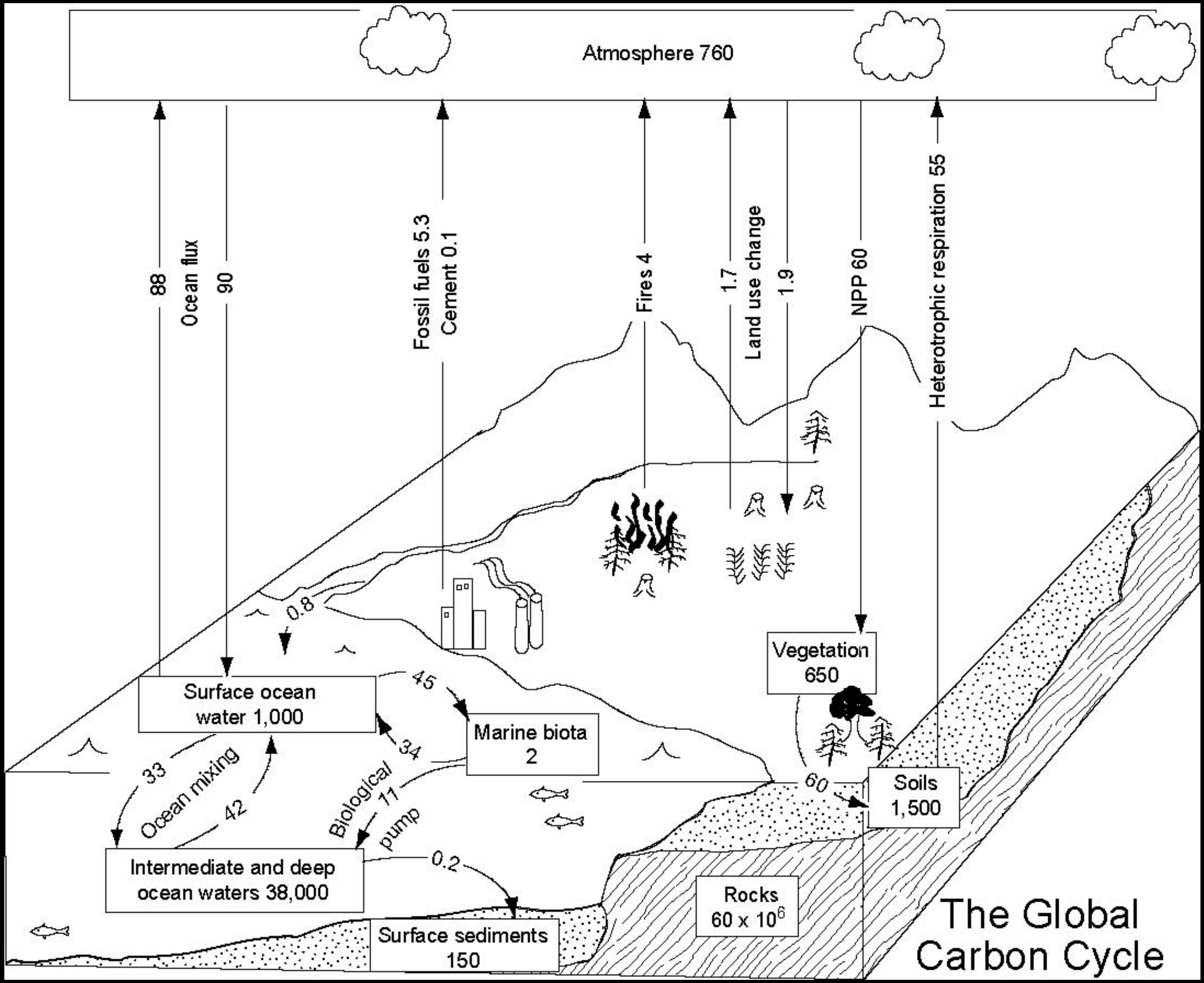
The influence of tree species composition on carbon (C) cycling in forest soils

Who cares about soil C?



From Chapin, F.S. et al. 2002. Principles of Terrestrial Ecosystem Ecology. 2002. Springer.

Where is the C?

Biome†	No. samples‡	Land area† (10^{12} m^2)	SOC content (kg/m^2) by depth (m) 0–3	0–1	1–2	2–3	Total SOC storage (10^{15} g) by depth (m) 0–3	0–1	1–2	2–3
Boreal forest	648, 118	12	12.5 (8.8)	9.3 (7.0)	2.4 (2.9)	0.8 (2.1)	150	112	29	10
Crops	1271, 837	14	17.7 (12.9)	11.2 (7.7)	3.8 (4.2)	2.7 (3.4)	248	157	53	38
Deserts	285, 161	18	11.5 (8.2)	6.2 (3.4)	2.9 (3.2)	2.4 (3.4)	208	112	52	44
Sclerophyllous shrubs	62, 38	8.5	14.6 (7.9)	8.9 (3.9)	3.3 (3.0)	2.4 (2.0)	124	76	28	20
Temperate deciduous forest	60, 41	7	22.8 (13.6)	17.4 (10.8)	3.3 (3.7)	2.1 (2.4)	160	122	23	15
Temperate evergreen forest	123, 85	5	20.4 (12.0)	14.5 (8.4)	3.6 (3.7)	2.3 (2.6)	102	73	18	12
Temperate grassland	121, 83	9	19.1 (10.9)	11.7 (6.6)	4.2 (3.7)	3.2 (2.8)	172	105	38	28
Tropical deciduous forest	29, 24	7.5	29.1 (14.6)	15.8 (9.2)	7.4 (4.4)	5.8 (3.3)	218	119	56	44
Tropical evergreen forest	36, 30	17	27.9 (8.9)	18.6 (10.4)	5.4 (3.1)	3.9 (2.2)	474	316	92	66
Tropical grassland/savanna	35, 27	15	23.0 (19.9)	13.2 (8.7)	5.5 (6.1)	4.2 (5.1)	345	198	83	63
Tundra	51, 12	8	18.0 (15.2)	14.2 (14.1)	2.4 (3.1)	1.4 (2.1)	144	114	19	11
Global average	2721, 1456	121					2344	1502	491	351

Jobbagy and Jackson, 2000
Ecological Applications

Now we're in the forest, but where is the C?

TABLE 2. Northern Hemisphere carbon pools in the forest sector, 1990.

Forest C pools (Pg C)	Forested land: Live veg.	Dead wood	Forest floor	SOC
Canada	12.9	3.5	7.7	37.8
United States				
Alaska	0.6	†	0.5	3.7
Coterminous	12.7	†	2.6	18.9
Europe§	7.7	1.0	0.7	13.0
Russia	33.7	8.9	12.0	127.2
China	4.6	n.a.	0.9	21.0
Other§	4.7	n.a.	n.a.	n.a.
Totals‖	77	13	24	222

Goodale et al, 2002
Ecological Applications

What controls the size of the soil C pool?

