variability of ^{137}Cs deposition differ among cedar and oak stands?
4. Does routing and residence time at tree stand affect the isotopic composition (evaporation loss) in branchflow and stemflow?

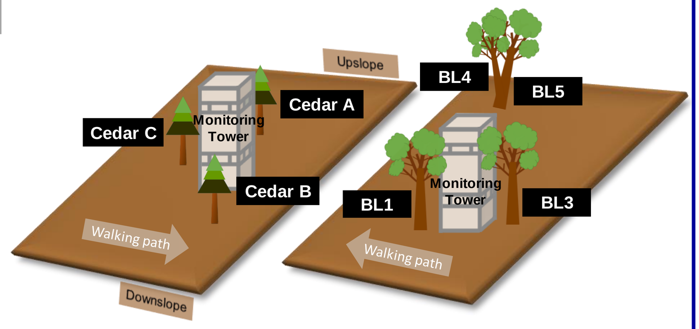
Methodology

Location of the study site:

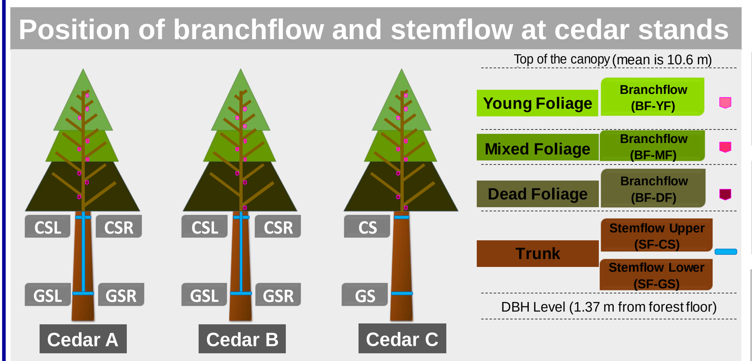
Kawamata Town, Yamakiya District, Fukushima Prefecture



Location of the tree stands



Position of branchflow and stemflow at cedar stands

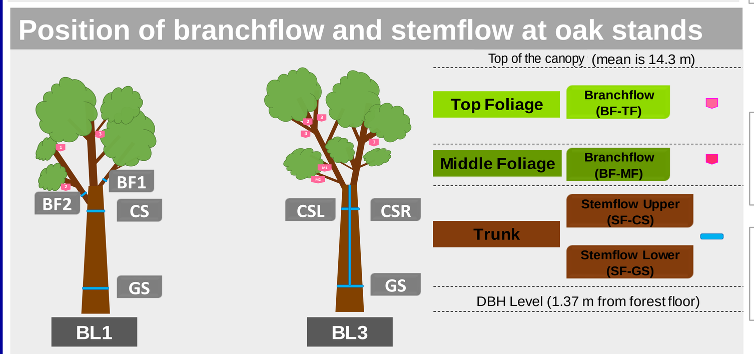


Cedar A
DBH: 60.3 cm
Basal area: 0.286 m²

Cedar B
DBH: 50.0 cm
Basal area: 0.196 m²

Cedar C
DBH: 59.8 cm
Basal area: 0.281 m²

Position of branchflow and stemflow at oak stands



BL1
DBH: 85.57 cm
Basal area: 0.575 m²

BL3
DBH: 89.1 cm
Basal area: 0.624 m²

Laboratory analysis

- High-purity n-type germanium co- axial gamma-ray detector (EGC25-195-R, Canberra-Eurisys, Meriden, CT, USA), coupled with Amplifier (PSC822, Canberra-Eurisys, Meriden, CT, USA), and with multichannel analyzer (DSA1000, Canberra, France).
- Energies set to 662 keV (^{137}Cs) and 605 keV (^{134}Cs) peaks.

