ICP Forests

ALTERRA WAGENINGEN UR

WSL

Continental-scale forest growth in Europe is driven by management and further modulated by Nitrogen deposition

Etzold, Sophia, Ferretti, Marco, Reinds, Gert Jan, Solberg, Svein, Gessler, Arthur, Waldner, Peter, Schaub, Marcus, Simpson, David, Benham, Sue, Hansen, Karin, Ingerslev, Morten, Jonard, Mathieu, Karlsson, Per Erik, Lindroos, Antti-Jussi, Marchetto, Aldo, Manninger, Miklos, Meesenburg, Henning, Merilä, Päivi, Nöjd, Pekka, Rautio, Pasi, Sanders, Tanja GM, Seidling, Walter, Skudnik, Mitja, Thimonier, Anne, Verstraeten, Arne, Vesterdal, Lars, Vejpustkova, Monika, de Vries, Wim

ICP Forests Scientific Conference, Birmensdorf

éclaire

Work package 9: Synthesis and meta-analysis of measurements of plant and soil responses

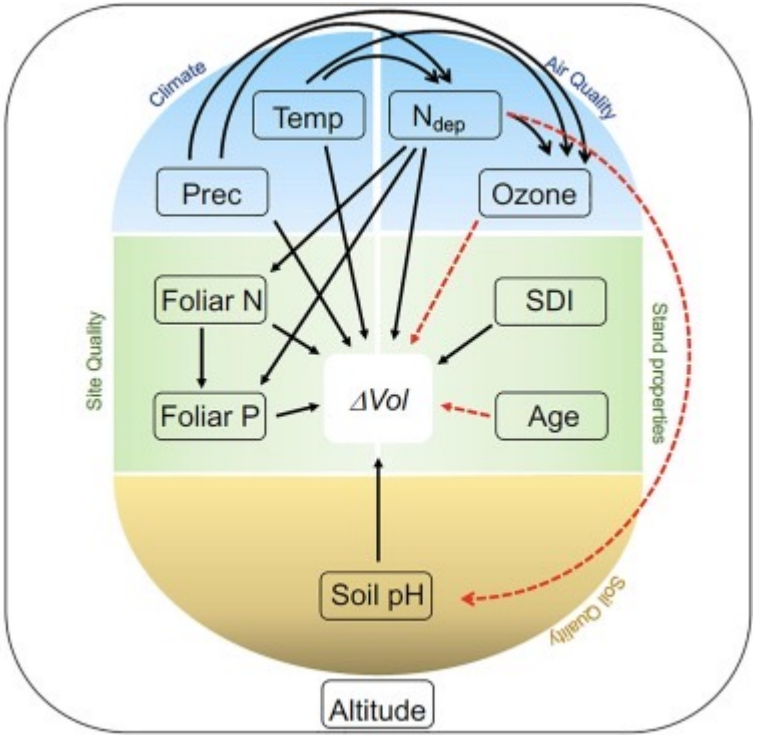
A 15-year monitoring study

Started in 2011 under the guidance of Matthias Dobbertin and Wim de Vries

Aim: To identify combined and concurrent impacts of multiple factors on forest growth, including climate, air pollution, site and stand properties.

Hypotheses:

1) Stand characteristics have a generalized effect on forest growth
2) Climate influence on growth is species-specific
3) **Effect of N-deposition on growth is non-linear**
4) **Ozone has a generalized negative relationship with forest growth**



A 15-year monitoring study

442 ICP-Forests Level II monitoring plots (nearly 100’000 trees) in 23 European countries

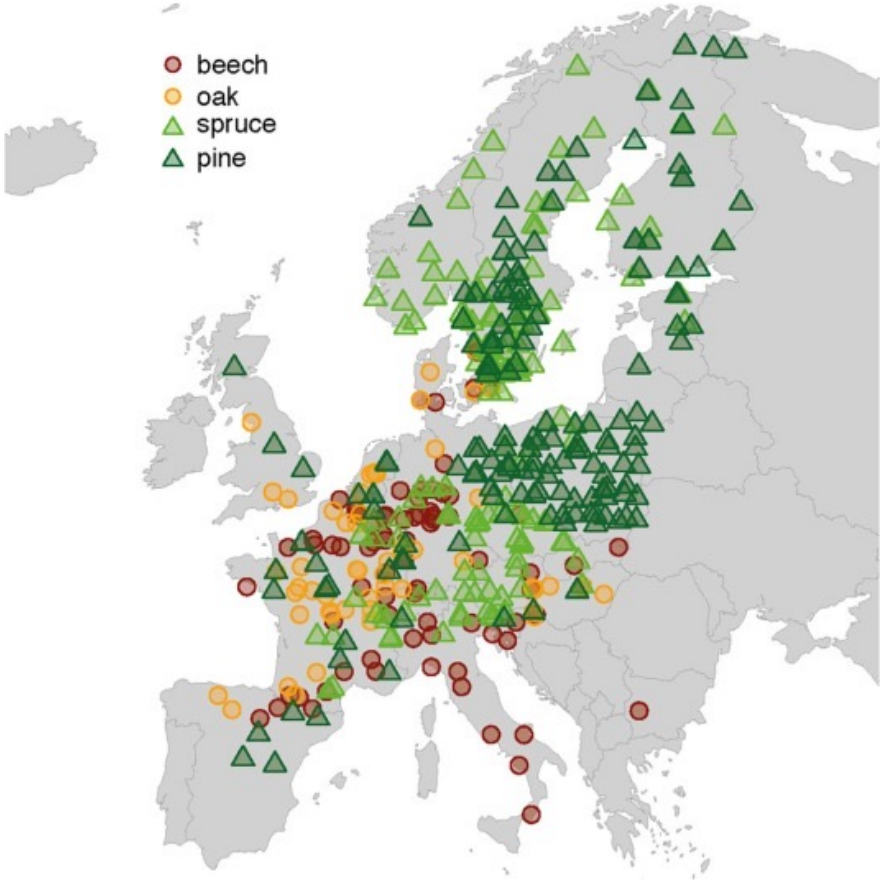
Plot selection criteria:

- dominated by beech, oak, pine or spruce (>70% basal area)
- not fertilized or intensively managed
- > 3 growing periods between two inventories

Response variable = Stem increment (*⊿Vol*)

- recorded every five to ten years in 1995, 2000, 2005, 2010 → three inventories

Inventory	*N plots*
1995-2000	389
2000-2005	327
2005-2010	175
1995-2010	134



A 15-year monitoring study

Explaining variables:

- Stand properties: SDI and stand age
- Climate: **Temperature, Precipitation, Drought indicators**
- Air quality: N deposition ($N_{depICPF}$, $N_{depEMEP}$),
  Ozone (POD_1, AOT40)
- Site quality: foliar N and P concentration, soil pH

ENSEMBLES dataset E-OBS
Related to growing period

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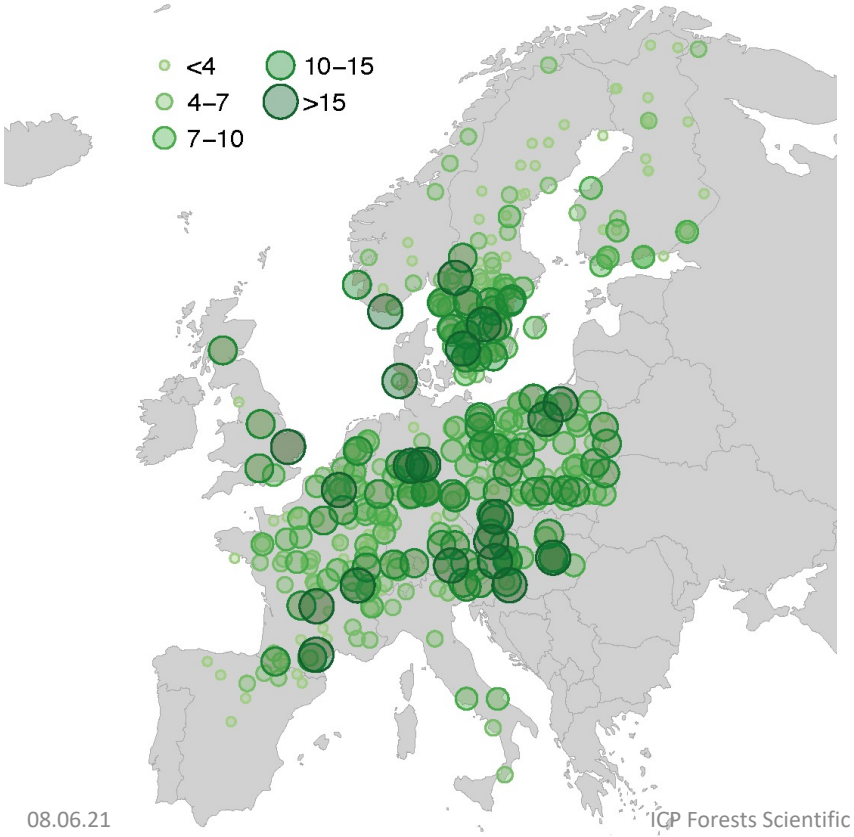
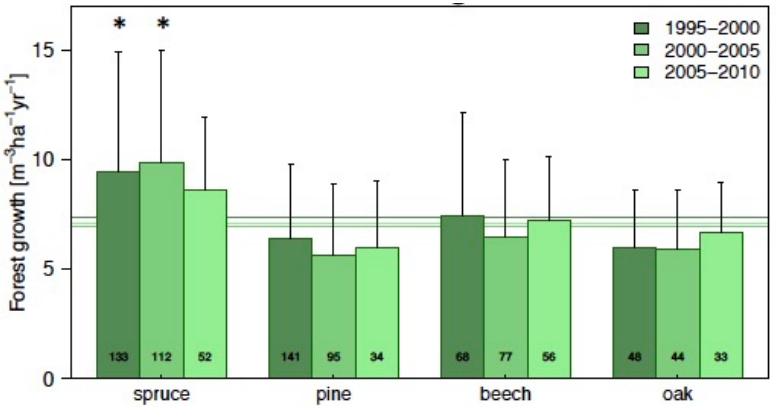
Two multivariate statistical approaches:

- **Linear mixed effect models:** nested design, time series
- **Structural equation modelling**: test complex hypotheses involving multiple causal pathways (relationships between intercorrelated variables)

European forest growth (stem increment)

Forest increment [$m^3\ ha^{-1}yr^{-1}$] 1995-2000





- **Highest growth** in **Central Europe** and for **spruce** forests
- **Variable temporal trends**

Mixed-effects model

Forest increment ~ stand properties + climate + air quality + site quality + soil pH, ~random=plot
Average over best models (ΔAIC<4)

