THÜNEN

LWF Bayerische Landesanstalt für Wald und Forstwirtschaft

NW-FVA Nordwestdeutsche Forstliche Versuchsanstalt

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Mechanisms explaining N stock and acidity dynamics in German forests between 1990 and 2007 - and possible climate change feedbacks

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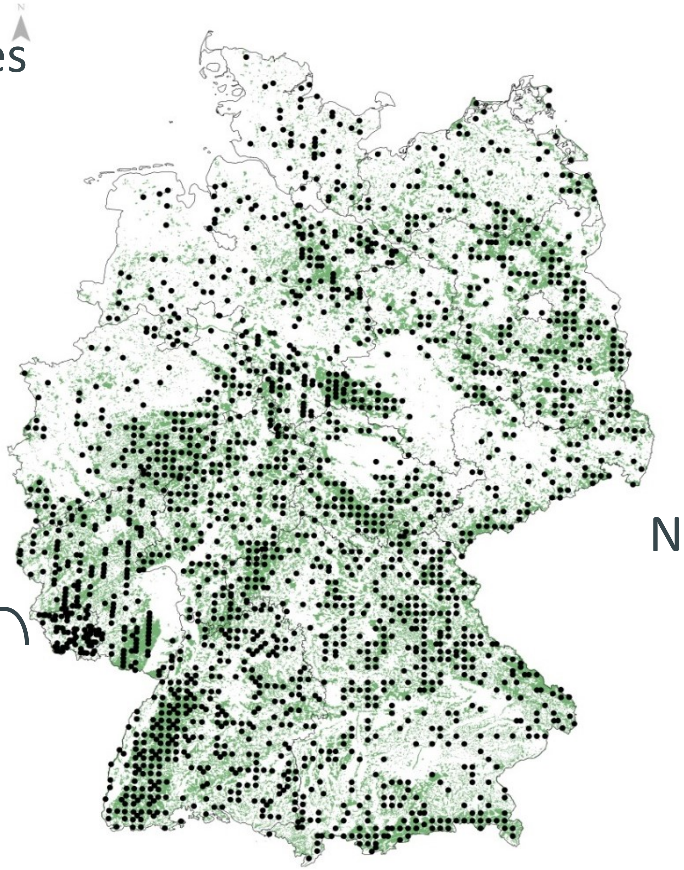
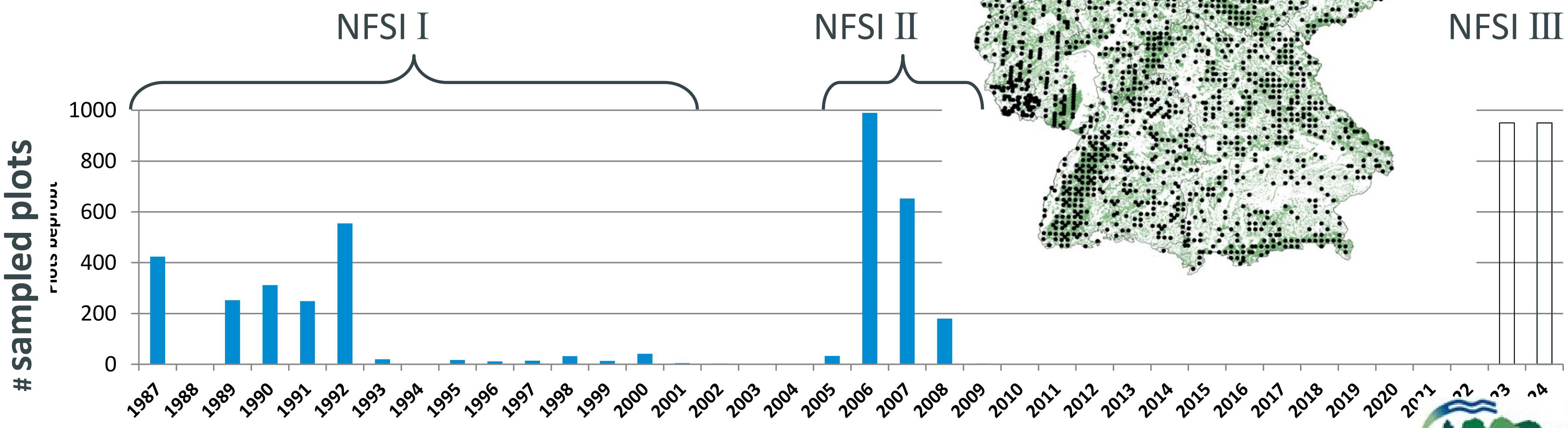
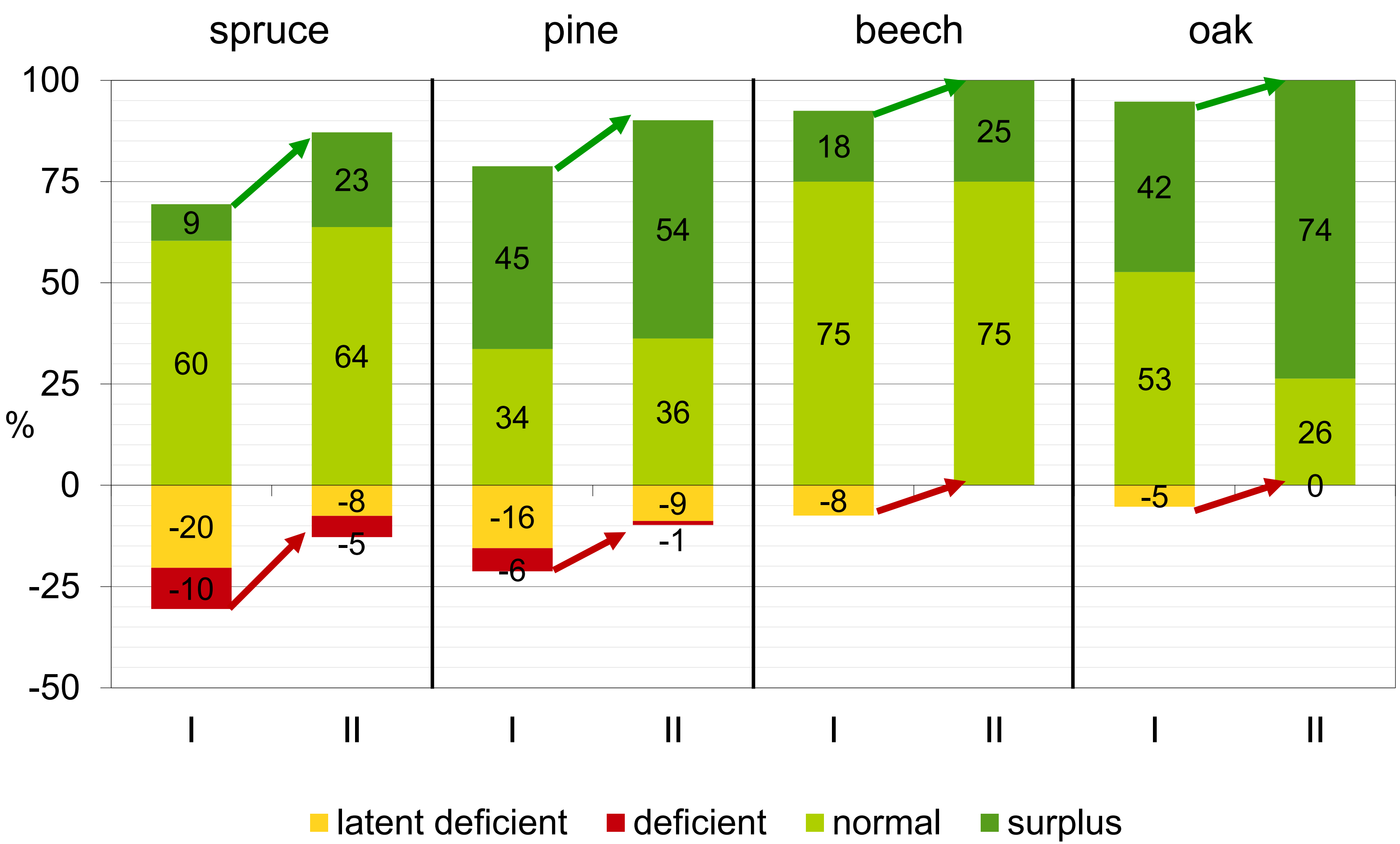
National Forest Soil Inventory in Germany

- Spatially representative sampling of forest soil in Germany (8 x 8km grid)
- Sampling of mineral soil, organic layer, soil solution, and leaves
- Complemented by forest inventory 2012
- About 1800 sampling points in forests
- Repetition: roughly every 15 years