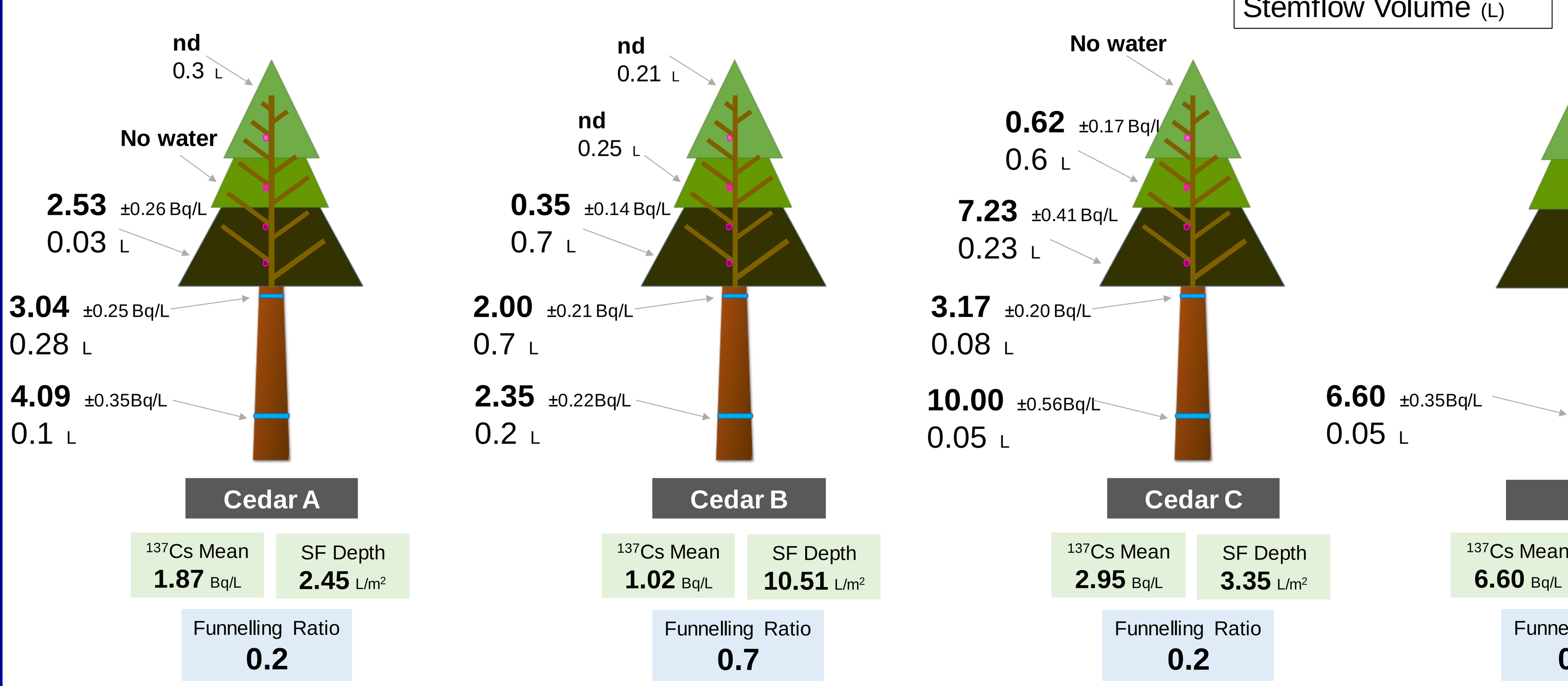
- Stable isotope of δ^{18}O and δD of all samples was analyzed using a laser-based water isotope analyzer (L1102-i, Picaro, inc., Sunnyvale, CA).
- Each water sample was measured by 8 times, and the mean of the later 5 time of the measurement was used for further analysis.

