Former land use and tree age affects nitrate leaching from European forest soils

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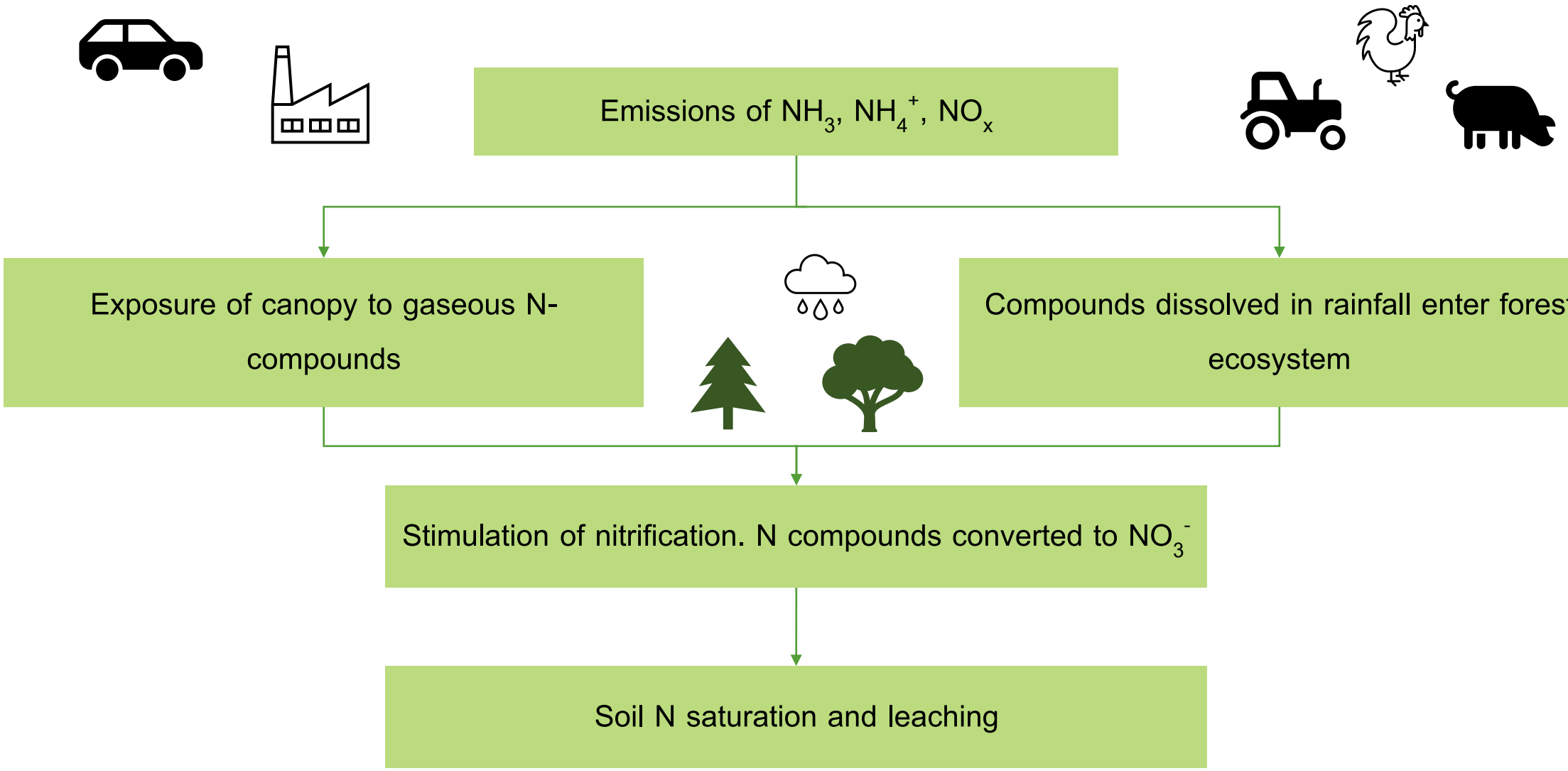
Nitrogen deposition and European forest ecosystems



The literature

Climate: rainfall, temperature

Soil pH and C:N ratios

Tree species

Altitude and slope

Many other studies exist outside of the long-term monitoring datasets and identify other influential variables

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N leaching across European forests: Derivation and validation of empirical relationships using data from intensive monitoring plots

C. van der Salm [a,*], W. de Vries [a], G.J. Reinds [a], N.B. Dise [b,c]

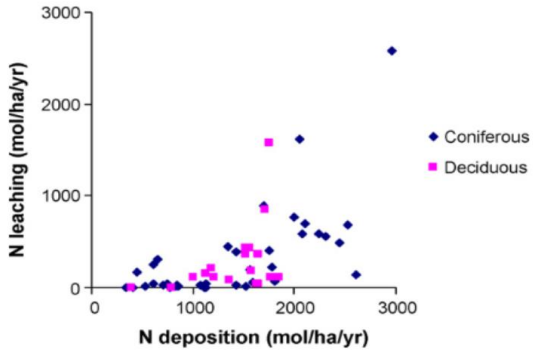

Fig. 3. N leaching fluxes for coniferous and deciduous forest sites in the selected dataset as a function of the total N-deposition flux (mol/(ha year)).

