Effects of differences in aboveground dead organic matter types on the stand-scale necromass and CO2 efflux estimates in a subtropical forest in Okinawa Island, Japan

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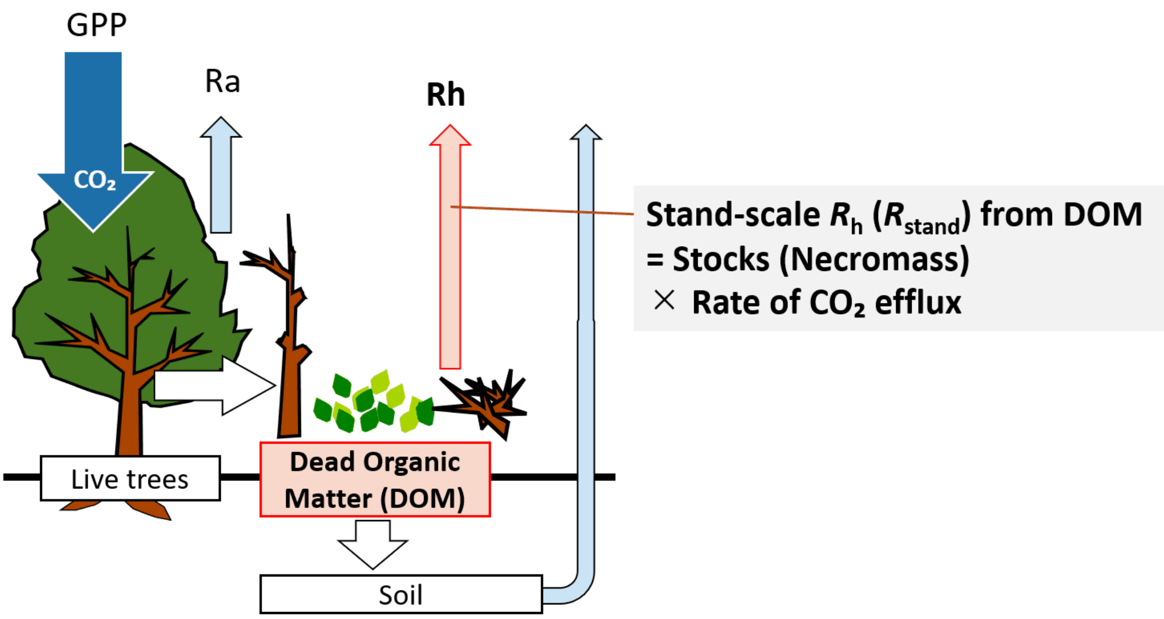
PRESENTED AT:

1. INTRODUCTION

Short explanation



We aimed to quantify the effect of each DOM type on total necromass, total Rstand, and estimate error of total necromass and Rstand.

For this aim, we investigated characteristics of necromass and Rstand from DOM in a subtropical forest in Okinawa island, Japan.

Long explanation

1-1. What is dead organic matter (DOM) ?

Dead organs of plants, especially dead matter of trees (e.g., leaf litter, fine woody debris, coarse woody debris).

1-2. Is the DOM important?

Yes. DOM contributes to forest carbon cycling especially carbon stocks and carbon sources.

1-3. What is research gaps?

- Although DOM have various types, few studies have considered effects of differences in each DOM types on the stand-scale estimates of carbon storage (necromass) and CO2 efflux (Rstand).
- Although spatial variability in DOM necromass differs for each type, there has been little attention given to evaluating the effects of spatial variability of each DOM type on necromass and Rstand estimates.

