

Changes in leaf nitrogen and phosphorus content from observations and a land surface model: evidence for increasing nutrient imbalance in Europe

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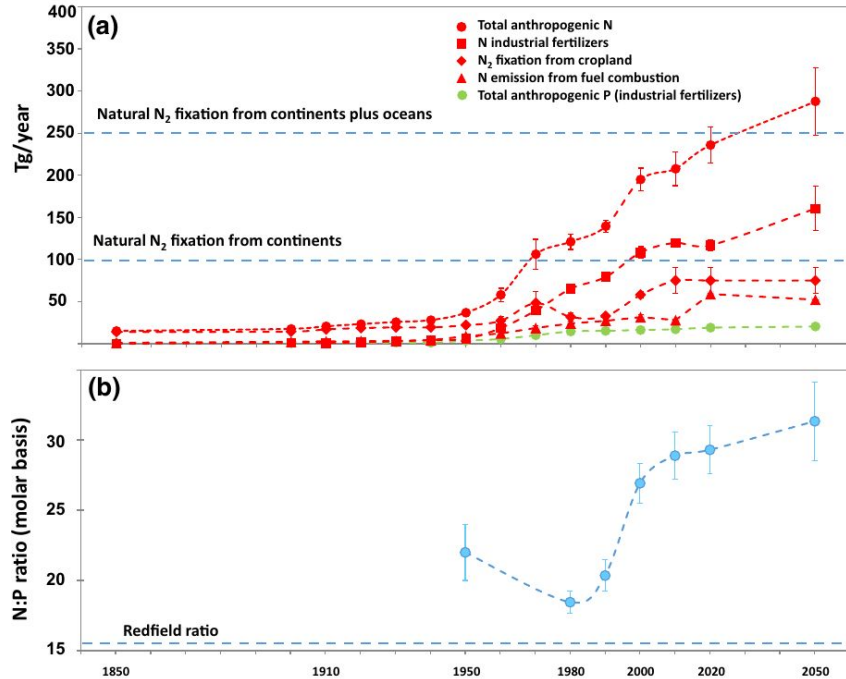
Why do we expect changes in leaf nutrient content?

Increased
atmospheric CO₂
can lead to
increased plant
growth

But higher plant
growth means more
nutrient demand
which can lead to
nutrient limitation

Plants often
decrease their
tissue nutrient
content in response
to nutrient
limitation

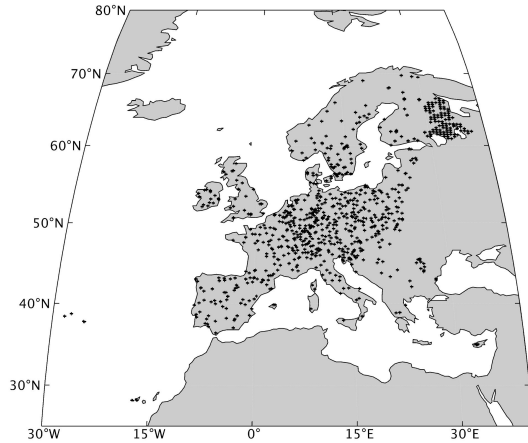
Why do we expect a nutrient imbalance?



Increased N input to ecosystems through anthropogenic atmospheric deposition

But no P input of the same magnitude. This means that systems previously N limited can move towards a P limitation

The ICP Forests network provides leaf nutrient content data across Europe for over two decades