[Research question 1] ^{137}Cs partitioning at cedar and oak stands

Vertical variation of ^{137}Cs at cedar stands

Sampling on 27th December 2018

^{137}Cs Activity ±SD (Bq/L)
Stemflow Volume (L)

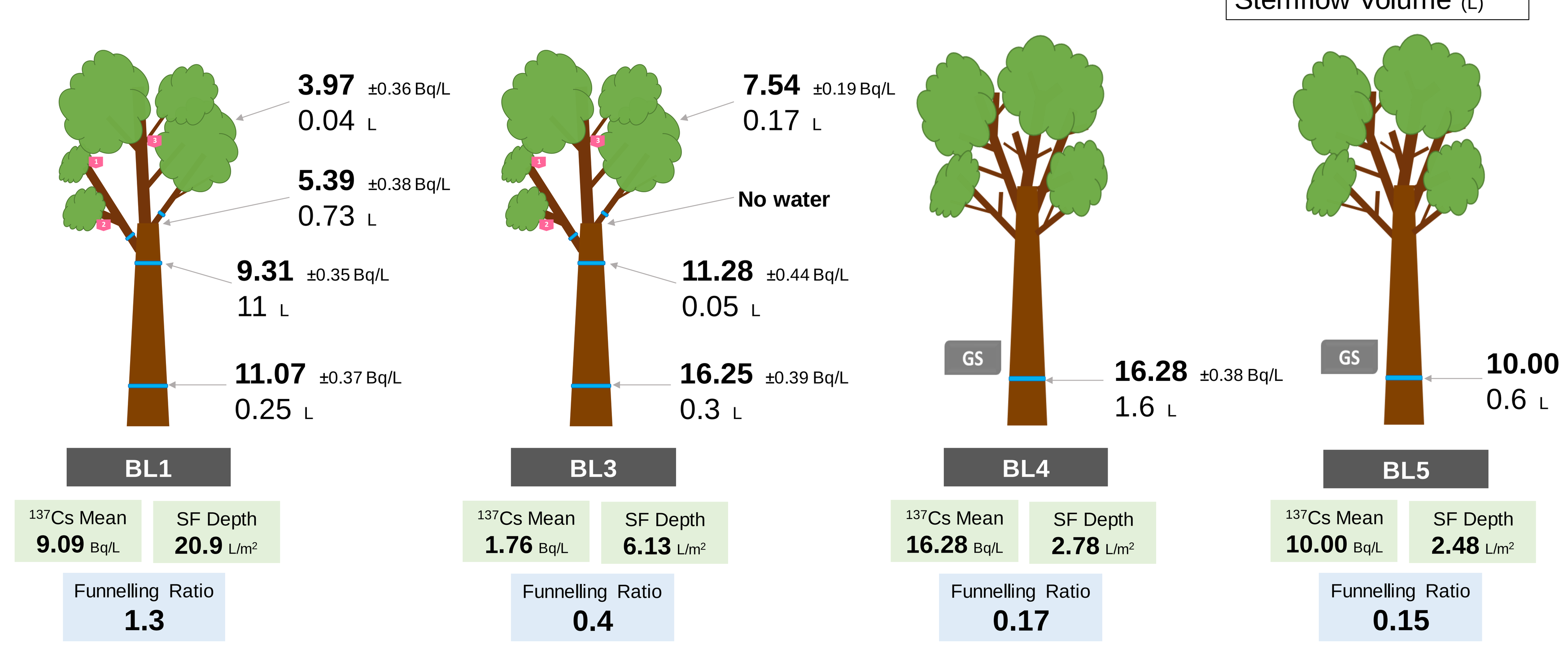


^{137}Cs concentration was larger from dead foliage as compared to mixed and young foliage at the branchflow.