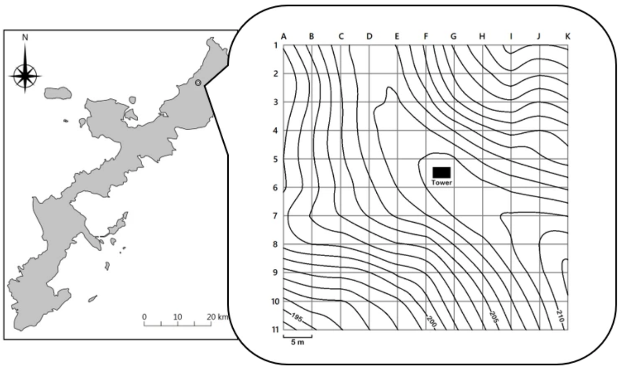
1-4. What we do?

We examined

- (1) the contribution of each DOM type to total necromass and total Rstand from above-ground DOM,
- (2) spatial distribution pattern of necromass of each DOM type,
- (3) the optimal sampling plots area and arrangement for the accurate estimates of necromass and Rstand based on the spatial distribution pattern of each DOM type,
- (4) effect of spatial variability in each DOM type on the estimate error in total necromass and total Rstand from above-ground DOM.

2. METHODS

2-1. Study site



Location
Northern part of Okinawa Island (N26°45′, E128°12′)

Forest Type
Sub-tropical Evergreen broad-leaved forest

Area
50 × 50 m (0.25 ha)