Foliar N content increased between 1990 and 2007



Fleck et al.: Mechanisms explaining N stock and acidity dynamics

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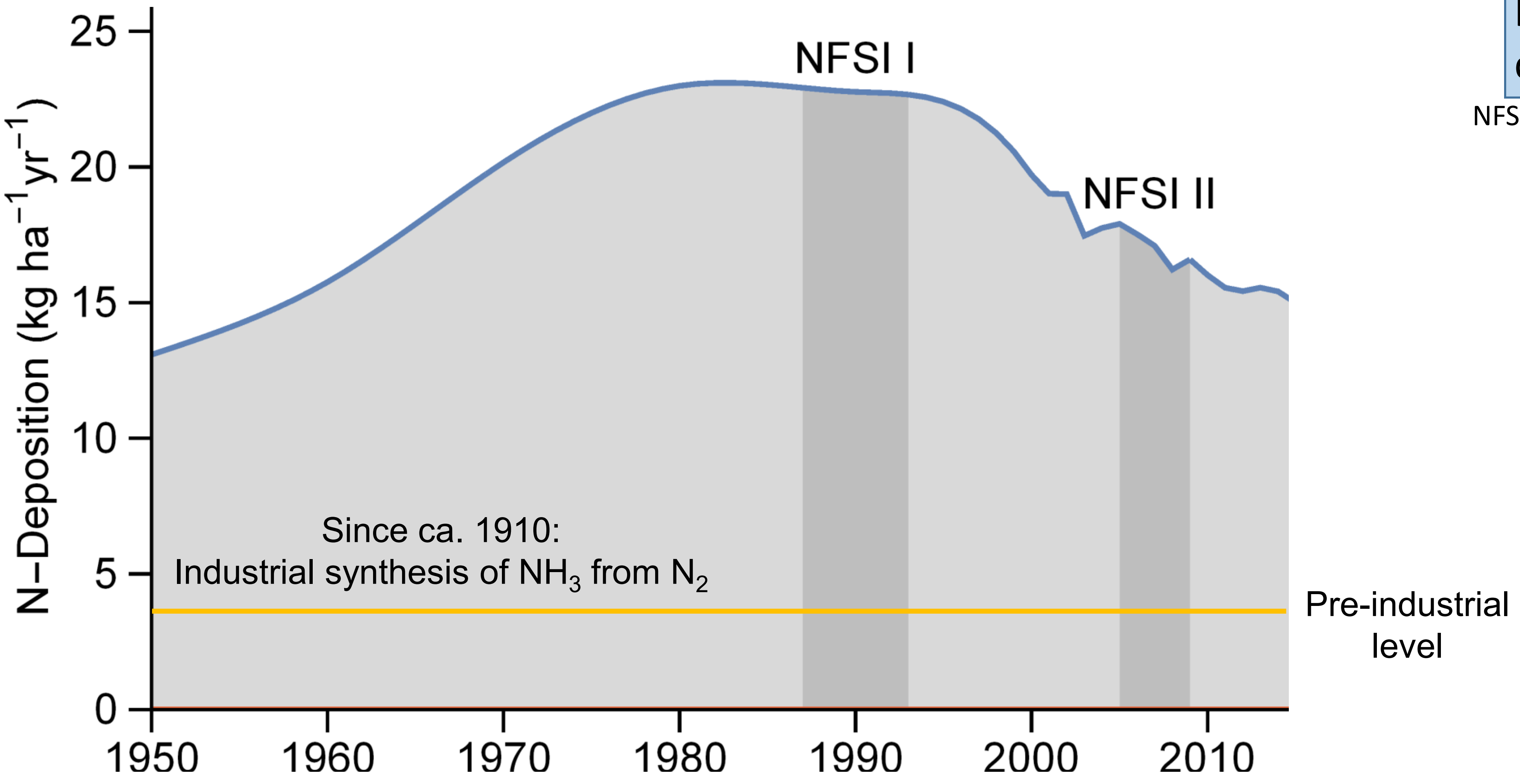
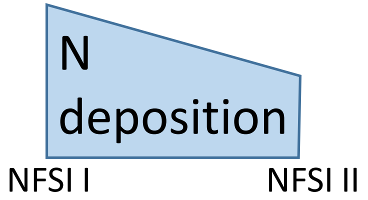
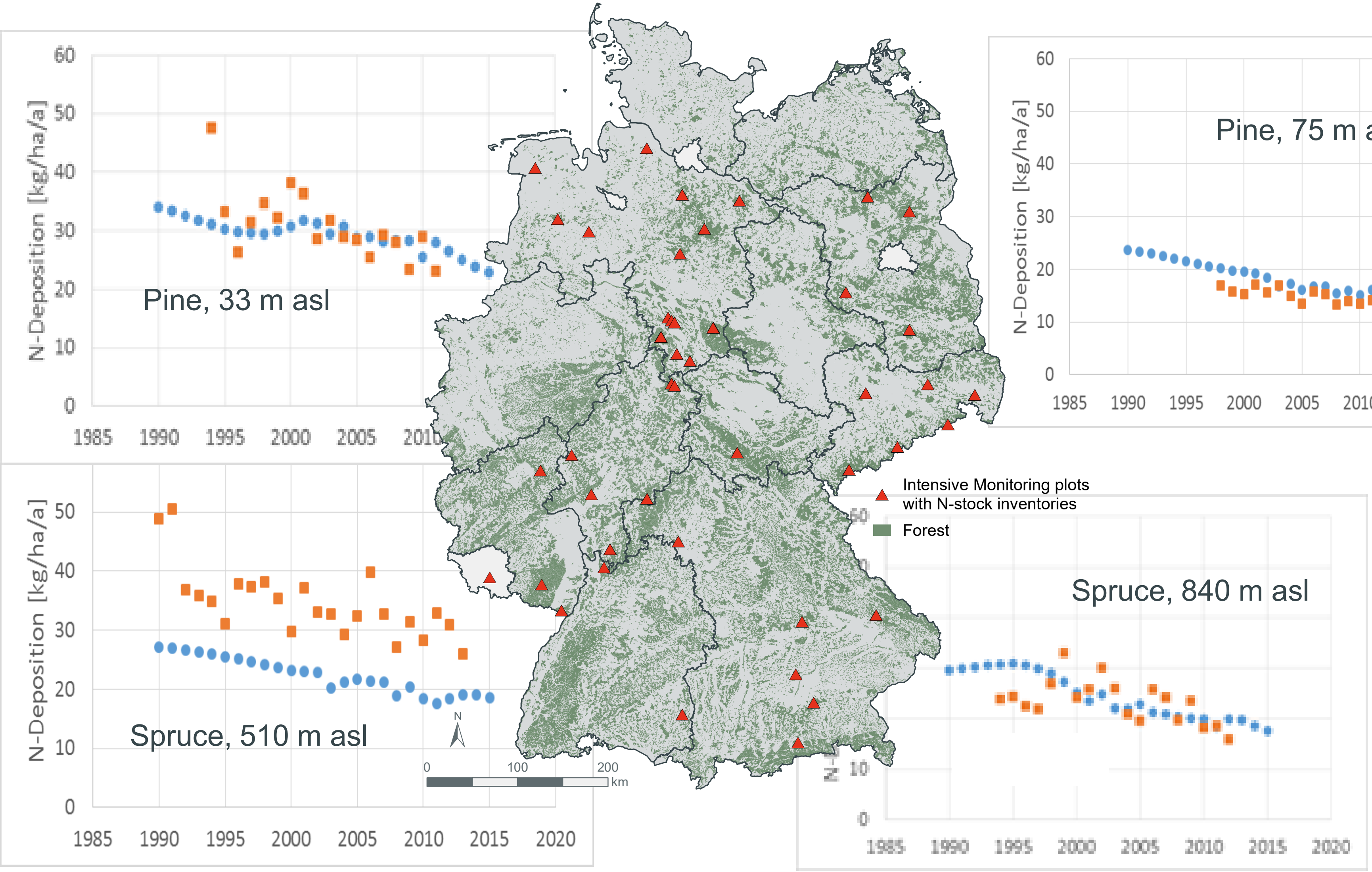
N input from deposition decreased by more than 20%

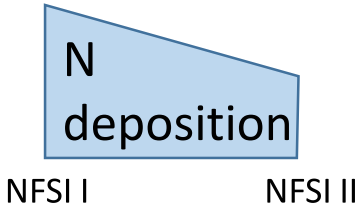




Fleck et al.: Mechanisms explaining N stock and acidity dynamics

Decreasing N-deposition: confirmed by Level II plots





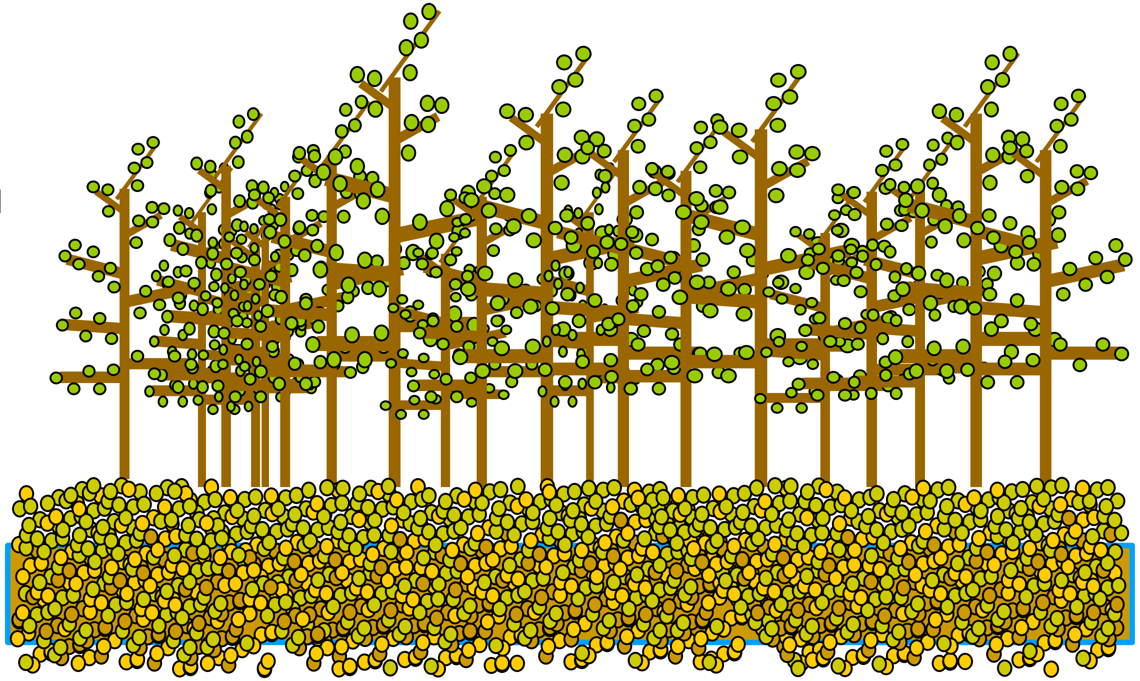
C/N ratio increased inspite of higher foliar N nutrition