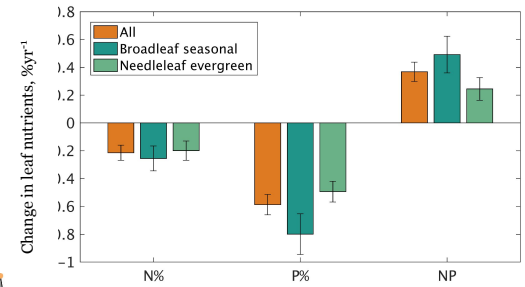
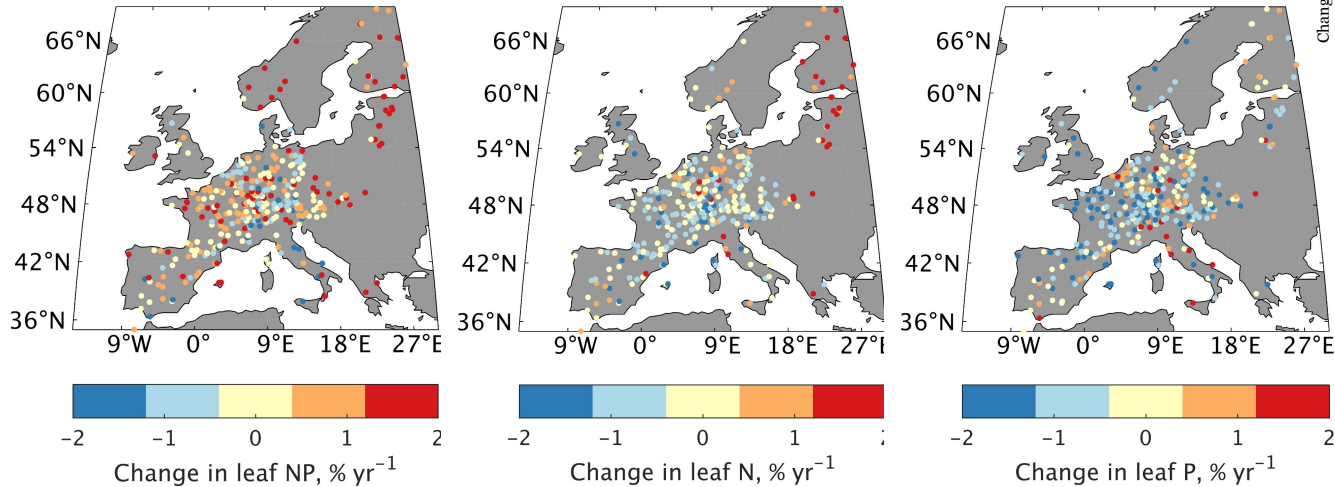


Geographic distribution
of sites.
Data available from
1990-2014.

Network of sites with repeated,
standardised measurements.

The ideal tool for exploring changes
in leaf nutrient content over time.

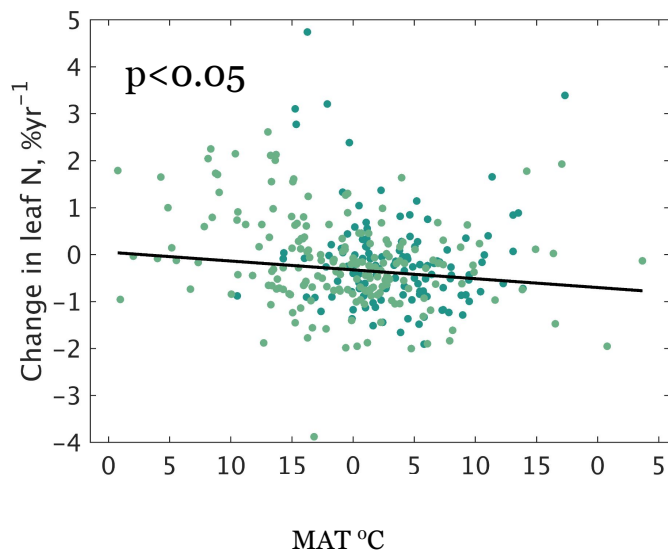
A first look at the data



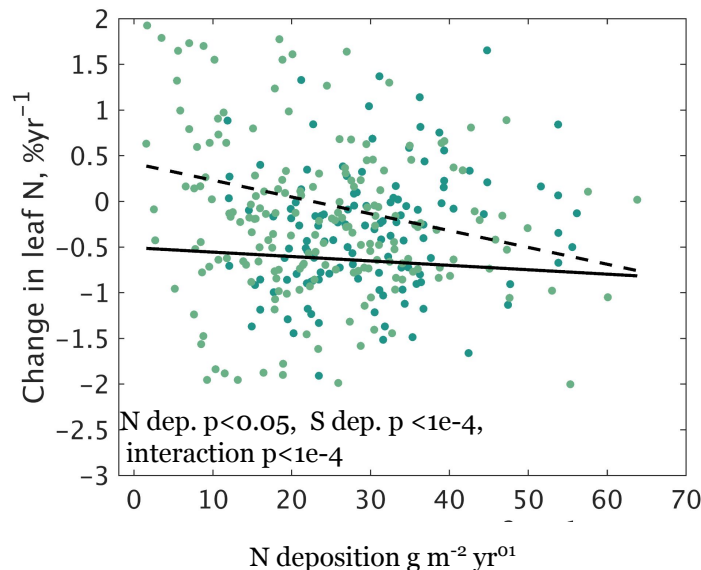
Overall, we observe a decrease in leaf nutrient content and an increase in leaf N:P ratio but a large spatial variation.

So far so good
but what drives
the spatial
variation?

Change in leaf N driven by climate, N and S deposition



Increase in leaf N in colder regions, potentially driven by changes in soil N availability with warming.