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	Spruce	Pine	Beech	Oak
N obs /plots	223/126	145/81	133/55	99/41
N models	8	27	51	65
Adj.R^2	0.60	0.62	0.35	0.53
stand **SDI**	∩	+		+
stand **Stand Age**	∩	-	-	-
climate **Temperature**	+	+	(+)	(+)
air **N deposition**	+		∩	
Site quality **Foliar N**	+			
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Soil **Soil pH**	+			
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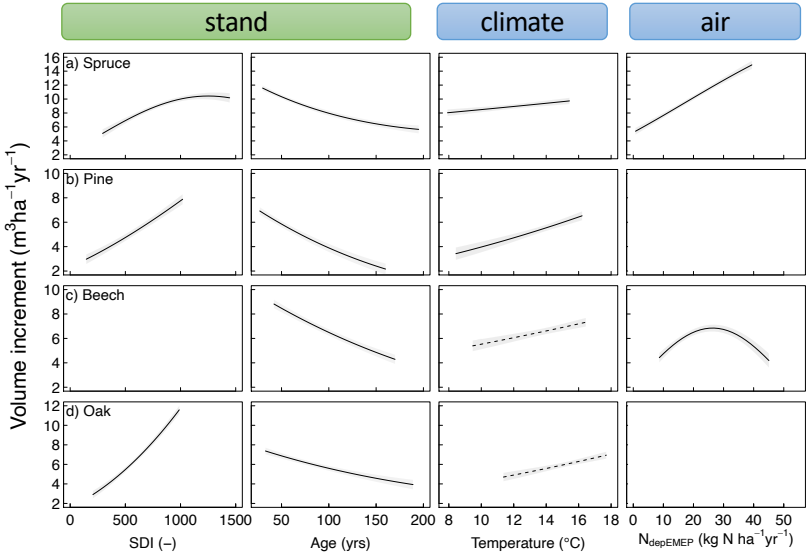

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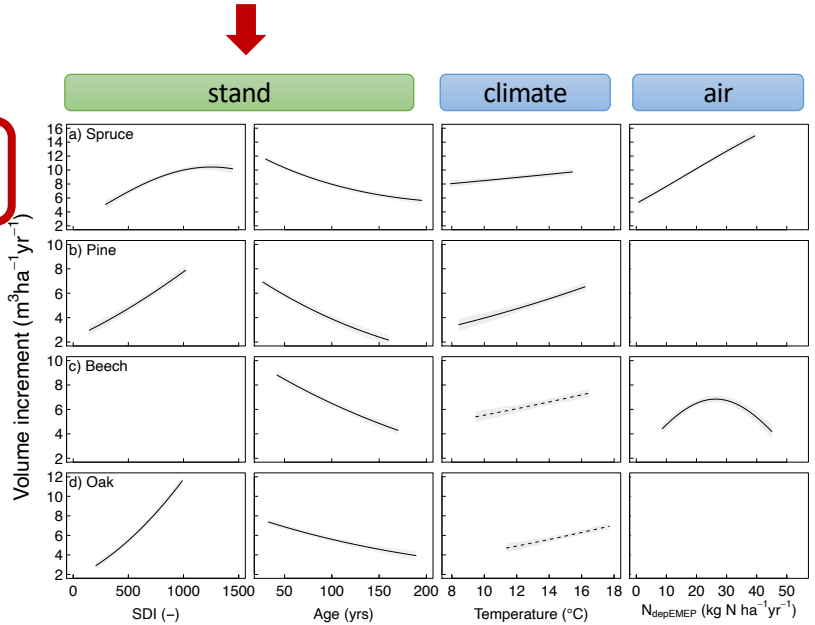

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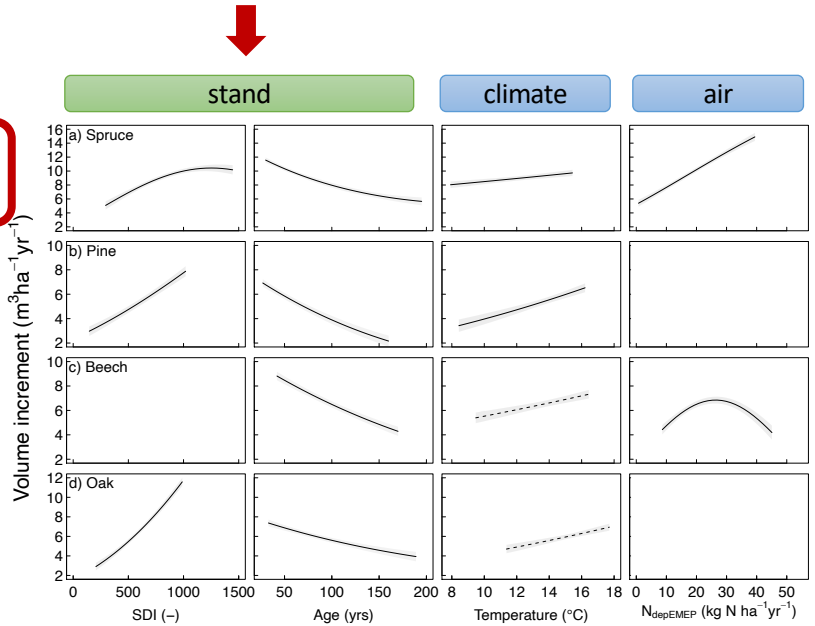

➢ **Strong relationship** of **increment** to **SDI** and **stand age**

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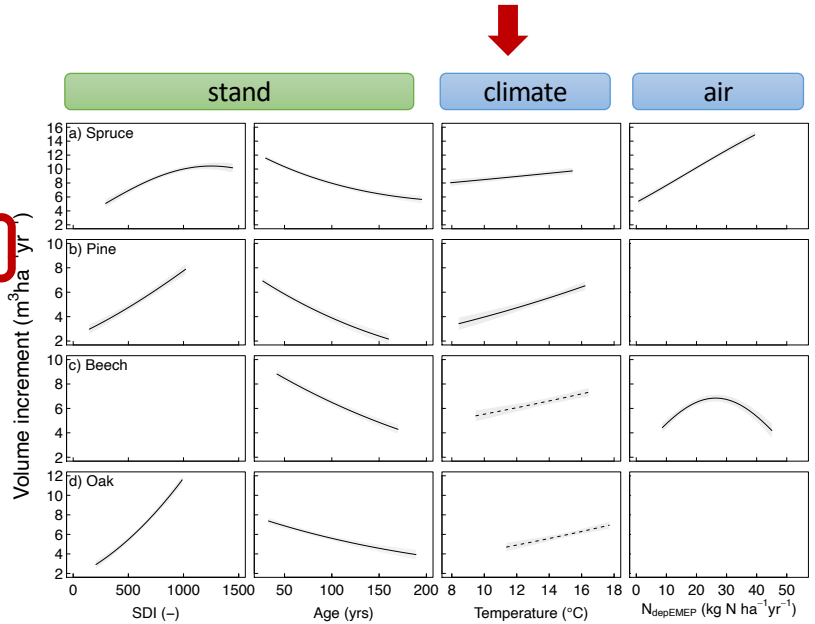

