Methane in Upland Forest Trees

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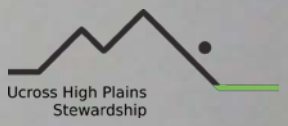

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Fieldwork and Sample Processing

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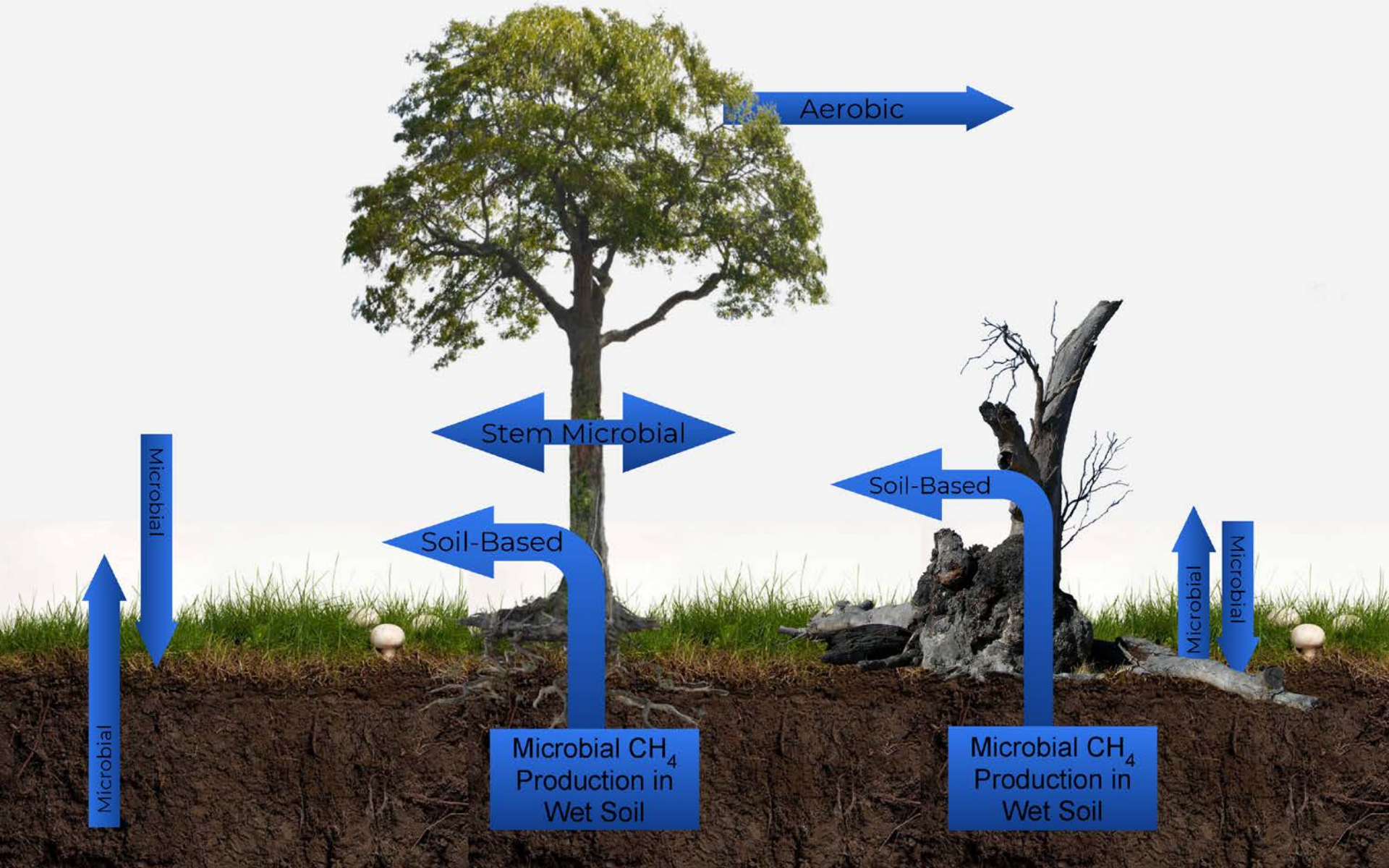
CH_4 Production and Consumption in Forests