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Nitrogen input together with ecosystem nitrogen enrichment predict nitrate leaching from European forests

J. A. MACDONALD*†, N. B. DISE†, E. MATZNER‡, M. ARMBRUSTER‡§, P. GUNDERSEN¶ and M. FORSIUS**

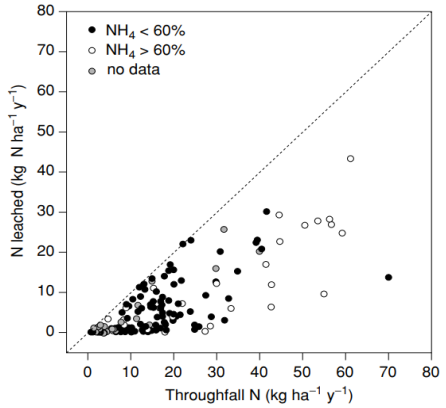

Fig. 1 N input in throughfall vs. NO_3^- leached (kg N ha^{-1} y^{-1}). Leached $NO_3^- = 0.46^*$ throughfall N−1.87 ($n = 181$, $P < 0.05$, $r^2 = 0.62$). Open symbols represent sites where the input of N was dominated by ammonia (> 60%).

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Predicting dissolved inorganic nitrogen leaching in European forests using two independent databases☆

N.B. Dise[a,*], J.J. Rothwell[a], V. Gauci[b], C. van der Salm[c], W. de Vries[c]

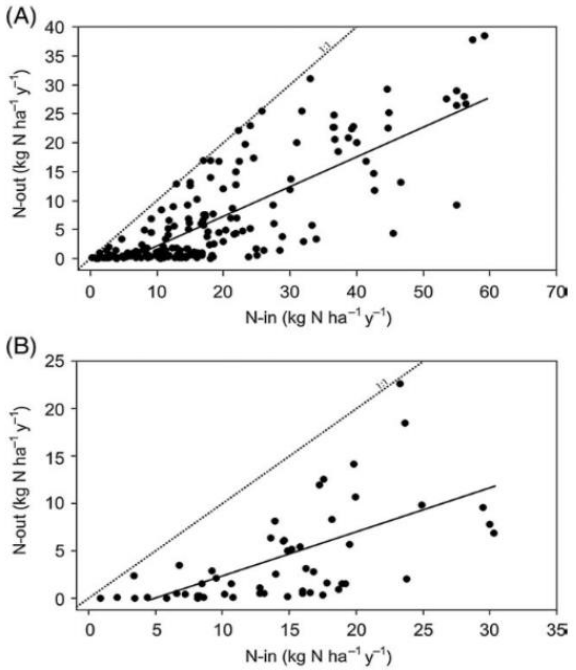


Fig. 1 – Dissolved inorganic nitrogen leached (N-out) vs. dissolved inorganic nitrogen input in throughfall (N-in) for IFEF (A) and Level II (B) sites. Regression line is shown as solid line. Note the different scales on the x-axes.

Our Aims

Determine whether the literature aligns with the findings from the long-term monitoring datasets

Investigate the effect of soil type, tree species, former and surrounding land use on the relationship between N-in and N-out

Literature search

Scopus

Clarivate

Web of Science™

ProQuest
Part of Clarivate

CABI

Species
Fagus sylvatica
Quercus petraea/robur
Betula pendula
Picea sitchensis
Pinus Sylvestris
Picea abies

Other considerations:

- Units
- Nitrate leaching *fluxes* only
- Throughfall nitrate only, not ammonium deposition

Exposures	**Outcome**	**Variables to explain exposure/outcome relationships**
Tree species	Relationship between nitrate leaching fluxes and throughfall nitrate concentrations	Organic layer C:N ratio
Soil order		Mineral topsoil (0-10cm) C:N ratio
Land use history		Organic layer pH
Proximity to agriculture		Mineral topsoil (0-10cm) pH
Average annual temperature		Soil texture
Average annual precipitation		

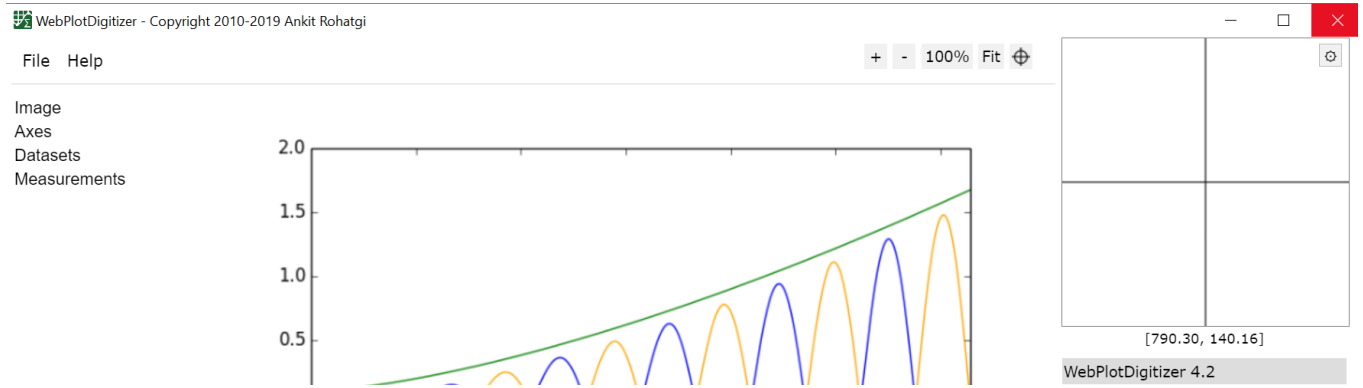
Data extraction

Literature included:

65 sites across 16 papers.

