Is there a role for N-fixers in forest management?

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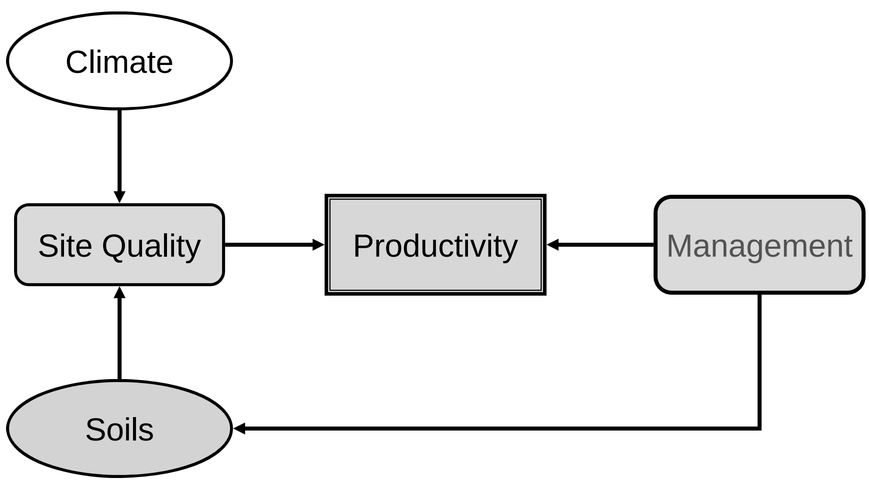
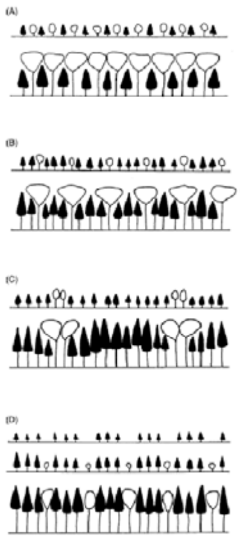
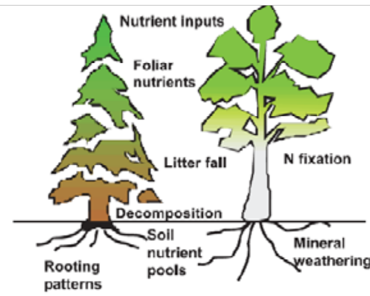
Examples in Europe



Mixtures in forest ecosystems

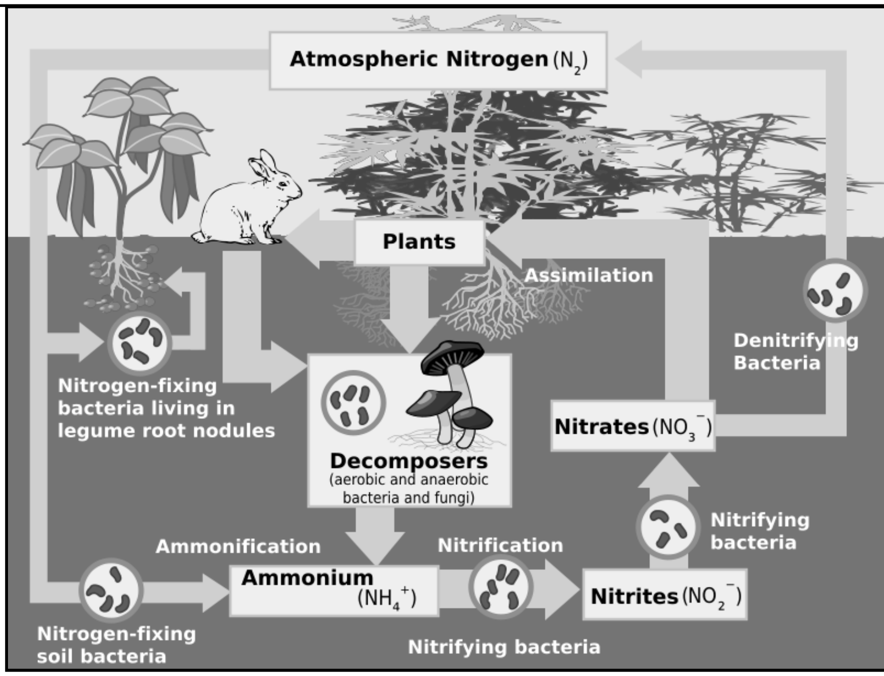


- Competition for resources
- Complementary Attributes
- Facilitation



<u>Sources:</u> Rothe & Binkley (2001) *Can. J. For. Res.* and Kelty (2006) *For. Ecol. Manage*.

