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Methane Emissions from the Stems of Living Trees in Upland Forests

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Outline

1. Do plant-based CH_4 emissions constitute a distinct source?

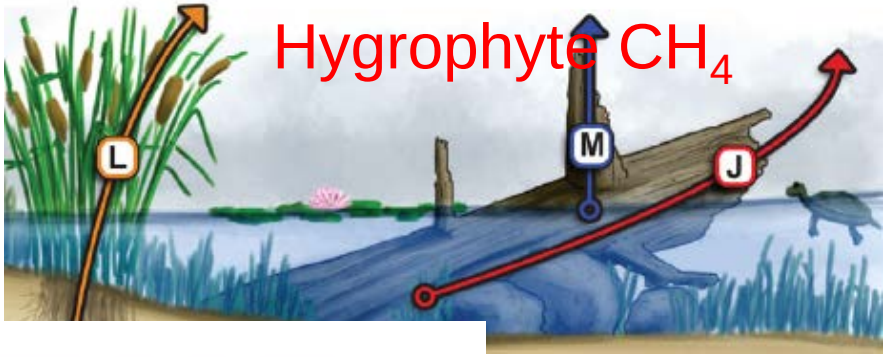
2. CH_4 production / emissions in / from the heartwood / stems of living trees

3. Factors controlling CH_4 production in heartwood

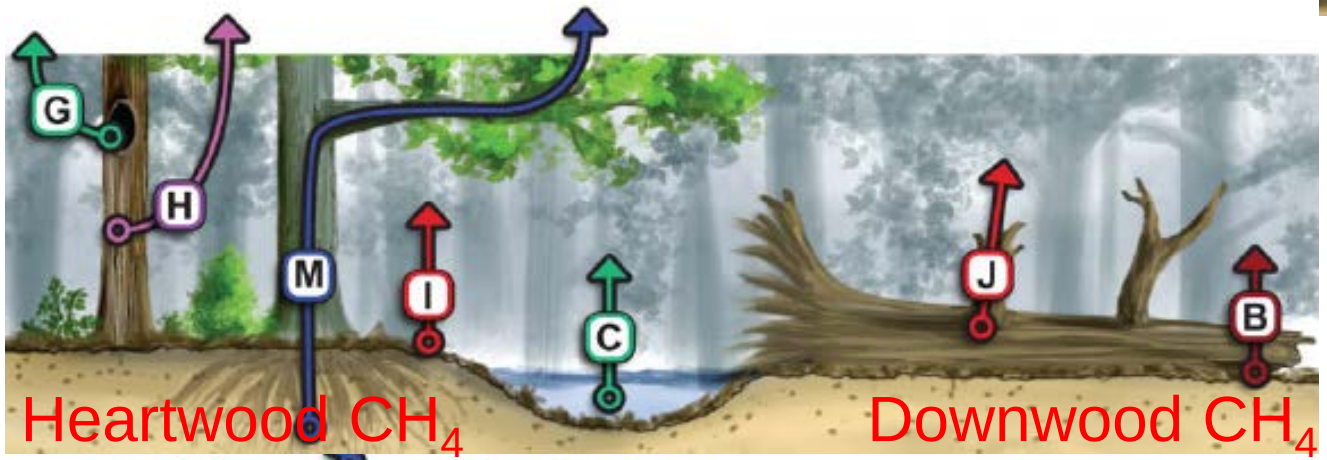
4. Perspective: Novel and large source?

Are plant-based CH_4 emissions a distinct source?