Individual studies

Afforestation chronosequences



	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
1	ors	Title	Publicati	Journal	Species	Type	Latitude	Longitud	Country	name	Former_L	Site.soil.	Order	Throughf	Leaching	Obs_year	Planted	Age	pH_O	pH_010	pH_1030	CN_O	CN_010	CN_1030	Soil.textu	Clay	Silt	Sand	MAT	MAP	Foliar.P.e	Foliar.P.u	Foliar.N.e	Foliar.N.u	Foliar_NI	Foliar_P	Foliai
2	' J,	BASE CAT	1997	Water, ai	P.abies	Conifer	7.19284	48.2058	France	Strengba	Rotation	Acid disti	Inceptisc	18.2	22.4	1988-199	1903	85	NA	3.7	3.7	NA	12.6	12.6	Medium	22.2	20.1	57.7	6	1250	NA		NA		NA	NA	NA
3	' J,	BASE CAT	1997	Water, ai	F.sylvatic	Broadlea	7.19284	48.2058	France	Strengba	Old grow	Podzol	Podzol	7.8	2.4	1988-199	1848	140	NA	4	4.1	NA	8.1	8.1	Sandy loa	11.8	22.5	65.7	6	1250	NA		NA		NA	NA	NA
4	Di	Nitrogen	2011	Water, ai	F.sylvatic	Broadlea	14.4417	47.8417	Austria	Zoebelbc	Old grow	Lithic and	Leptosol	16.8	7.4	1993-2006	NA	NA	5.7	6.7	6.9	NA	NA	NA		NA	NA	NA	7.2	1650	NA		NA		NA	NA	NA
5	Di	Nitrogen	2011	Water, ai	P.abies	Conifer	14.4417	47.8417	Austria	Zoebelbc	Rotation	Chromic c	Cambisol	21.6	19.7	1993-2006	1910	83	5.3	6.3	6.6	NA	NA	NA		NA	NA	NA	7.2	1650	NA		NA		NA	NA	NA
6	H,	N deposi	2004	Biogeoch	P.abies	Conifer	7.21434	48.2054	France	Aubure, \	Old grow	Dystric ca	Cambisol	20.6	43.6	1994-199	1914	80	NA	3.5	NA	NA	15.5	NA	Clay loan	20	23	57	5.4	1000	NA		NA		NA	NA	NA
7	H,	N deposi	2004	Biogeoch	F.sylvatic	Broadlea	7.21434	48.2054	France	Aubure, \	Coppice	haplic pc	Podzol	7.6	0.9	1994-199	1854	140	NA	3.7	NA	NA	18.5	NA	Sandy loa	11	22	67	5.4	1000	NA		NA		NA	NA	NA
8	' J,	The effec	1994	Europear	P.abies	Conifer	4.76613	49.8821	France	Chateau-	Rotation	Typic Dry	Inceptisc	51.7	40.4	1992-199	1934	58	NA	3.9	3.7	NA	19.1	14.4		NA	NA	NA	8	1300	NA		NA		NA	NA	NA
9	' J,	The effec	1994	Europear	F.sylvatic	Broadlea	4.76613	49.8821	France	Chateau-	Coppice	Typic Dry	Inceptisc	20.3	13.6	1992-199	NA	NA	NA	4.3	4	NA	14.2	14.8		NA	NA	NA	8	1300	NA		NA		NA	NA	NA
10	A,	Depositi	2002	Plant anc	F.sylvatic	Broadlea	11.0833	48.3	Germany	Hoglwalc	Old grow	Dystric ca	Cambisol	23.0898	0.9722	1994-199	1904	90	NA	NA	NA	NA	NA	NA		NA	NA	NA	7.6	850	NA		NA		NA	NA	NA
11	A,	Depositi	2002	Plant anc	P.abies	Conifer	11.0833	48.3	Germany	Hoglwalc	Rotation	Dystric ca	Cambisol	48.1239	36.4575	1994-199	1909	85	NA	NA	NA	NA	NA	NA		NA	NA	NA	7.6	850	NA		NA		NA	NA	NA
12	an	Role of s	2010	Global ch	Q.robur/p	Broadlea	9.61944	55.96	Denmark	Mattrup,	Arable	Coarse-lc	Alfisol	7.57282	31.1538	2004-200	1973	31	4.3	4.5	NA	27	13	NA	Sandy loa	14	14	71	7.3	825	NA		NA		NA	NA	NA
13	an	Role of s	2010	Global ch	P.abies	Conifer	9.61944	55.96	Denmark	Mattrup,	Arable	Coarse-lc	Alfisol	29.5146	28.8462	2004-200	1973	31	4.4	4.5	NA	29	13	NA	Sandy loa	14	14	71	7.3	825	NA		NA		NA	NA	NA
14	an	Role of s	2010	Global ch	F.sylvatic	Broadlea	9.61944	55.96	Denmark	Mattrup,	Arable	Coarse-lc	Alfisol	8.54369	38.8462	2004-200	1973	31	4.5	4.3	NA	33	12	NA	Sandy loa	14	14	71	7.3	825	NA		NA		NA	NA	NA
15	an	Role of s	2010	Global ch	Q.robur/p	Broadlea	12.0631	55.4231	Denmark	Valo, Zea	Old grow	Coarse-lc	Alfisol	8.54369	1.15385	2004-200	1973	31	4.6	3.8	NA	24	18	NA	Sandy loa	10	19	72	7.8	631	NA		NA		NA	NA	NA
16	an	Role of s	2010	Global ch	P.abies	Conifer	12.0631	55.4231	Denmark	Valo, Zea	Old grow	Coarse-lc	Alfisol	22.3301	0.38462	2004-200	1973	31	NA	3.7	NA	25	18	NA	Sandy loa	10	19	72	7.8	631	NA		NA		NA	NA	NA
17	an	Role of s	2010	Global ch	F.sylvatic	Broadlea	12.0631	55.4231	Denmark	Valo, Zea	Old grow	Coarse-lc	Alfisol	10.8738	9.61538	2004-200	1973	31	4.3	3.8	NA	27	18	NA	Sandy loa	10	19	72	7.8	631	NA		NA		NA	NA	NA
18	ani	Leaching	2005	Plant anc	Q.robur/p	Broadlea	7.41487	52.5457	Germany	Grumsmu	Old growth forest		Podzol	12.322	1.61	2001-200	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	10.7	727	NA		NA		NA	NA	NA
19	ani	Leaching	2005	Plant anc	P.sylvestr	Conifer	7.63643	52.353	Germany	Heiliges	Old growth forest		Podzol	42.17	16.224	2001-200	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	10.3	845	NA		NA		NA	NA	NA
20	cie	A decade	2011	Environm	F.sylvatic	Broadlea	7.41019	47.227	Switzerla	Bettlachs	Old grow	Rendzic l	Leptosol	12.0921	2.19388	1999-200	1841	158	NA	6.5	NA	NA	NA	NA	Clay	56	1	43	6	1149	NA		NA		NA	NA	NA
21	cie	A decade	2011	Environm	F.sylvatic	Broadlea	6.68476	46.577	Switzerla	Lausanne	Old grow	Dystric ca	Cambisol	12.5814	14.848	1999-200	1851	148	NA	3.9	NA	NA	NA	NA	Sandy loa	17	21	62	7.6	807	NA		NA		NA	NA	NA
22	cie	A decade	2011	Environm	F.sylvatic	Broadlea	9.07481	47.1708	Switzerla	Schanis,	Old grow	Eutric car	Cambisol	19.5514	20.0664	1999-200	1871	128	NA	5	NA	NA	NA	NA	Clay loan	41	9	50	7.9	733	NA		NA		NA	NA	NA
23	cie	A decade	2011	Environm	P.abies	Conifer	7.79968	46.7177	Switzerla	Beatenbe	Old grow	Podzol	Podzol	9.10241	0	1999-200	1791	208	NA	2.8	NA	NA	NA	NA	Clay	87	4	9	4.6	1511	NA		NA		NA	NA	NA
24	et	Impact of	2012	Atmosph	F.sylvatic	Broadlea	3.80417	51.0697	Belgium	Wijendal	Arable	Endogley	Umbrisol	50.0028	5.95985	1994-201	1935	59	2.7	2.7	NA	22	21	16		NA	NA	NA	11	867	NA		NA		NA	NA	NA