Dominant tree species
Castanopsis sieboldi

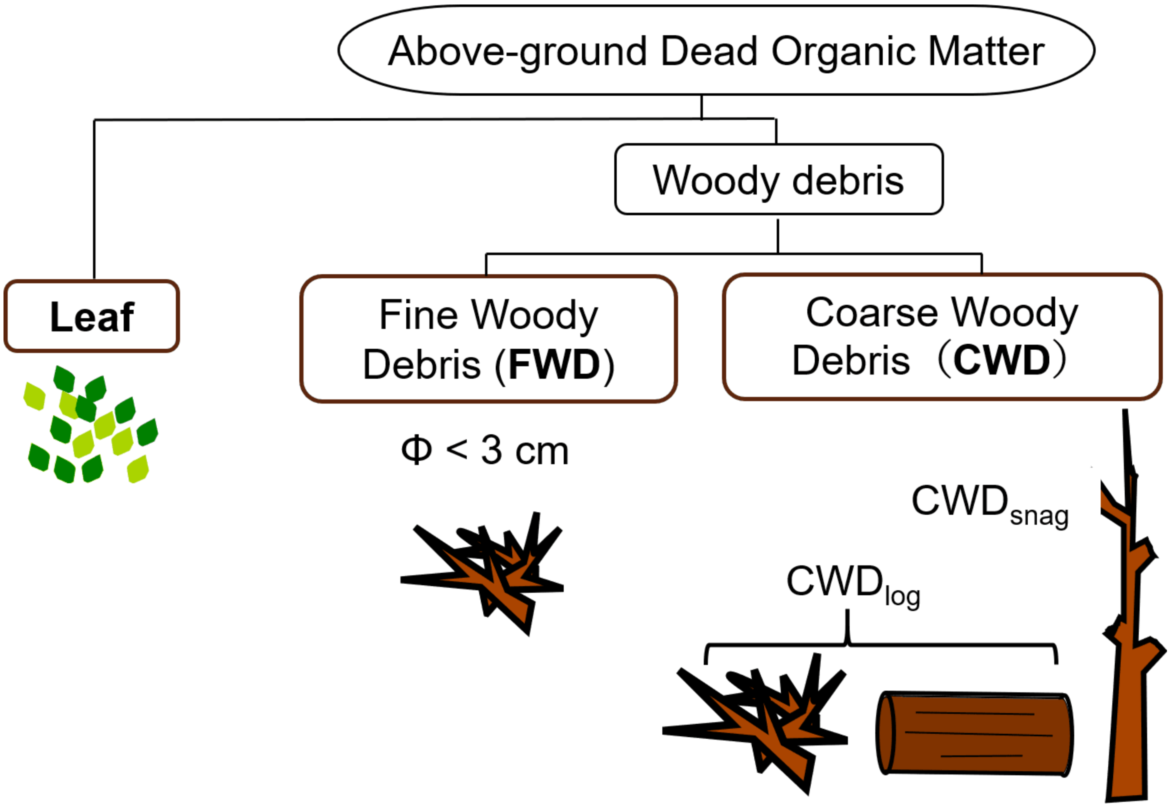
Trees density
6268 trees ha^{-1}

Mean annual temparture
20.7°C

Mean annual precipiration
2505.5 mm

- A subtropical evergreen broad-leaved forest, in the northern part of Okinawa Island, southwestern Japan (26°45′N, 128°12′E, 190–210 m a.s.l.).
- The annual mean temperature : 20.7 °C.
- The annual precipitation: 2505.5 mm.
- Typhoons approached Okinawa Island 49 times between 2010 and 2019

2-2. Sampling targets



- **We separated above-ground DOM** as follows; leaf litter, fine woody debris (FWD; < 3 cm diameter), downed coarse woody debris (CWDlog), and standing or suspended coarse woody debris (CWDsnag).

2-3. Necromass estimation

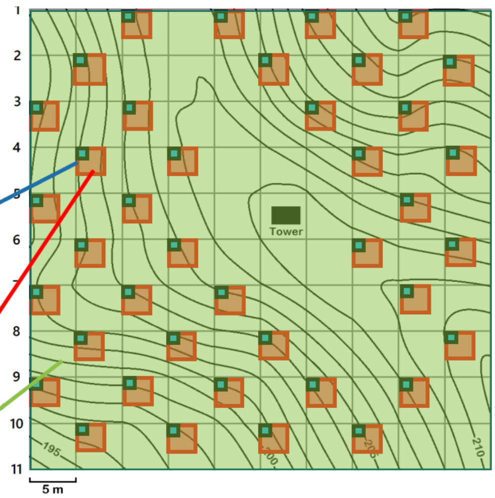
Necromass (g C m^{-2})

Sampling Area

		Target	Area (m²)
	Leaf and Twig		10
CWD	Log	3～10cm	120
CWD	Log	10～20cm	490
CWD	Log	20cm以上	2500
CWD	Snag		2500

Date：2019/6/30，7/14，9/18～20，9/25

Sampling Plots



Leaf, Twig, and Small CWD

▷Retrieve DOM → Measure dry weight

Big CWD

▷①Measure length and diameter →②Calculate volume (cm^3)

→③Estimate dry weight (volume × wood density (g cm^{-3}))

We installed samping plots as follows.

- Leaf litter and twig (FWD) : 40 subplots (0.25 m² each, blue filled area).

- CWDlog: 40—100 subplots (red filled area).

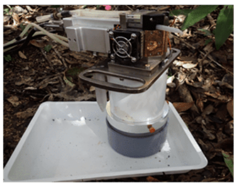
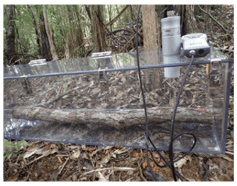
- CWDsnag: 100 subplots (25 m² each, light green filled area).

We measured necromass as carbon stock (g C m^{-2}) by measuring dry mass of DOM.

- **For leaf litter, FWD, and small size-CWDlog.**
  - Dry mass was measured by direct sampling.

- **For big size-CWDlog and CWDsnag.**
  - Dry mass was estimated by its volume and wood density.