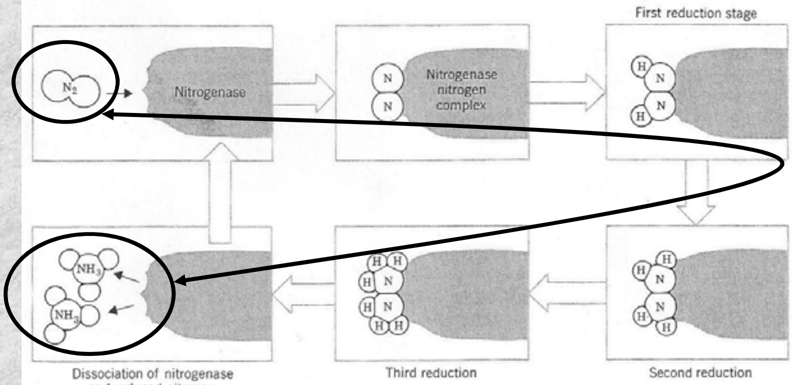
Why nitrogen fixers?



Source: http://en.wikipedia.org/wiki/File:Nitrogen_Cycle.svg

N-fixing symbionts

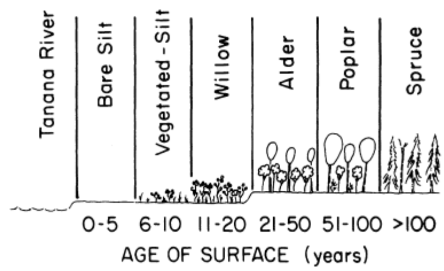
Figure 11-4
Simplified series of steps in nitrogen fixation. (Adapted from Delwiche, in *The Science Teacher*, Vol. 36, No. 3, p. 19, March 1969.)



Source: Foth (1984) *Fundamental of soil Science*

Where does this N addition matter?

Soils with inherently low N status
(e.g., newly developed / young soils)



Example: ALDER (*Alnus*) on floodflains

Source: Bonanza Creek LTER website; Walker (1989) *Arct. Alp. Res.*

Where does this N addition matter?

Soils where N status has been
lowered (e.g., by fire)

Snowbrush (*Ceanothus*)
In the western US

1983

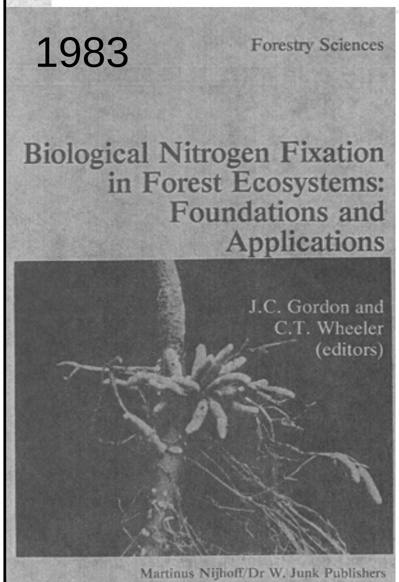


Table 2. Nitrogen accretion in some North American ecosystems containing nodulated plants.

Plant species	Stand age	Nitrogen accretion	Reference no.
	years	kg ha^{-1} year^{-1}	
Alnus glutinosa	0–40	40	13
A. incana	0–5	362	14
	0–10	170	14
	0–20	156	14
A. sinuata	0–5	35	15
A. rubra	2–15	320	16
	0–30	208	17
	0–38	85	18
	0–14	163	19
	14–24	81	19
	24–65	40	19
	30–39	80–120	20
	0–40	100	21
A. rugosa	0–18	167	22
	0–16	85	23
Ceanothus spp.	—	60	24
	0–15	0–20	17
	0–10	72–108	25
	0–15	84	26
	0–17	80	27
	0–11	32	28
	0–12	100	29
Lespedeza spp.	0–4	100+	J. R. Jorgensen, pers. co
Lotus scoparius	—	78	30
Lupinus excubis	—	55	30
Lupinus leucophyllus	—	7	J. M. Geist, pers. com.
Lupinus sericeus	—	10	J. M. Geist, pers. com.
Myrica cerifera	—	120	Fisher, pers. com.
Myrica pensylvanica	leaf litter	16–32	31
Purshia spp.	—	64	32
Robinia pseudoacacia	—	44	33.
Trifolium subterraneum	0–4	100+	J. R. Jorgensen, pers. com., 1981