Oxygen in Tree Stems

Study	[O2]	Ecosystem Type	Species Studied
Bushong 1907	1.24%	Not specified	*Unspecified Populous sp.*
Chase 1937	0.02-18.29%	Upland Forest	*Quercus rubra, Quercus macrocarpa, Ulmus americana, Populus deltoides, Pinus strobus*
Jensen 1967	5.5-7.5%	Upland Hardwood Forest	*Quercus rubra*
Van Der Kamp *et al.* 1979	0.02-2.90	Upland Hardwood Forest	*Populus delectans*
Eklund 1990	5.6-15.1%	Upland Conifer Forest	*Picea abies*
Eklund 1993	5-19%	Upland Hardwood Forest	*Quercus robar, Acer platanoides*
Eklund 2000	.5-21%	Upland Conifer Forest	*Picea abies*
Gansert *et al.* 2001	1-5%	Upland Hardwood Forest	*Betula pendula*
Mancuso and Marras 2003	1-5%	Greenhouse Study	*Olea europaea*
del Hierro *et al.* 2002	13-20%	Temperate Arboretum	*Fagus orientalis, Carya ovata, Larix sibirica, Laurus nobilis*
Pruyn *et al.* 2002	.5-20%	Upland Conifer Forest	*Pseudotsuga menziesii*
Spicer and Holbrook 2004	3-20%	Upland Hardwood Forest	*Acer rubrum, Fraxinus americana, Tsuga canadensis, Quercus rubra*

CO_2 in Tree Stems

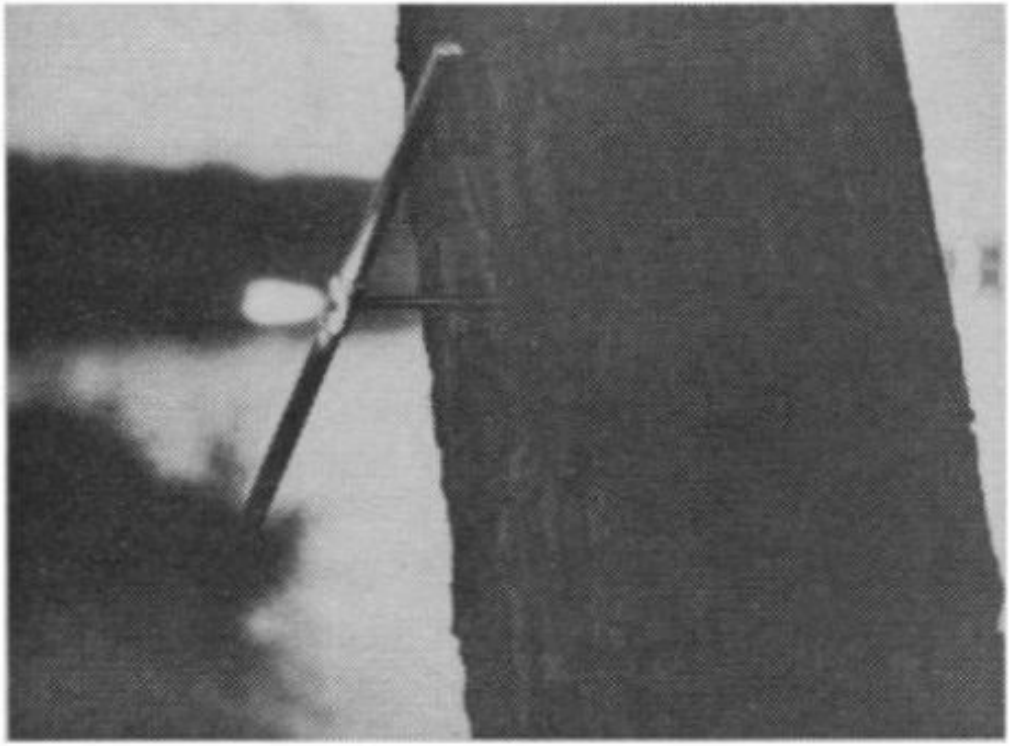
Table 1 Carbon dioxide concentrations ($[CO_2]$) measured *in situ* in stems or branches of trees