Aerobic CH_4

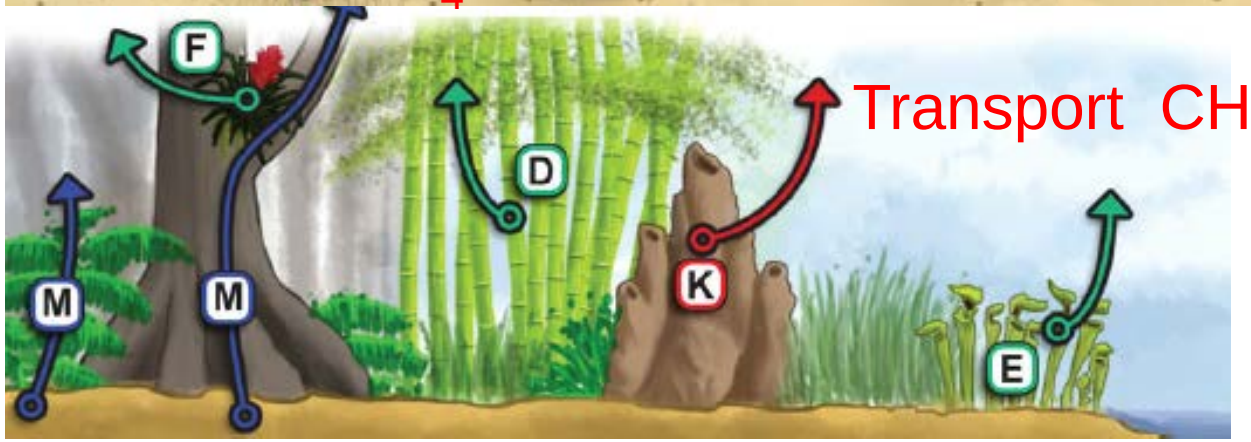


Hygrophyte CH_4



Heartwood CH_4

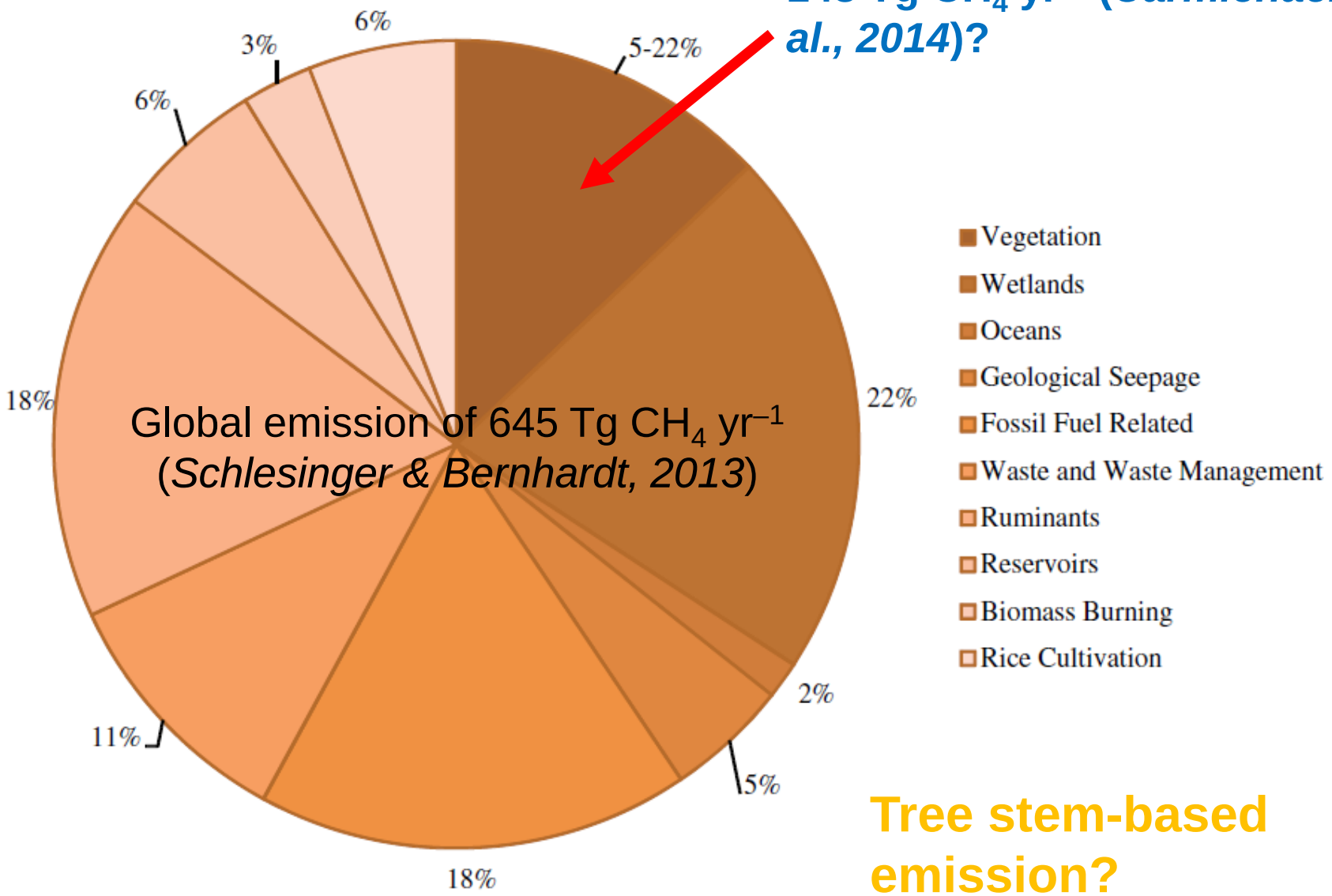
Downwood CH_4



Transport CH_4

Carmichael et al. 2014

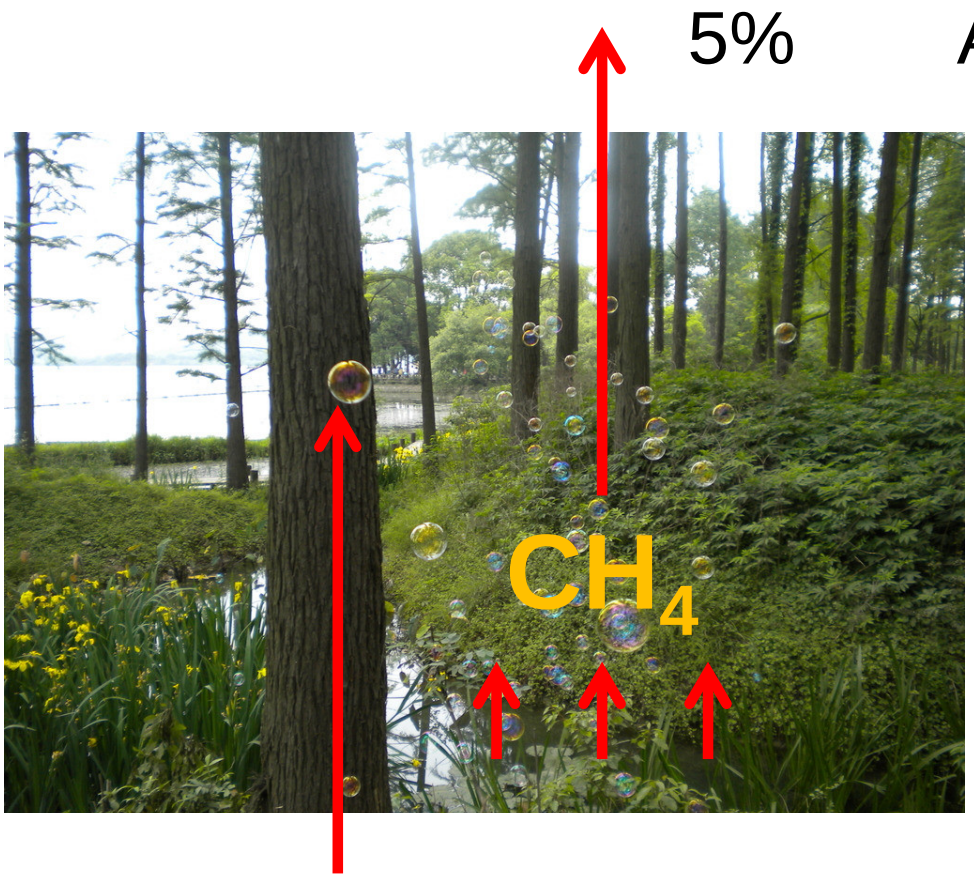
Plant-based emission of 32–143 Tg CH_4 yr^{-1} (*Carmichael et al., 2014*)?



Global emission of 645 Tg CH_4 yr^{-1} (*Schlesinger & Bernhardt, 2013*)

Tree stem-based emission?

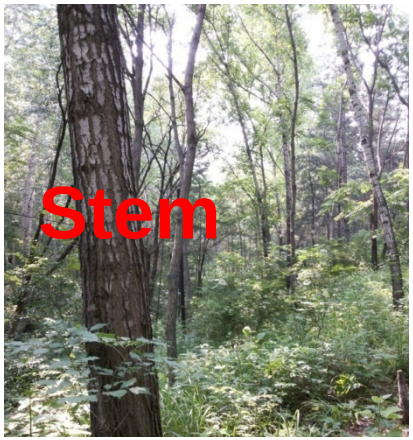
Forest Wetlands versus Upland Forests




Upland Forests

Outline

2. CH_4 production / emissions in / from the heartwood / stems of living trees



New Phytologist

Research

Methane emissions from the trunks of living trees on upland soils

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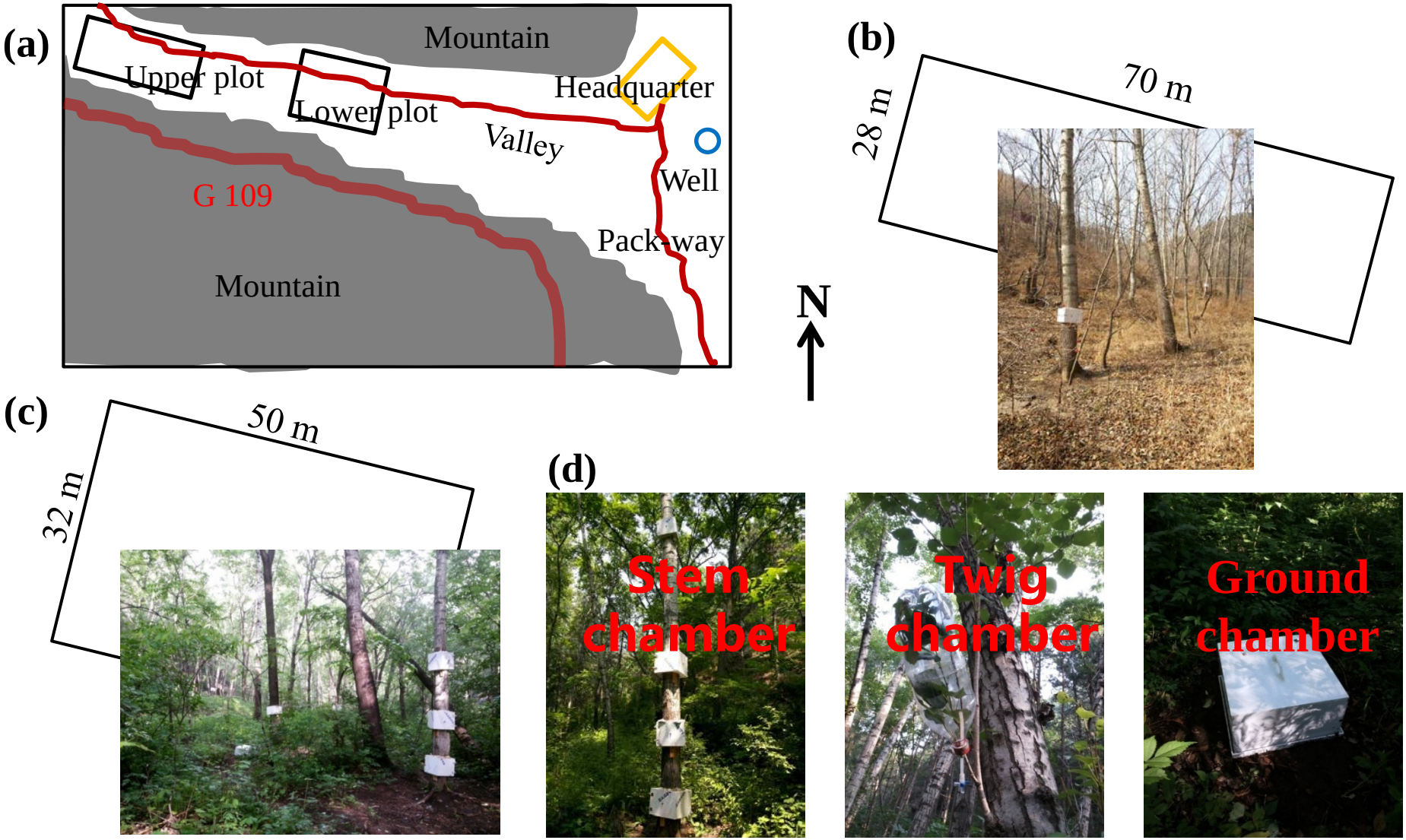
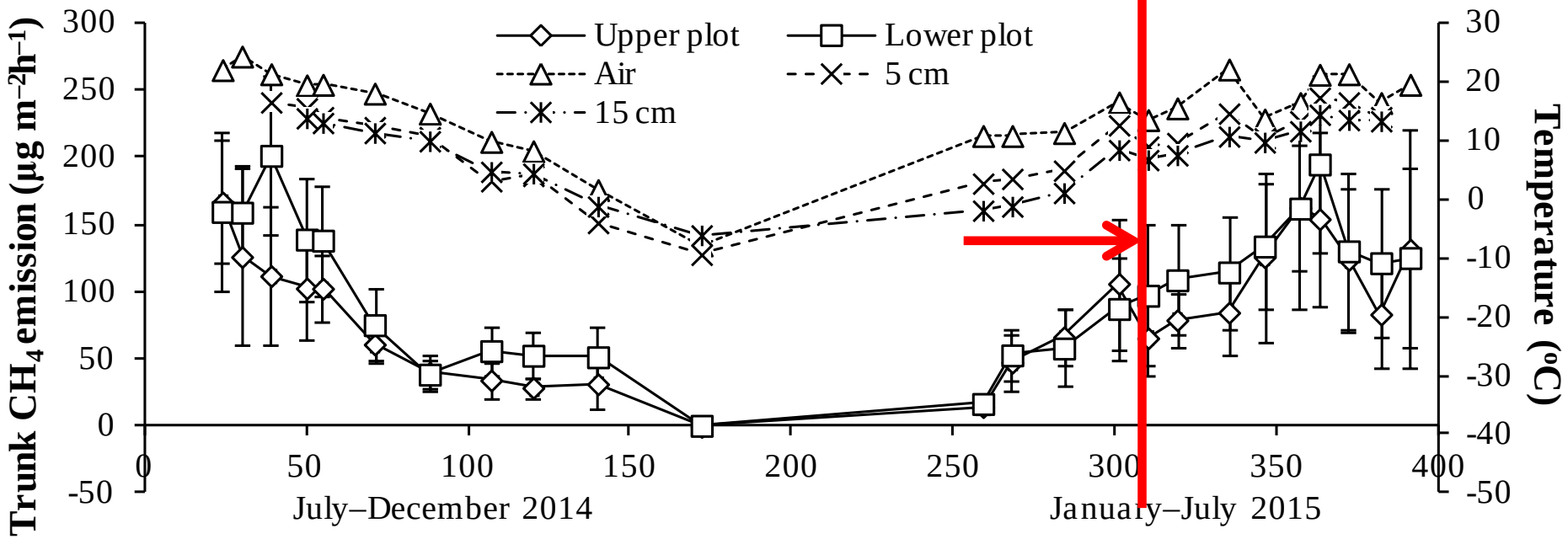
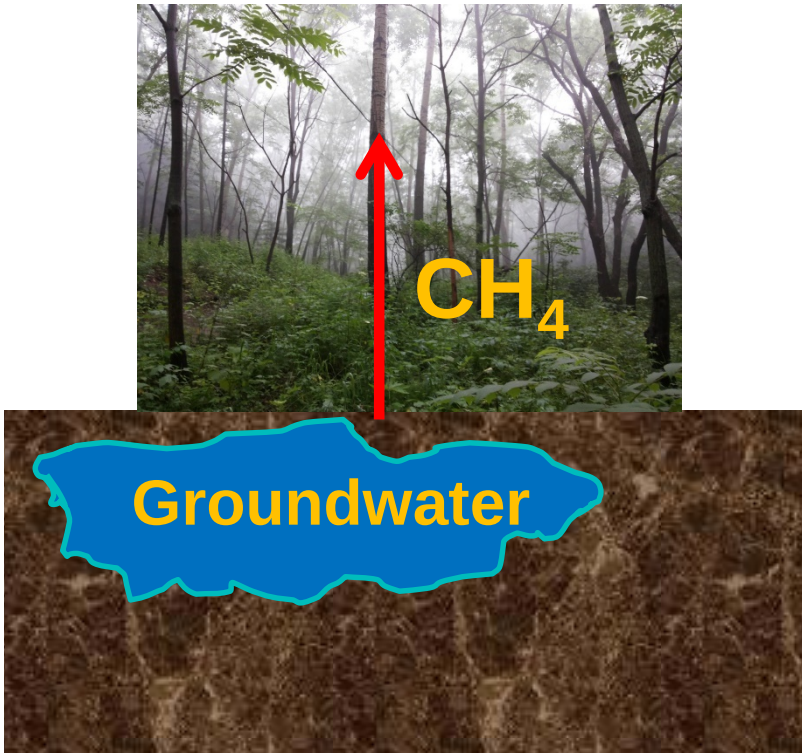
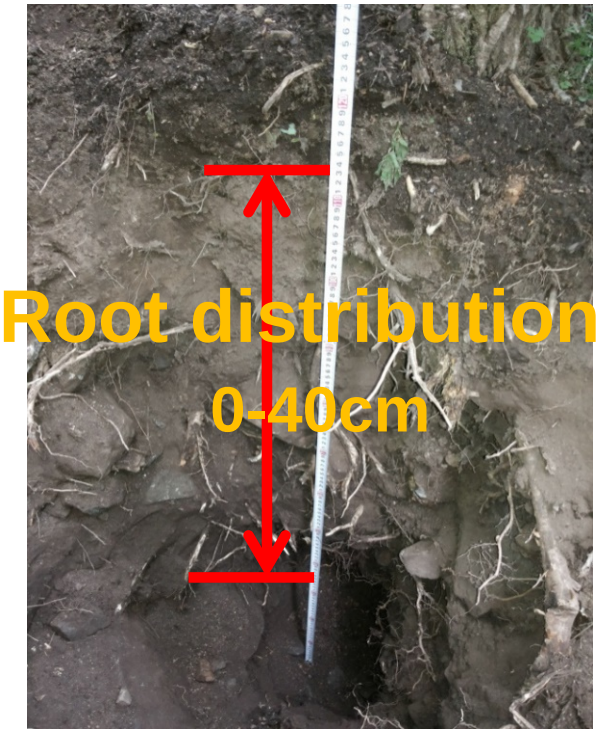