Trends 1990-2014
Results from linear mixed effects model

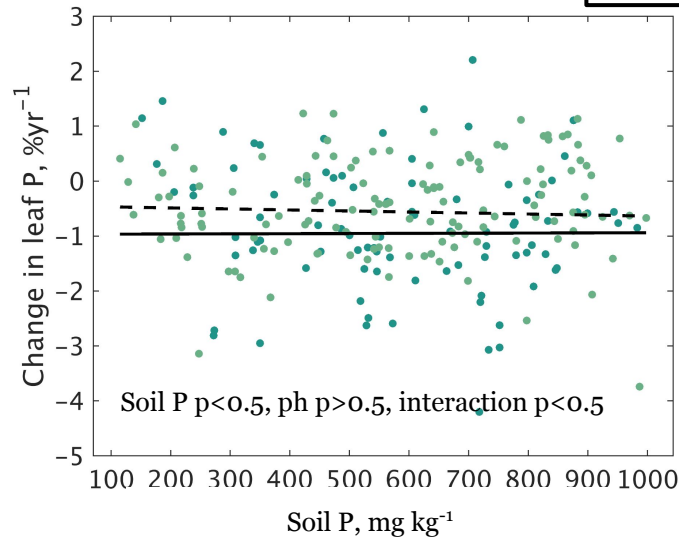
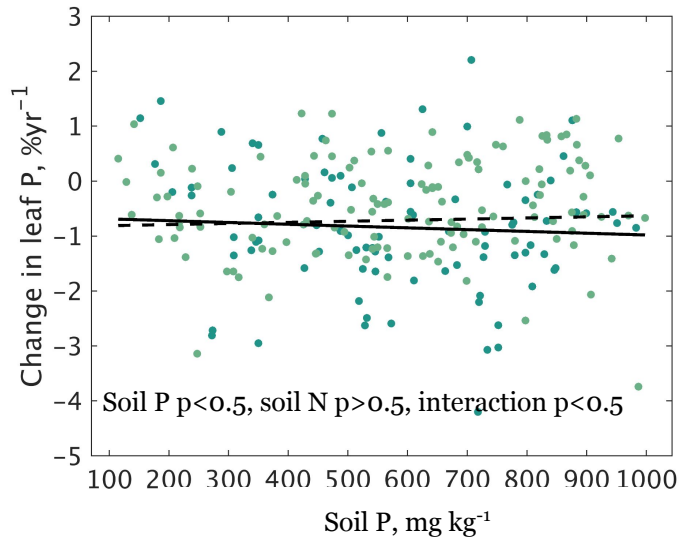
Interaction between nitrogen and sulphur deposition. Higher levels of N deposition associated with S deposition are detrimental due to changes in soil acidity and canopy leaching.

Change in leaf P driven by nutrient availability

— Low soil N
- - - High soil N

Broadleaf seasonal
Needleleaf deciduous

— Low soil ph
- - - High soil ph

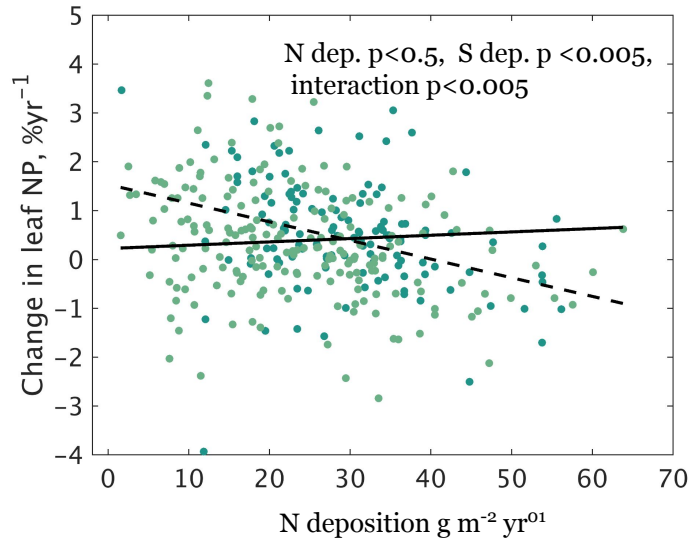


Trends 1990-2014

Results from
linear mixed
effects model

Interactions between soil N and P availability and ph loosely
drives changes in leaf P content.

Change in leaf NP ratio follows drivers of leaf N changes



At low s deposition levels, leaf NP ratio increase with higher N input from deposition, as expected from theory. But higher S deposition leads to the opposite trend.

However, levels of anthropogenic S deposition have decreased more than N deposition inputs, which means that this pattern might be relevant for historical trends only.