- **Strong relationship** of **increment** to **SDI** and **stand age**
- **Positive temperature** signal for **coniferous forests**

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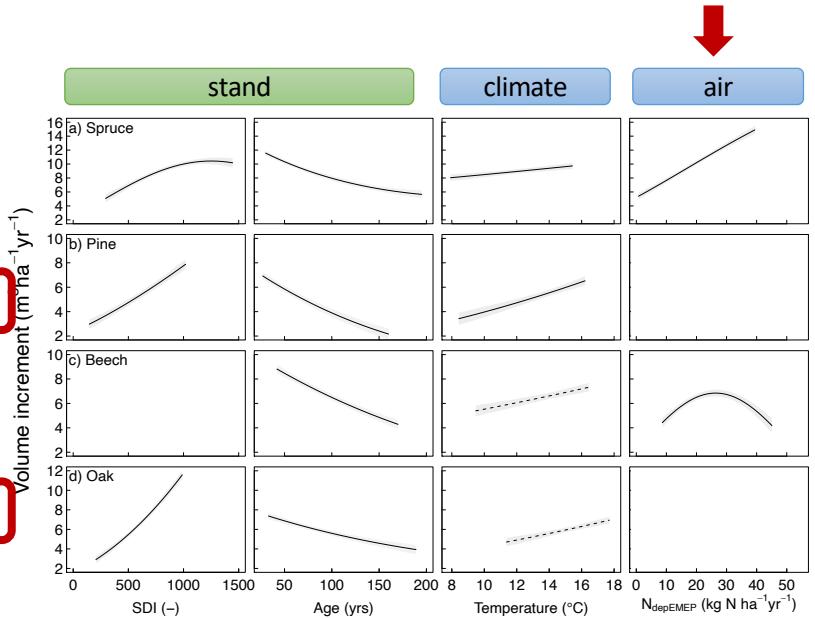

➢ **Non-linear N response** for **beech, negative interaction** with **foliar N concentration** for **spruce** and **beech**

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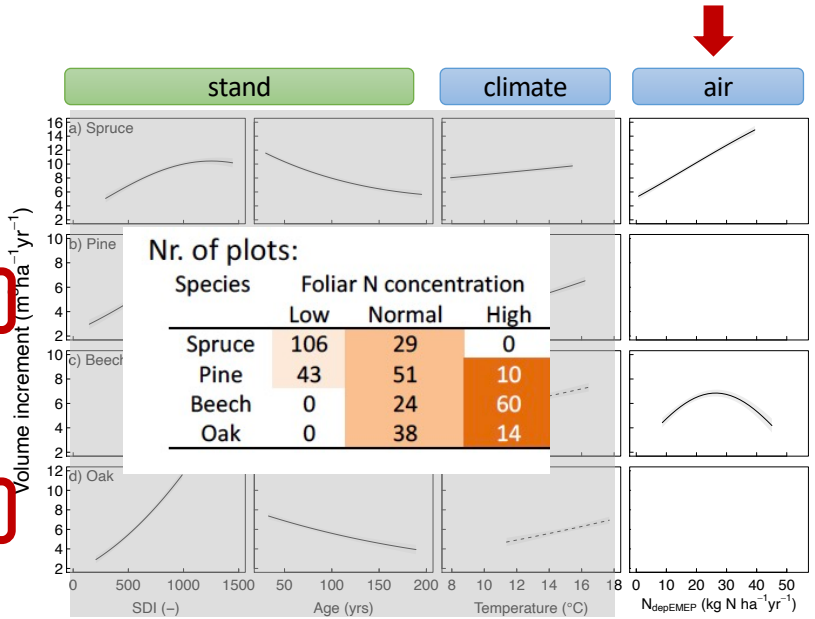
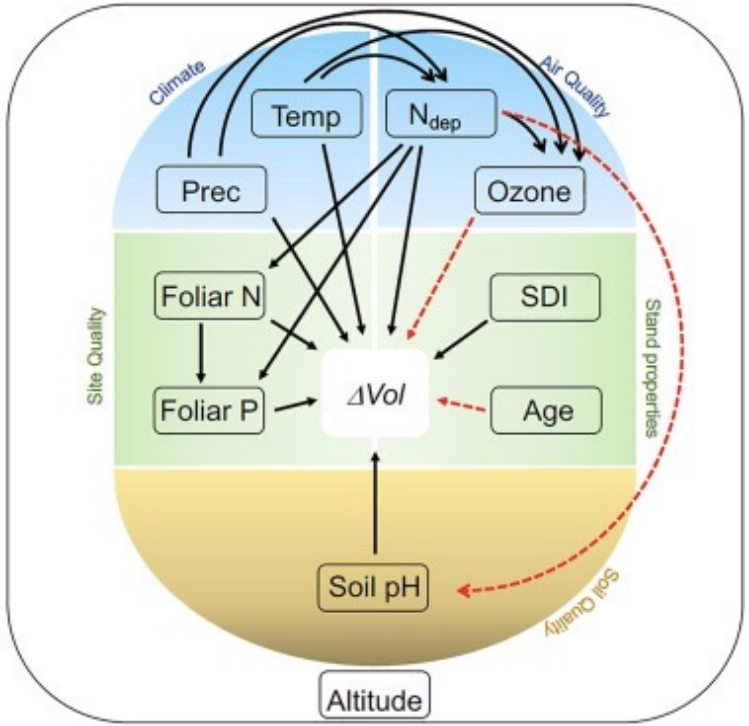


- **Non-linear N response** for **beech, negative interaction** with **foliar N concentration** for **spruce** and **beech**
- **Beech** reacts **most sensitive** to **N deposition**, most plots already **N saturated**

Structural Equation Modelling



Structural equation modeling (SEM) is used to test complex hypotheses involving multiple causal pathways (relationships between intercorrelated variables) and to evaluate whether data are consistent with the model (Grace, 2006).