INPUT → **Soil organic C (SOC)** → OUTPUT

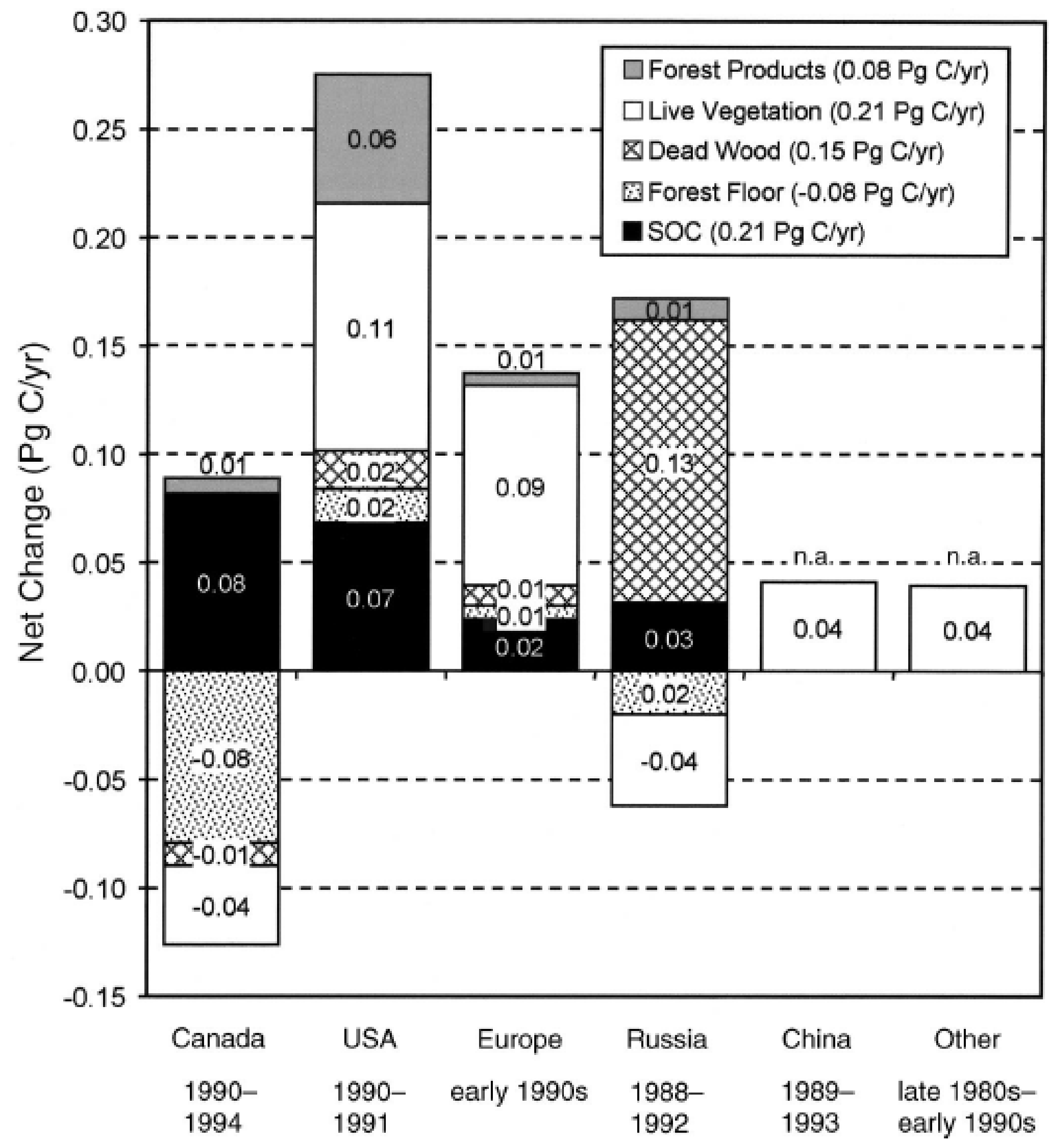
INPUT	OUTPUT
Dead plants, animals, microbes	Microbial Decomposition
Litter production (leaf and fine root)	Litter chemistry (leaves)
Climate / Environmental conditions	Climate / Environmental conditions
Soil mineralogy, texture, structure	Soil mineralogy, texture, structure

How much is SOC in forests changing?

Table 2
Comparison of stocks and fluxes for each forest carbon pool in 2005

Pool	Stocks (%)	Net change
Trees	35	49
Down dead wood	3	11
Understory	1	0
Forest floor	8	1
Forest soils	48	2
Wood products	2	10
Landfilled wood	3	27

Woodbury et al, 2007
Forest Ecology and Management



Goodale et al, 2002
Ecological Applications

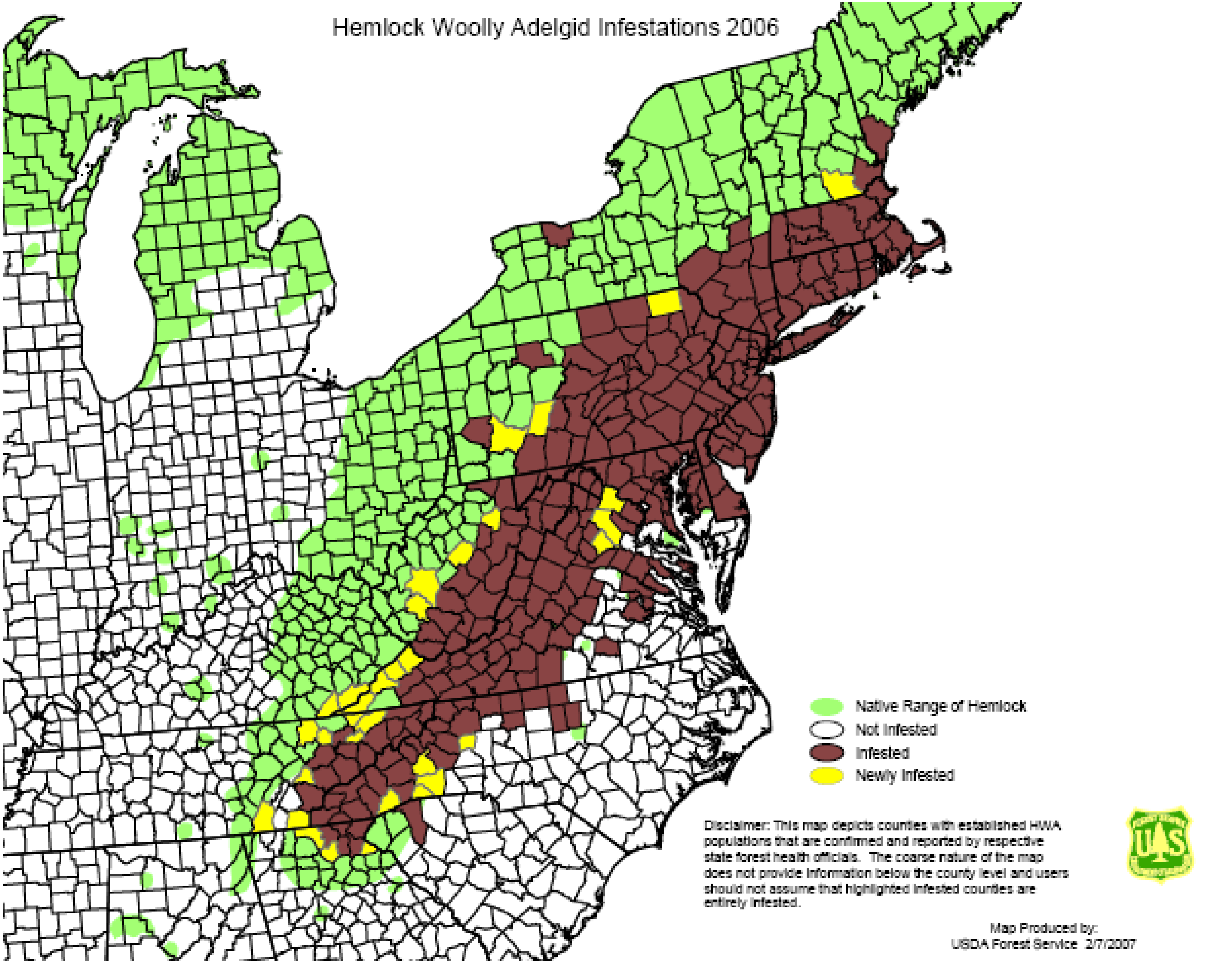
Country	Fowl (1000 ha)	Soil						Trees			
		Carbon stock			Carbon sink			Carbon stock		Carbon sink	
		Tg	kg m^{-2}	Proportion of total (%)[b]	Tg yr^{-1}	g m^{-2} yr^{-1}	Proportion of total (%)[b]	Tg	kg m^{-2}	Tg yr^{-1}	g m^{-2} yr
N Europe											
Denmark	452	28	6.2	54	0.2	34	24	23	5.2	0.5	108
Finland	23373	1122	4.8	65	2.0	8	28	607	2.6	5.1	22
Norway	9565	279	2.9	58	0.8	8	27	200	2.1	2.1	22
Sweden	28015	1327	4.7	59	2.5	9	17	921	3.3	12.1	43
Subtotal	61405	2757	4.5	61	5.4	9	21	1751	2.9	19.9	32
NW Europe											
Belgium	620	26	4.2	44	0.1	24	24	33	5.4	0.5	74
Ireland	429	5	1.3	38	0.1	30	21	9	2.1	0.5	113
Netherlands	334	13	3.8	35	0.4	107	41	24	7.1	0.5	152
UK	2380	66	2.8	43	0.8	32	31	87	3.6	1.7	71
Subtotal	3763	110	2.9	42	1.4	37	31	152	4.1	3.1	83
Central Europe											
Austria	3877	275	7.1	44	2.4	61	50	351	9.0	2.4	61
France	13504	469	3.5	40	4.4	33	37	700	5.2	7.5	55
Germany	10734	729	6.8	42	9.0	84	49	993	9.3	9.4	88
Switzerland	1186	119	10.0	46	0.5	43	61	140	11.8	0.3	27
Subtotal	29301	1592	5.4	42	16.2	55	45	2183	7.5	19.6	67
S Europe											
Greece	6123	50	0.8	43	0.1	1	70	67	1.1	0.0	1
Italy	8550	171	2.0	31	2.6	31	31	386	4.5	6.0	70
Portugal	3102	70	2.3	47	0.2	5	40	78	2.5	0.2	8
Spain	25622	191	0.7	47	0.0	0	0	214	0.8	5.5	22
Subtotal	43397	482	1.1	39	2.9	7	20	745	1.7	11.8	27
Total	137866	4940	3.6	51	25.9	19	32	4833	3.5	54.4	39