Foliar N

NFSI I NFSI II

C/N ratio

22,4 24,0



C/N ratios of **organic layer - 5cm** of the mineral soil increased by

+0,09 yr^{-1}

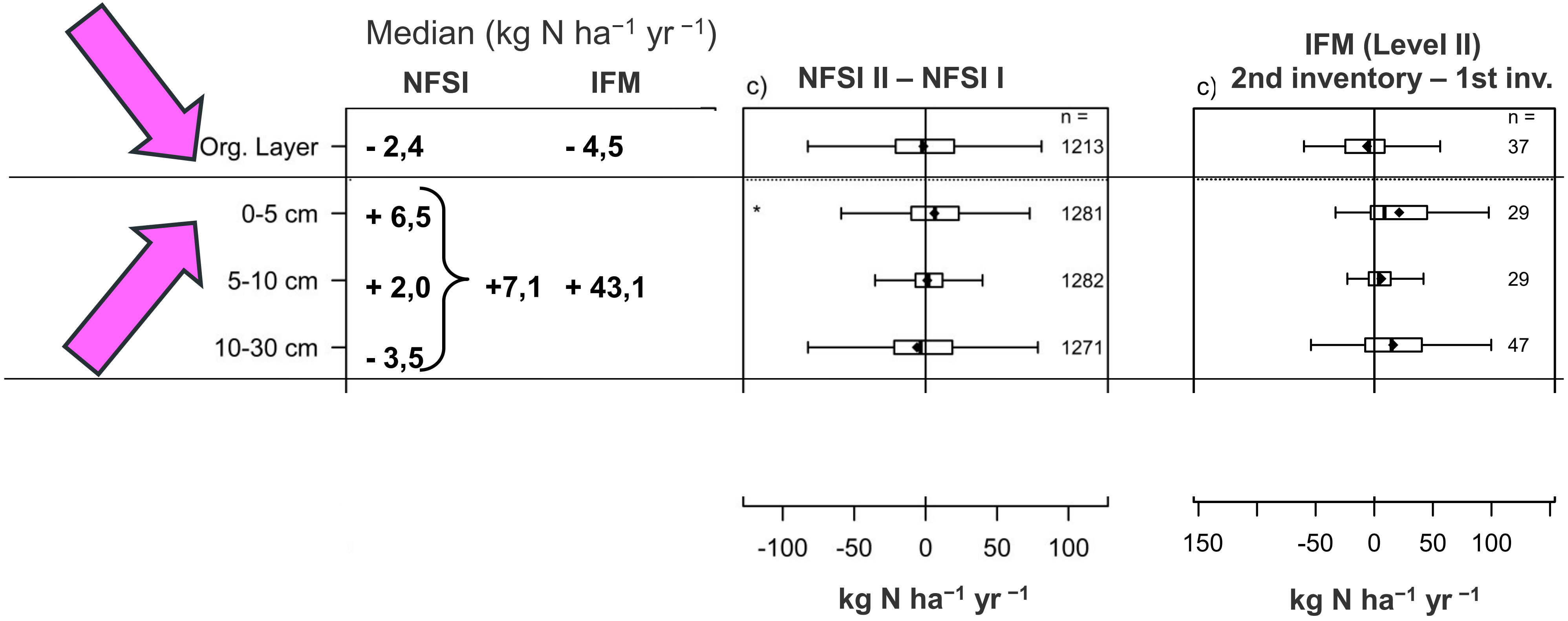
C/N ratio

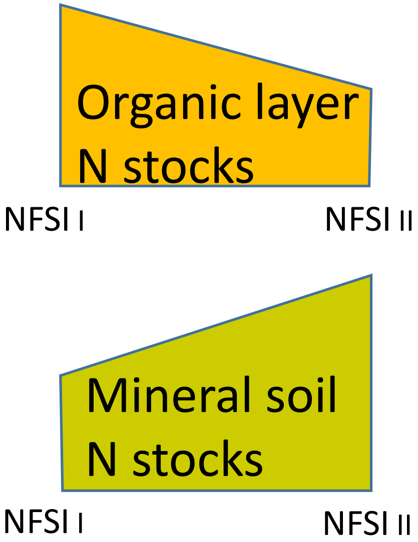
NFSI I NFSI II

Foliar N

NFSI I NFSI II

Soil Layers‘ N stocks: Opposing trends confirmed by IFM plot data

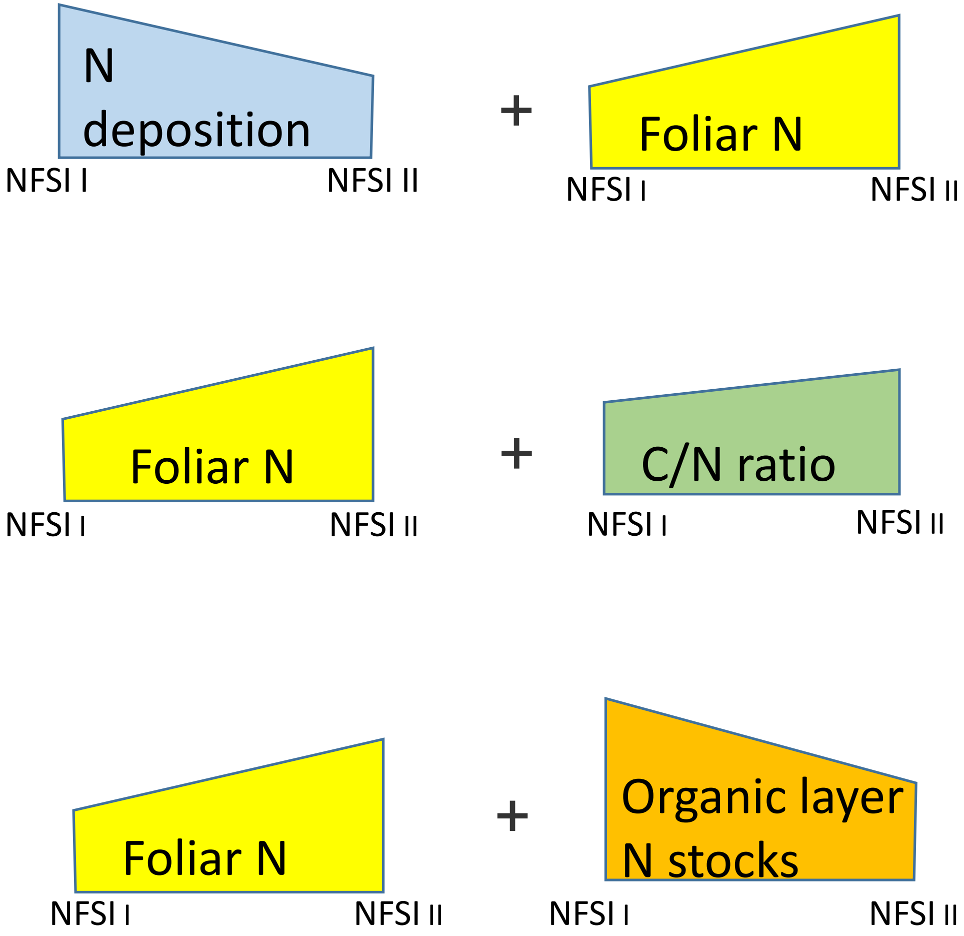




Lowest layers not shown:

Decreasing trends based on very low N concentrations were not confirmed

Apparent contradictions



Q1. Where does additional foliar N come from?

Q2. How can C/N ratios rise, when foliar N increases?

Q3. Why did organic layer N stocks decrease, when foliar N contents increased?