Vertical variation of ^{137}Cs at Oak stands

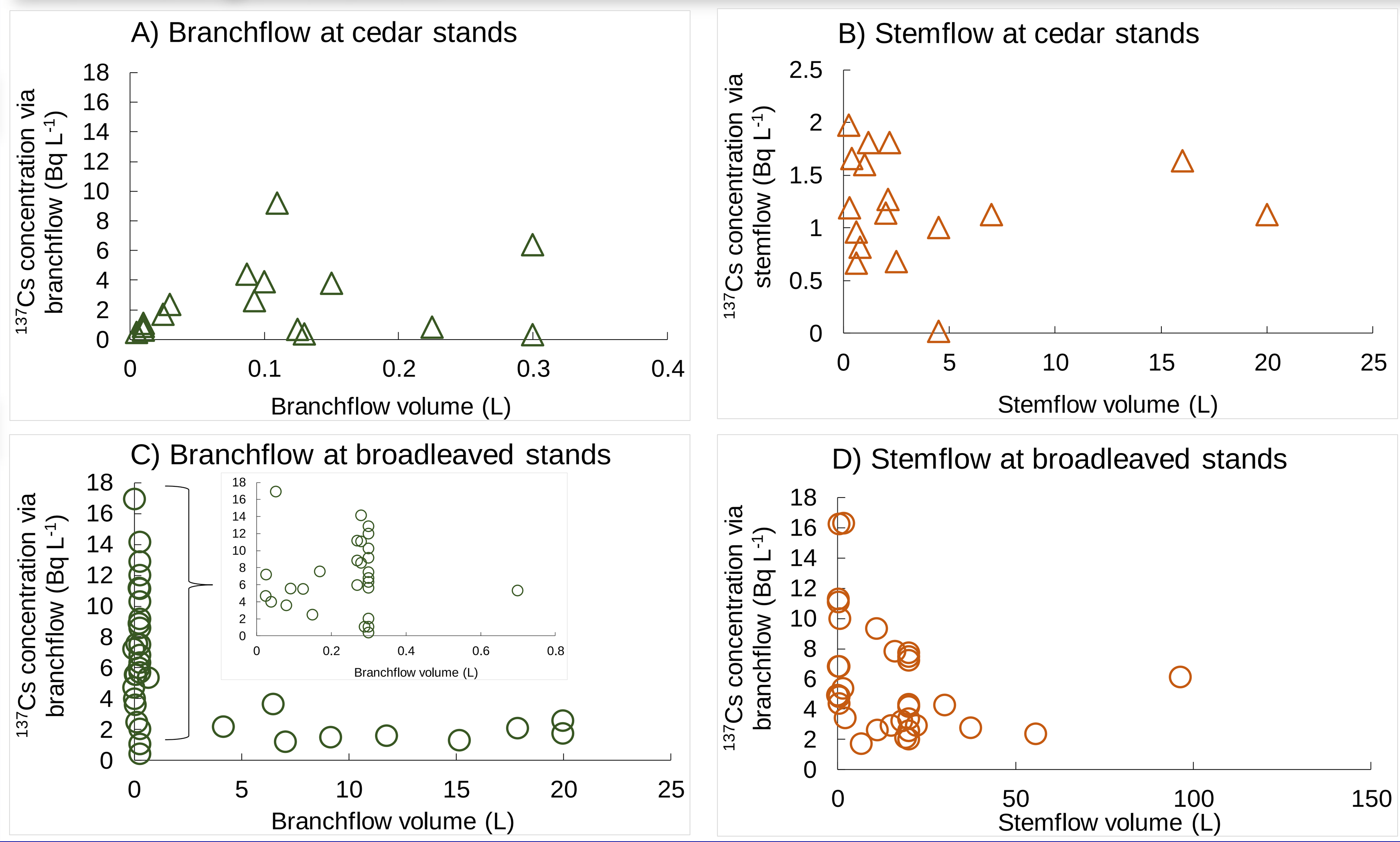
Sampling on 27th December 2018

^{137}Cs Activity ±SD (Bq/L)
Stemflow Volume (L)