United States Department of Agriculture
Forest Service
Pacific Northwest Forest and Range Experiment Station
General Technical Report PNW-182
July 1985

The Role of the Genus *Ceanothus* in Western Forest Ecosystems

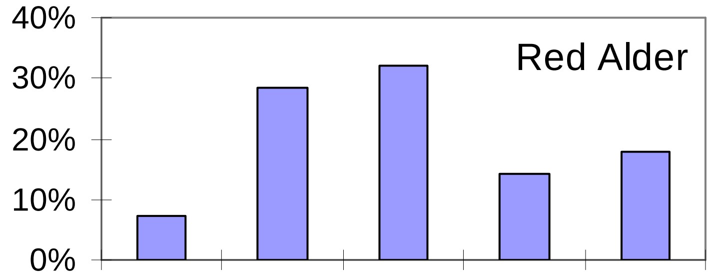
PNW-GTR-182 (1985)

Table 1--Estimated rates of N accretion or N_2 fixation on forest and chaparral sites in the Western United States

Ceanothus species and location	Accretion or fixation	Stand age	Source	Method
	kg/ha/yr	years		
Ceanothus velutinus, H. J. Andrews Experimental Forest, Oregon	1/ 42-48 3/ 95-100	0 and 12	Binkley and others 1982	chronosequence
C. velutinus, H. J. Andrews Experimental Forest, Oregon	3/ 101	17	McNabb & Cromack 1983	acetylene reduction
C. velutinus, Cascade Range, Oregon	1/ 56 3/ 84	0-15	Youngberg and others 1979	accretion
C. velutinus, Cascade Range, Oregon	1/4/ < 0-40 1/4/ < 0-46 (96)	2-33	Binkley unpublished data, Zavitkovski and Newton 1968	chronosequence; accretion
C. velutinus, Cascade Range, Oregon	3/ 72-108	0-10	Youngberg and Wollum 1976	accretion
C. sanguineus, Vancouver Island, British Columbia	1/ 24-80 3/ 45-80	10	Binkley and Husted 1983	accretion, based on spatial variation
C. greggii var. *perplexans*, San Diego County, California	30.1	25	Kummerow and others 1978	acetylene reduction
C. crassifolius, San Dimas Experimental Forest, Southern California	1/ 28 2/ 76	0-13	Zinke 1969	accretion

30-70 kg N ha^{-1} yr^{-1}

Some N fixation rates - alder



Pure red alder ~100 kg N ha^{-1} yr^{-1}
Mixed stands ~ 50 kg N ha^{-1} yr^{-1}
other alder spp 2-15 kg N ha^{-1} yr^{-1}

Sources: Binkley *et al* (1994) IN: *Biology and Management of alder*

Growth effects – Ceanothus

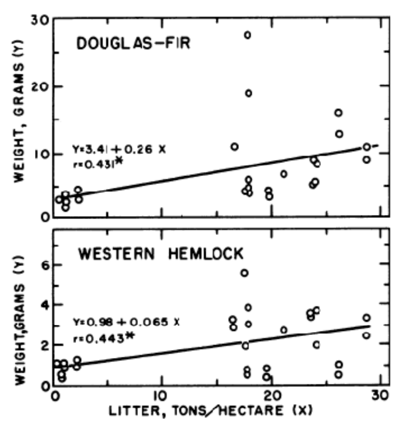


FIG. 8. Effect of increasing levels of snowbrush litter on growth of Douglas-fir and western hemlock seedlings as measured by fresh weight of tops at the age of 8.5 months.