Review_Final

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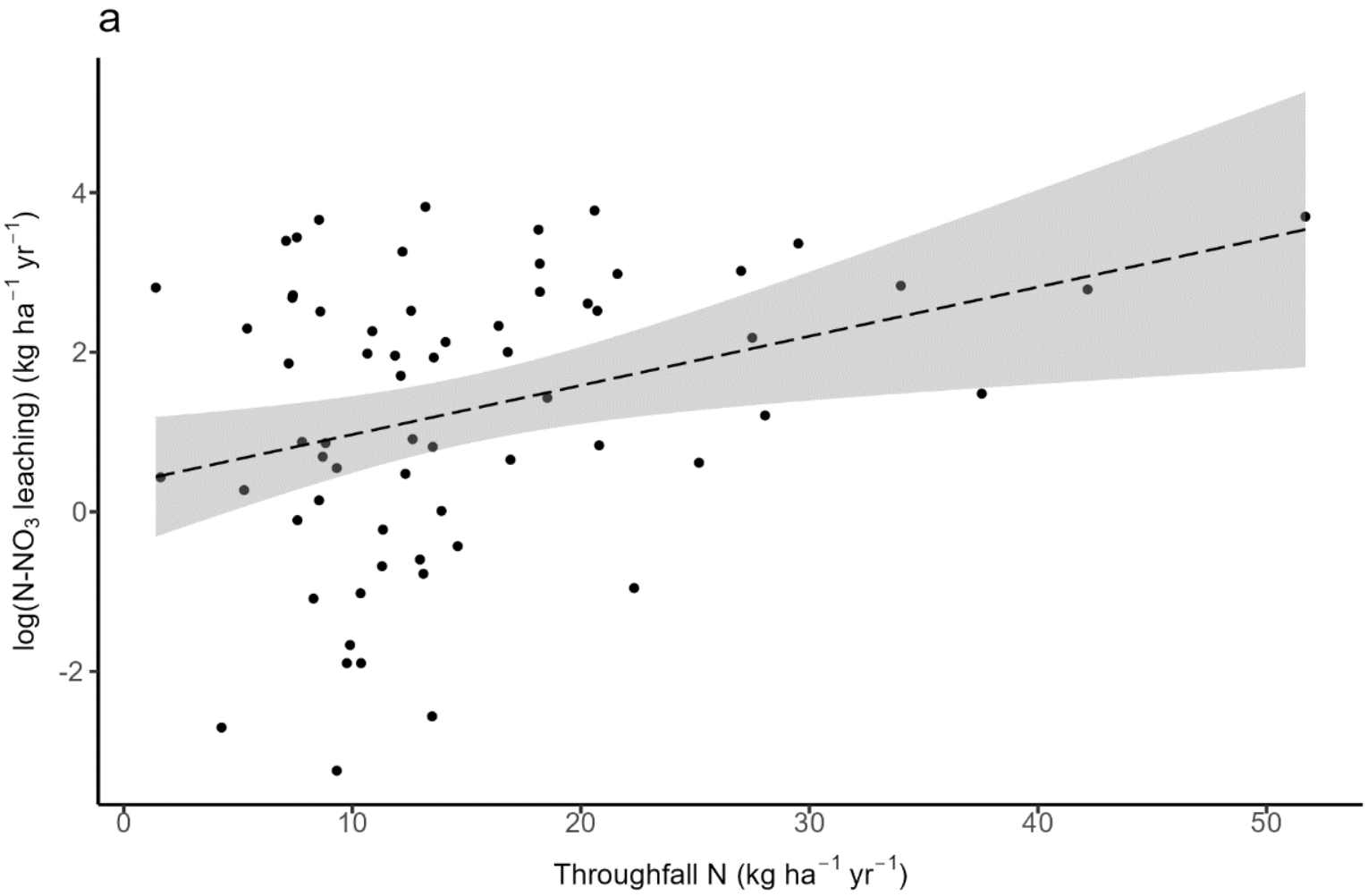
N leaching positively related to throughfall nitrate

There was a significant ($p < 0.05$) positive relationship between nitrate leaching and throughfall nitrate ($y = 0.35x+0.06$).