The trees are changing . . .

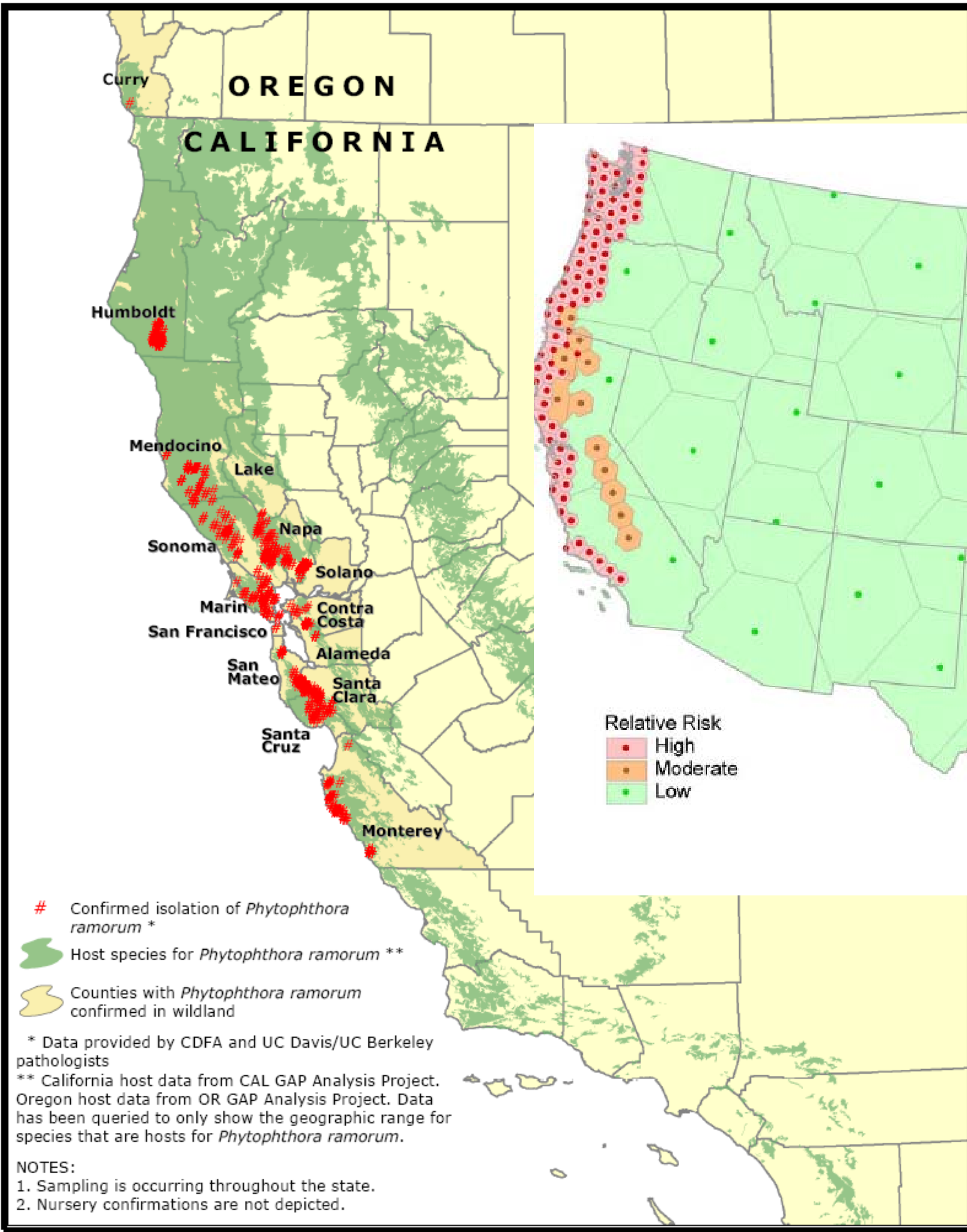
Region, location	Presettlement white oak (percentage)	Present-day dominants (percentage)
Northeast		
Massachusetts		
Connecticut Valley	45	Maple (30), **oak[a] (22),** hemlock (15), pine (11), birch (11)
Pellham Hills	38	Maple (27), **oak[a] (21),** hemlock (15), birch (15), pine (11)
Central uplands	21	Maple (24), **oak[a] (23),** pine (16), birch (12), hemlock (12)
Eastern lowlands	59	**Oak[a] (35),** maple (23), pine (21), birch (8)
Central Massachusetts	27	White pine (23), black oak (21), red oak (19), **white oak (9)**
Eastern New York	36	Maple (30), chestnut oak (14), red oak (10), pine (9), **white oak (4)**
Mid-Atlantic		
Central Pennsylvania		
Allegheny Mountains	19	Red maple (35), **white oak (19),** red oak (11), chestnut oak (9)
Ridge and Valley region	21	Chestnut oak (28), red maple (14), red oak (14), **white oak (13)**
Valleys	41	**White oak (43),** red maple (15), black cherry (10), pine (7)
Ridges	11	Chestnut oak (43), red oak (19), red maple (14), **white oak (1)**
Northwest Pennsylvania	21	Red maple (22), black cherry (14), hemlock (7), **white oak (3)**
Southeast Pennsylvania	30	Chestnut oak (26), red maple (18), black oak (15), **white oak (4)**
Southeast Pennsylvania	33	Box elder (23), red maple (19), ash (8), elm (7), **white oak (1)**