- **Interactions of site quality and N_{dep}**
- **Interactions of ozone and N_{dep}**

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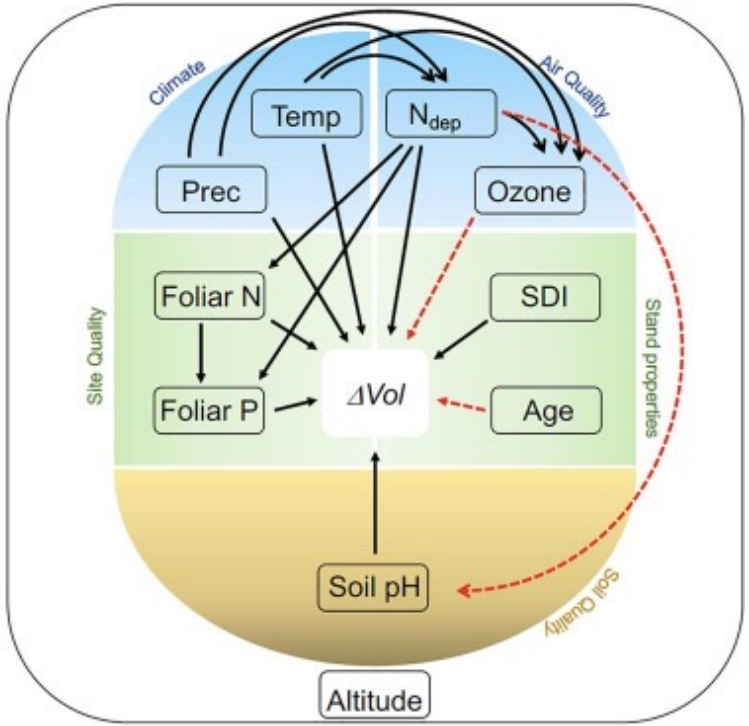

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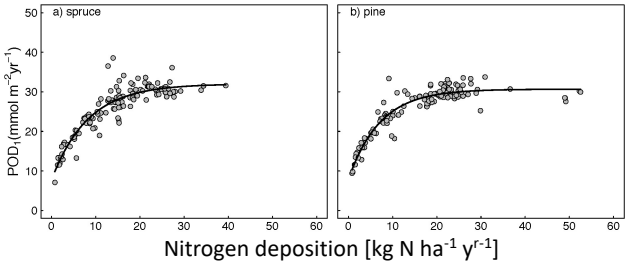

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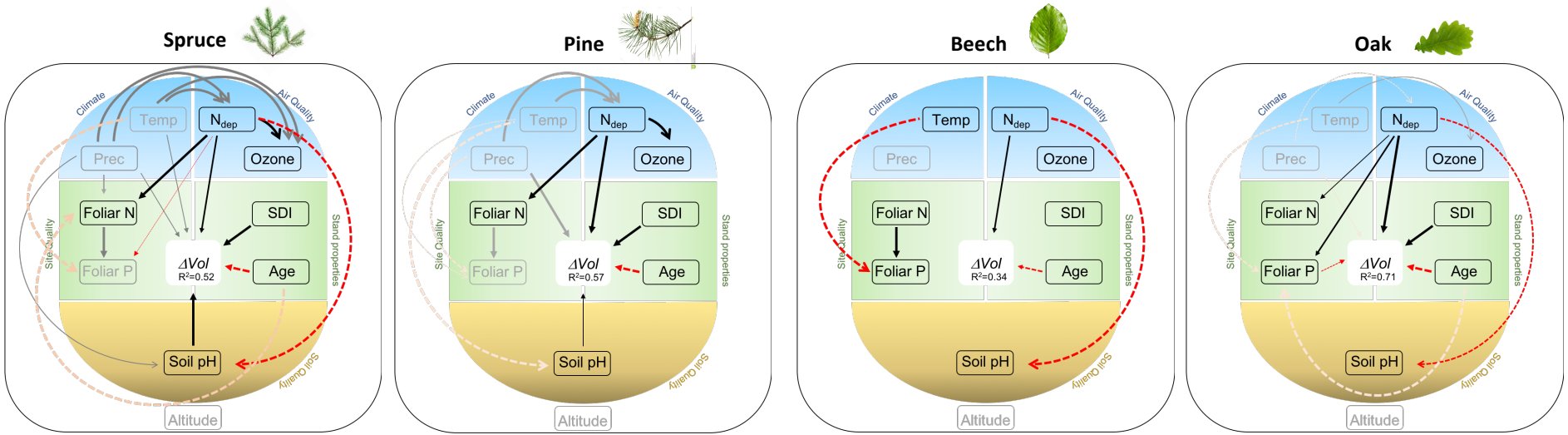