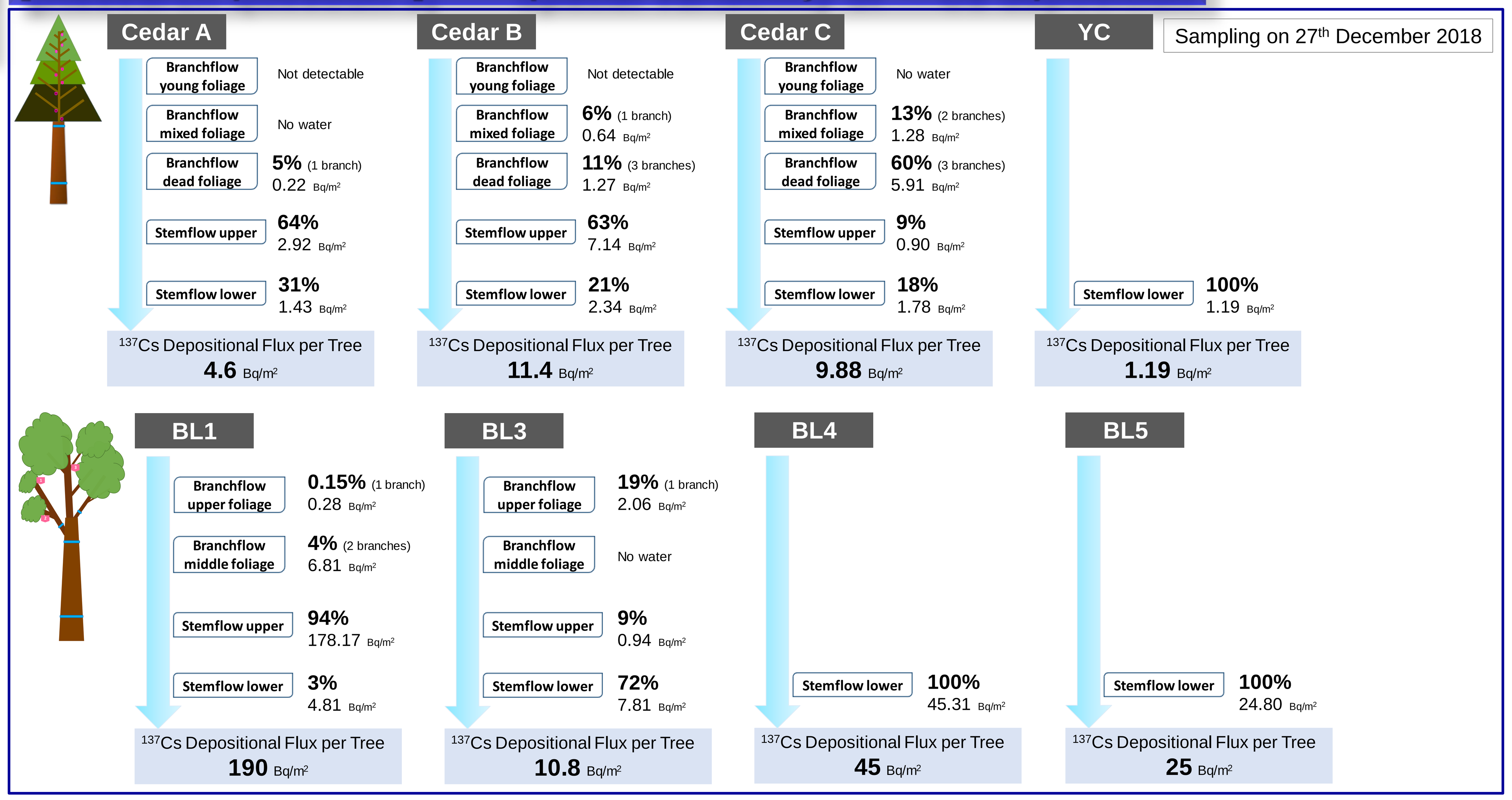
Radiocesium leached more in lower stemflow of the trunk compared to upper trunk stemflow, possibly due to the increased residence time of stemflow on the lower reaches of the trunk.