Seedlings
(< 1yr)

Source: Zavitkovski & Newton (1969) Ecology

Growth effects – Ceanothus

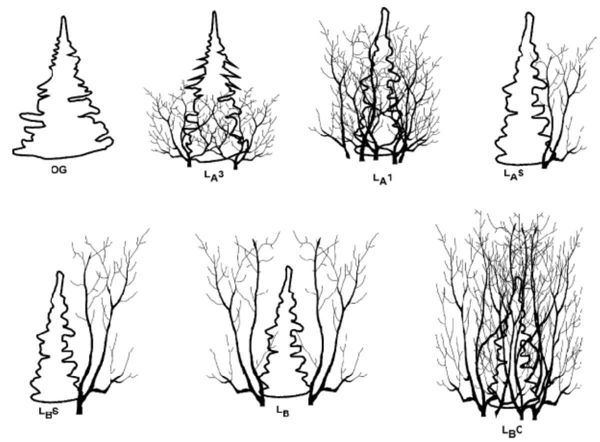
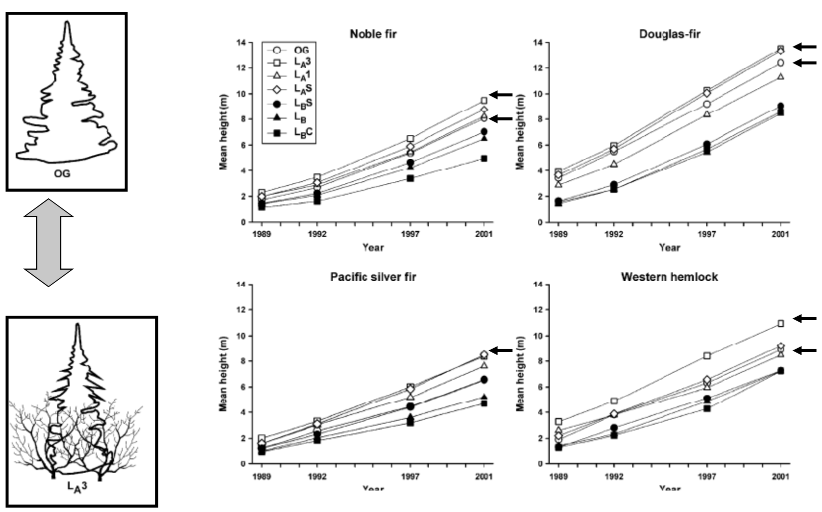


Fig. 2. Schematic showing relative crown positions and codes for the planted conifers and the naturally occurring *Ceanothus*. OG, open-grown; L_A3, leader 3 or more years above *Ceanothus*; L_A1, current leader above *Ceanothus*; L_AS, leader above *Ceanothus* canopy and *Ceanothus* only on one side; L_BS, leader below *Ceanothus* canopy and *Ceanothus* only on one side; L_B, leader below *Ceanothus* canopy and not directly covered, L_BC, leader below *Ceanothus* canopy and directly covered (note this figure is only intended to show crown interactions with the conifer and the shrub; crown depth or form are not implied).

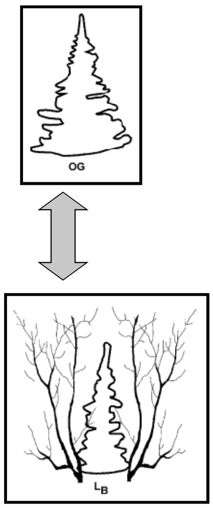
Source: Erickson& Harrington (2006) *For. Ecol. Manage.*