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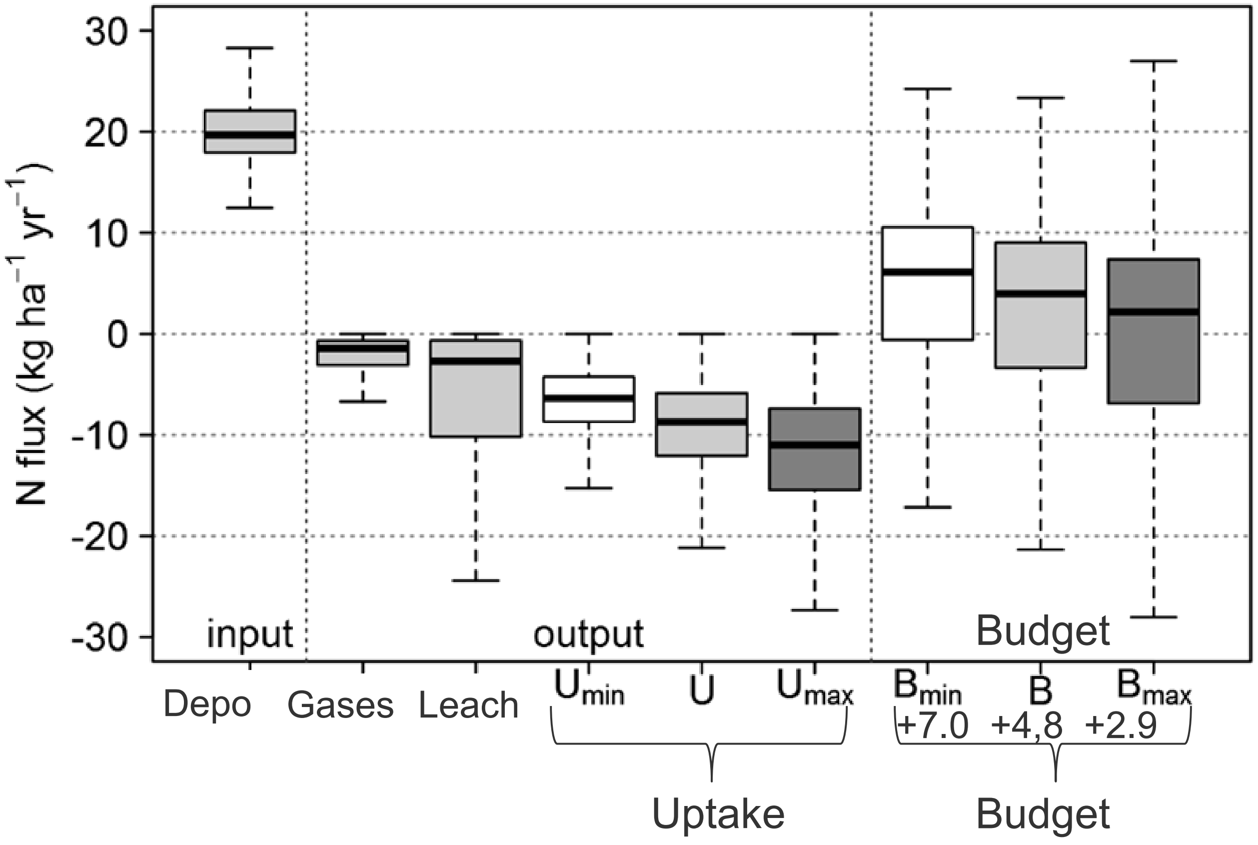
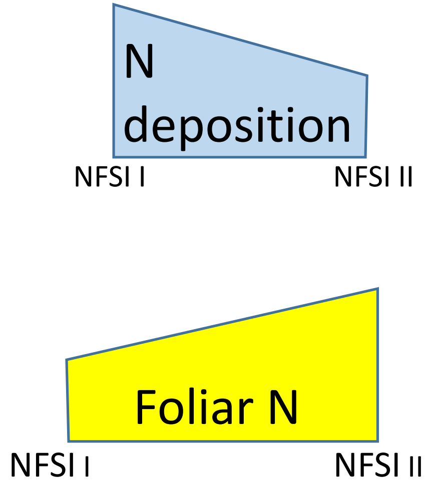
N budget estimation confirms continued N accumulation in the ecosystem





Calculated based on:
NFSI II – 1:2 soil extract data with model Brook90
NFSI plot forest inventory 2012 + NFI3 growth rates

+4,8 kg N ha^{-1} yr^{-1}

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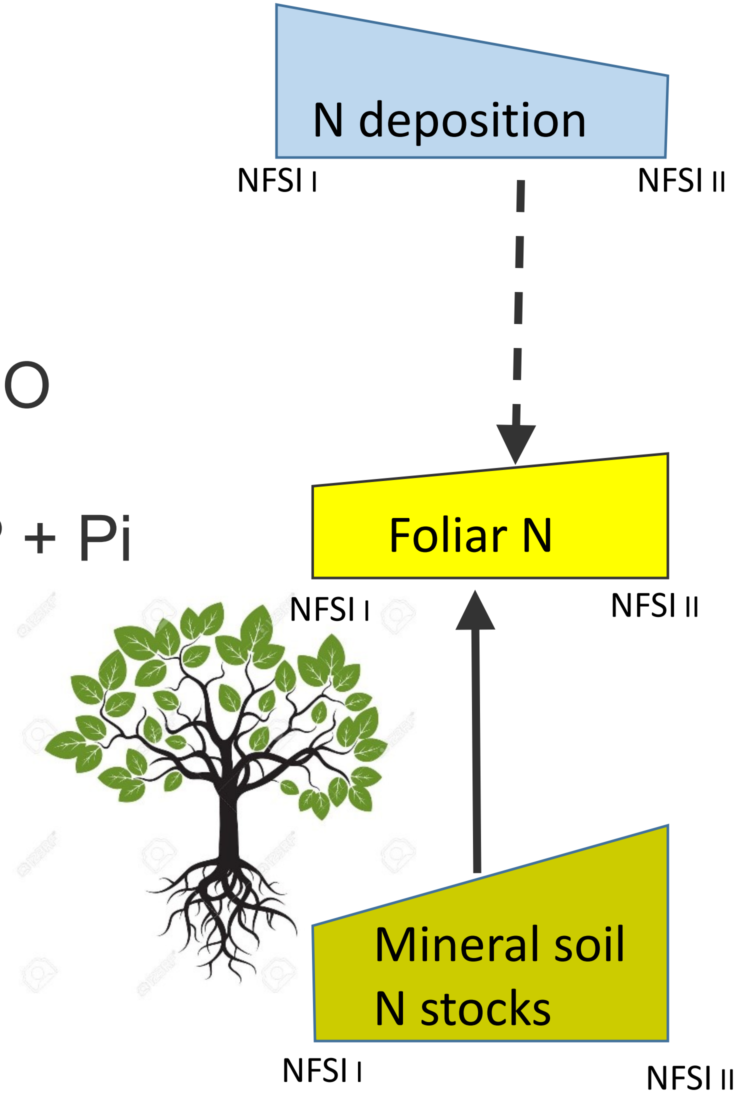
Q1. N uptake by roots determined foliar N nutrition, not deposition

N assimilation

1. step: $NO_3^- + NADH + H^+ \rightarrow NO_2^- + NAD^+ + H_2O$

2. step: $NO_2^- + 6\ Fd_{red} + 8\ H^+ \rightarrow NH_4^+ + 6\ Fd_{ox} + 2\ H_2O$

3. step: $Glutamate + NH_4^+ + ATP \rightarrow Glutamine + ADP + Pi$



N assimilation requires energy-rich compounds that are not easily available at the leaf surface.

N assimilation from occult deposition did apparently not play a dominant role.