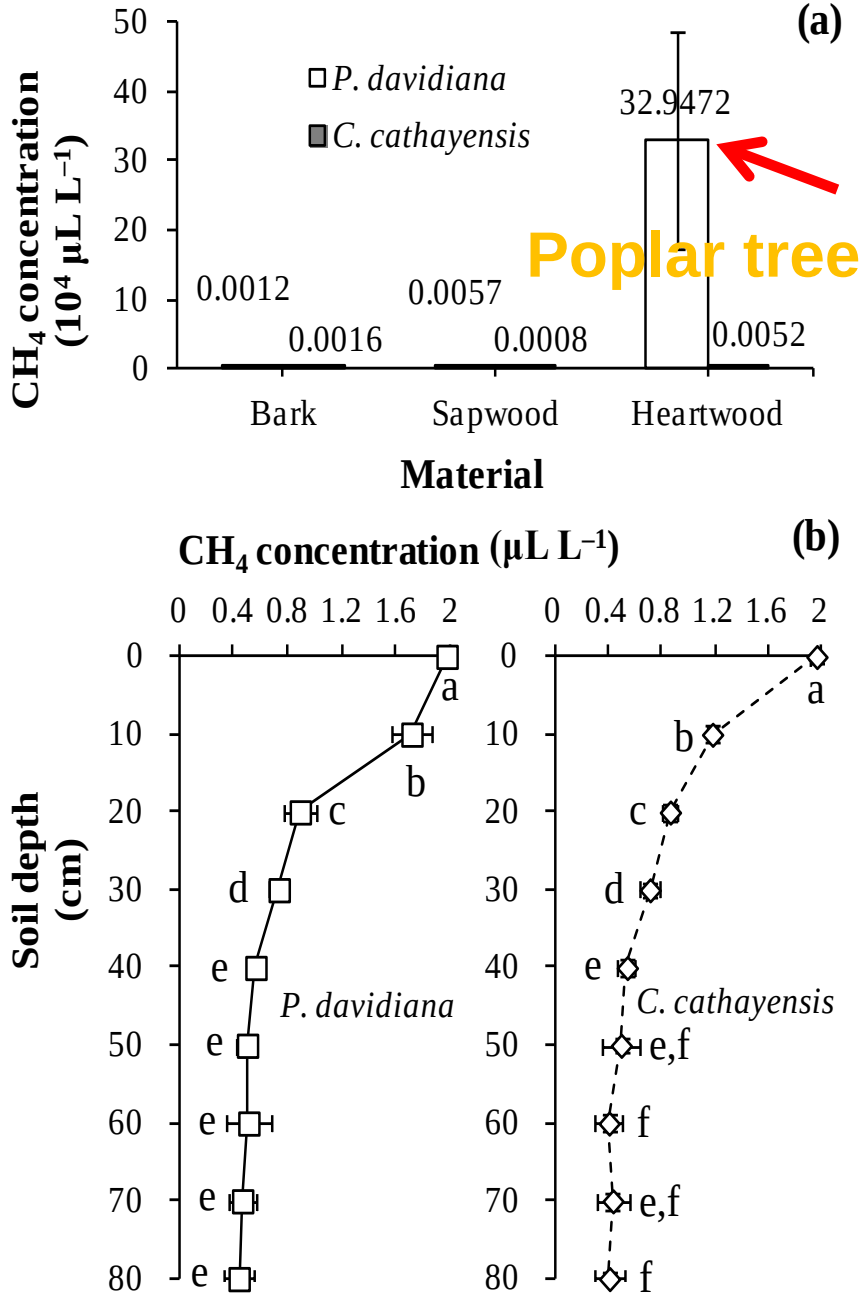
The experimental layout in the Beijing Forest Ecosystem Station (a), the upper plot (b), the lower plot (c), and chambers (d).