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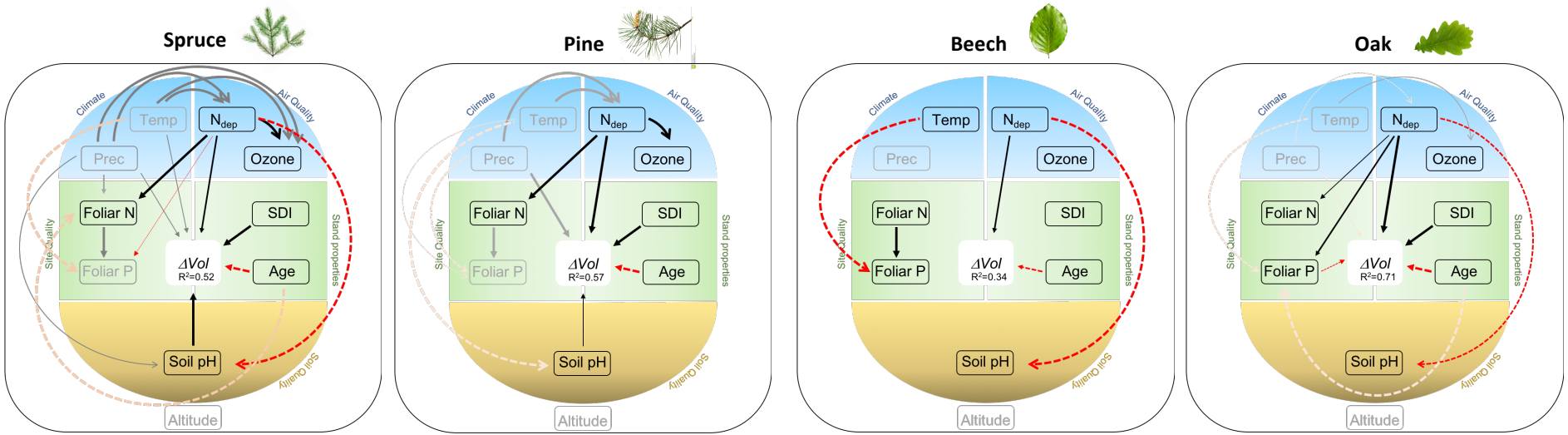
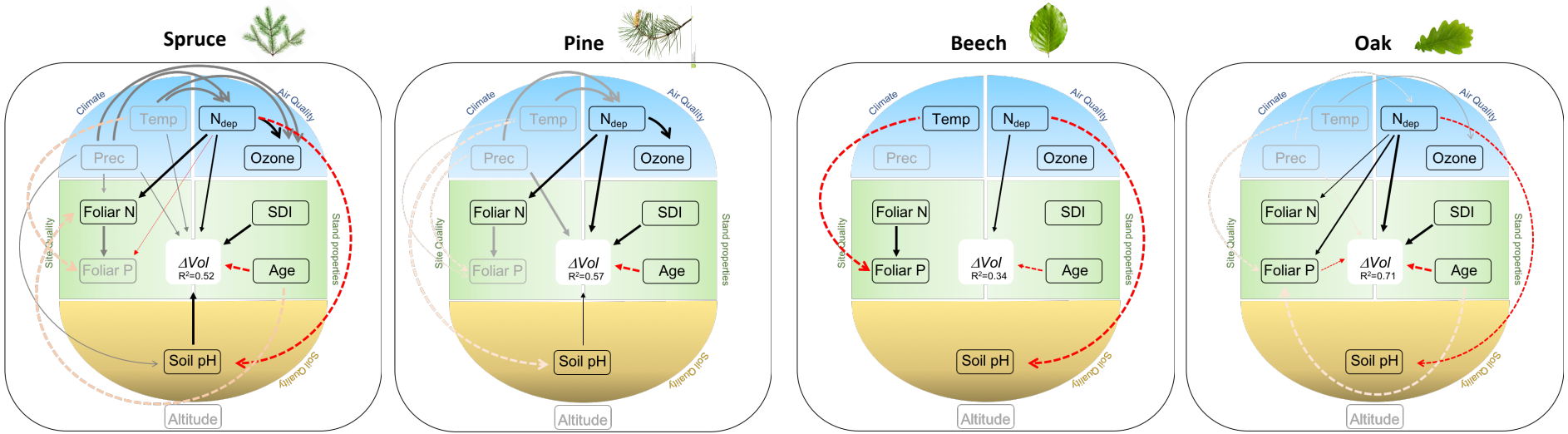


- **N dep** is important driver of forest increment, **positive** relationship to **forest growth**, **decreasing soil pH** for most species
- N dep increases **foliar N**, variable effect on foliar P

Structural Equation Modelling

- Interactions of ozone and N_{dep}



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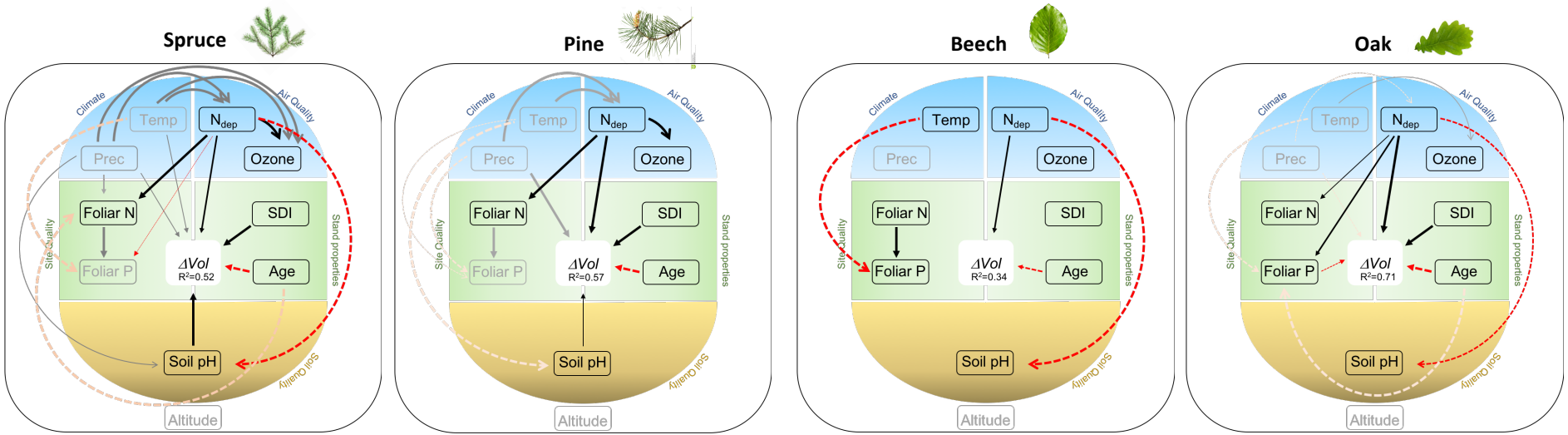