2-4. Rstand estimation

	Leaf litter, FWD	**CWD_{log}**	**CWD_{snag}**
			
	(g CO_2 g^{-1} yr^{-1})		(g CO_2 m^{-2} yr^{-1})
Date	**Jun-Dec.2019**	**May-Dec.2019**	**2017-2019**

Stand scale-CO_2 efflux

= Annual CO_2 efflux per weight or area

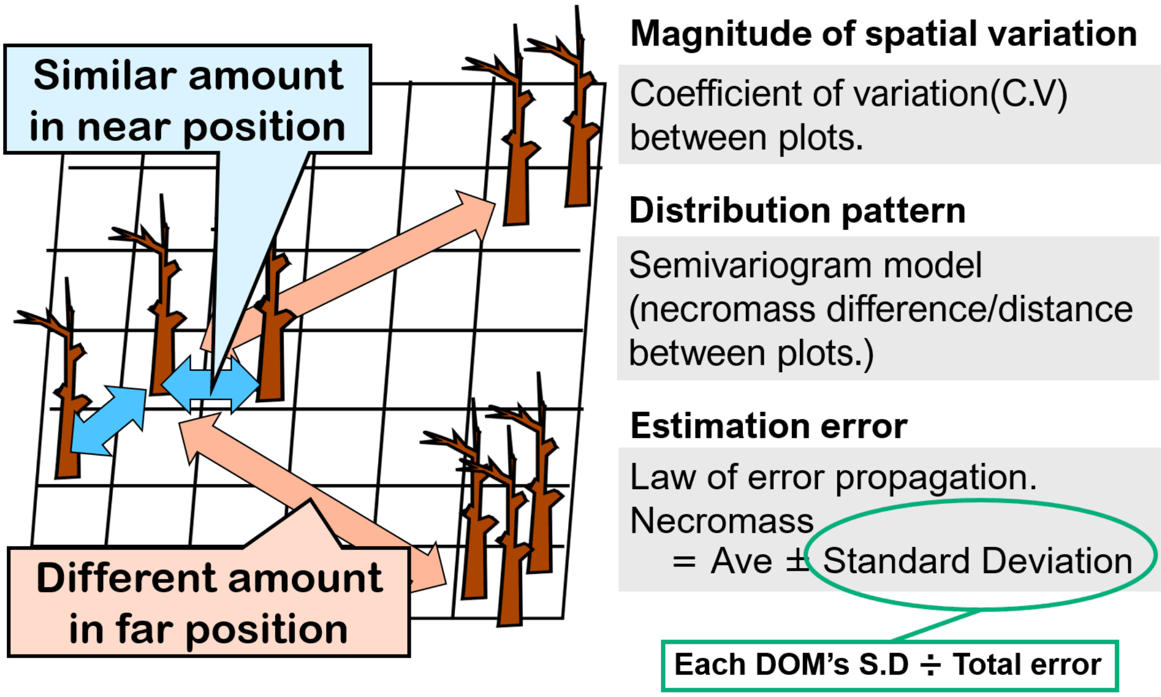
× Necromass or Total Surface area

- Using DOM of *Castanopsis sieboldii* (dominant species), CO2 efflux of DOM was measured.

- Based on measured CO2 efflux data, soil temperature, and soil water content, CO2 efflux estimation model was generated; then, annual CO2 efflux in 2019 was estimated.

- Rstand (g C m^{-2} yr^{-1}) was estimated by annual CO2 efflux and necromass.