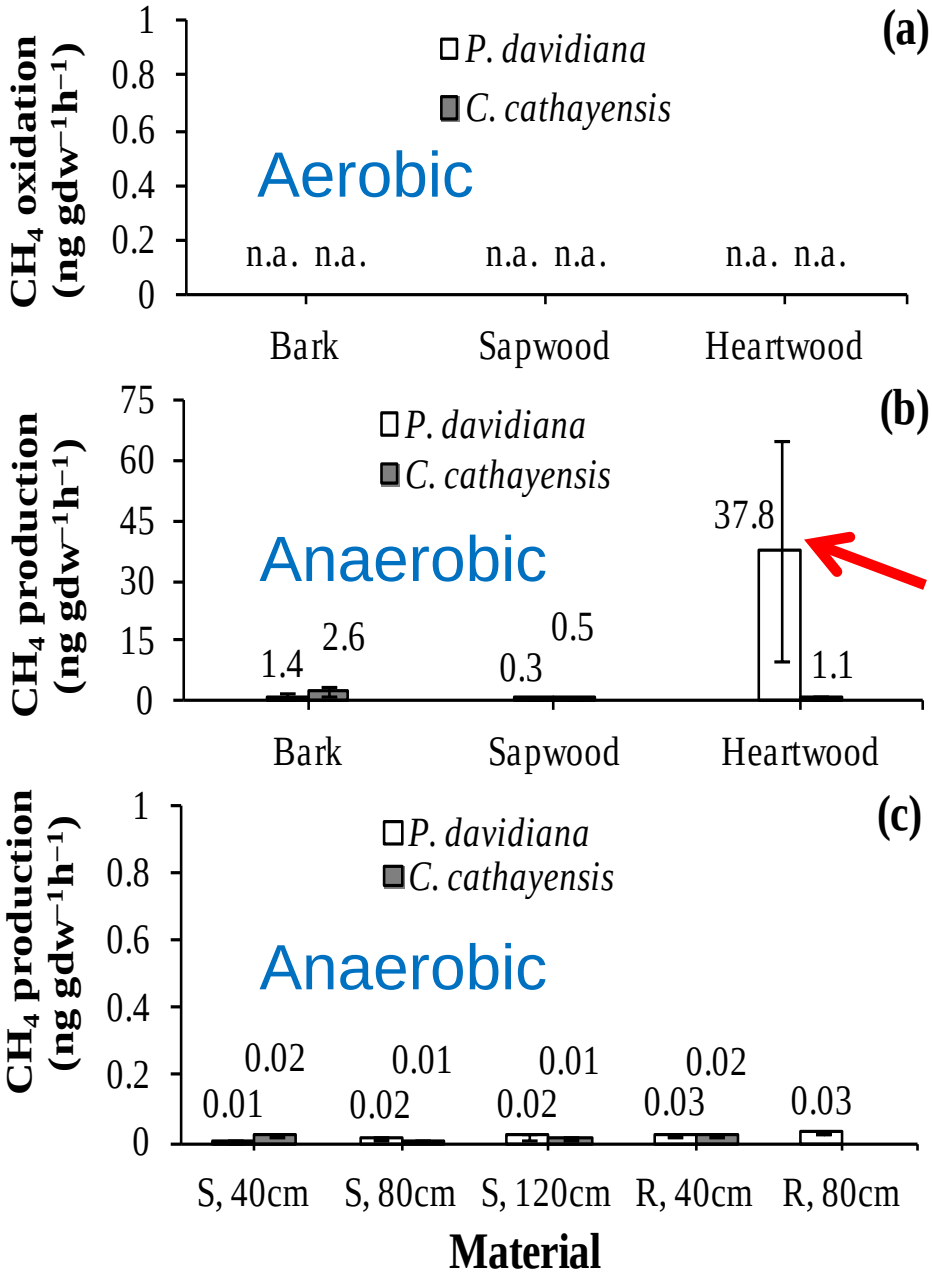
July 2014 – July 2015


Upper plot
Lower plot
Air
5 cm
15 cm
Trunk CH_4 emission (μg $m^{-2}h^{-1}$)
Temperature (°C)
July–December 2014
January–July 2015


CH_4
Groundwater


Root distribution
0-40cm


(a)
CH_4 concentration (10^4 µL L^{-1})
50
40
30
20
10
0
P. davidiana
C. cathayensis
32.9472
Poplar tree
0.0012
0.0016
0.0057
0.0008
0.0052
Bark
Sapwood
Heartwood
Material
(b)
CH_4 concentration (µL L^{-1})
0 0.4 0.8 1.2 1.6 2
Soil depth (cm)
0
10
20
30
40
50
60
70
80
a
b
c
d
e
e
e
e
P. davidiana
a
b
c
d
e
e,f
f
e,f
f
C. cathayensis


(a)
CH4 oxidation (ng gdw−1h−1)
1
0.8
0.6
0.4
0.2
0
P. davidiana
C. cathayensis
Aerobic
n.a. n.a.
n.a. n.a.
n.a. n.a.
Bark
Sapwood
Heartwood
(b)
CH4 production (ng gdw−1h−1)
75
60
45
30
15
0
P. davidiana
C. cathayensis
Anaerobic
1.4
2.6
0.3
0.5
37.8
1.1
Bark
Sapwood
Heartwood
(c)
CH4 production (ng gdw−1h−1)
1
0.8
0.6
0.4
0.2
0
P. davidiana
C. cathayensis
Anaerobic
0.01
0.02
0.02
0.01
0.02
0.01
0.03
0.02
0.03
S, 40cm
S, 80cm
S, 120cm
R, 40cm
R, 80cm
Material

CH_4 production in the heartwoods of living *P. davidiana* in a small terrace in the Xiaolongmen Forest Farm.

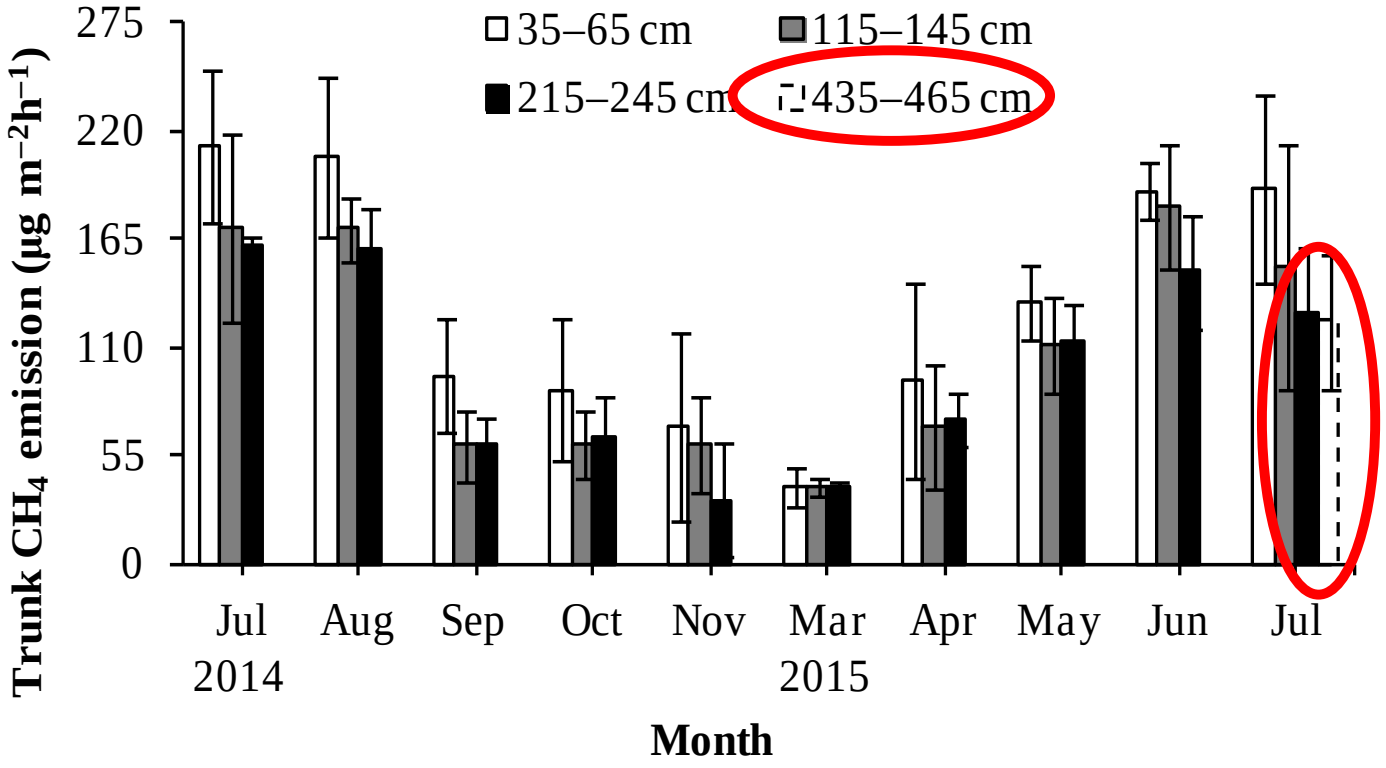
Position	Average age (y)	Trunk diameter (cm)	Heartwood		
			Water content (%)	CH_4 concentration ($\mu L\ L^{-1}$)	CH_4 production ($ng\ gdw^{-1}h^{-1}$)
118°44'6.8"E, 31°57'3.5"N 1150 m above sea level	20	47.3 (5.7)	68.5 (3.0)	$23.6\ (20.0) \times 10^4$	81.64 (63.09)

Value is Mean (SD), n = 5 for trunks.

Wood materials were sampled in August 9, 2015.