➢ **No significant impact** of **POD_1** on forest increment on European scale

Summary

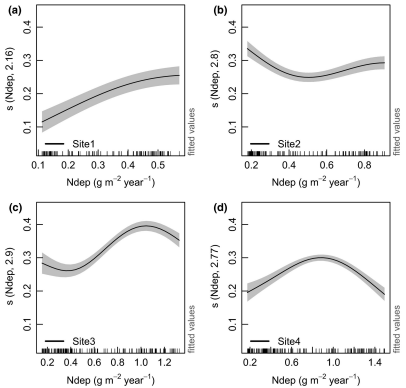
1) Stand characteristics (**SDI** and **stand age**) were the **most important predictors** for forest growth on European scale. → Management activities have potential to influence forest growth even under recent changes in climate and air pollution.

Altman et al., 2013; Foster et al., 2015; Henttonen et al., 2017; Maes et al., 2019

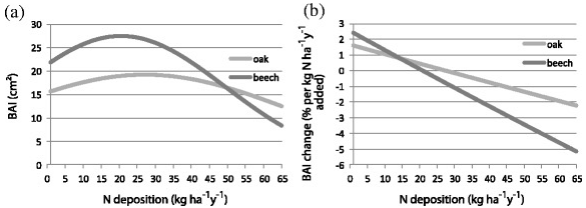
Summary

1) Stand characteristics (**SDI** and **stand age**) were the **most important predictors** for forest growth on European scale. → Management activities have potential to influence forest growth even under recent changes in climate and air pollution.

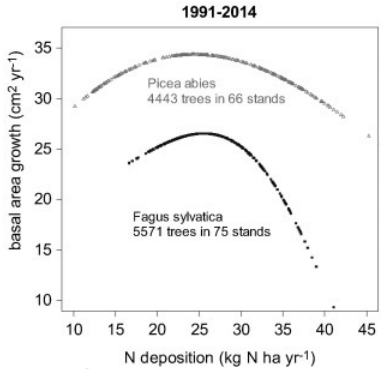
2) **N deposition** was the **most important environmental driver** of forest growth with a **generally positive**, but in some cases **non-linear relationship**, with a **tipping point** at 24–34 kg N ha^{-1} yr^{-1}. N_{dep} was involved in **negative interactions** with **foliar N** concentrations and **soil pH**. Especially **beech** reacted sensitive to N deposition.



Gentilesca et al. 2018, GCB



Kint et al. 2012, Climatic Change



Braun et al. 2017, Science of Total Env

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3) **Limited evidence for significant relationship** of **ozone** and forest growth on the European level, likely due to **counteracting effect** with temperature, N deposition.

Verrykt et al., 201z; Ferretti et al., 2018; Braun et al., 2017; Cailleret et al., 2018

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- Consider non-linear N dep responses in models!
- Follow-up study with data up to 2020 would be interesting!