2-5. Analysis of spatial heterogenity and its effects



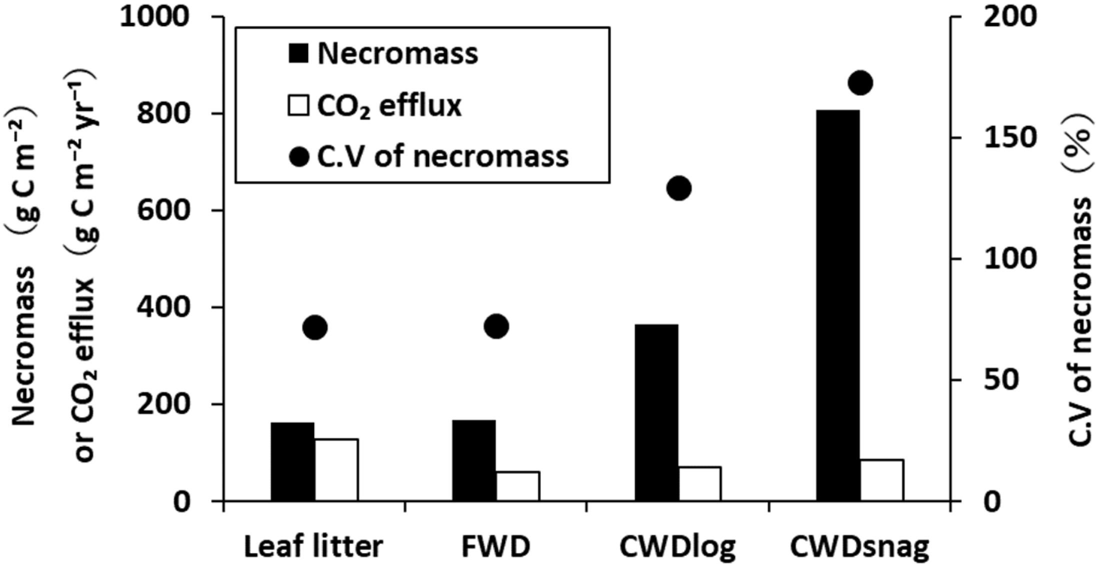
- The magnitude of spatial variability in each DOM type was evaluated by the coefficient of variation (CV) of necromass.

- The spatial distribution patterns were evaluated using semivariograms of necromass values.

- Although necromass and R_{stand} estimates can have various sources of errors in measurement procedures, this study focused on the potential errors induced by the spatial variability of each DOM type in the total necromass and total R_{stand} estimates. We defined the potential error induced by the spatial variability using the law of propagation.

3. RESULTS

3-1. Necromass, CV of necromass, and Rstand



Necromass

- Total necromass: 1499.7 g C m^{-2}.
  - Leaf litter: 161.2 g C m^{-2} (11%).
  - FWD: 167.2 g C m^{-2} (11%).
  - CWDlog: 363.3 m^{-2} (24%).
  - CWDsnag: 807.9 g C m^{-2} (54%).
- CWD, especially CWDsnag showed highest contribution.

CV of necromass

- **The CVs of the necromass**
  - CWD showed high CV (CWDlog: 130 %, CWDsnag: 173%).
  - →These were approximately two-fold higher than that of leaf litter (72%) and FWD (73%).
  - Leaf litter and FWD: observed in all sampling plots; on the contrast, CWDlog and CWDsnag were observed in 38 of the 40 plots and 66 of the 100 plots, respectively.

Rstand

- Total Rstand: 340.6 g C m^{-2} yr^{-1}.
  - Leaf litter (127.6 g C m^{-2} yr^{-1}, 37%).
  - FWD (59.3 g C m^{-2} yr^{-1}, 17%).

- CWDlog (69.7 g C m^{-2} yr^{-1}, 20%).

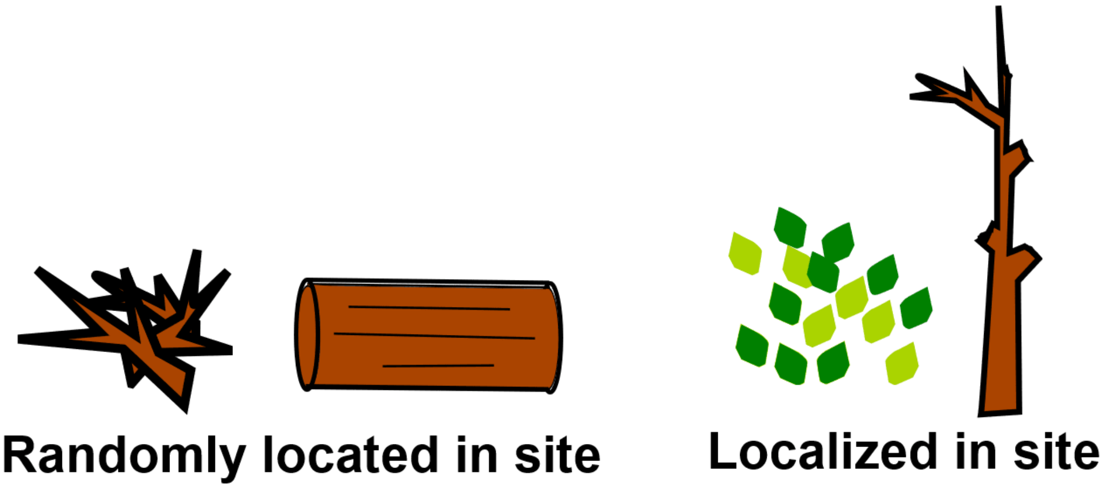
- CWDsnag (84.0 g C m^{-2} yr^{-1}, 25%).