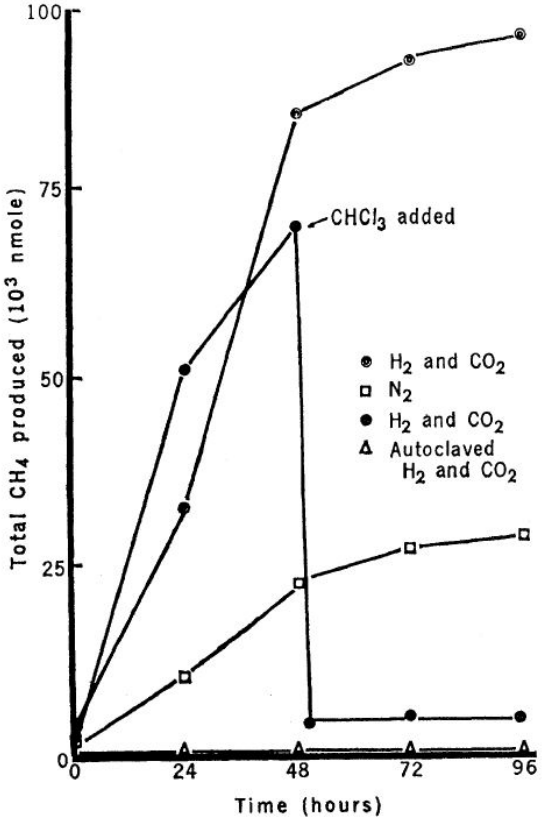
Species	$[CO_2]$	Method	Reference
Tracheid anatomy			
Pinus radiata	1.2–13.5	CA	MacDougal & Working (1933)
Sequoia sempervirens	0.8–10.4	CA	MacDougal & Working (1933)
Pinus strobus	1.1–12.3	CA	Chase (1934)
Picea abies	2–10	GC-MS	Eklund (1990)
Pinus sp.	0.3–2.0	IRGA	Hari *et al.* (1991)
Pinus strobus	0.1–0.2	GC	Cernusak & Marshall (2000)
Pinus taeda	1.0–8.0	Microelectrode	Maier & Clinton (2006)
Ring porous anatomy			
Quercus agrifolia	1.2–15.1	CA	MacDougal (1927)
Parkinsonia microphylla	0.0–15.9	CA	MacDougal & Working (1933)
Quercus agrifolia	1.2–26.3	CA	MacDougal & Working (1933)
Quercus borealis	0.4–5.5	CA	Chase (1934)
Quercus macrocarpa	0.4–3.0	CA	Chase (1934)
Ulmus americana	0.8–16.3	CA	Chase (1934)
Quercus rubra	13.5–16.5	CA	Jensen (1967)
Quercus robur	3.0–9.0	GC-MS	Eklund (1993)
Quercus alba	3.8–5.1	Microelectrode	McGuire & Teskey (2002)
Quercus alba	1.6–15.1	Microelectrode	Teskey & McGuire (2002)
Quercus robur	0.3–3.4*	Microelectrode	Saveyn *et al.* (2007b)
Diffuse porous anatomy			
Populus deltoides	7.2	CA	Bushong (1907)
Populus macdouglii	1.4–18.2	CA	MacDougal (1927)
Salix lasiolepis	5.0–13.1	CA	MacDougal (1927)
Juglans major	5.0–22.0	CA	MacDougal & Working (1933)
Populus macdougalii	0.0–18.5	CA	MacDougal & Working (1933)
Populus tremuloides	5.4	CA	MacDougal & Working (1933)
Salix lasiolepis	6.2–13.3	CA	MacDougal & Working (1933)
Populus deltoides	0.3–25.2	CA	Chase (1934)
Acer platanoides	2–4	GC-MS	Eklund (1993)
Betula pendula	3.0	IRGA	Levy *et al.* (1999)
Distemonanthus benthamianus	3.2	IRGA	Levy *et al.* (1999)
Musanga cecropioides	8.5	IRGA	Levy *et al.* (1999)
Liriodendron tulipifera	2.9–8.9	Microelectrode	McGuire & Teskey (2002)
Liriodendron tulipifera	1.9–15.9	Microelectrode	Teskey & McGuire (2002)
Fagus grandifolia	2.0–4.5*	Microelectrode	McGuire & Teskey (2004)
Liquidambar styraciflua	1.5–2.8*	Microelectrode	McGuire & Teskey (2004)
Platanus occidentalis	1.7–3.5*	Microelectrode	McGuire & Teskey (2004)
Fagus sylvatica	2.5–2.5	Microelectrode	Saveyn *et al.* (2006)
Populus deltoides	9.5–12.7	Microelectrode	Steppe *et al.* (2007)
Platanus occidentalis	6.9–12.1	NDIR	Teskey & McGuire (2007)
Populus deltoides	3.9–17.6	NDIR	Saveyn *et al.* (2007c)

Measurements were made using microelectrodes or nondispersive infrared (NDIR) sensors, or in extracted gas samples using chemical absorption (CA), gas chromatography (GC), mass spectrometry (MS), or infrared gas analysis (IRGA). All measurements were made in the gas phase and are expressed as a percentage, except where noted *, in which case they are expressed as mmol l^{-1} (liquid phase).