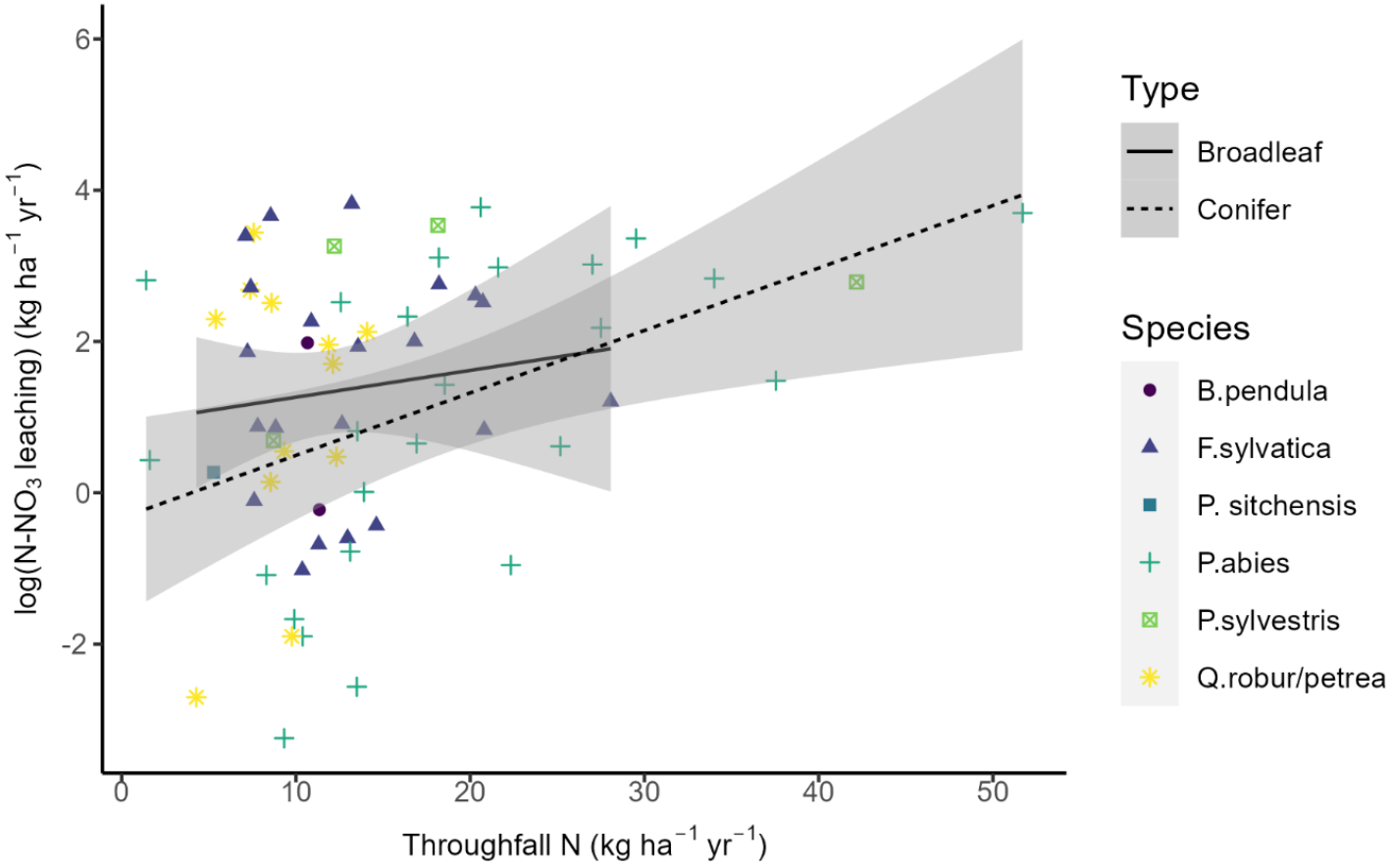


1: Throughfall nitrate and tree species predict nitrate leaching…

Stepwise AIC: $R^2 = 0.11$, $p = 0.04$

Difference in gradients not statistically significant (Figure 2, ANCOVA, $F = 0.547$, $p > 0.05$).

Even representation of broadleaf and conifers (n= 34 and 30 respectively)