[Research question 2] ^{137}Cs leaching via branchflow and stemflow generation

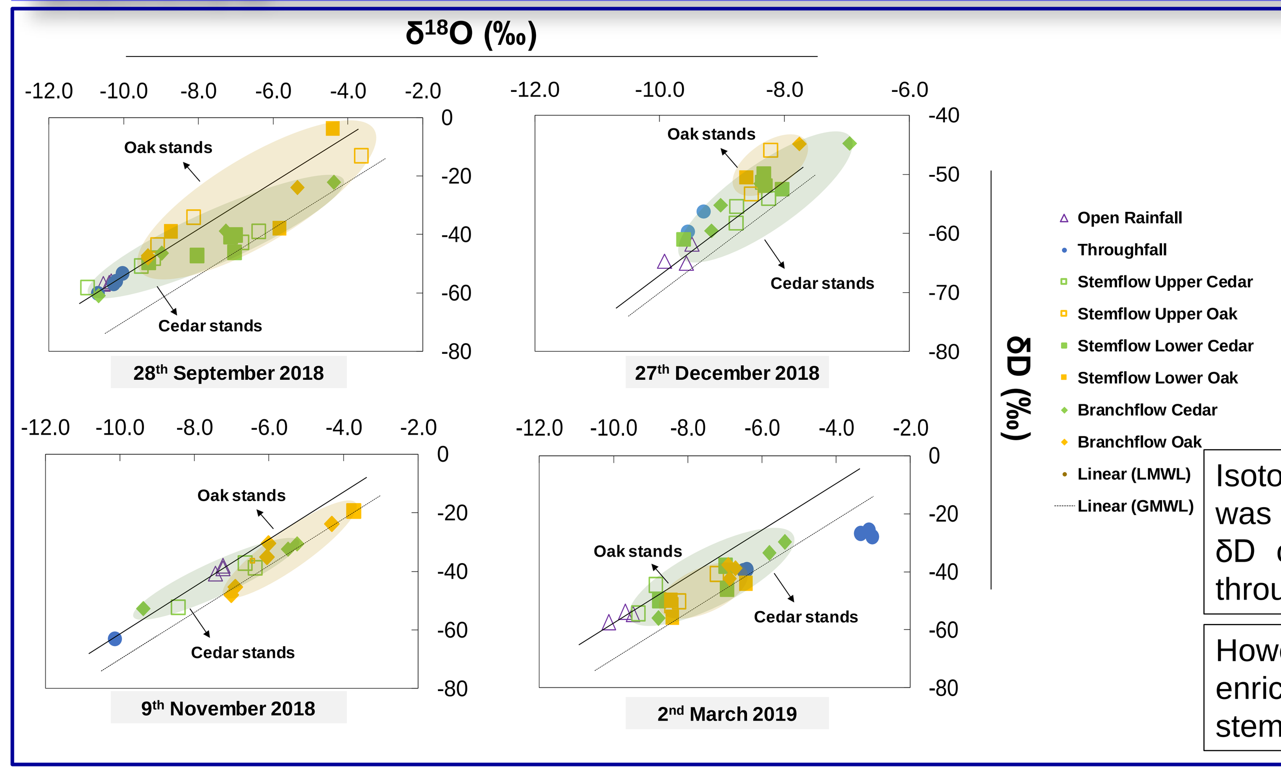


[Research question 3] Spatial variability of ^{137}Cs deposition

Sampling on 27th December 2018



[Research question 4] Isotopic composition via branchflow and stemflow



Isotopic composition of branchflow was generally enriched in δ^{18}O and δD compared to open rainfall and throughfall.

However, the differences in enrichment between branchflow and stemflow remain unclear.

Conclusions

1. Focusing on the tree stand, the results of ^{137}Cs concentration shows that the canopy remained the major contribution of the ^{137}Cs leaching. Interestingly, branchflow of dead foliage showed the highest ^{137}Cs concentration as compared to branchflow of mixed and younger foliage due to interception during initial fallout.
2. Branchflow and stemflow generation did not affect the ^{137}Cs leaching process. A higher range of ^{137}Cs leaching was detected even though a small branchflow volume was collected.
3. Significant variability of ^{137}Cs depositional flux per tree stand was detected among the tree species and between cedar stand and oak stand, with the oak stand generally exhibiting higher a ^{137}Cs depositional flux than the cedar stand.
4. The magnitude of isotopic variation differed between cedar and oak stands. However, more sampling work is needed especially during rainfall period at summer.

References

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