Previous studies

Our study


35–65 cm
115–145 cm
215–245 cm
435–465 cm
Trunk CH4 emission (µg m−2h−1)
275
220
165
110
55
0
Jul
Aug
Sep
Oct
Nov
Mar
Apr
May
Jun
Jul
2014
2015
Month

CH_4 flux calculations and CH_4 budget estimates

Table 1 Annual budget of CH_4 in the forest ecosystem

Component		Jul 2014	Aug	Sep	Oct	Nov	Dec	Jan 2015	Feb	Mar	Apr	May	Jun	Jul	Annual
		CH_4 flux (μg $trunk^{-1}h^{-1}$ for tree or μg $m^{-2}h^{-1}$ for soil)													
Tree	*Populus davidiana*														
	Trunk I	1345.3	1318.1	517.9	530.8	309.9	n.a.			312.3	606.2	922.4	1240.1	1083.4	
	Trunk II	1125.0	1118.8	342.2	398.9	215.6				309.7	502.4	819.8	1137.4	841.4	
	Trunk III	1185.7	1170.7	411.1	437.7	276.2				310.2	525.9	837.4	1160.6	936.0	
	Twig and leaf		n.a.	n.a.											
	Carya cathayensis									n.a.	n.a.	n.a.	n.a.		
	Larix gmelinii									n.a.	n.a.	n.a.	n.a.		
Soil		-74.5	-73.2	-60.3	-50.6	-47.0	-12.1			-19.3	-39.2	-58.2	-79.5	-57.2	
		Plot-wide CH_4 (g $plot^{-1}$)													
Tree	Mean	76.2	75.2	25.6	28.5	16.2				19.4	33.0	53.7	71.3	59.6	**390.7**
	Range	70.3~84.1	69.9~82.4	20.7~31.3	24.9~33.2	13.0~18.7				19.4~19.5	30.4~36.7	51.2~57.6	68.8~75.0	52.6~67.1	**359.8~430.3**
Soil		-88.7	-87.2	-69.5	-60.2	-54.1	-14.4	-14.4	-13.9	-23.0	-45.1	-69.3	-91.6	-68.1	**-621.1**

Plot-wide CH_4 were estimated using the parameters of living tree species, such as the 84 trunks of living *P. davidiana* in the lower plot of 1600 m^2 (Tree bases were assumed as zero and not excluded in plot area) and the mean 15.3 m trunk height of *P. davidiana* (see Table S1).

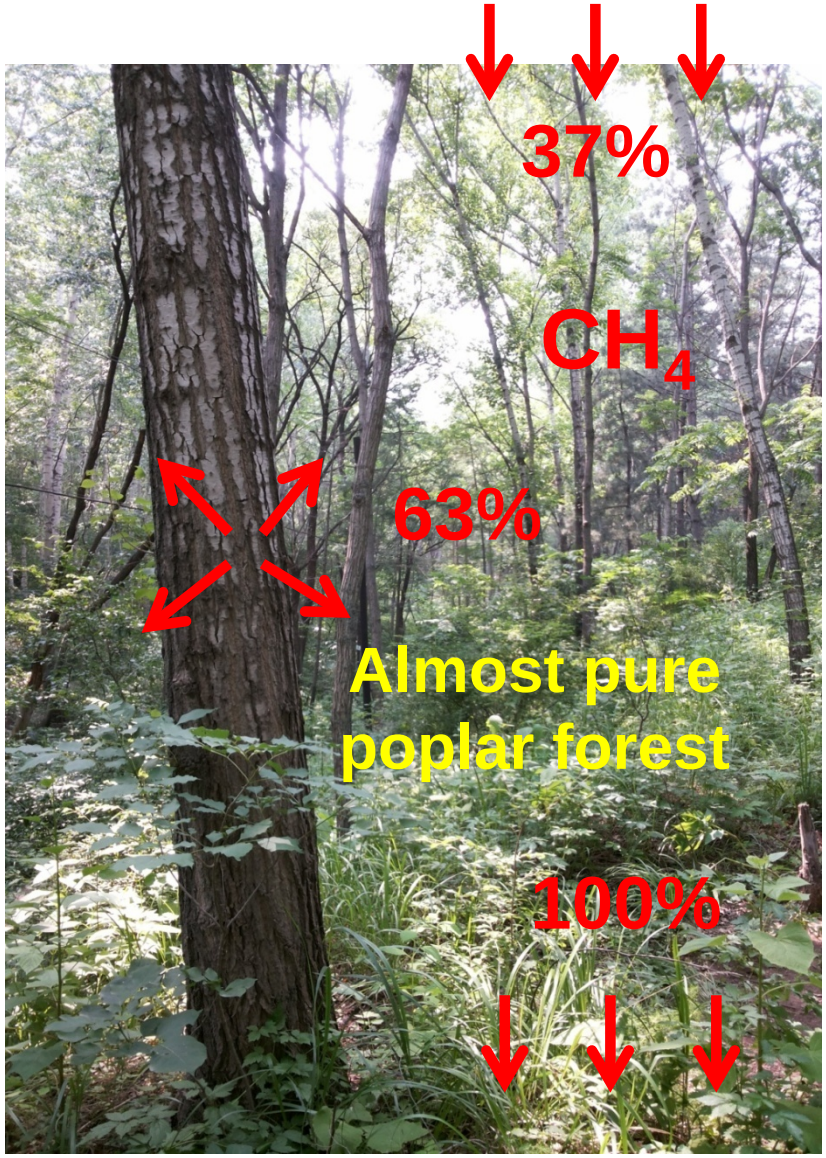
Trunk I, II, and III indicate trunk CH_4 emissions calculated by arithmetic average, logarithm function, and power function, respectively.

Annual CH_4 is the sum of those in months; CH_4 in July is an average of two values in July 2014 and July 2015.

The CH_4 fluxes measured were undetectable and defined as n.a. for not applicable (no data available).

Traditional hypothesis

Our result



Outline

3. Factors controlling CH_4 production in heartwood

Tree species with capacity of substantial CH_4 production in heartwood

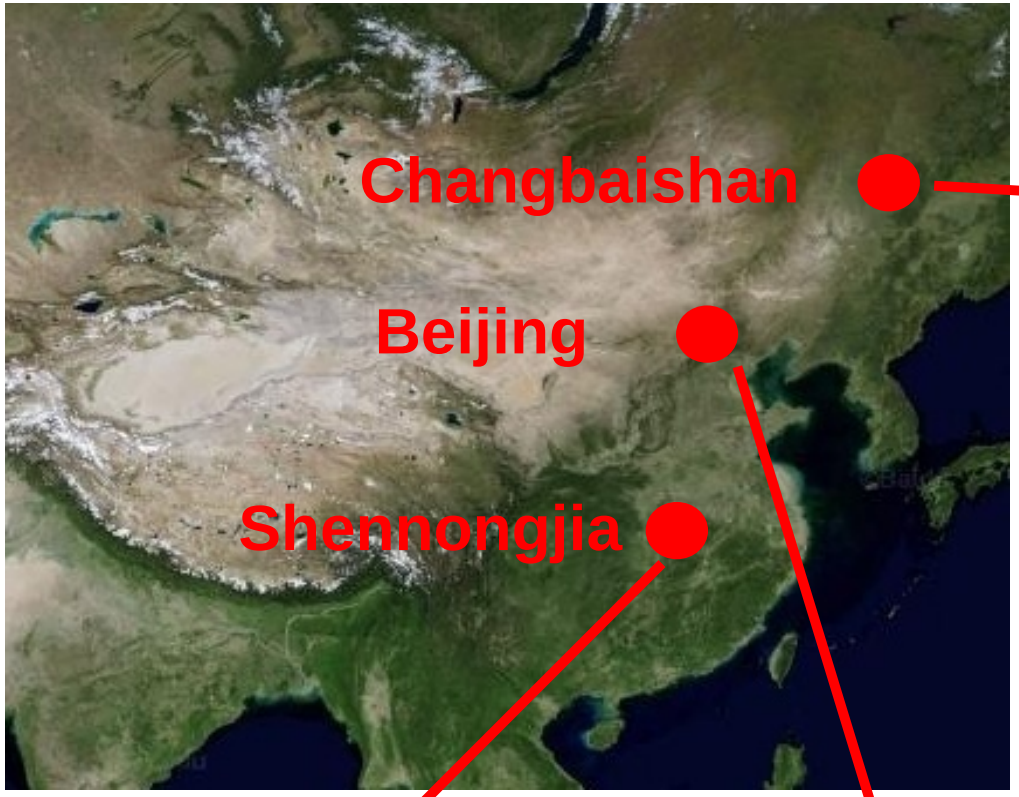
Temperature
Water content
(*Wang et al., 2017, Journal of Geophysical Research: Biogeosciences*)

Most of tree species with no capacity of substantial CH_4 production in heartwood (*Wang et al., 2017*)

Even if high water content, no CH_4 production!