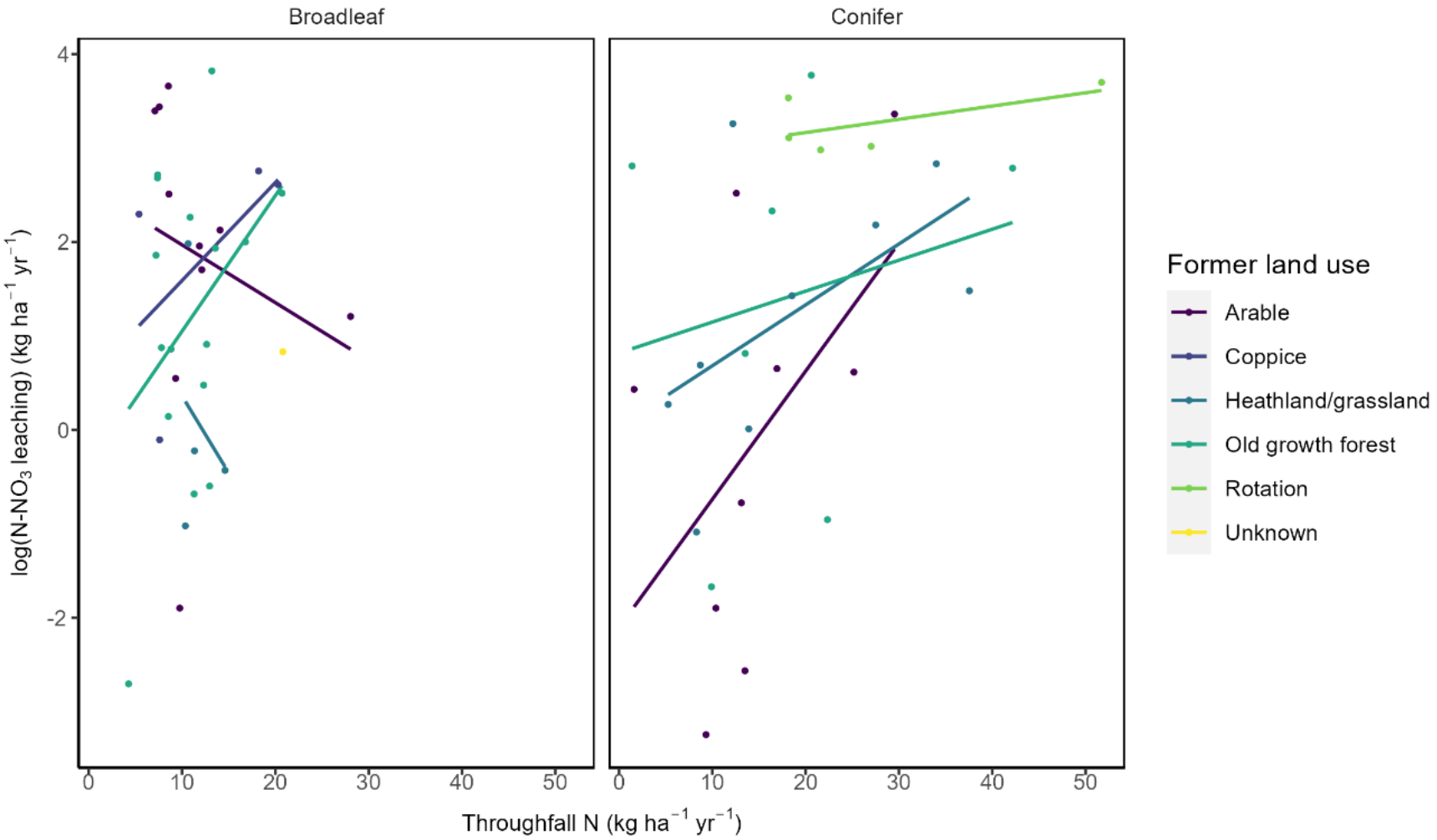


2. …until sites on arable land are excluded

Former arable soils planted with broadleaves displayed unexpected relationship with throughfall N.

Therefore removed datapoints on arable soils and reran the stepwise AIC.

Throughfall, former land use and soil order were then the best predictors : R^2=0.46, p = 0.06



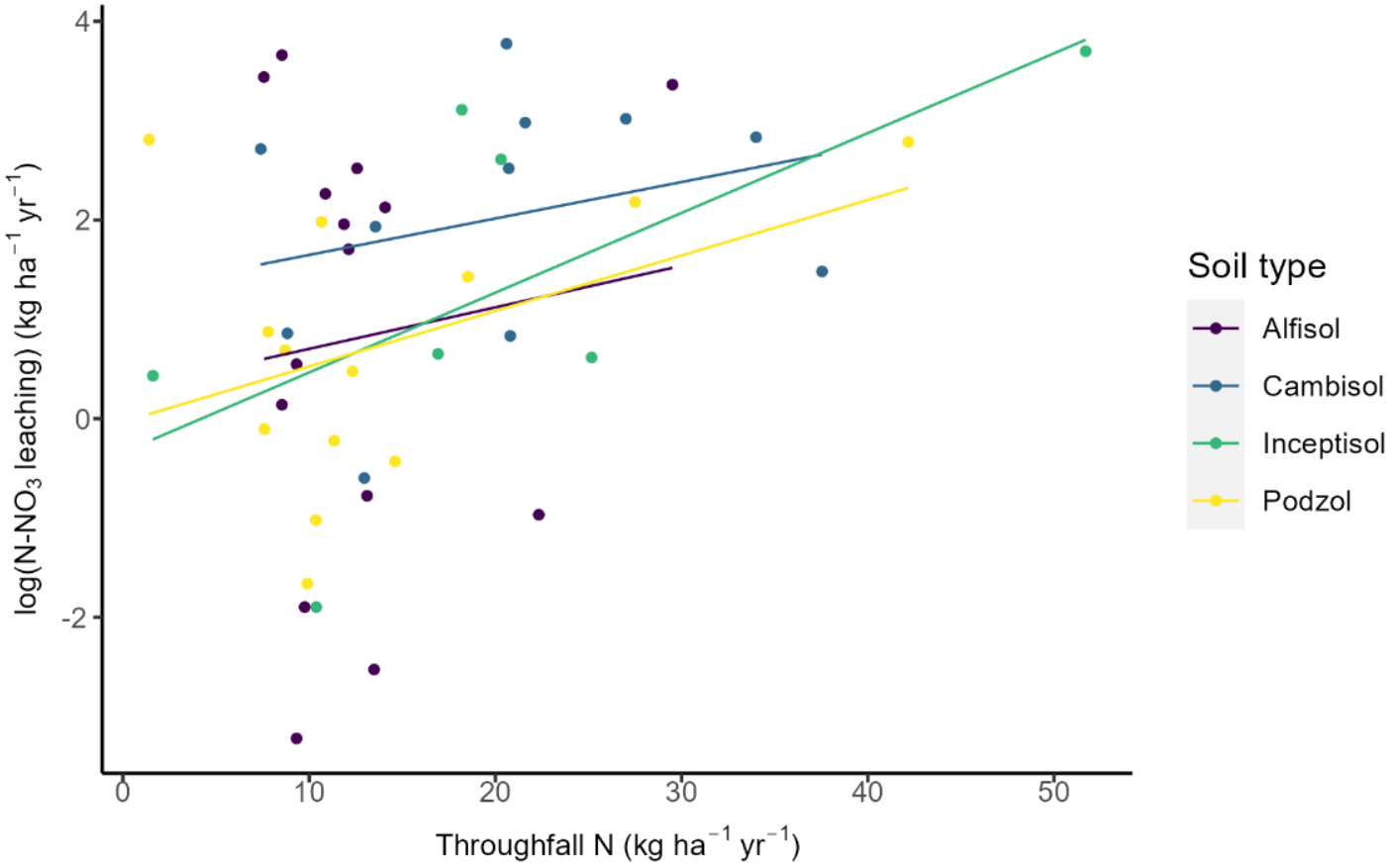
3: The behaviour of arable sites afforested with broadleaves may be related to differences in the nutrient status of different soils