Trunk-based Microbial Methanogenesis

Methane Formation in Living Trees: A Microbial Origin
Author(s): J. G. Zeikus and J. C. Ward
Source: *Science*, New Series, Vol. 184, No. 4142 (Jun. 14, 1974), pp. 1181-1183





Methane in the Eastern Forest

Collaborator	Institution
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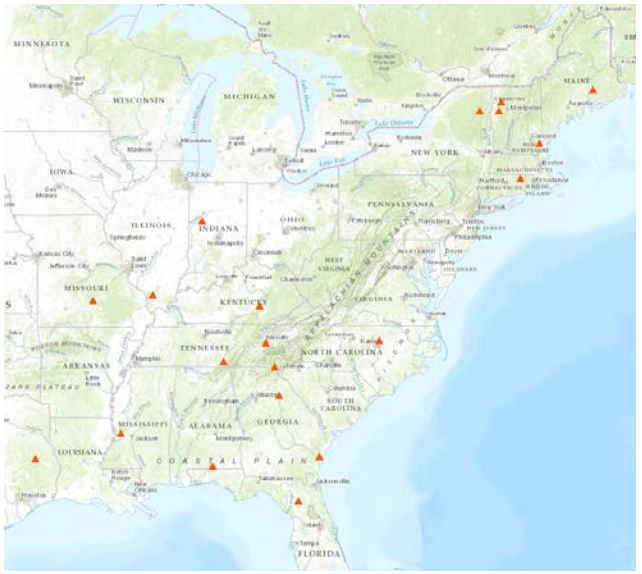