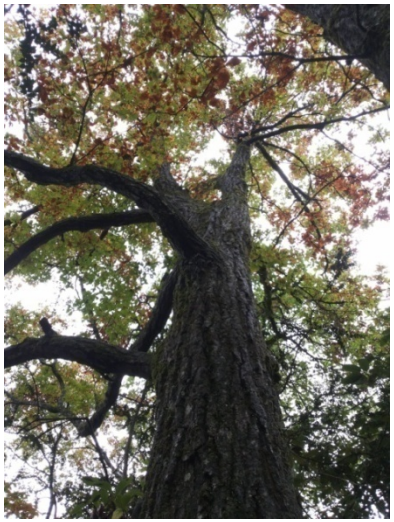
Why?
Secondary metabolites, e.g. carbohydrates , phenolic compounds?
(Unpublished)

Field investigation



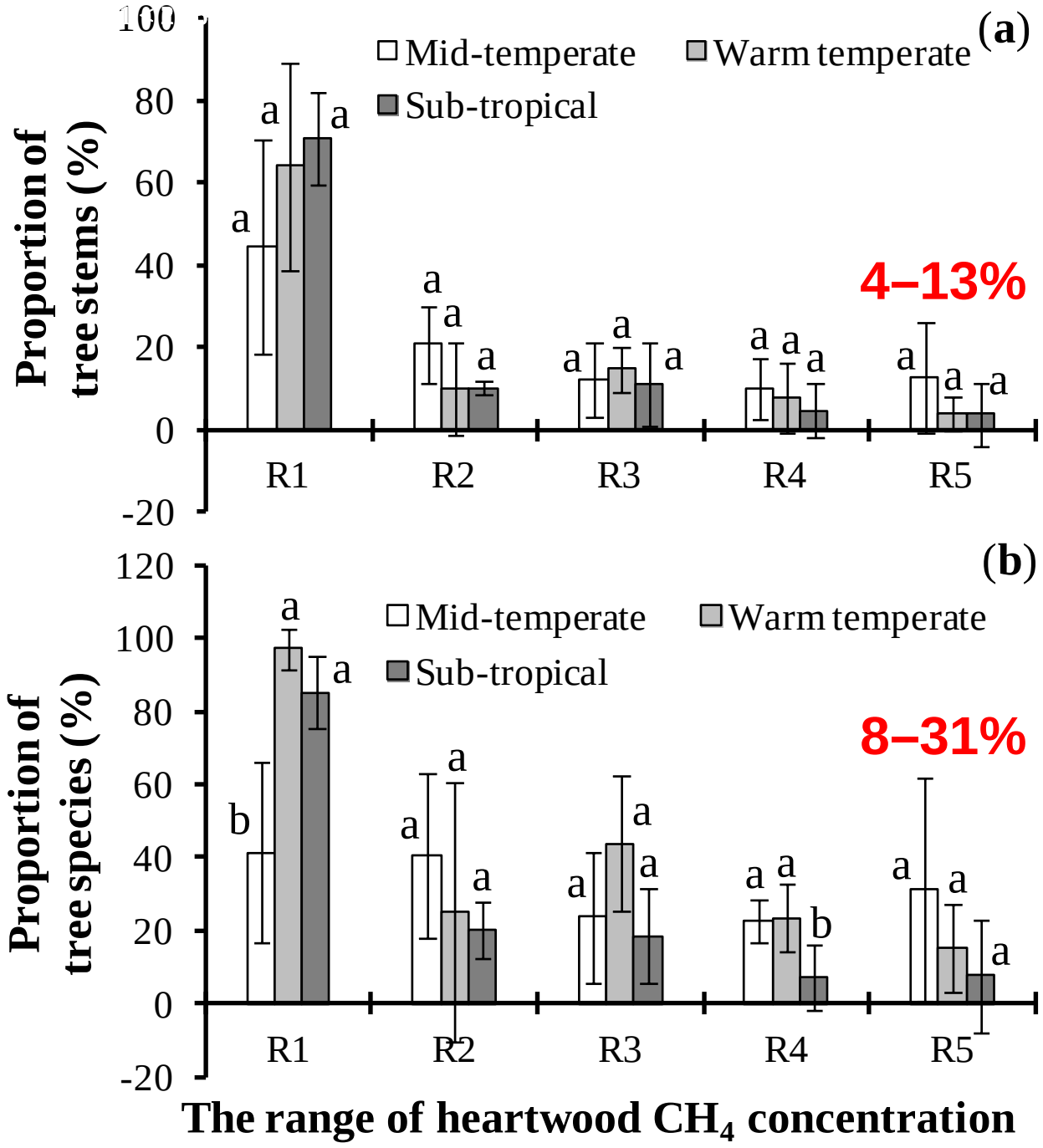
N

20×20 m^2 plots




宜昌木姜子
Litsea ichangensis


琪桐



The ranges:

R1 < 21.6

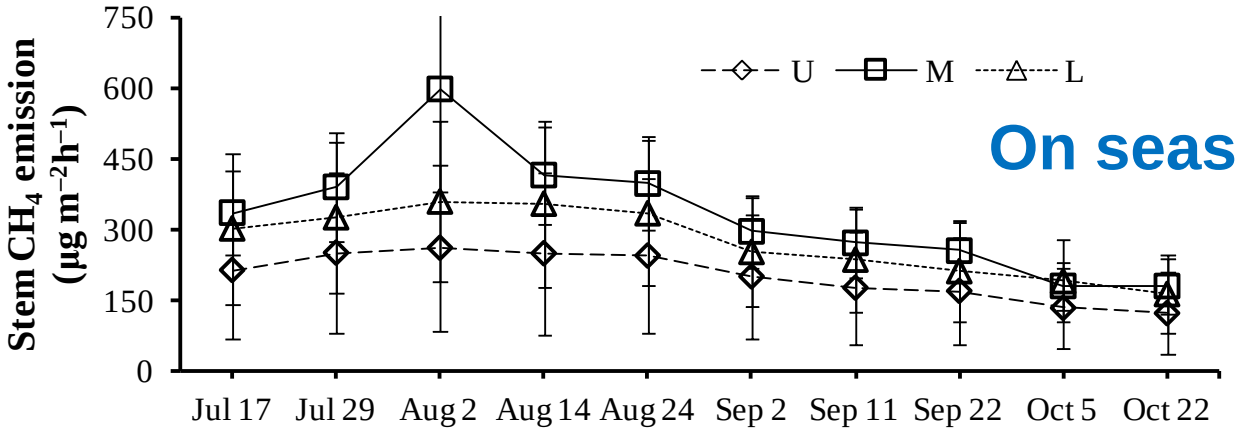
21.6 ≤ R2 < 100

100 ≤ R3 < 1,000

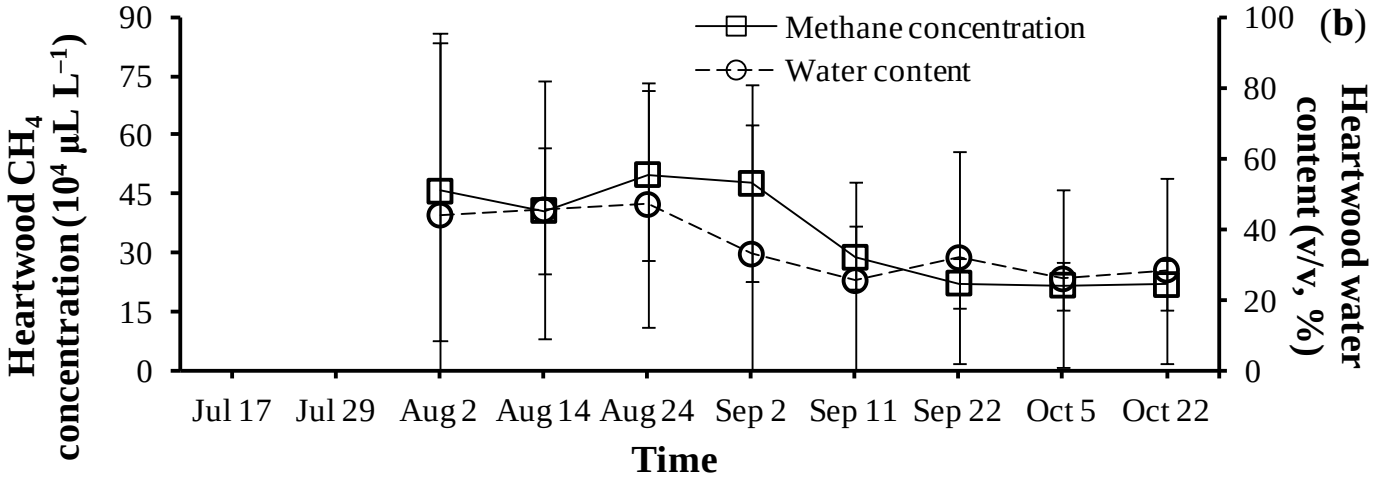
1,000 ≤ R4 < 10,000

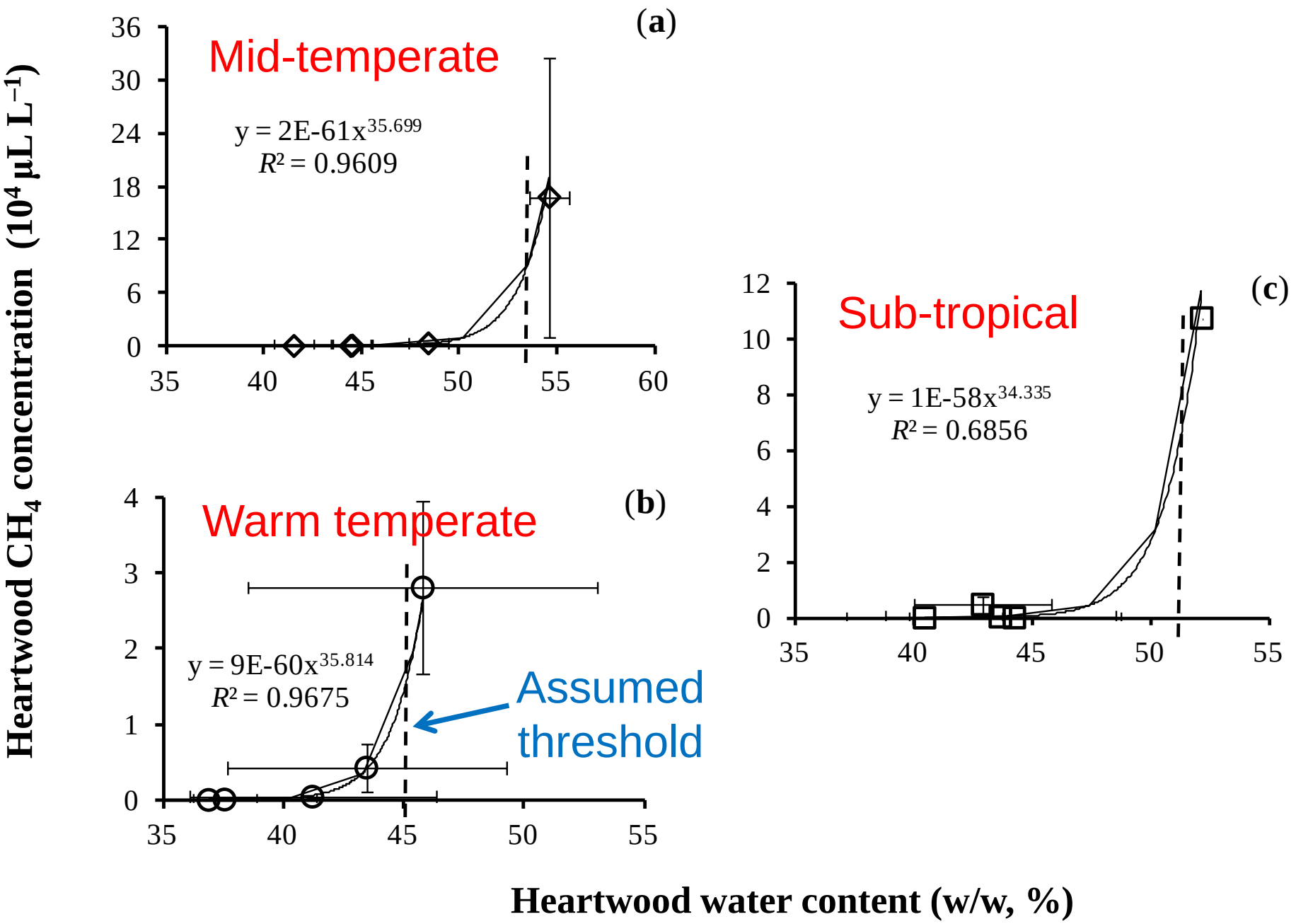
R5 ≥ 10,000 μL L^{-1}

CH_4 emission?

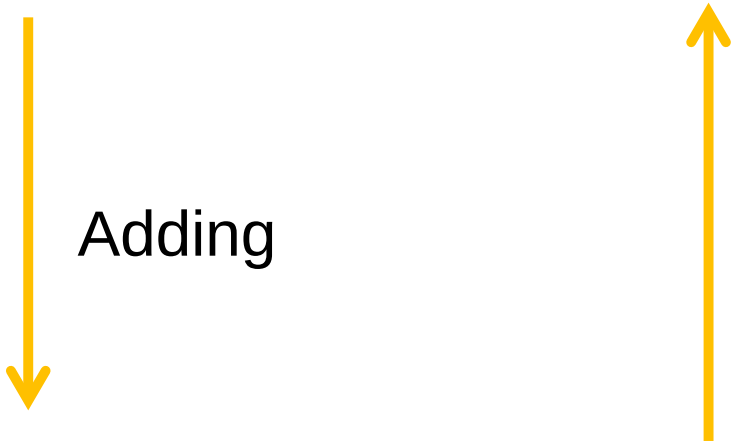


On seasonal scale




(a)
Mid-temperate
y = 2E-61x^35.699
R² = 0.9609
(b)
Warm temperate
y = 9E-60x^35.814
R² = 0.9675
Assumed threshold
(c)
Sub-tropical
y = 1E-58x^34.335
R² = 0.6856
Heartwood CH4 concentration (10⁴ µL L⁻¹)
Heartwood water content (w/w, %)

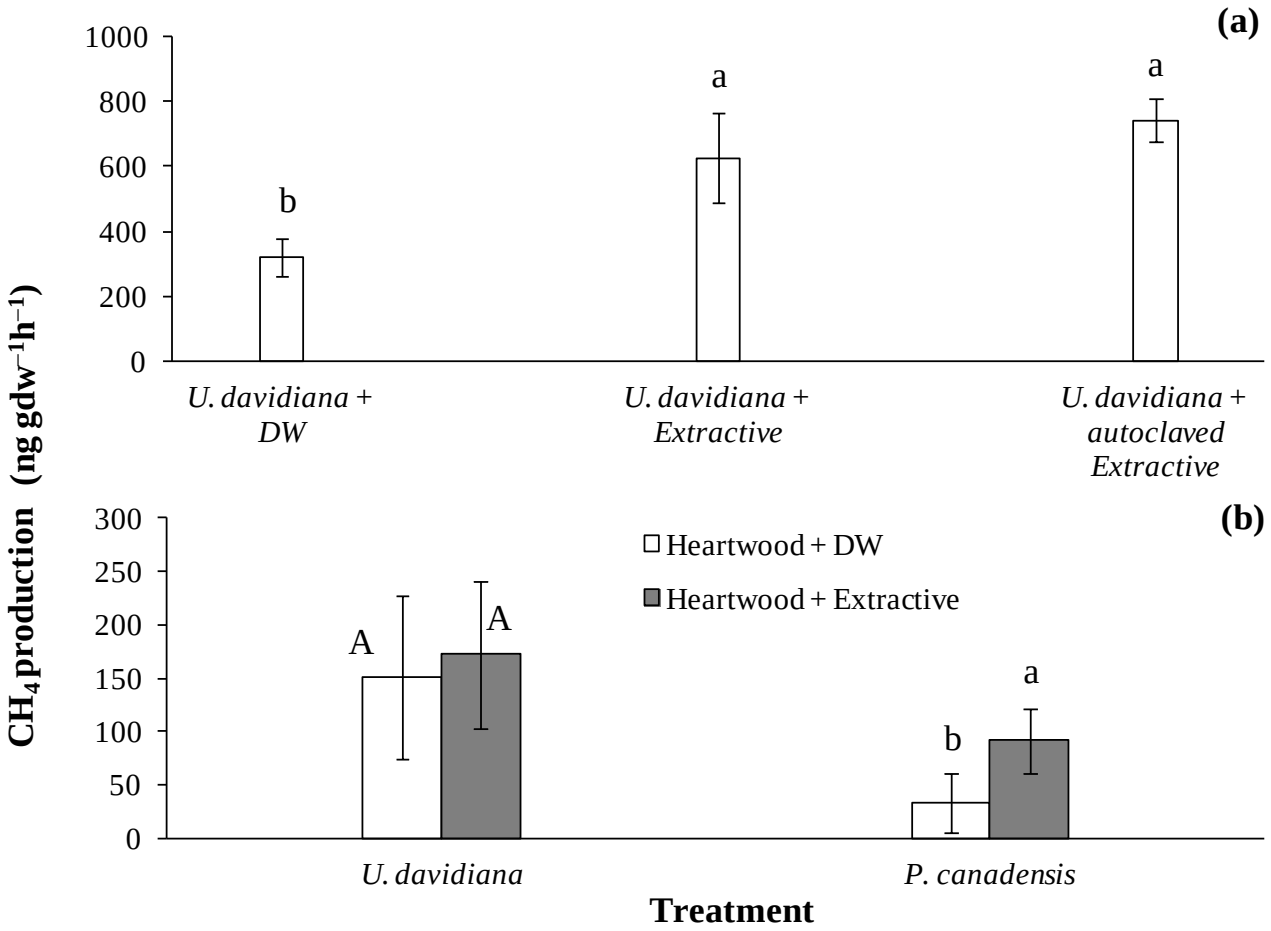
Extractive solution of heartwood of a tree species that has no capacity of substantial CH_4 production in heartwood