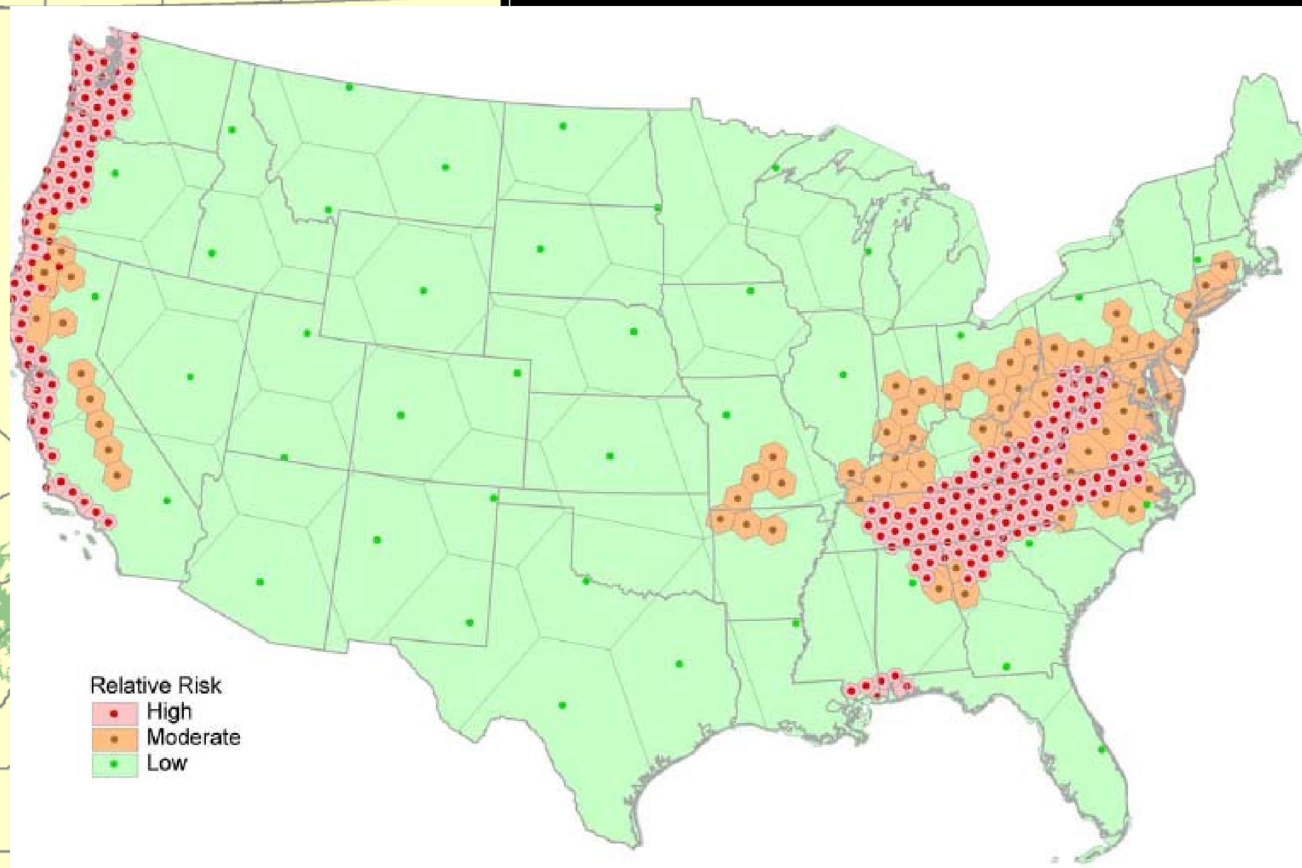
Abrams, 2003
Bioscience

Hemlock Woolly Adelgid Infestations 2006



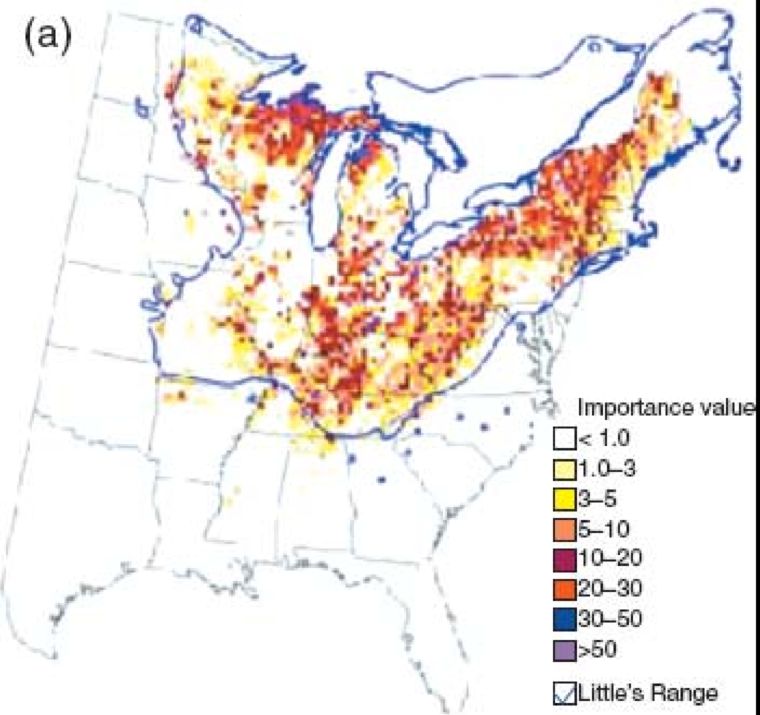
Distribution of Sudden Oak Death as of December 20, 2006