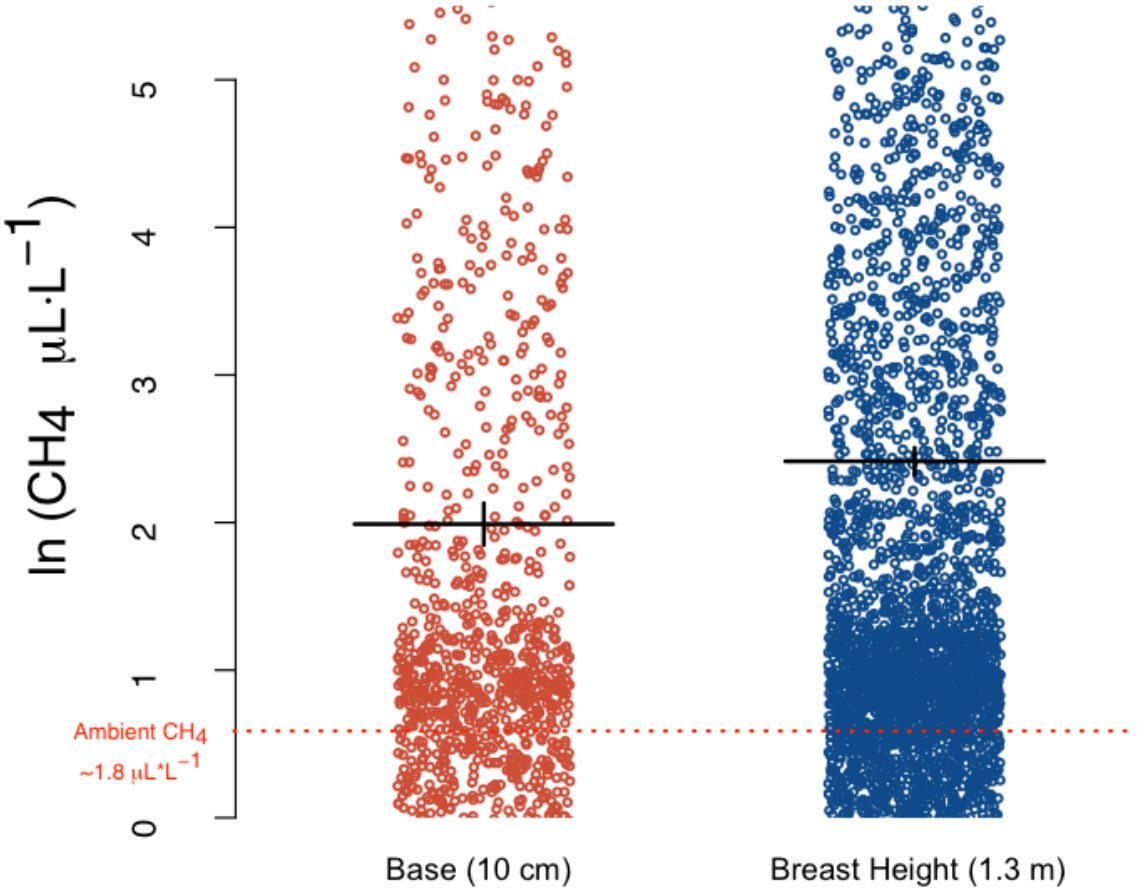
Middlebury EVS Protocol Check

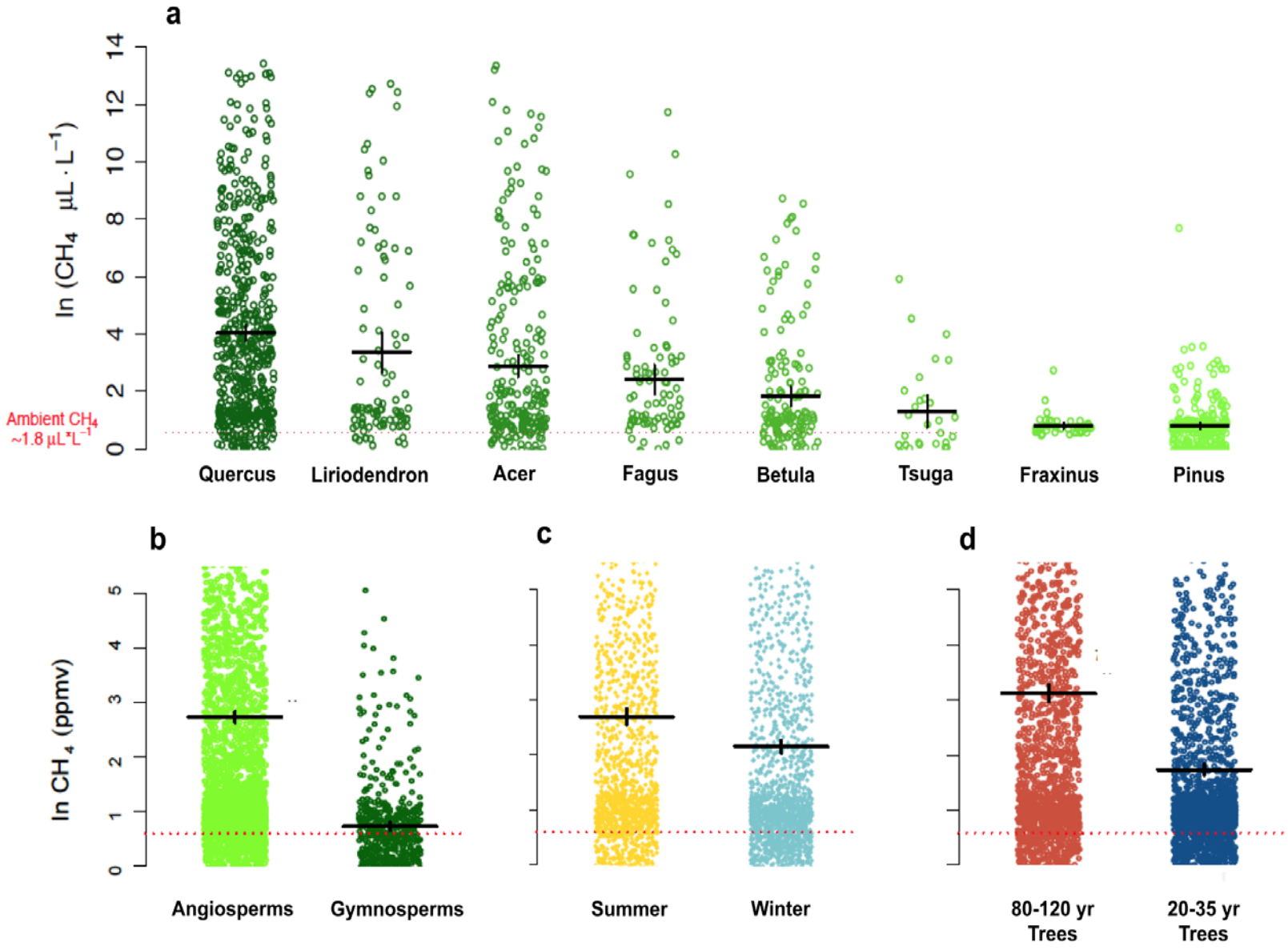
- Old sugar maples, CH_4= 8434ppm
- Young sugar, [CH_4] ~ 2ppm
- Beech and paper birch not significantly elevated
- In elevated trees, DBH [CH_4] 250x Base [CH_4]