Adding

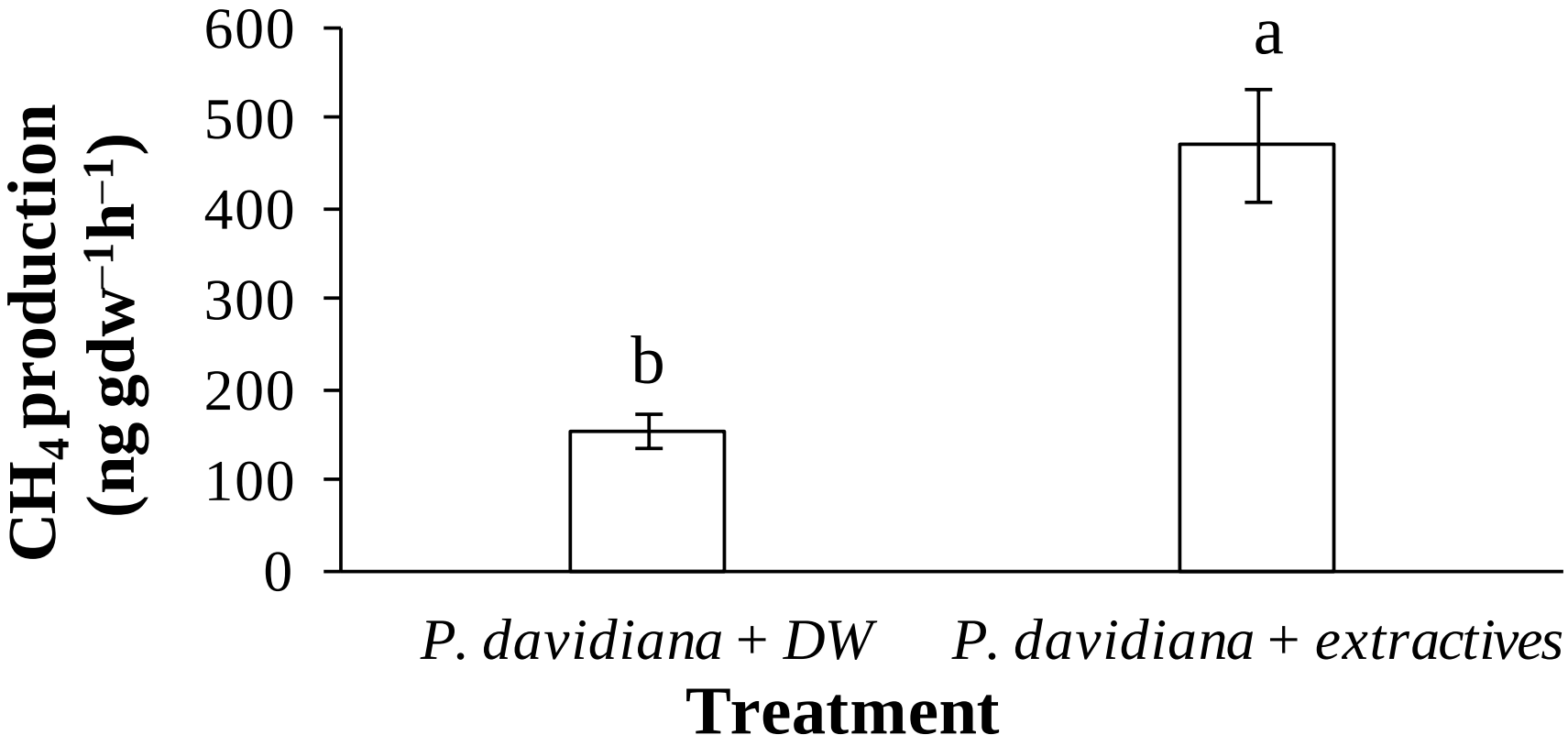
Answering why no capacity of substantial CH_4 production

Fresh heartwood of another tree species that has the capacity of substantial CH_4 production in heartwood



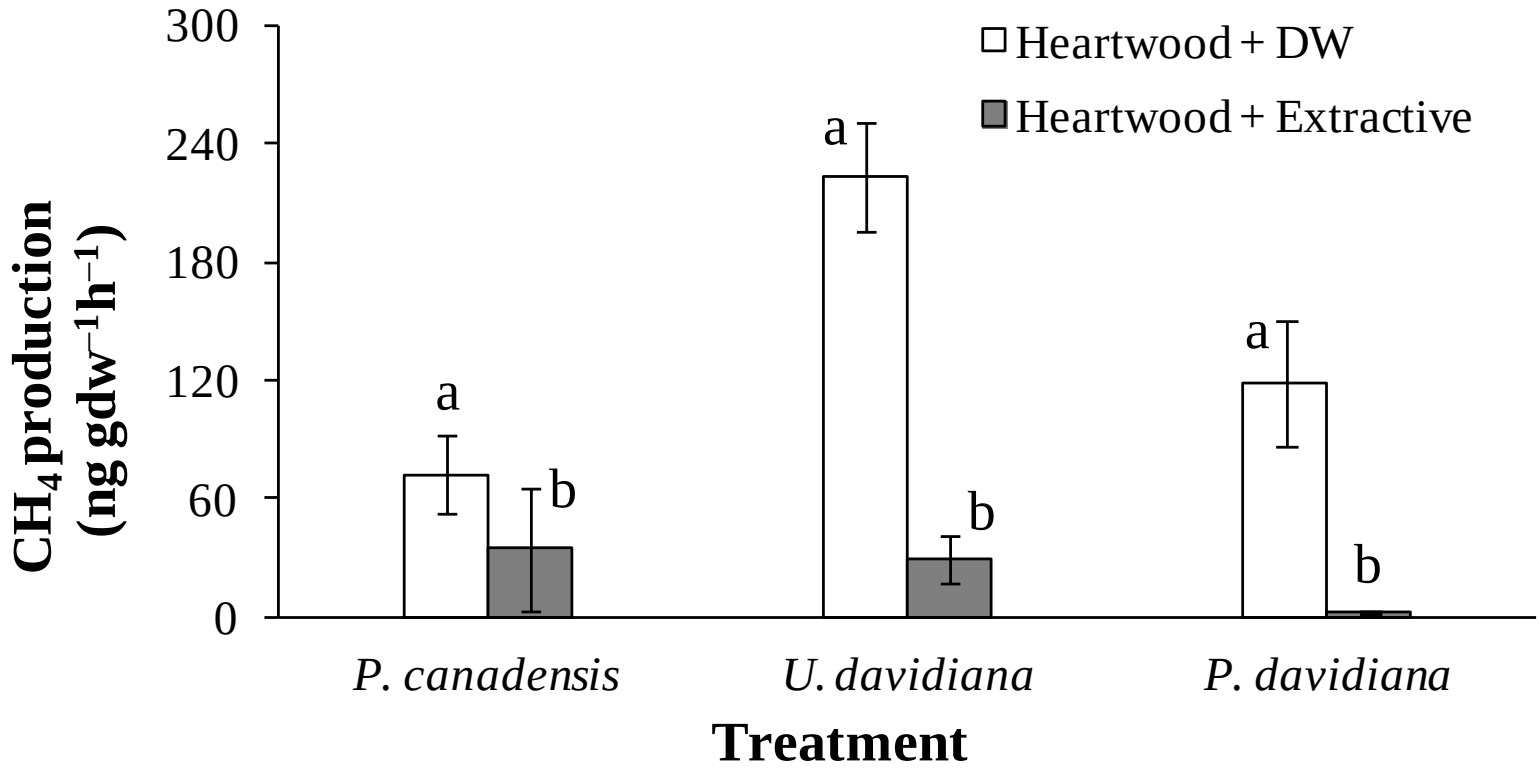
Water-soluble extractives enhanced microbial CH_4 production.

(a) Treatments are the 1 g heartwood of *Ulmus davidiana* + 1 mL Deionized Water, + Extractive (1 mL heartwood extractive solution of *Salix matsudana* (no CH_4 production)*)* and + autoclaved Extractive. **(b)** Treatments are the 1 g heartwood of *U. davidiana* or *P. canadensis* + 1 mL DW and + 1 mL heartwood extractive solution of *P. tabuliformis* (no CH_4 production).



Ethanol-soluble extractives enhanced microbial CH_4 production, when ethanol's effect was removed.

Treatments are the 0.8 g fresh heartwood of *Populus davidiana* + 1 mL DW and + 1 mL 100% E extractive solution of *Pinus tabuliformis* (no CH_4 production) evaporated and then 1 mL DW added.



Acetone-soluble extractives inhibited microbial CH_4 production, when acetone's effect was removed.

Treatments were the 1 g fresh heartwood of *P. canadensis* or *U. davidiana* + 1 mL DW or 1 mL heartwood extractive solution of *P. tabuliformis* (no CH_4 production), the 1 g fresh heartwood of *P. davidiana* + 1 mL DW or + 1 mL heartwood extractive solution of *S. matsudana* (no CH_4 production).

No substantial CH_4 in the heartwood of most tree species in upland forests, when other variables are appropriate

Net effect of secondary metabolites on microbial CH_4 production in heartwood?

Inhibition!

Summary

- For tree species with capacity of substantial CH_4 production, when temperature was not a limiting factor for CH_4 production in summer and autumn, and thus, most of the CH_4 production may be explained by **water content** in the heartwood of living trees.

- For tree species with no capacity of substantial CH_4 production, net effect of **secondary metabolites** may inhibit microbial CH_4 production in the heartwood.

Perspective: Novel and large source?

1, Ecogeography: temporal and spatial distribution, the magnitude of CH_4 emission?

2, CH_4 production mechanism and dynamics?

3, More relationships between CH_4 production/emission and factors?


Thank you for attention