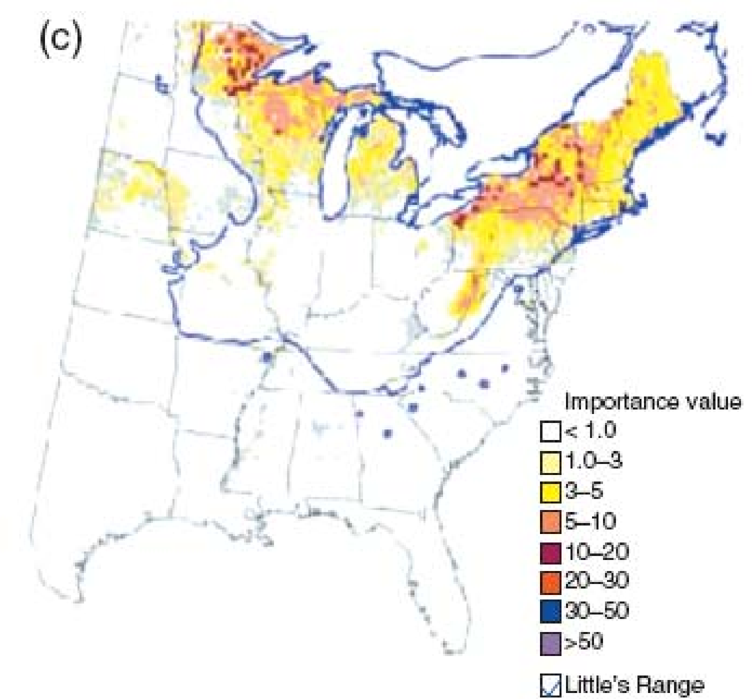




↑ US Forest Service

← California Oak Mortality Task Force





Lovett and Mitchell 2004
Frontiers in Ecology and the Environment

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Pool	Stocks (%)
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Forest soils	48
Wood products	2
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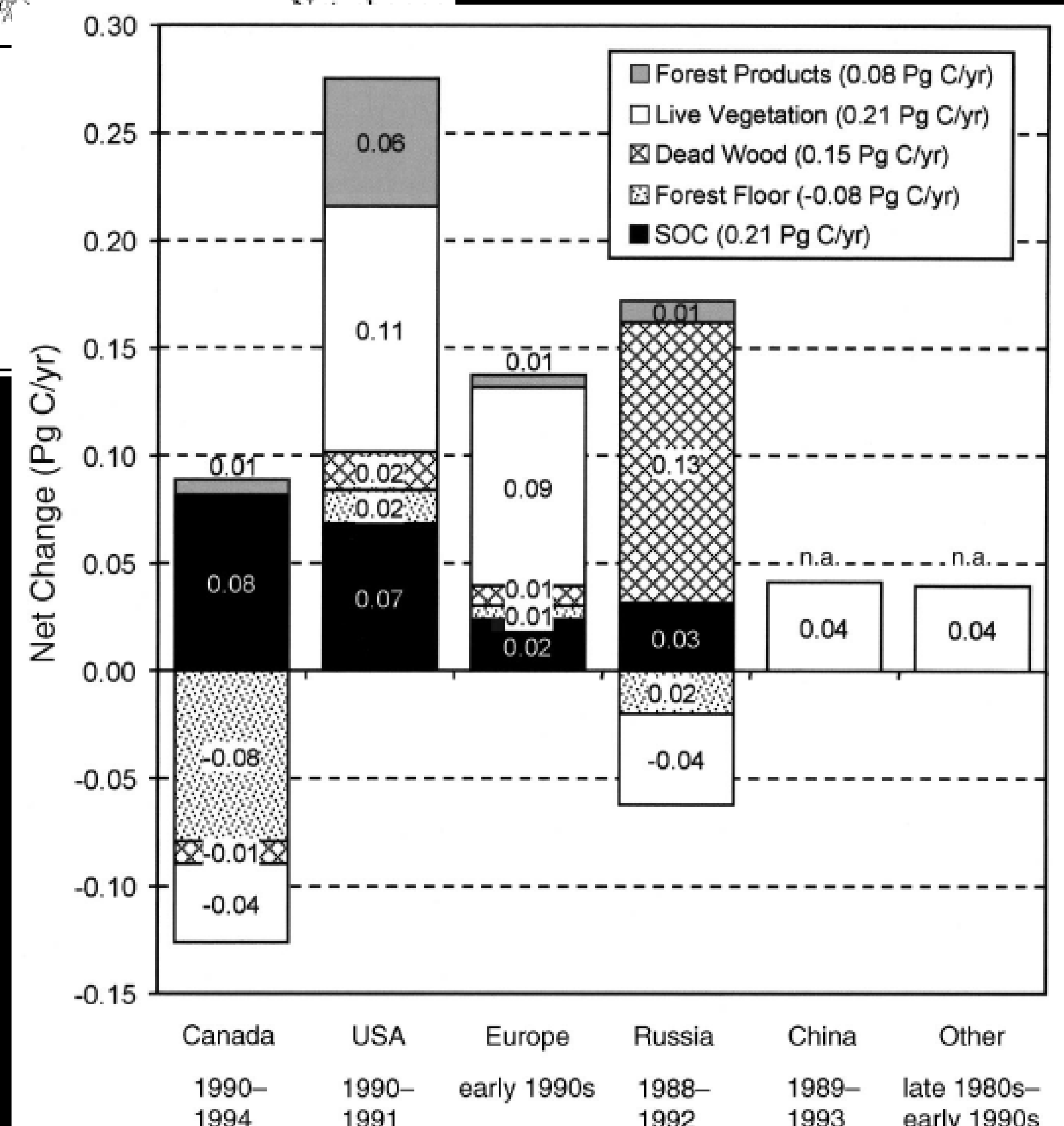
Woodbury et al, 2007
Forest Ecology and Management



Goodale et al, 2002
Ecological Applications

What controls the size of the SOC pool?

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INPUT	OUTPUT
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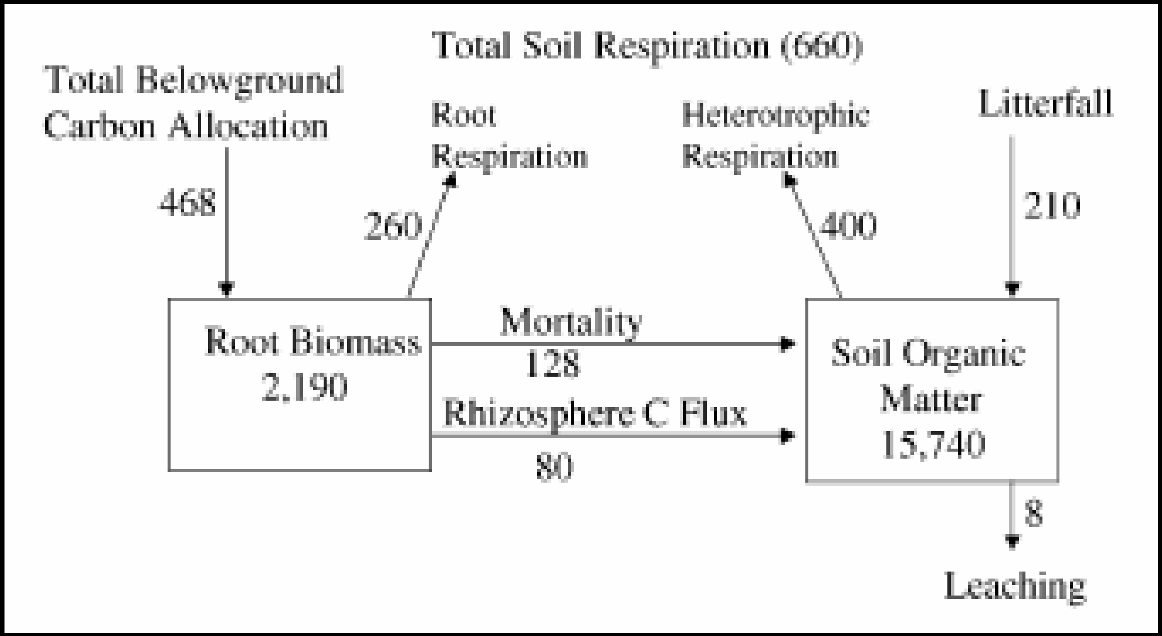
Soil mineralogy, texture, structure	Soil mineralogy, texture, structure

What are we doing?

How do different tree species influence C cycling in soil?

How does variation in leaf and fine root traits of tree species influence soil C cycling?