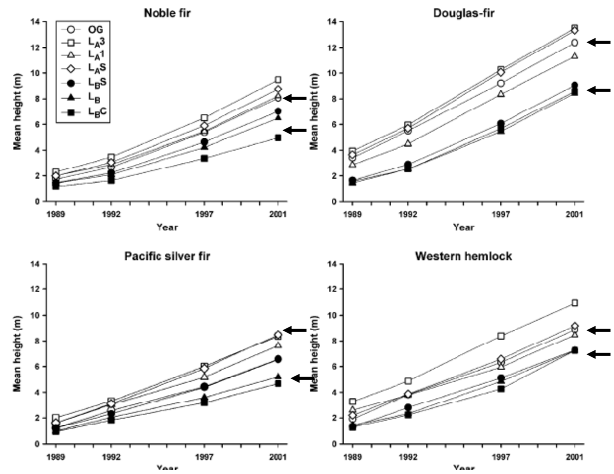
Conifer Growth effects – Ceanothus



Source: Erickson& Harrington (2006) *For. Ecol. Manage.*

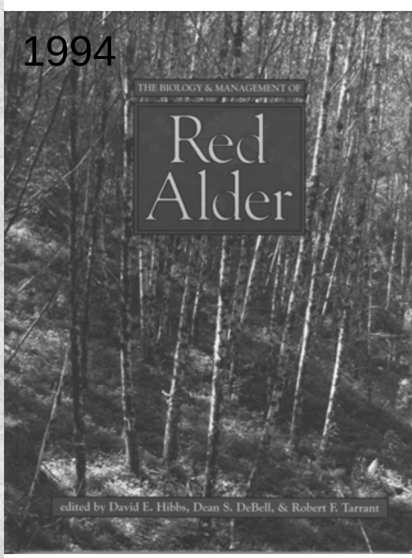
Growth effects – Ceanothus





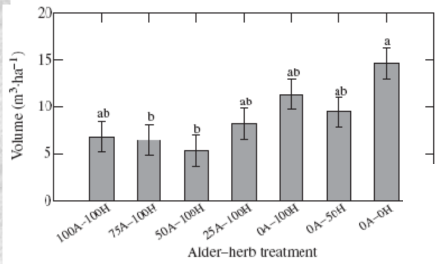
Source: Erickson& Harrington (2006) *For. Ecol. Manage.*

1994

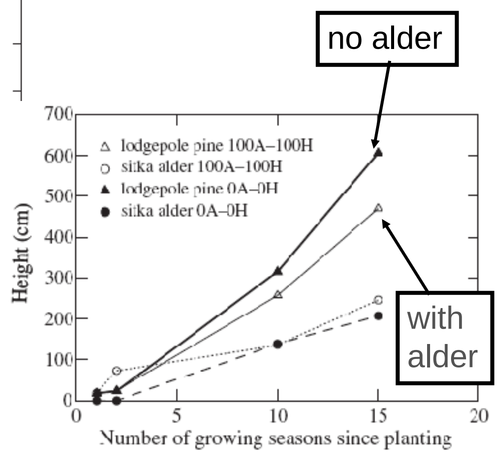


The alder story………

Lodgepole pine regeneration - Sitka alder

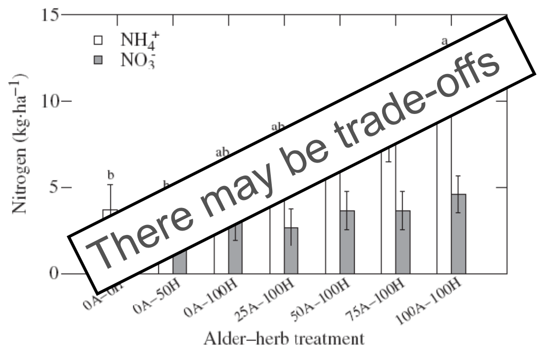


Increasing alder removal



Source: Simard et al (2006) *Can. J. For. Res.*

Lodgepole pine regeneration - Sitka alder



no alder

lots alder

Loss of N availability benefit

Decrease in survival

Source: Simard et al (2006) *Can. J. For. Res.*

Alder effects – soil N status

Table 2. Total nitrogen content of Douglas-fir and red alder ecosystems (vegetation + forest floor + soil to 50 cm depth) at the three study sites in Washington .

Location	Red alder (kg ha^{-1})	Douglas-fir (kg ha^{-1})	Percent increase†	Estimated net annual accumulation (kg ha^{-1} yr^{-1})
Thompson site	8,900	4,100	120	96
Pack Forest‡ low fertility	4,600	1,000	360	80
Pack Forest‡ high fertility	4,600	3,000	51	35

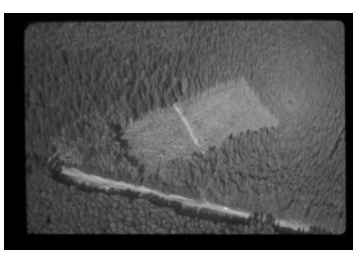
†Percent increase = $\frac{\text{Total N in red alder} - \text{Total N in Douglas-fir}}{\text{Total N in Douglas-fir}}$.

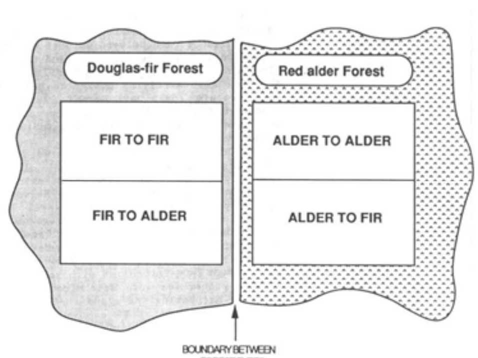
‡Adapted from Bigger and Cole, 1983.