There was a significant association between soil orders and different former land uses (Chi-squared, $X^2=42.8$, $p < 0.001$).

Former arable sites afforested with broadleaved species were typically found on alfisols.

Alfisols are nutrient rich, and arable soils can have high P content.

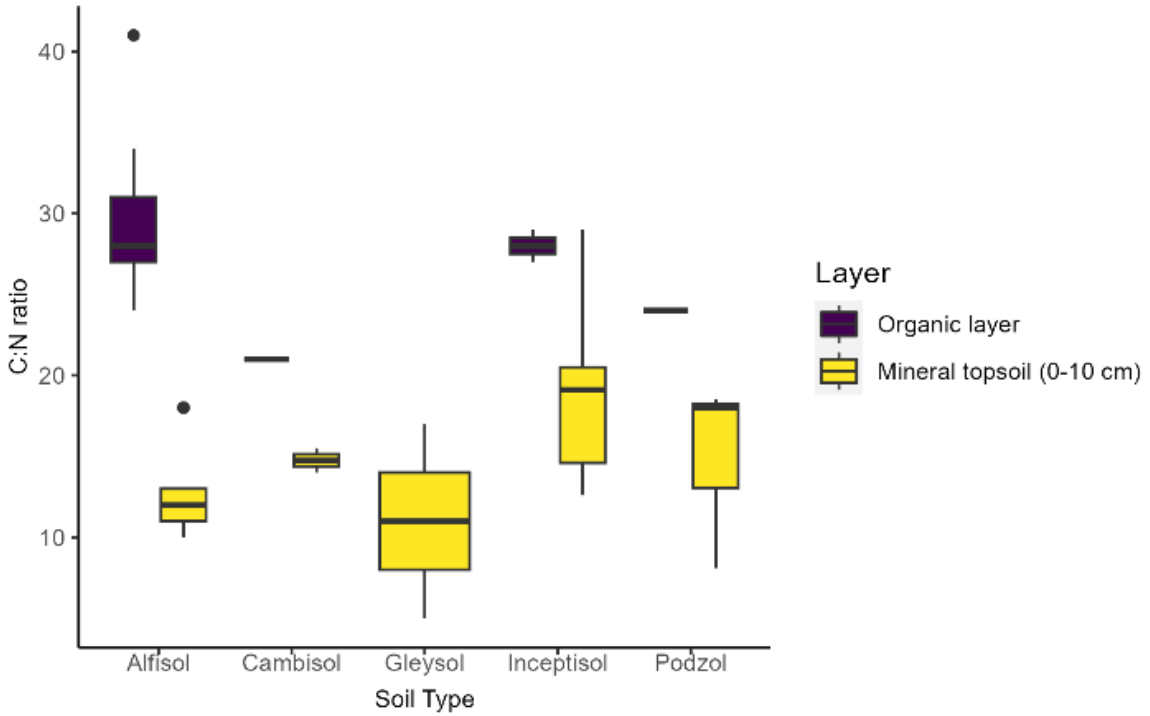
Broadleaf trees have a higher demand for P than conifers, and when lots of nutrients are available broadleaves grow well and can retain more N despite high inputs.