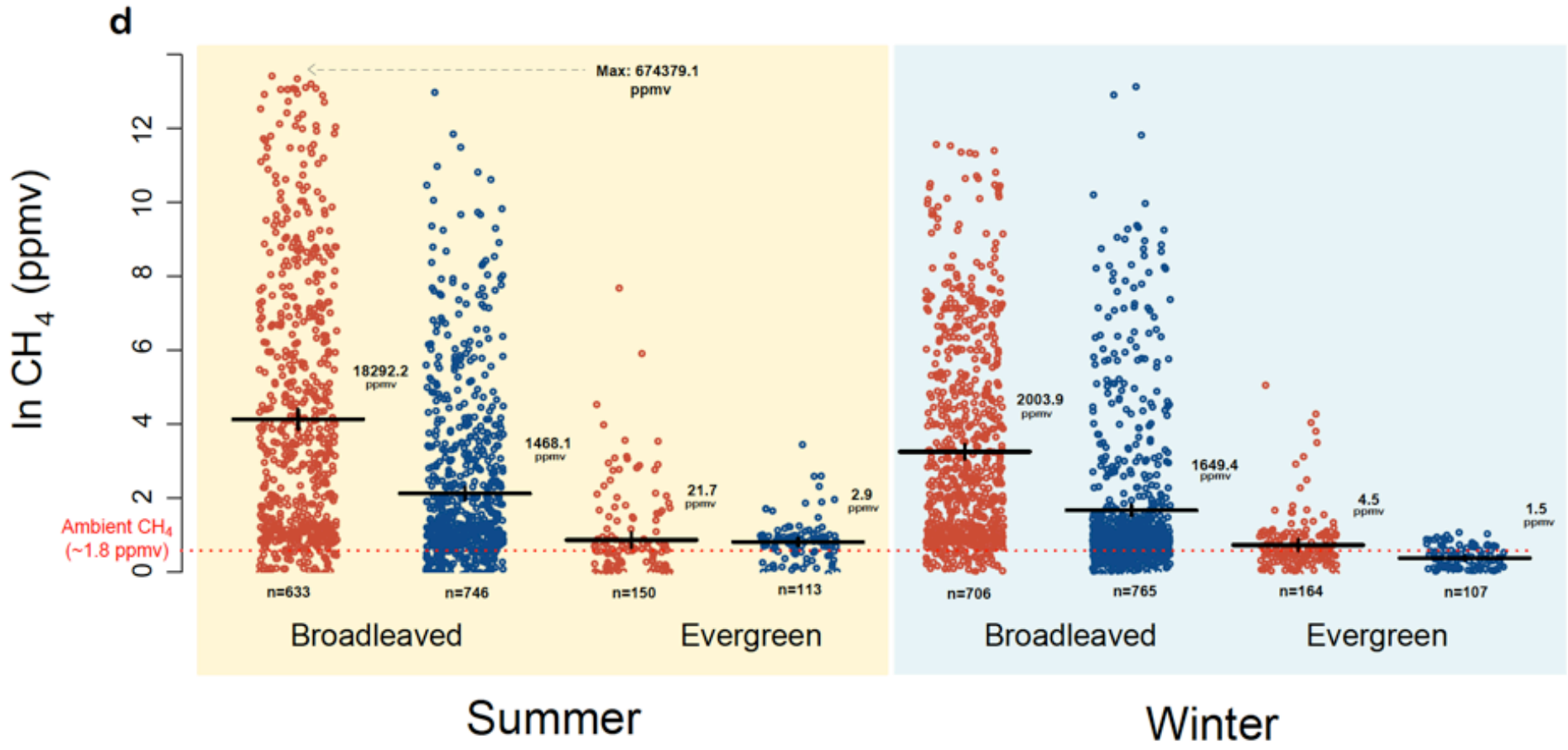
Eastern Forest Methane Assessment

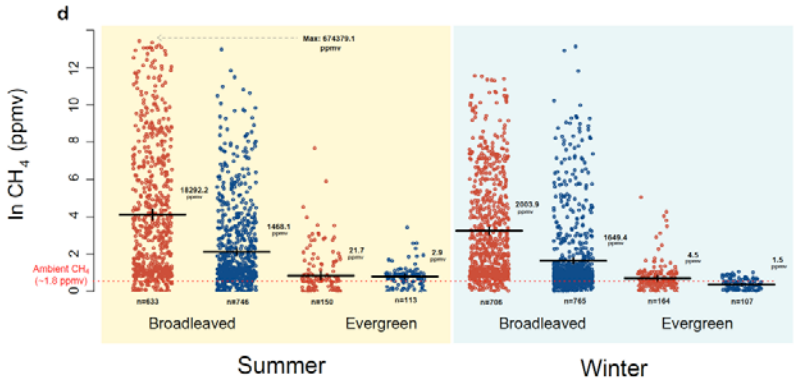
- Paired “old” (80-150+ yr) vs. “young” (20-30 yr)
- 23 Sites representing 20 forest types
- Two samples, spring/late Summer
- N=4471| 1/3 base |32 species