Source: Van Miegroet et al. (1990) *Proc. 7th North Amer. For. Soils. Conf*.

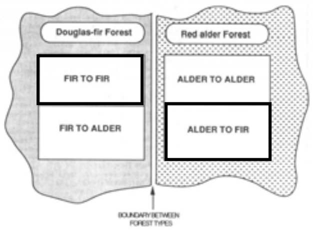
Growth effects previous alder sites

Conversion experiment @ Thompson Site, WA





Growth effects previous alder sites

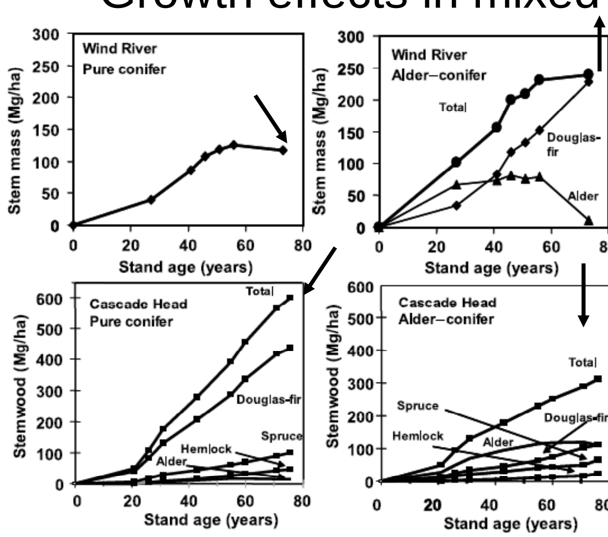


Conversion experiment
@ Thompson Site, WA

DF to DF

Alder to DF

Growth effects in mixed stands

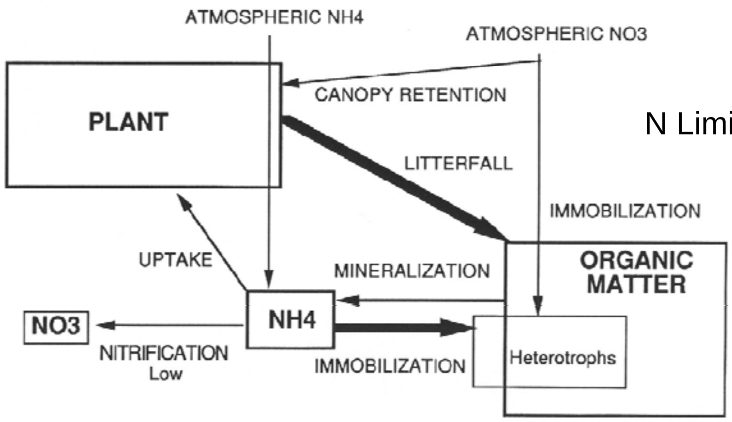


N-Poor site:
Facilitation

N-Rich site:
Competition

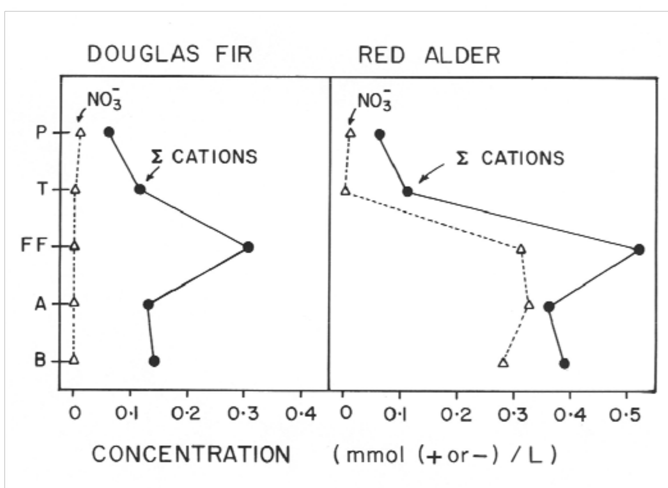
Source: Binkley (2003) *Can. J. For. Res.*