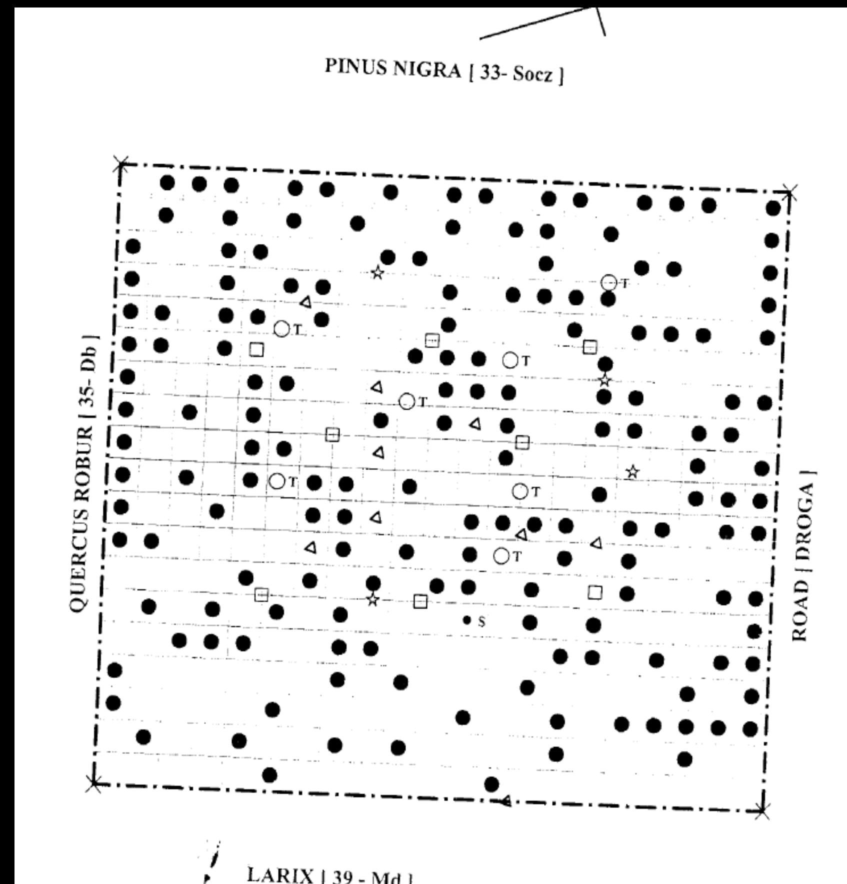


Fahey et al. 2005 *Biogeochemistry*

Study site

Experimental design

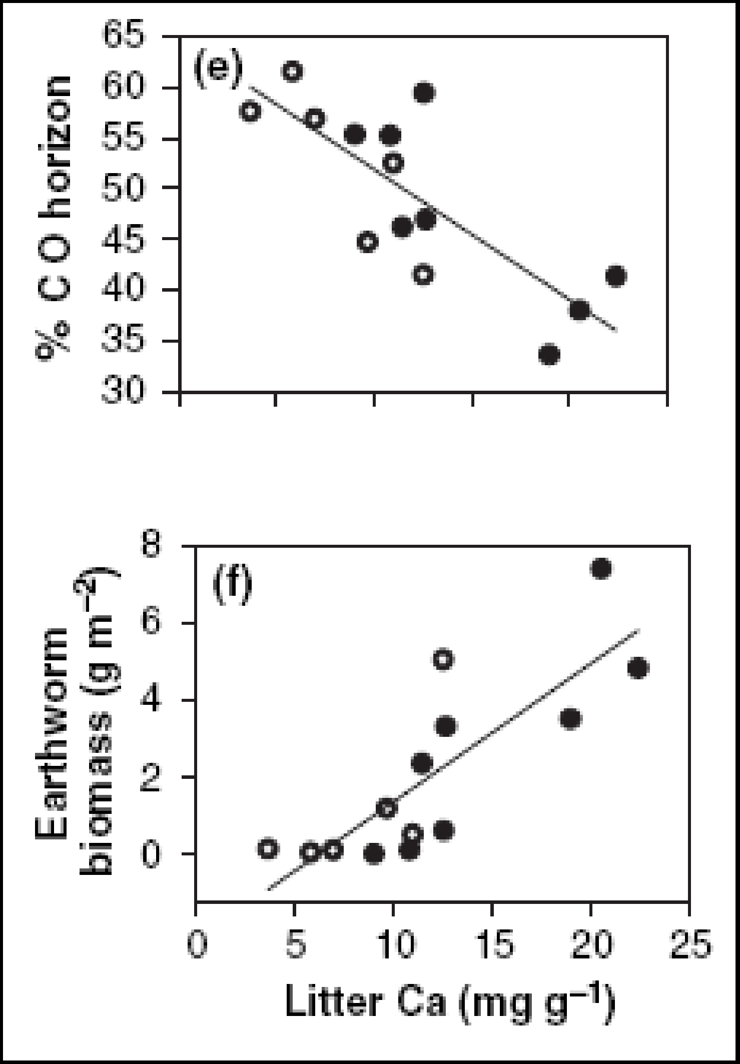
Ac ps	Pi ab	Qu ro	1	2	3
Ac pl	Fa sy	Ps me	6	5	4
Ti co	Ab al	La de	7	8	9
Pi ab	Qu ro	Ac ps	12	11	10
Fa sy	Ps me	Ac pl	13	14	15
Ab al	La de	Ti co	18	17	16
Qu ro	Ac ps	Pi ab	19	20	21
Ps me	Ac pl	Fa sy	24	23	22
La de	Ti co	Ab al	25	26	27
30	29	28	La de	Ca be	Be pe
31	32	33	Pi ab	Qu ru	Pi ni
36	35	34	Ps me	Qu ro	Pi sy
37	38	39	Ca be	Be pe	La de
42	41	40	Qu ru	Pi ni	Pi ab
43	44	45	Qu ro	Pi sy	Ps me
48	47	46	Be pe	La de	Ca be
49	50	51	Pi ni	Pi ab	Qu ru
54	53	52	Pi sy	Ps me	Qu ro



Species	Leaf litter production‡ (kg ha^{-1} yr^{-1})	Root production† (cm yr^{-1})	Leaf litter N‡ (mg g^{-1})	Leaf litter Ca‡ (mg g^{-1})	Leaf litter lignin‡ (mg g^{-1})
Abies alba	**802**	20.9	12.5	12.5	304
Acer platanoides	2801	**127.1**	6.5	19	**124**
Acer pseudoplatanus	3715	86.8	9.4	20.5	164
Betula pendula	2559	NA	12.6	12.6	**384**
Carpinus betulus	1662	NA	11	9	140
Fagus sylvatica	3091	33.3	8.4	12.7	242
Larix decidua	1293	18.4	8.7	7	316
Picea abies	1845	31.1	9.9	11	213
Pinus nigra	2794	38	**5.4**	**3.7**	238
Pinus sylvestris	3293	25.2	6.8	5.8	176
Pseudotsuga menziesii	1181	**2.9**	7.2	9.7	246
Quercus robur	2237	22.1	**12.7**	11.5	230
Quercus rubra	**5595**	NA	7.1	10.8	196
Tilia cordata	2901	42.1	12.2	**22.4**	375