DBH vs. Base [CH_4]

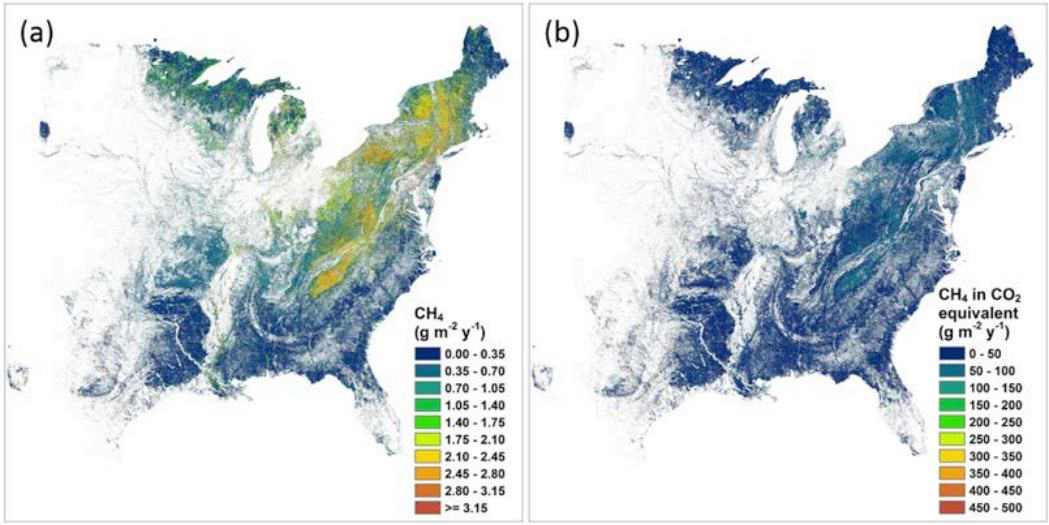



a
ln (CH4 µL · L−1)
0
2
4
6
8
10
12
14
Ambient CH4
~1.8 µL*L−1
Quercus
Liriodendron
Acer
Fagus
Betula
Tsuga
Fraxinus
Pinus
b
ln CH4 (ppmv)
0
1
2
3
4
5
Angiosperms
Gymnosperms
c
Summer
Winter
d
80-120 yr
Trees
20-35 yr
Trees