Change in N status & Dynamics



N Limiting

Alder– soil effects



Source: Van Miegroet et al., 1984 *J. Environ. Qual.*

		CEC	Ca	Mg	K
		mmolc/kg			
0 - 7cm	DF	164 ± 10	55 ± 24	7.7 ± 2.8	4.9 ± 1.5
	RA	191 ± 32	30 ± 16	4.1 ± 2.3	3.9 ± 1.3
7-15 cm	DF	112 ± 19	24 ± 12	3.4 ± 1.5	3.0 ± o.7
	RA	148 ± 20	15 ± 3	1.9 ± 0.6	2.4 ± 0.8
15 - 30 cm	DF	93 ± 20	12 ± 6	2.9 ± 0.8	2.1 ± 0.4
	RA	113 ± 7	20 ± 7	2.4 ± 1.7	1.5 ± 0.7
30 - 45 cm	DF	101 ± 16	12 ± 13	1.9 ± 1.8	1.6 ± 0.5
	RA	109 ± 10	27 ± 15	3.8 ± 2.6	1.4 ± 0.7

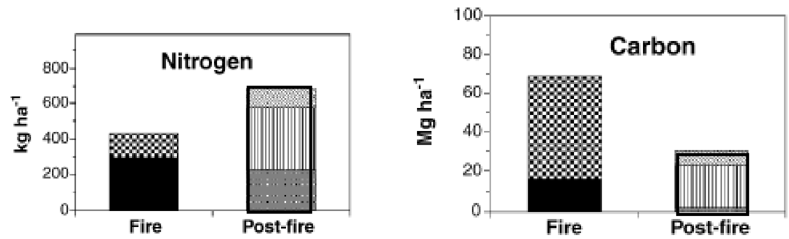
Source: Homann et al., 1992 *Biogeochemistry*

Red alder effects – Soil properties

- Soil organic matter increase:
  26-62 Mg ha^{-1} (~50yrs)
- Increase in CEC
- Decline in soil bulk density
- Decline in soil pH (<1 pH unit)

Source: Bormann et al. (1994) *Biology and Management of Alder*

Burn + Ceanothus effects – Soil effects



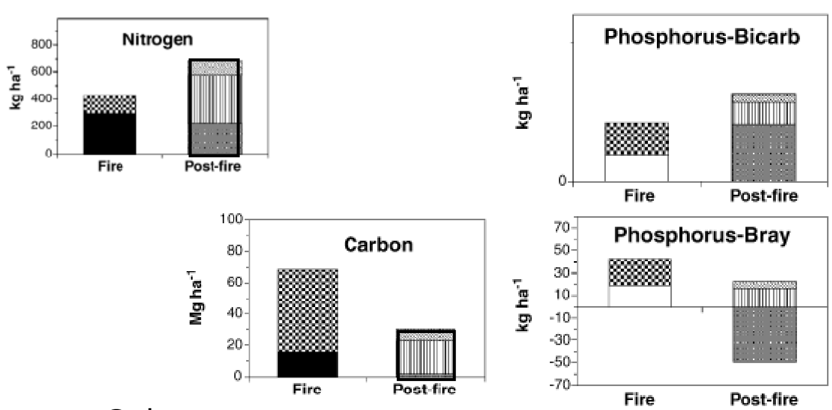
- SOC conc (A hor up); SOC accum. O
- Increase in exchangeable cations
- Increase in soil pH (burn?)