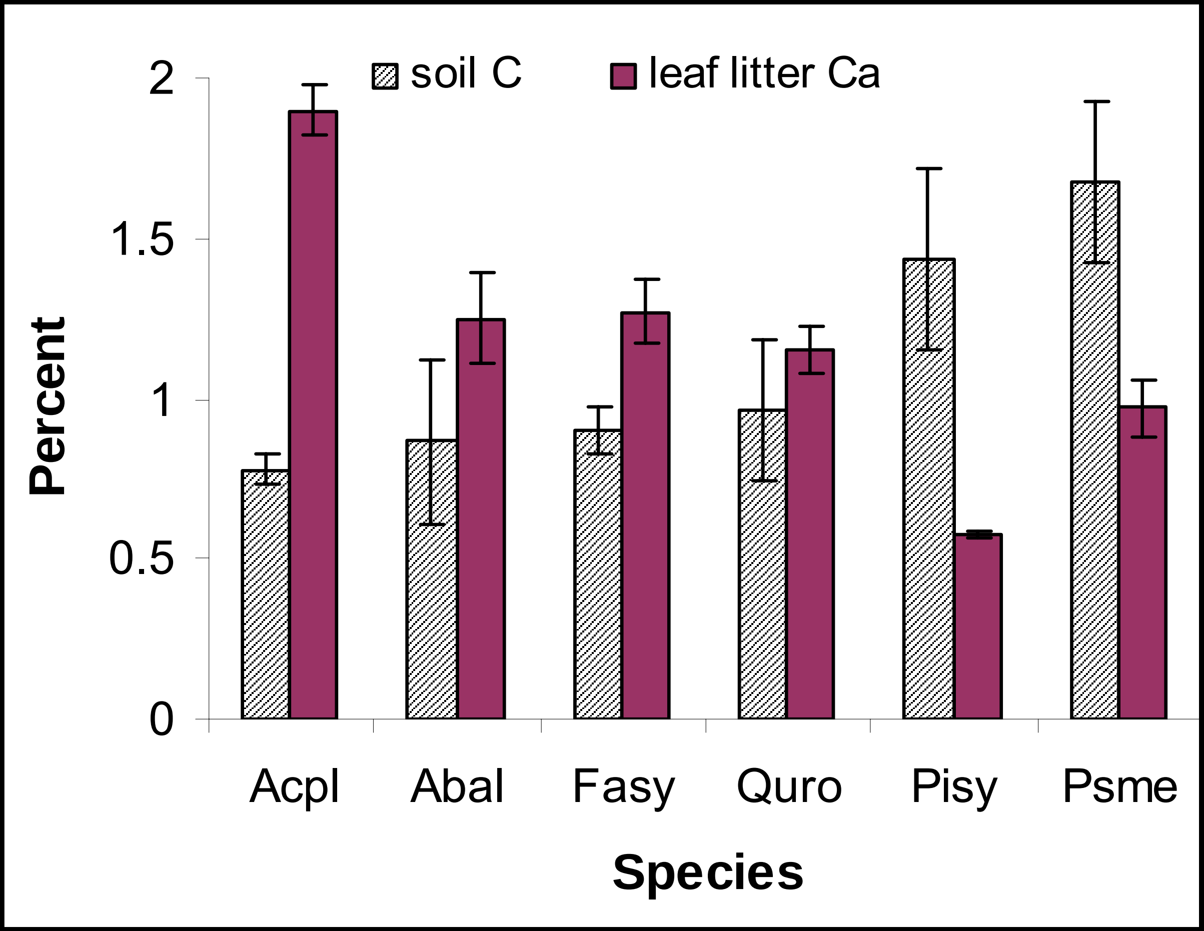
‡from Reich et al. 2005 †from Withington et al. 2006