- Reflecting the high necromass, Rstand of CWD showed highest contribution.

3-2. Semivariograms of necromass

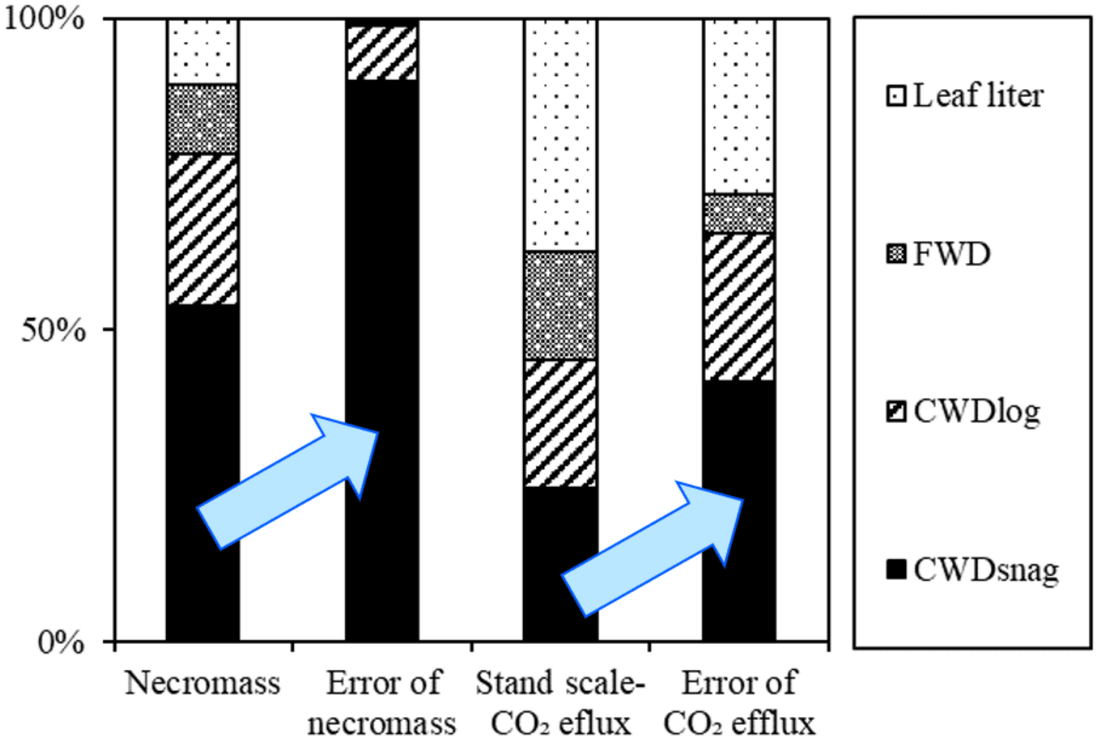
Model	Leaf	FWD	CWD_{log}	CWD_{snag}
	Exponential	Liner	Liner	Spherical
Range(m)	31.20	> 50	> 50	43.60
Nugget	0.01	0.10	0.75	1.27
Sill	0.04	0.10	0.75	2.54
R^2	0.73	0.16	0.02	0.96