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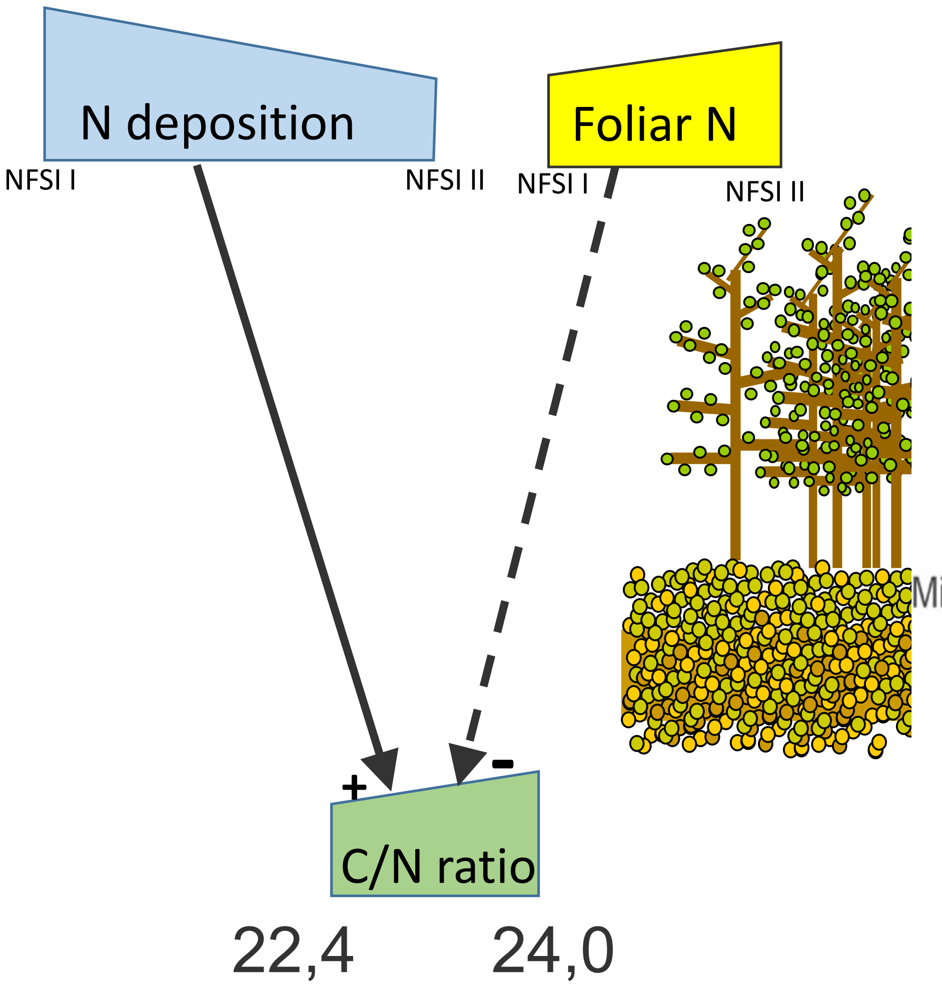
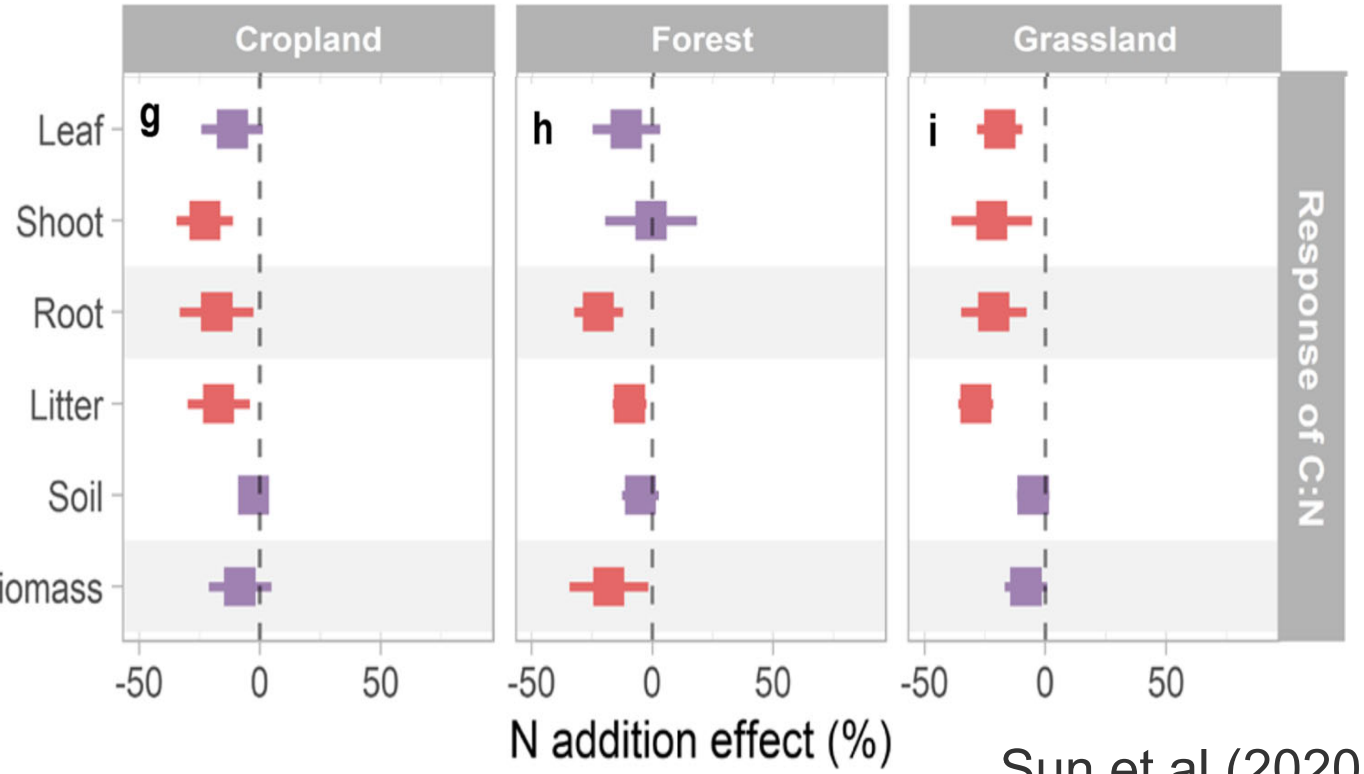
Q2. C/N ratio increased due to decreasing deposition





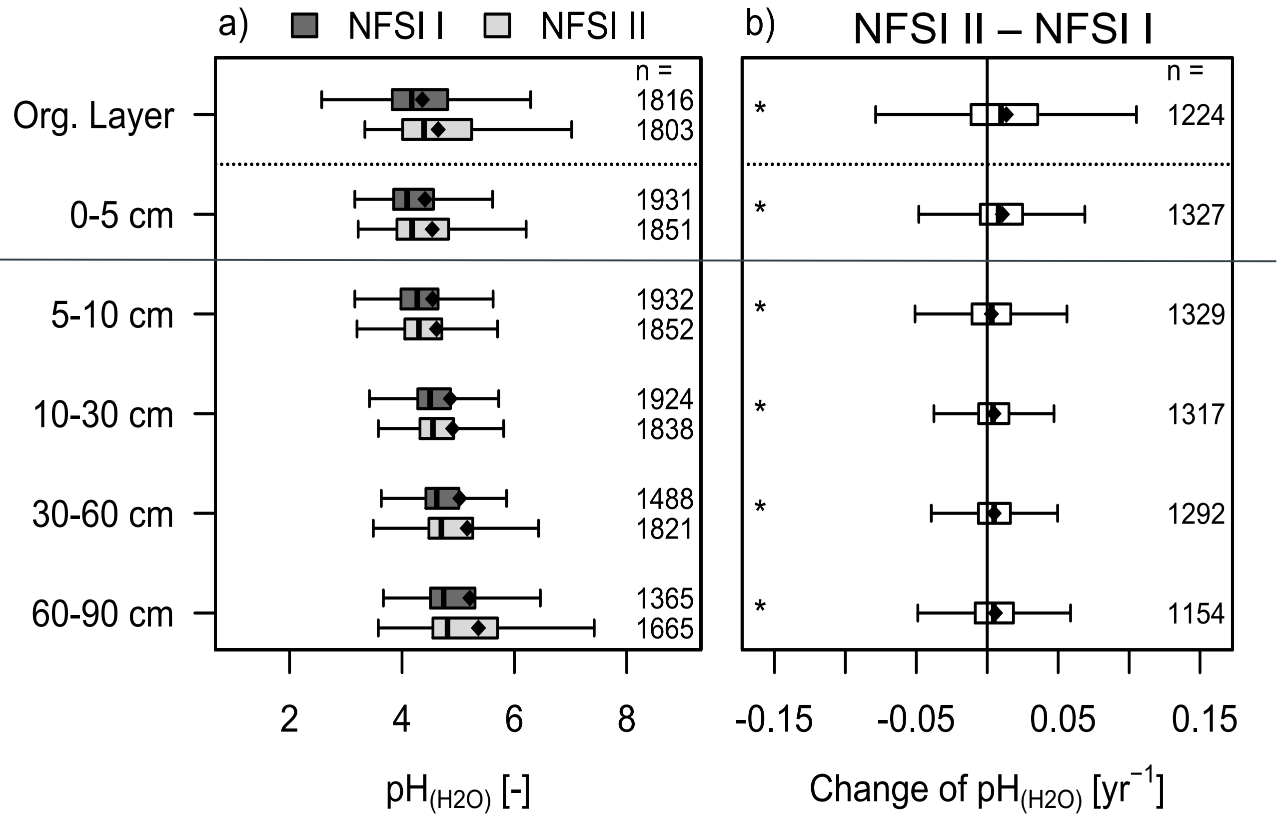
Sun et al (2020)

pH values increased down to 5cm depth

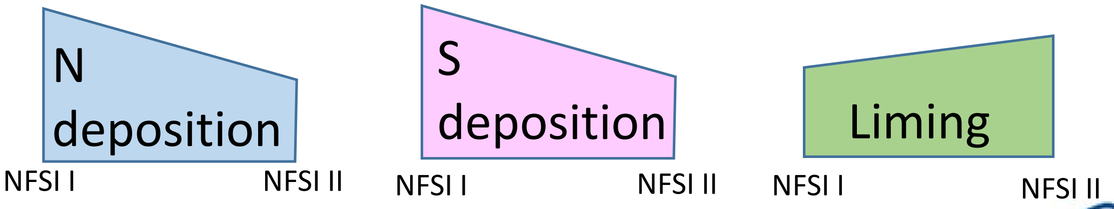
pH:

+0.01yr⁻¹

pH unchanged



Causes for pH-increase in uppermost soil compartments



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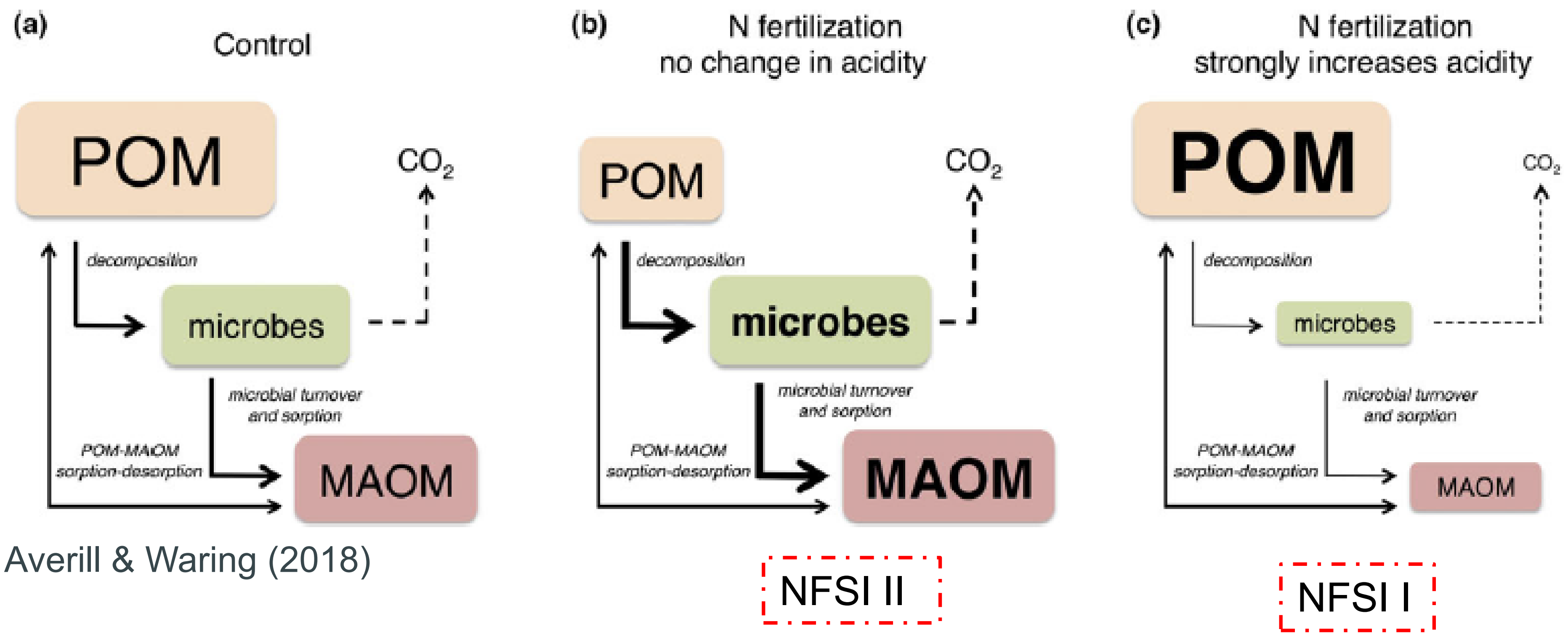
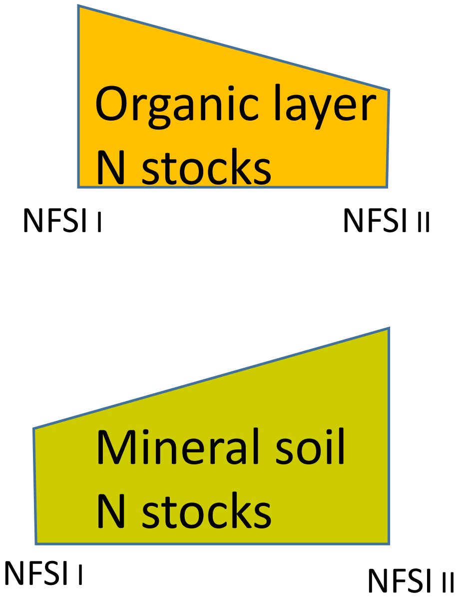
Reduced acidity in upper soil compartments increases microbial decomposition



Averill & Waring (2018)

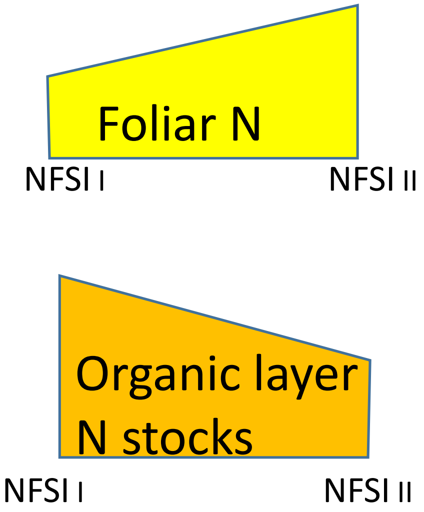


Particulate **O**rganic **M**atter : Leaf litter, Fineroot litter

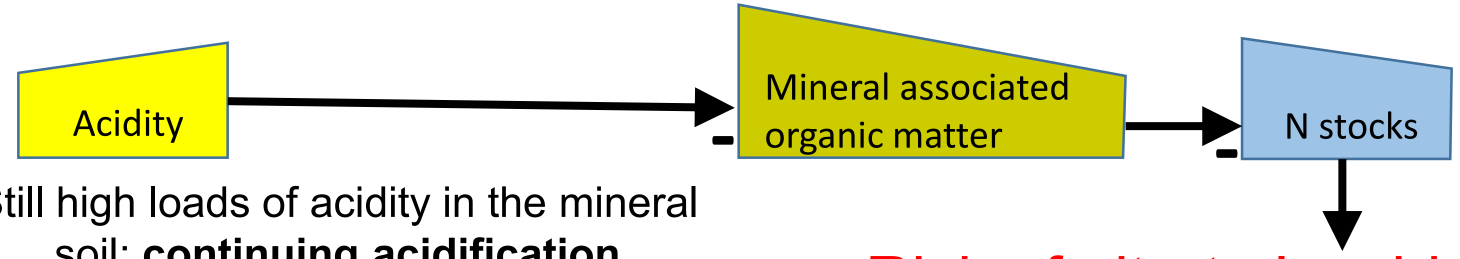
Mineral-**A**ssociated **O**rganic **M**atter : Microbial Necromass, Exudates, Clay-Humus-Complexes

Q3: Liming on acid-sensitive plots confirms shift to deeper layers

	Limed	Unlimed	
Organic Layer	↘ - 7,8	- 0,7	kg N ha^{-1} a^{-1}
Upper Mineral Soil (0 – 30cm)	↗ + 11,8	↘ - 11,6	kg N ha^{-1} a^{-1}



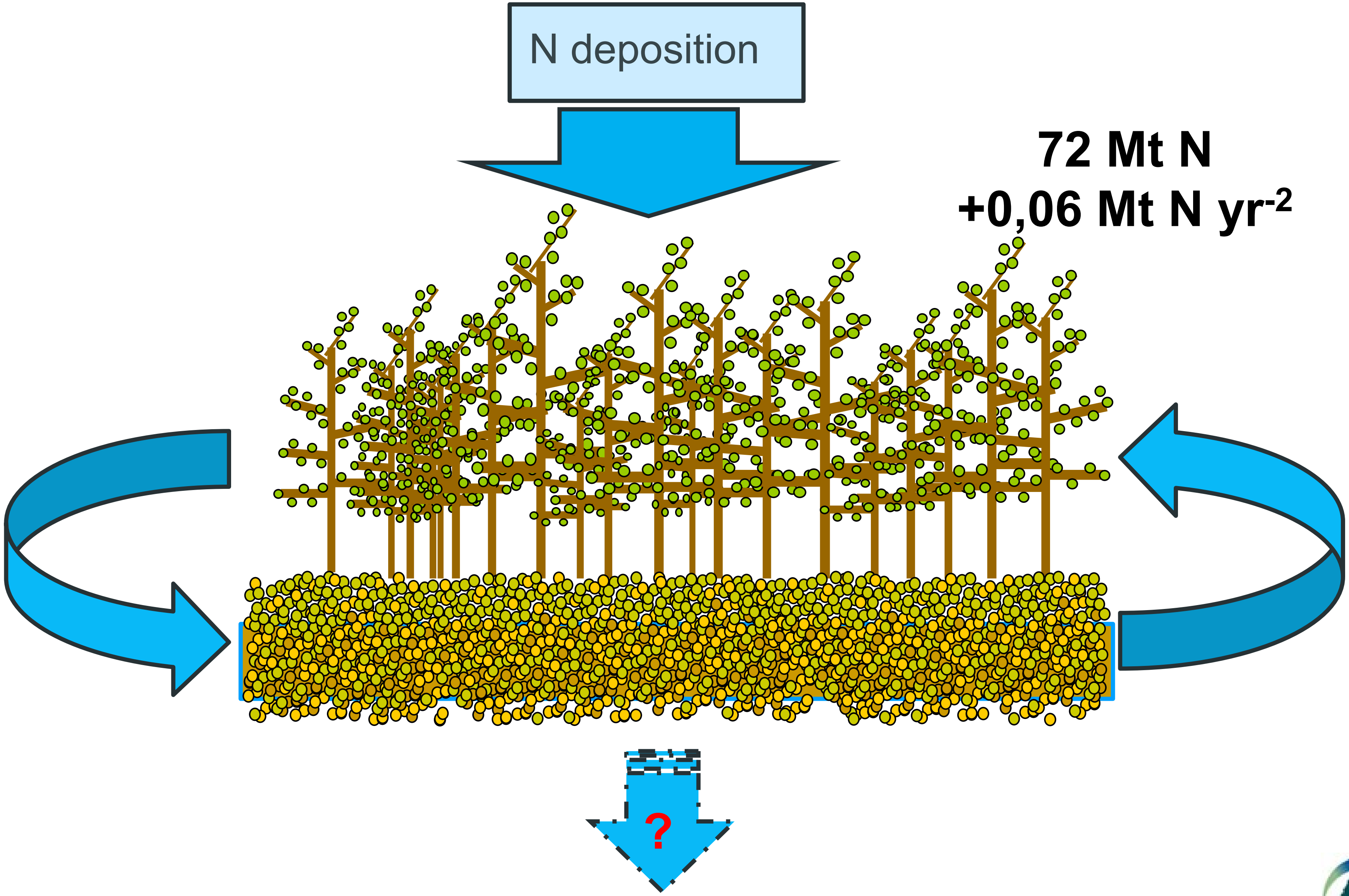
Deeper Mineral Soil on acid sensitive plots