Gains Losses

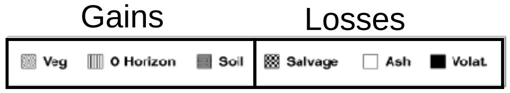
Little Valley, NV

Source: Johnson et al. (2005) *For. Ecol. Manage*

Burn + Ceanothus effects – Soil effects



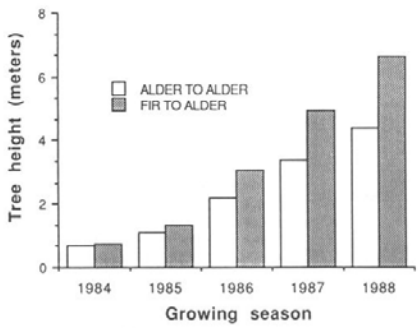
Gains Losses



Little Valley, NV

Source: Johnson et al. (2005) *For. Ecol. Manage*

Alder & the big surprises



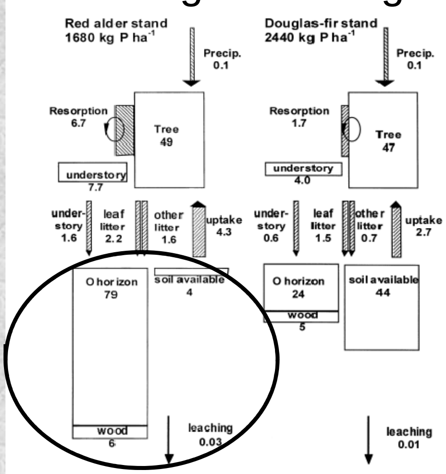
Conversion experiment
@ Thompson Site in WA

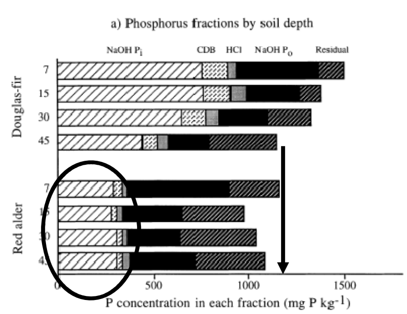
DF to alder

Alder to alder

Source: **Cole et al.,** 1990 *WASP*

Change in P biogeochemistry under alder



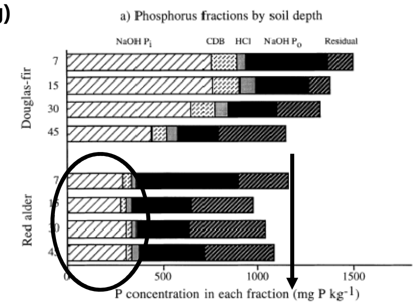


There is a redistribution in P towards **organic forms**

Sources: Compton et al. , 1997 *Can. J. For. Res.* & 1998 *Forest Ecol. Manage.*

Change in P biogeochemistry under alder

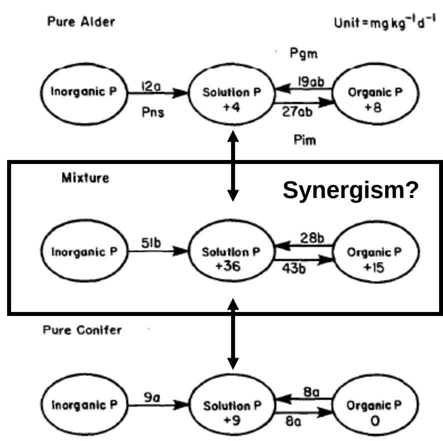
Sample[a]	N	P (mg/kg)
Leaf 1988		
First rotation	30 800	1250
Second rotation	29 400	1150
S effect		≤0.10
Litter 1988		
First rotation	28 100	817
Second rotation	24 547	761
S effect	≤0.01	
Leaf 1989		
First rotation	29 500	1710
Second rotation	31 200	1480
D effect	≤0.05	
S effect		≤0.001
D×S effect	≤0.001	≤0.10
Litter 1989		
First rotation	30 800	922
Second rotation	27 500	611
D effect	≤0.001	≤0.001
S effect		≤0.001
D×S effect	≤0.01	≤0.05



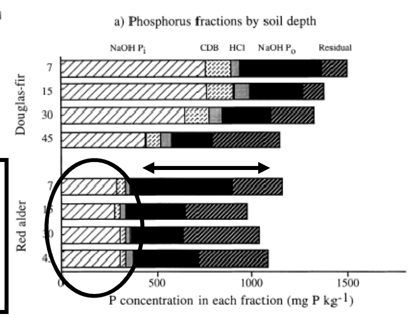
The redistribution to organic forms **decreases** P availability

Sources: Compton et al. , 1997 *Can. J. For. Res.* & 1998 *Forest Ecol. Manage.*

Change in P biogeochemistry under alder



Zou et al. (1995) *Soil Sci. Soc. Am. J.*



Compton et al. (1998) *FEM*

BUT……
The effect of alder on P availability differs between pure and mixed stands

In summary
N fixers: friend or foe?

- N fixers have an ameliorative effect on N availability
- Important in post-fire C sequestration
- Growth effect on other spp: from facilitation to competition
- Other soil properties may also change

Is there a role for N-fixers in forest management?

YES

But… as with children….

they need to be kept in check and should not run the show unsupervised…