- Exist of spatial autocorrelation was difffered by DOM type.
  - Leaf litter: spatial bias within < 31 m
  - FWD: no spatial autocorrelation (sill = nugget)
  - CWDlog: no spatial autocorrelation (sill = nugget)
  - CWDsnag: spatial bias within < 42 m



- →These results illustrate that leaf litter and CWDsnag were distributed locally, whereas FWD and CWDlog were randomly spread throughout the study site.

3-3. Necromass and Rstand



The proportion of potential error in the total necromass estimates

- Leaf litter (0.6%).
- FWD (0.7%)
- CWDlog (9%)
- CWDsnag (90%)
- →The total CWD accounted for the largest proportion of both total necromass (78%) and potential error in the total necromass estimates (99%).

The proportion of potential error in the total Rstand estimates

- Leaf litter (17%)
- FWD (4%)
- CWDlog (15%)
- CWDsnag (64%)
- →The total CWD accounted for the largest proportion for both total Rstand (45%) and potential error in the total Rstand estimates

(79%).

4. DISCUSSION

4-1. Necromass estimation.

- In our study area, CWD (1171.2 g C m–2) accounted for 78% of the total necromass of aboveground DOM.
  - Data sets of carbon stocks in Eurasian forests reported CWD necromass that ranged from approximately 29–5577 g C m–2, with an average of 712 g C m–2 (Schepaschenko et al., 2017).
  - The CWD necromass in the present study was approximately 1.5-fold higher than the overall average.
- The CWDsnag accounted for 69% of the total CWD at the study site, although previous studies reported that CWDsnag accounted for ≤ 50% of the total CWD in most forests (Sollins et al., 1980; Harmon et al., 1986; Pedlar et al., 2002; Kissing and Powers, 2010; Palace et al., 2012; Schepaschenko et al., 2017).
  - Jomura et al. (2007) reported that CWDsnag accounted for approximately 70% of the total CWD in a temperate broad-leaved secondary forest where many trees were considered as standing death due to widespread pest infestation.
  - Our study showed that as necromass, CWDsnag can contribute considerably to carbon stocks in forest ecosystems, particularly in forest systems similar to the forest studied here, which experiences frequent typhoon disturbance.

4-2. Rstand estimation.

- CWD accounted for 45% of the total Rstand from aboveground DOM.
  - It also accounted for 8% of soil respiration estimated at 1959 g C m^{-2} yr^{-1} in the study site (Matsumoto et al., submitted).
  - →In the tropical area, CO2 efflux from CWD may be not negligible for the carbon budget.

4-3. Charactarists of spatial variation of necromass.

- The magnitude of spatial variability in the necromass was greatest for CWD_{snag}, followed by CWD_{log}, FWD, and leaf litter.
- Spatial distribution pattern of DOM also differed by its type.
  - At the study site, spatial autocorrelation existed for leaf litter with a range of 31 m and CWDsnag with a range of 42 m, in contrast, no autocorrelation was found for FWD and CWDlog.
- This study showed that spatial variability in each DOM type affected not only the accuracy of necromass estimates, but also the accuracy of Rstand estimates.
  - In particular, the spatial variability in CWD was higher than those of leaf litter and FWD, resulting in a higher influence of CWD on both necromass and Rstand estimates.

        - →An accurate estimate of CWD necromass is important for Rstand estimation.

        - In addition, CWDsnag considerably influenced the necromass and Rstand estimates because of the high ratio of total necromass, despite the decomposition rate of CWDsnag being slower than that of CWDlog (Hararuk et al., 2017).