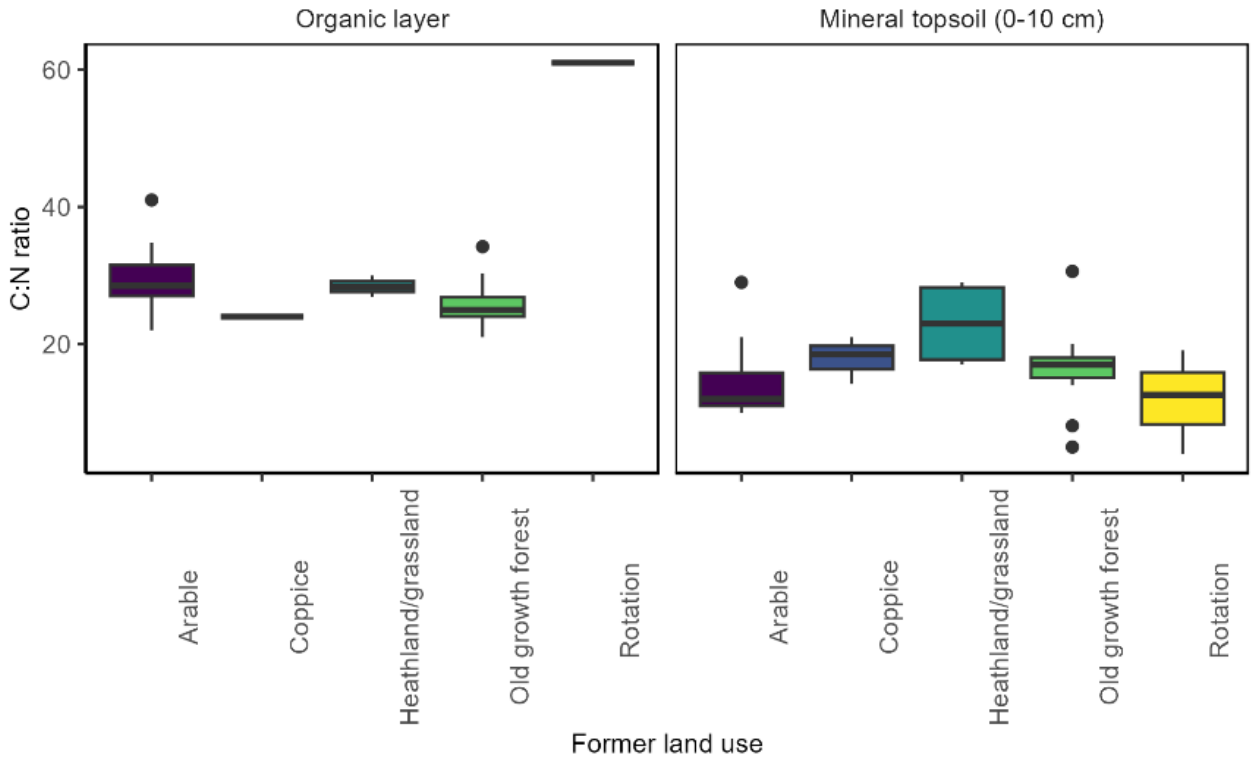


4: Soil order and former land use affected soil C:N ratios

Soil order affected mineral top soil C:N ratios and pH. Soil order affected organic soil C:N ratio but not pH.

Former land use affected organic layer C:N ratios but not mineral soil C:N ratios. Former land use did not affect soil pH.

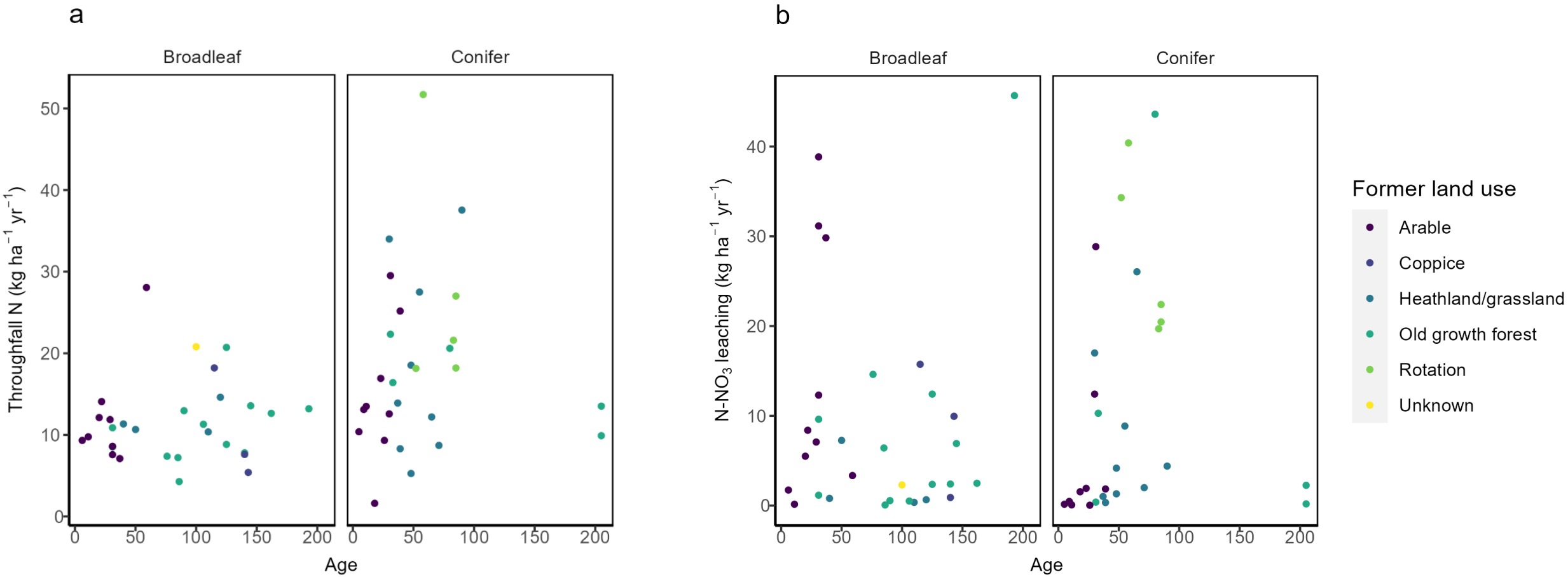




5: Former land use effects were linked with tree age effects

Trees on afforested arable land were generally younger than those planted on other former land uses.

Nitrate leaching increased with age until 50-80 years, then decreased.



Getting further evidence

	Further data on N-input vs N-output on secondary rotations, formerly coppiced land, and broadleaves planted on heathland/grassland
ICP Level II dataset	Data on available nutrients in soil solution e.g. P, to look for relationships with how this affects the N-input vs N-output relationship
	More data to assess interactions between variables
Other PhD work	Conversion of coniferous forest to broadleaved forest- effect on nitrate leaching, nitrification, soil C:N ratios

What does all of this mean practically?

Broadleaf trees planted on arable land may have unexpected responses in N-leaching to elevated deposition

What does all of this mean practically?

Broadleaf trees planted on arable land may have unexpected responses in N-leaching to elevated deposition

Tree harvesting and nutrient management regimes have long-term implications for soil N content

What does all of this mean practically?

Broadleaf trees planted on arable land may have unexpected responses in N-leaching to elevated deposition

Tree harvesting and nutrient management regimes have long-term implications for soil N content

Consider the timescale over which afforestation can provide benefits to water quality