Organic horizon

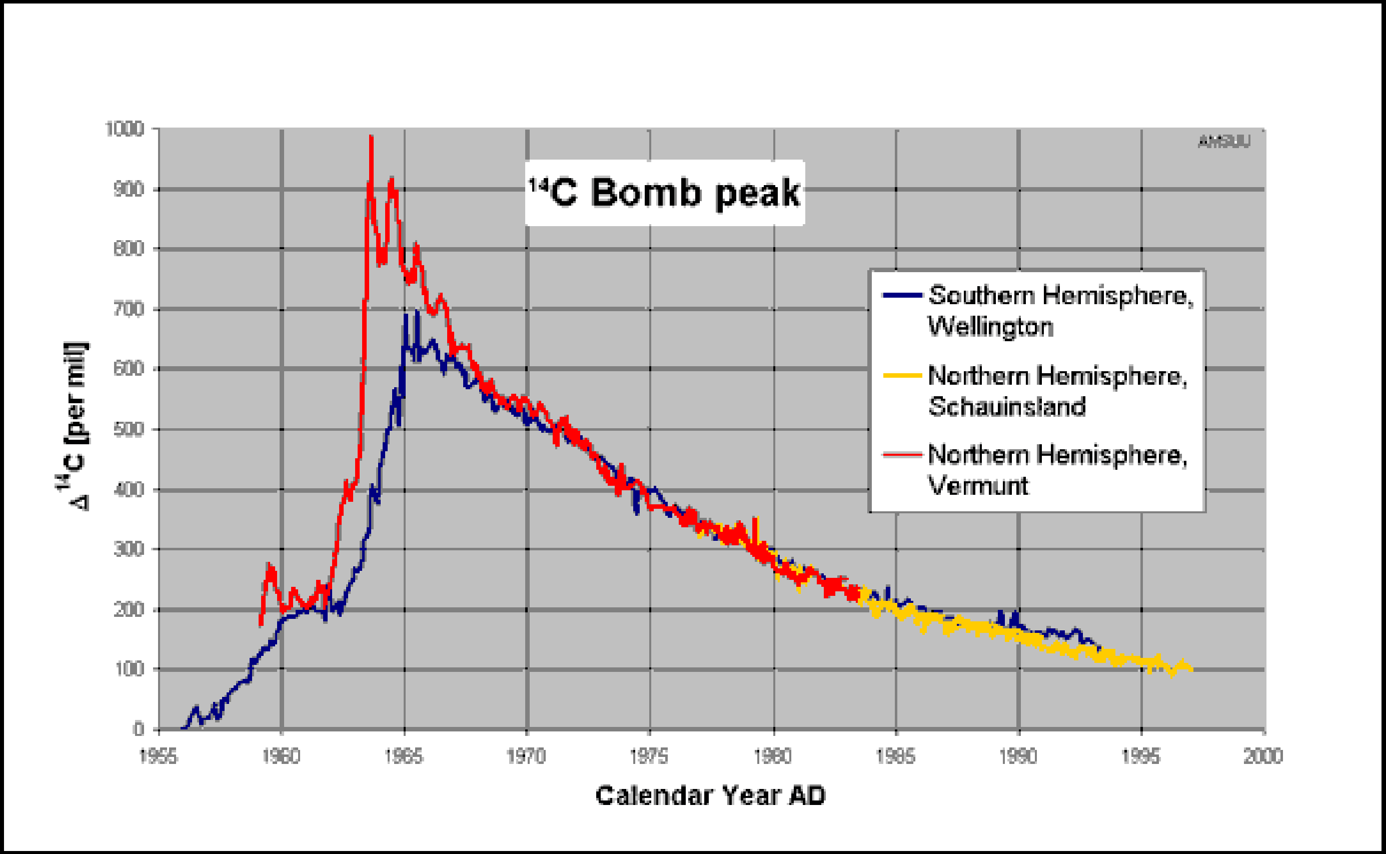


Reich et al. 2005
Ecology Letters

Mineral soil



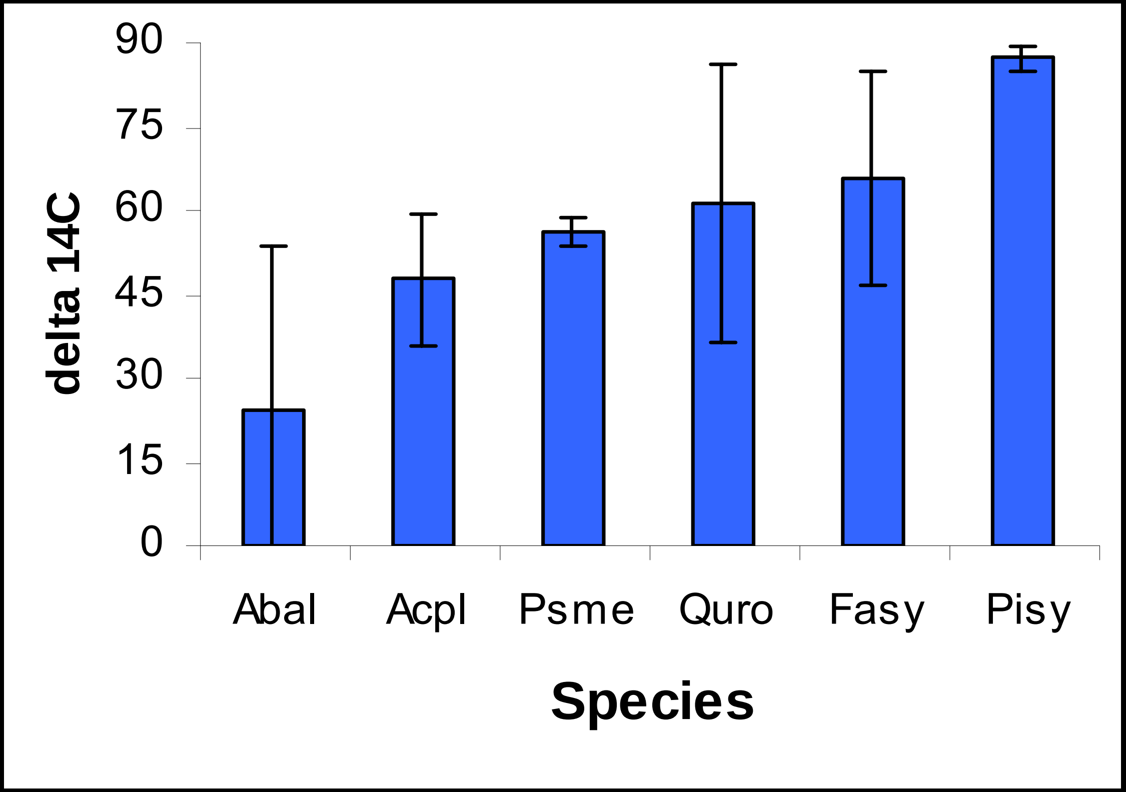
Radiocarbon



University of Utrecht

(http://www1.phys.uu.n/

ams/ radiocarbon.htm)



90
75
60
45
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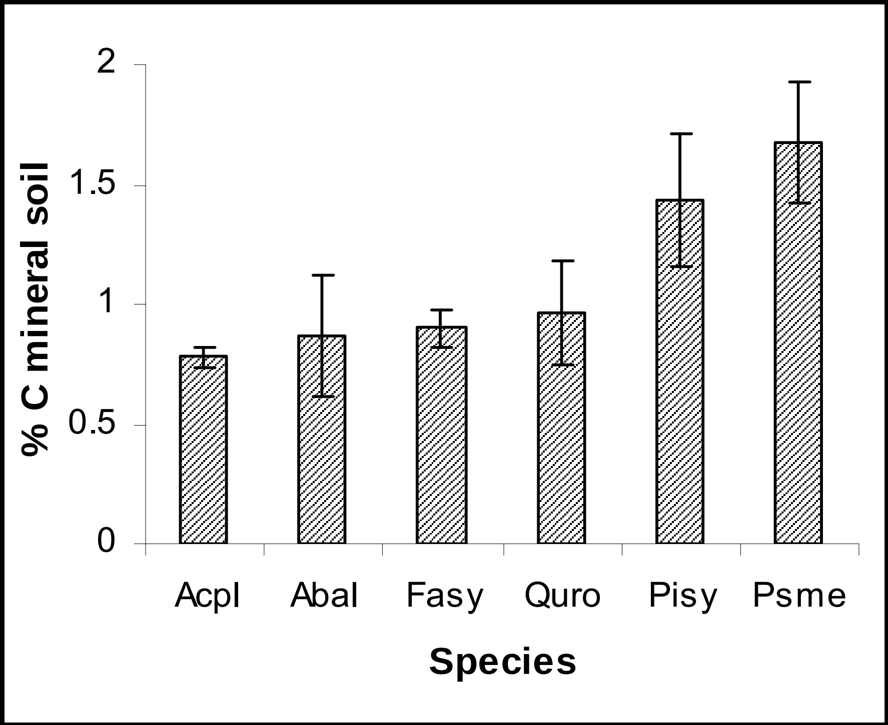
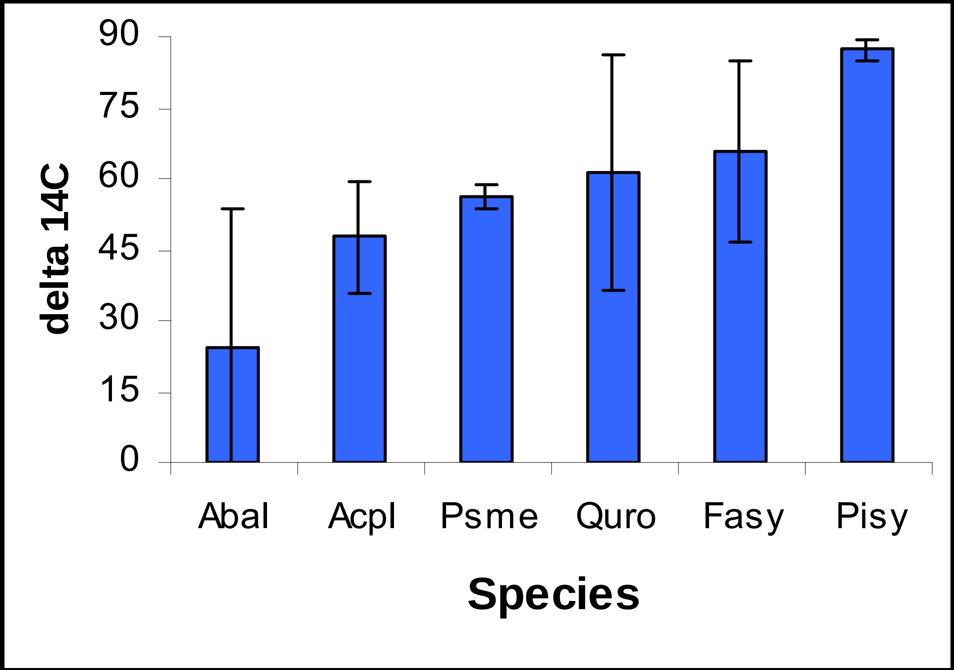
0
delta 14C
Abal
Acpl
Psme
Quro
Fasy
Pisy
Species



2
1.5
1
0.5
0
% C mineral soil
Acpl
Abal
Fasy
Quro
Pisy
Psme
Species



90
75
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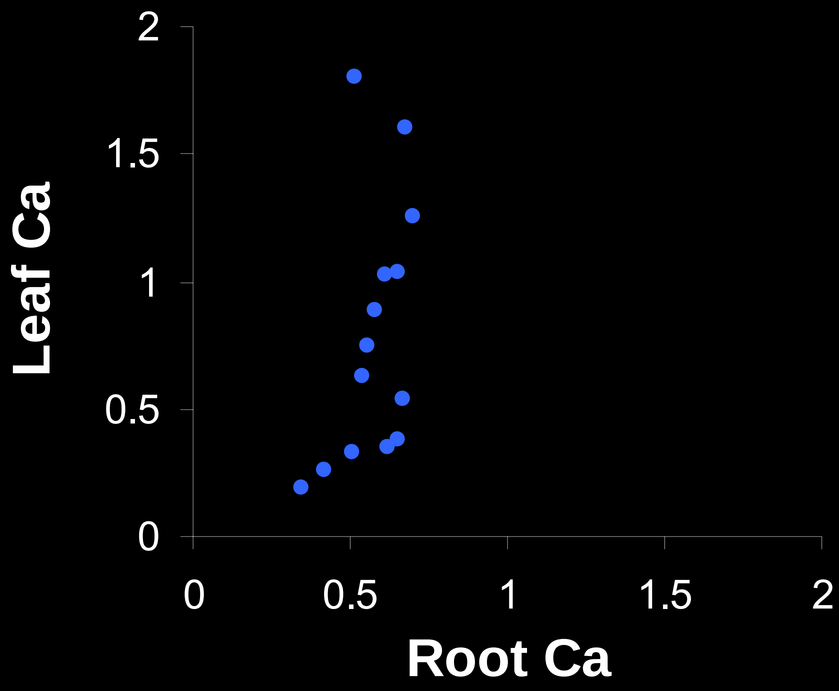
delta 14C
Abal
Acpl
Psme
Quro
Fasy
Pisy
Species

What else are we missing?



Unpublished data, Reich et al.

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