    - **It is also necessary to consider the effect of CWDsnag on necromass and Rstand estimates, especially in forests with frequent disturbance such as typhoons, cyclones, and beetle attacks, which can generate more CWDsnag.**

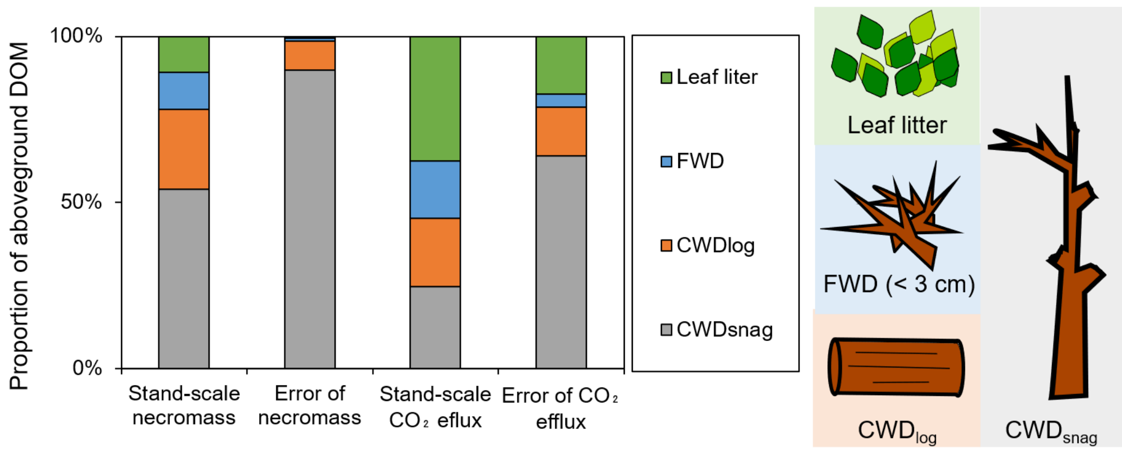
Q & A

Deteal of first author

[Updated constantly] Answers to questions raised by the AGU fall meeting 21' will be posted here.

ABSTRACT

Dead organic matter (DOM), which consists of leaf litter, fine woody debris (FWD; < 3 cm diameter), downed coarse woody debris (CWD_{log}), and standing or suspended coarse woody debris (CWD_{snag}), plays a crucial role in forest carbon cycling. However, the contributions of each DOM type on stand-scale carbon storage (necromass) and stand-scale CO_2 efflux (R_{stand}) estimates are not well understood. In addition, there is little knowledge of the effect of each DOM type on the accuracy of stand-scale estimates of total necromass and R_{stand}. This study investigated characteristics of necromass and R_{stand} from DOM in a subtropical forest in Okinawa island, Japan, to quantify the effect of each DOM type on total necromass, total R_{stand}, and estimate error of total necromass and R_{stand}. The CWD_{snag} accounted for the highest proportion (54%) of total necromass (1499.7 g C m^{-2}), followed by CWD_{log} (24%), FWD (11%), and leaf litter (11%). Leaf litter accounted for the highest proportion (37%) of total R_{stand} (340.6 g C m^{-2} yr^{-1}), followed by CWD_{snag} (25%), CWD_{log} (20%), and FWD (17%). The CWD_{snag} was distributed locally with 173% of the coefficient of variation for necromass, which was approximately two times higher than those of leaf litter and FWD (72–73%). Our spatial analysis revealed, for accurate estimates of CWD_{snag} and CWD_{log} necromass, sampling areas of ≥ 28750 m^2 and ≥ 2058–42875 m^2 were required, respectively, under the condition of 95% confidence level and 0.1 of accepted error. In summary, CWD considerably contributed to stand-scale carbon storage and efflux in this subtropical forest, resulting in a major source of errors in the stand-scale estimates. In forests where frequent tree death is likely to occur, necromass and R_{stand} of CWD are not negligible in considering the carbon cycling as in this study, and therefore need to be estimated accurately.



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