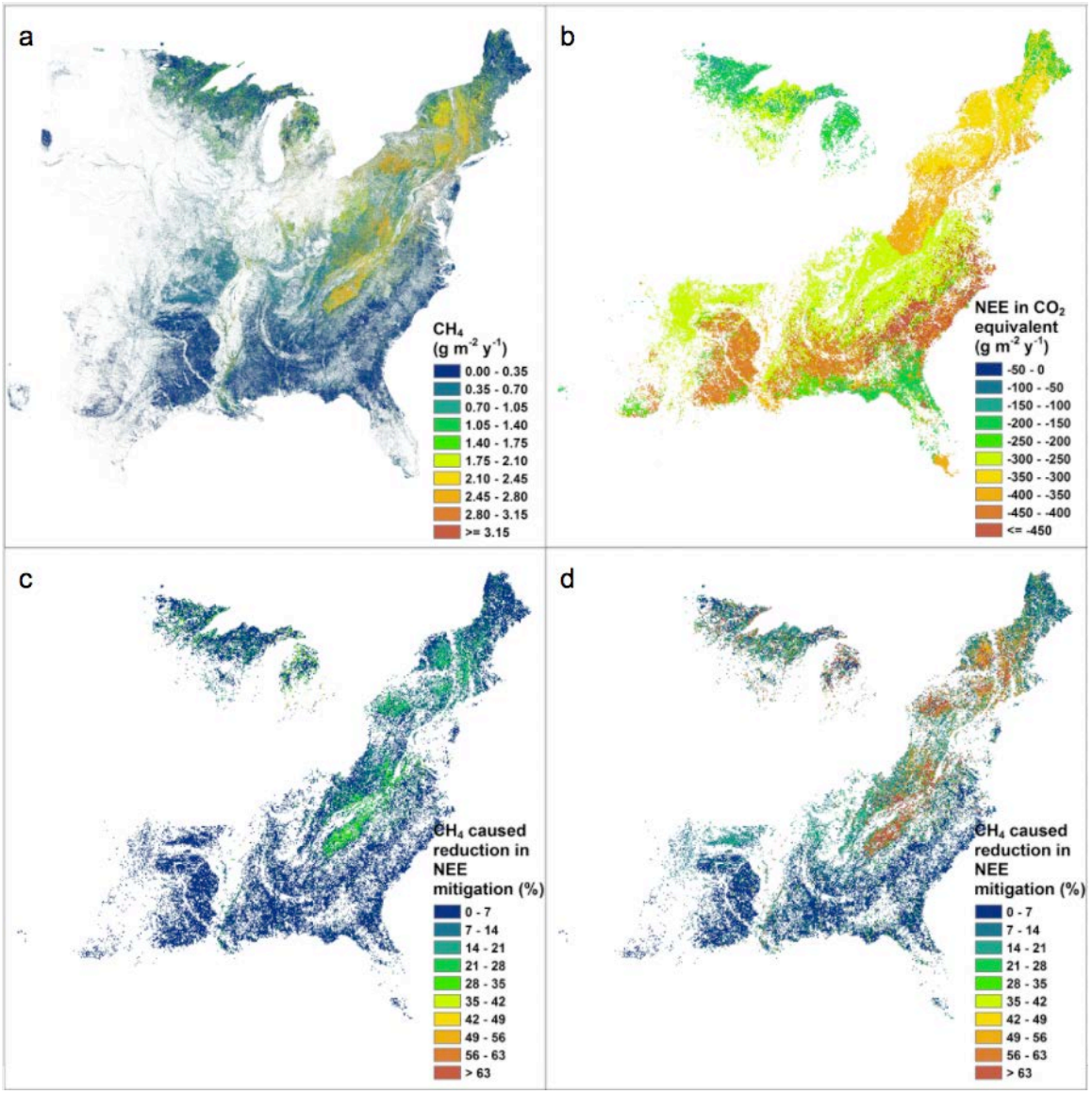

d
ln CH4 (ppmv)
0
2
4
6
8
10
12
Max: 674379.1 ppmv
18292.2 ppmv
1468.1 ppmv
21.7 ppmv
2.9 ppmv
2003.9 ppmv
1649.4 ppmv
4.5 ppmv
1.5 ppmv
Ambient CH4 (~1.8 ppmv)
n=633
n=746
n=150
n=113
n=706
n=765
n=164
n=107
Broadleaved
Evergreen
Broadleaved
Evergreen
Summer
Winter



$$F = -f\,\rho\rho_a D\frac{r_1}{r_2}\left(\frac{\partial\omega}{\partial r}\right)_{r_2}$$



Mapping Eastern Forest Methane



- **Mature Broadleaf**
  3.8×10^{7} µg CH_4 m^{-3} yr^{-1}
- **Young Conifer Stands**
  $7.6\times10^{4}\pm2.1\times10^{4}$ µg CH_4 m^{-3} yr^{-1}

- 1.1 Tg CH_4 yr^{-1} Easter Forest
- ~28 Tg CH_4 yr^{-1} Global
- 7% @ 100yr GWP of CH_4 28x CO_2
- 20% @ 20yr GWP CH_4 86x CO_2

Can't I Just Put a Tree in a Jar?

Species	DBH (cm)	Number of Observations	Mean CH_4 Flux ($\mu g\ m^{-2}\ hr^{-1}$)
Fagus grandifolia	56.1	10	139.0
Fagus grandifolia	56.2	10	131.2
Fagus grandifolia	53	10	192.9
Fagus grandifolia	44.9	10	58.5
Fagus grandifolia	31.4	10	27.9
Liriodendron tulipifera	31.8	10	37.3
Carya tomentosa	22.8	10	166.6
Fagus grandifolia	55.9	4	51.2
Quercus velutina	65.8	4	52.5
Quercus michauxii	65.9	4	45.5
Acer rubrum	17	4	70.0
Liriodendron tulipifera	71.1	4	43.0
Fagus grandifolia	47.1	4	40.5
Liquidambar styraciflua	34.8	4	33.7
Liquidambar styraciflua	27.2	4	28.9
Liquidambar styraciflua	21.9	4	15.2
Liriodendron tulipifera	92.6	4	35.9