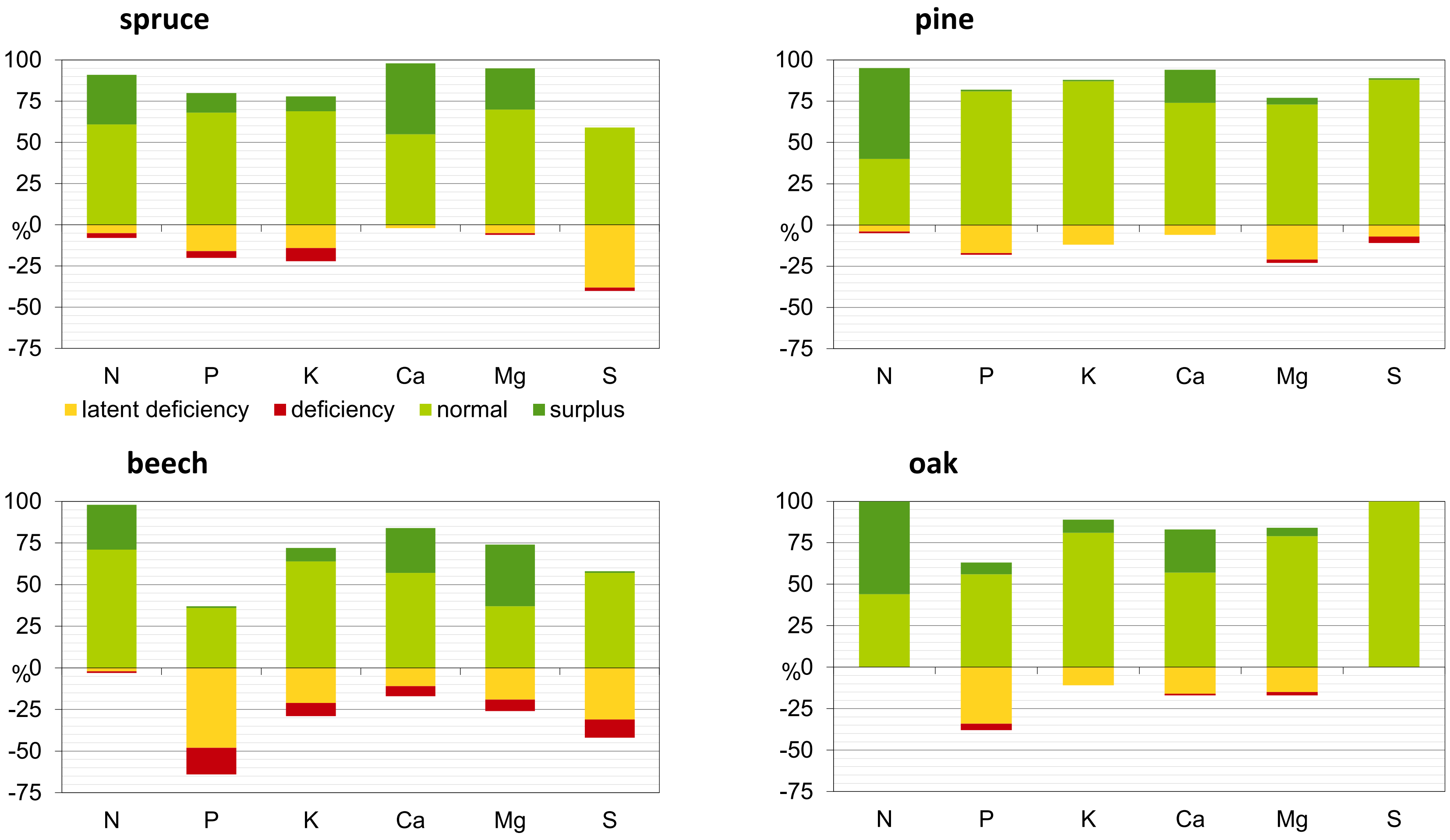
Still high loads of acidity in the mineral soil: **continuing acidification**

Risk of nitrate leaching

Forest ecosystem functioning: N recycling may still be afforded



Forest ecosystem functioning: Nutrient imbalances aggravated



Continued N accumulation

↓

Increased growth
(Etzold et al. 2020)