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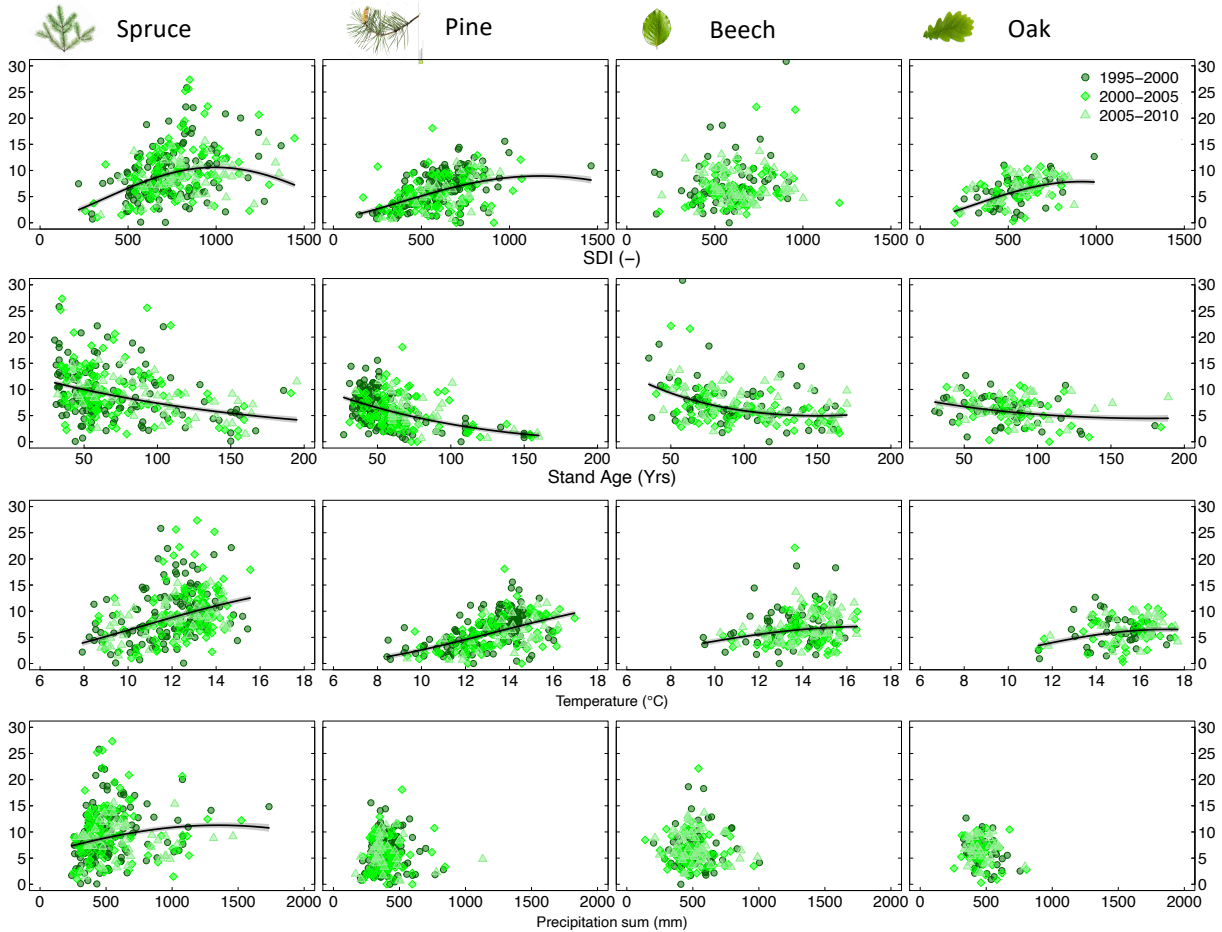
Etzold et al. (2020), *Forest Ecology and Management* 458, 117762

European forest growth (stem increment)

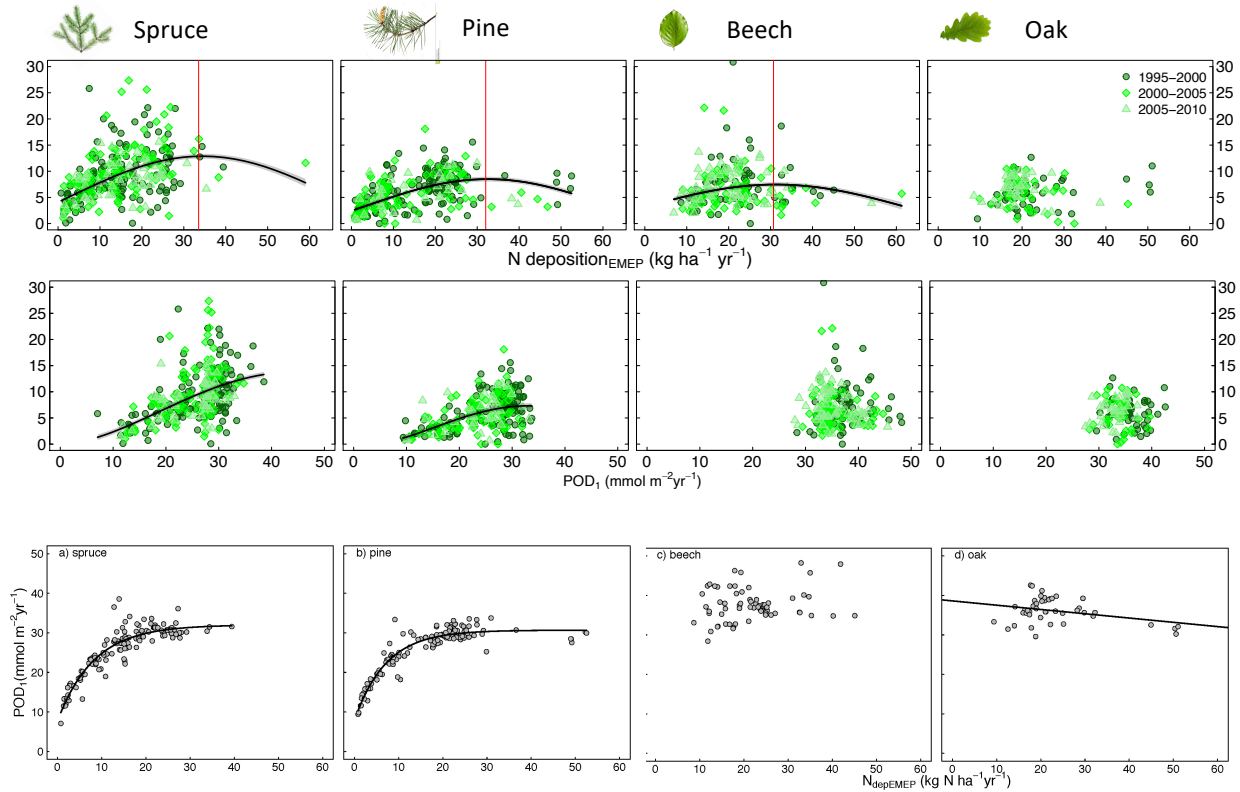


- **Increasing** increment with SDI, **saturation > 1000,** no significance for beech
- **Decreasing** increment with stand age
- **Increasing** increment with temperature
- **Weak relationship** of increment to **precipitation**

European forest growth (stem increment)

N deposition

POD_1



- **Non-linear response** of **increment** to **N_{dep}**
- **Saturation point** at approx. **25 to 30 kg N ha^{-1} yr^{-1}**

- **Positive** relationship of **increment** and **POD_1** in **coniferous forests**

- **Correlation** of **Ndep** and **POD_1**