Broadleaf seasonal
Needleleaf deciduous

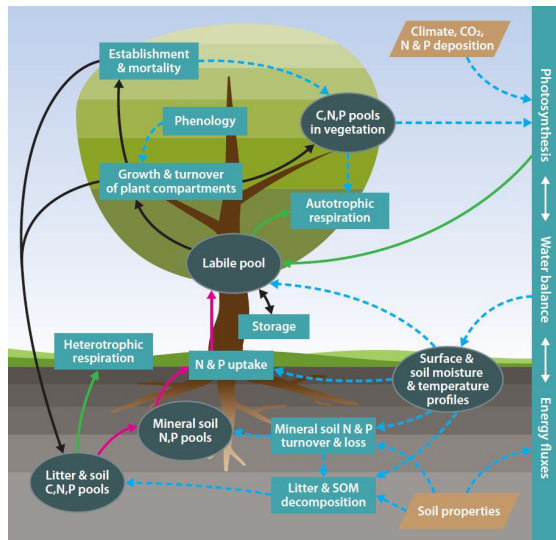
— Low S deposition
- - - High S deposition

Trends 1990-2014

Results from linear mixed effects model

This looks complicated,
is there anything we can
do to understand the
processes better?

What drives the
decrease in leaf
nutrients over time -
warming or elevated
CO₂?

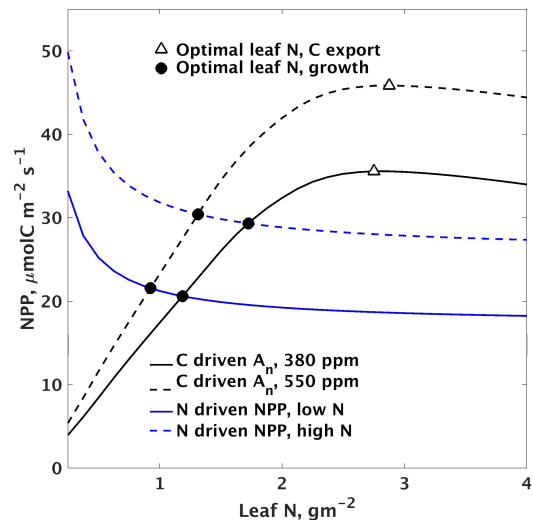


The QUINCY land surface model ([Thum et. al, 2019](#))

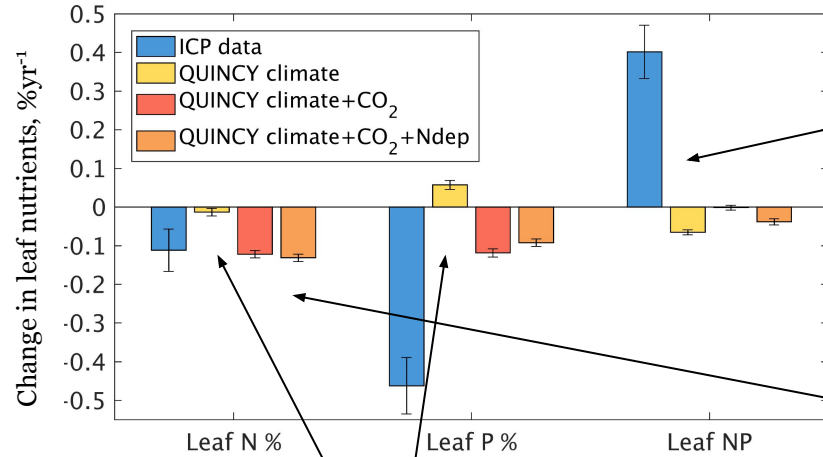
Using a nutrient-enabled land surface model allows us to test hypotheses and to investigate processes that are not easily measured

Dynamic leaf N based on optimality principles ([Caldararu et. al, 2020](#))

Dynamic P based on empirical function of P availability.



Preliminary QUINCY simulations



Underestimation of leaf P decrease and lack of change in leaf NP points to need for better representation of P processes, even though QUINCY includes a state-of-the art representation of ecosystem P.

Small effect of N deposition on change in leaf N, also shown by the shallow slope in the [observed relationship](#)

The model captures the decrease in leaf nutrient content and shows a smaller decrease in leaf N and increase in leaf P for simulations with transient climate but fixed CO₂. This indicates that decreases in leaf nutrients can be attributed to elevated CO₂.

Summary



- Leaf nutrient content across Europe decreases on average and the leaf NP ratio increases as expected from theory but there is a lot of spatial variability
- Changes over time in leaf N are driven by climate and atmospheric deposition, while changes in leaf P are driven by nutrient availability
- CHanges in leaf NP are driven by interactions between N and S deposition inputs, with high levels of deposition leading to a decrease in leaf N comparative to P potentially because of acidification effects
- A land surface model can help us investigate driving processes but an improvement of P plant process representation is needed.



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