↓

Deficiency of other elements

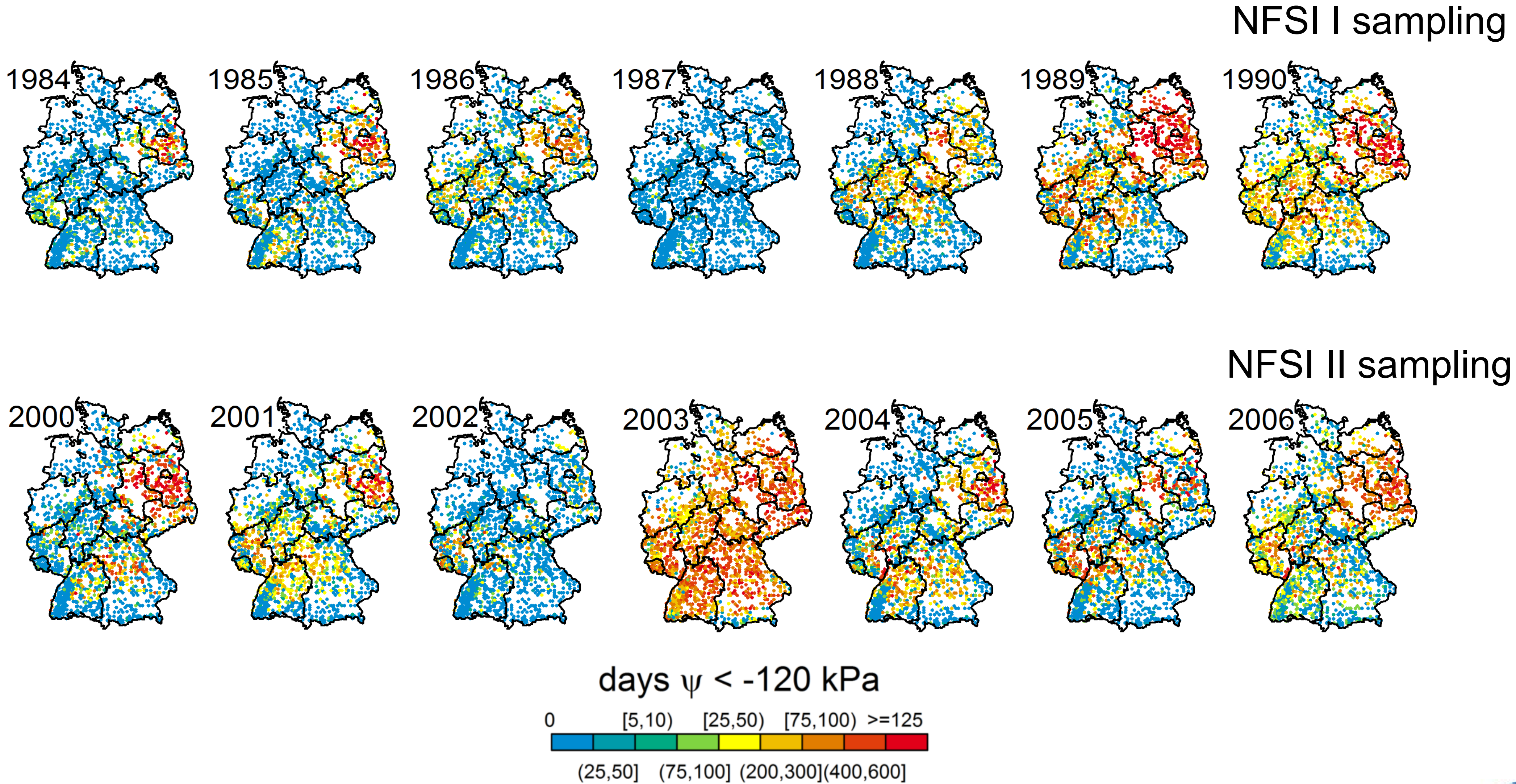
↓

Nutrient imbalances,
higher water requirements

↓

Stress

Climate change challenges drought sensitive forest ecosystems



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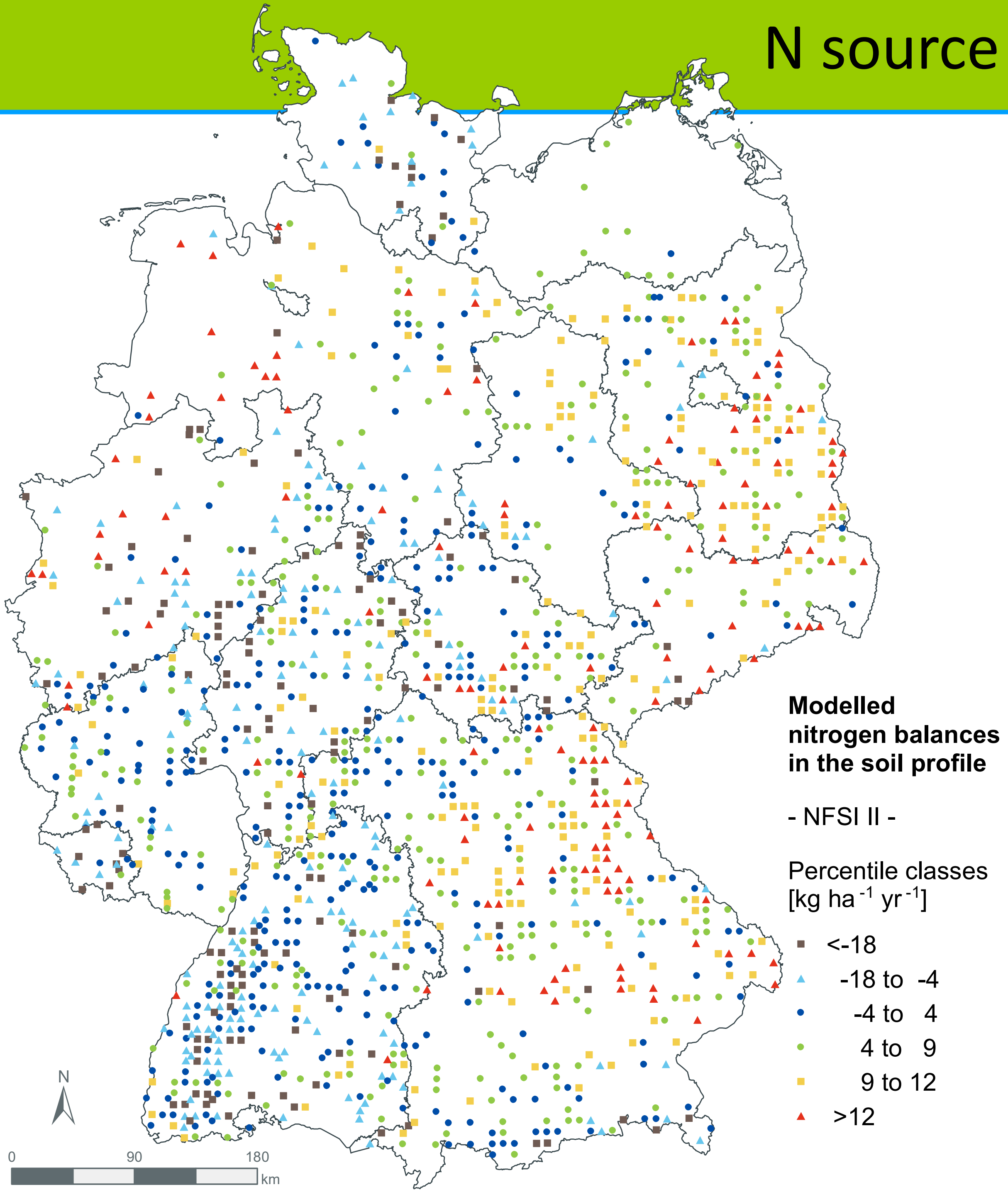
N source and sink status of forests in Germany



1/3 of the forest soils are N sources (negative N balance)

N losses mostly from acid-sensitive plots without liming

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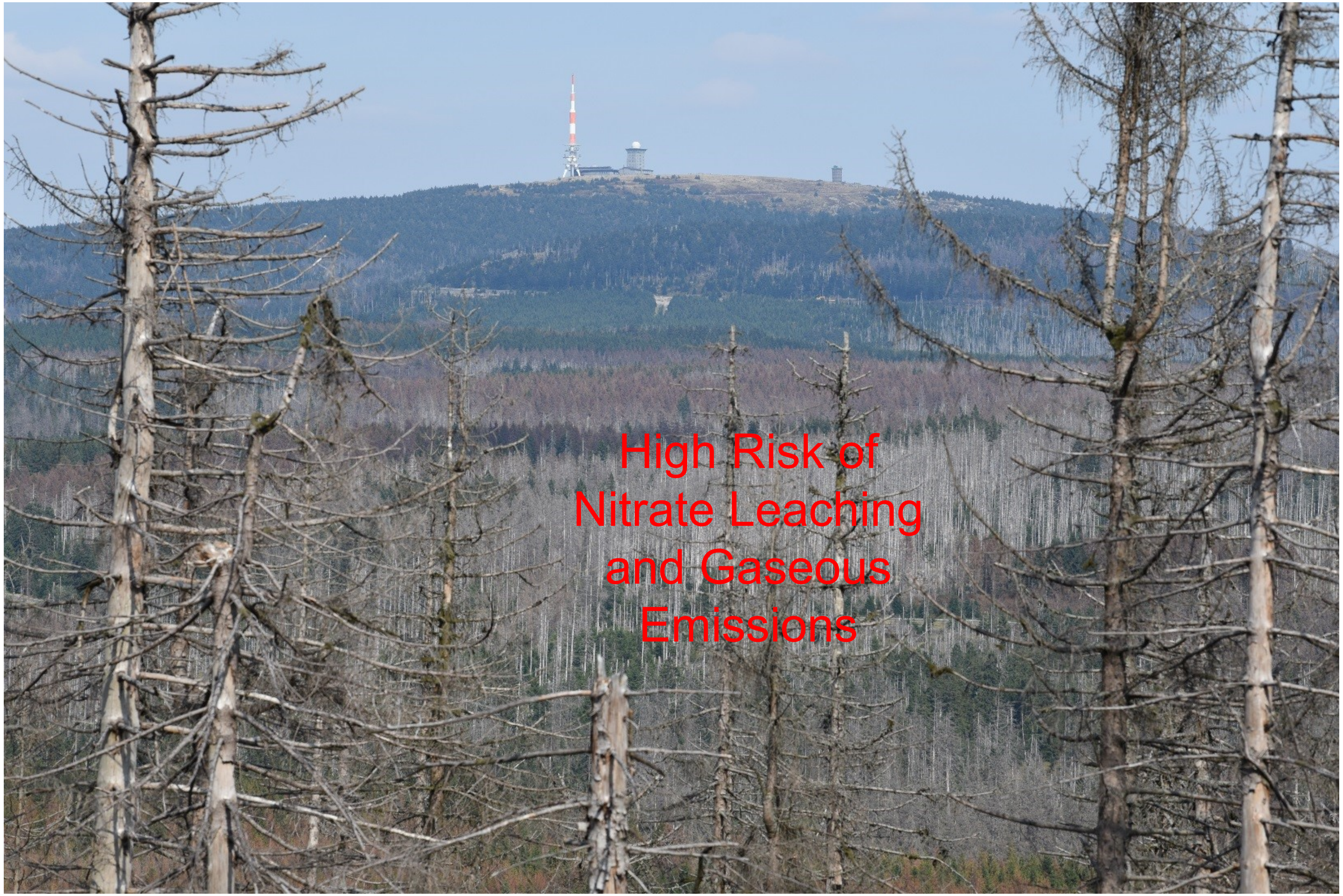
Forest soil N storage is put at risk through continued high N deposition



Spruce stands in the Harz mountains, September 2019

Photo: Jan Evers

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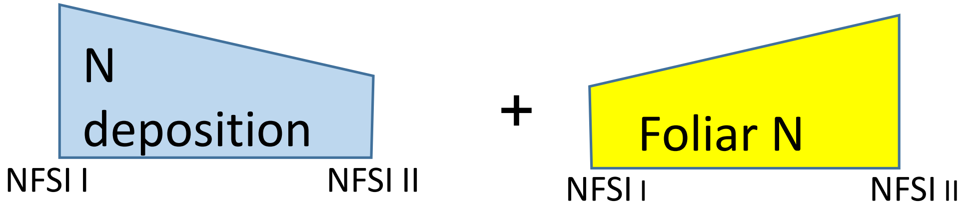
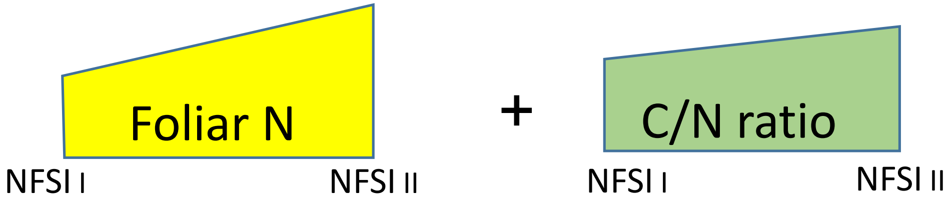
Conclusions I



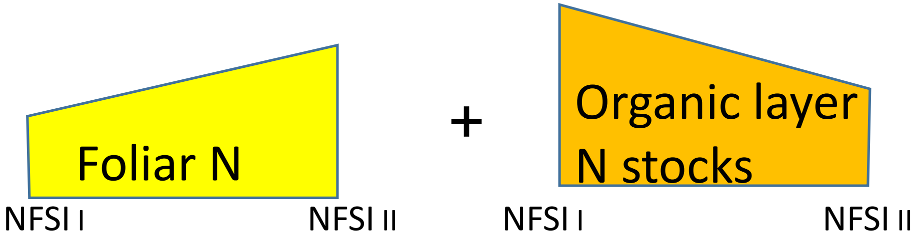
Q1. Where does additional foliar N come from?

- Direct N uptake from deposition did not play a dominant role, root uptake increased due to higher N concentrations in mineral soil.



Q2. How can C/N ratios rise, when foliar N increases?

- Decreasing N deposition was mainly responsible for increasing C/N ratios and contributed to reduced acidity in the organic layer.



Q3. Why did organic layer N stocks decrease, when foliar N contents increased?

- Reduced acidity in the organic layer accelerated microbial decomposition, leading to a shift of N to deeper layers

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Conclusions II

High atmospheric N deposition leads to…

- Growth stimulation
- Higher nutrient and water requirements
- Nutritional imbalances involving N:Mg, N:K, N:Ca or N:P ratios
- Reduced stability of forests e.g. in drought periods
- Reduction of N deposition is yet visible in the forest ecosystems (C/N ratio, acidity)
- But N stored in forest soils is still increasing under current deposition rates (72Mt + 60 kt/yr)
- Still high N deposition puts forests, their N storage, and their nutrient recycling function at risk under conditions of more frequent drought periods
- **Reduction of N deposition needs to be continued to reduce further N accumulation and to reduce water and nutrient stress.**