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BRIEF #4
2020

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Increased evidence of nutrient imbalances in forest trees across Europe

KEY MESSAGES

1. Nitrogen deposition affects phosphorus availability in European forests.
2. An imbalance in the ratio of foliar nitrogen to foliar phosphorus helps identify the effect of air pollution on forest trees.
3. Tree nutrition is outside the optimal range on 30% of intensive forest monitoring sites across Europe.
4. Nutrient imbalances can affect the resilience of the European forests to a changing climate.

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Tree mineral nutrition responds to environmental change

When studying forest responses to climate change it is important to consider tree nutrition. Enhanced atmospheric deposition of nitrogen, atmospheric carbon dioxide enrichment, and higher temperatures and longer growing seasons have stimulated tree growth in many parts of Europe. Increased tree growth can lead to increased nutrient demand. In forests where soils offer limited nutrient supply and where nutrients are removed from forest ecosystems through tree harvesting, tree mineral nutrition can deteriorate.

Nutrient levels in tree foliage reflect atmospheric and soil-related influences and are an important component of the ICP Forests monitoring scheme under the UNECE Air Convention. Foliar nutrient analyses have been undertaken at least once on 1061 Level II intensive forest monitoring sites in 31 countries since the 1990s. These data allow detailed analyses of interactions between nutrients, the detection of trends over time, and the study of tree responses to environmental change.

Image: D. Tolokonov, Unsplash.com

Why do N:P imbalances matter?

Nitrogen (N) and phosphorus (P) are the nutrients most limiting for tree growth in non-polluted environments. Over recent decades, however, high N deposition (originating mainly from combustion processes and agricultural activities) has gradually increased available N in European forest ecosystems and, combined with low P availability in most soils (supplied only through weathering of rocks and minerals), has resulted in many forests shifting from N limitation to P limitation.

High N deposition affects P availability and uptake through acidification of forest soils and the reduction of root biomass, mycorrhizal fungi and microbial activity. Although N deposition recently started to decrease, it remains at a very high level at many ICP Forests monitoring plots.

Assessing N:P imbalances in forest trees

Element concentrations in leaves and needles are a commonly used diagnostic tool for assessing nutrient availability, because foliar concentrations reflect element uptake by trees. Within ICP Forests, nutrient concentrations are measured at least every two years in leaves and needles collected from the upper crown. These measurements are then evaluated by comparing them to empirical reference values or by calculating nutrient ratios. This study uses the commonly applied reference values established by Mellert and Göttlein (2012). Ratios above the critical limits for adequate to optimal nutrition indicate P limitation or N excess, whereas values below the critical limits indicate N limitation.

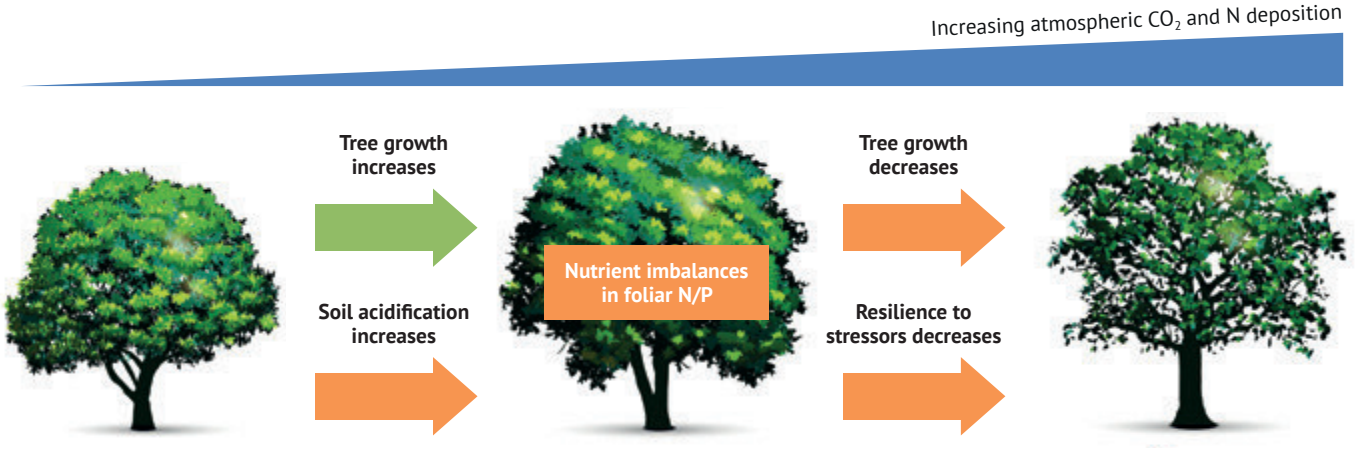
Results for five main tree species are shown, three broadleaf species: European beech (*Fagus sylvatica*) and temperate oaks (*Quercus robur* + *Quercus petraea*) and two coniferous species: Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) – from 469 sites in 26 countries across Europe.

◀ Collecting foliar samples from the top of a spruce tree.

Image: A. Fürst

Critical limits according to Mellert und Göttlein, 2012

	Critical foliar N:P ratios	
Broadleaf species	**Lower limit**	**Upper limit**
European beech	10.0	18.9
Temperate oaks	9.3	19.6
Coniferous species		
Scots pine	7.4	14.1
Norway spruce	6.3	11.7

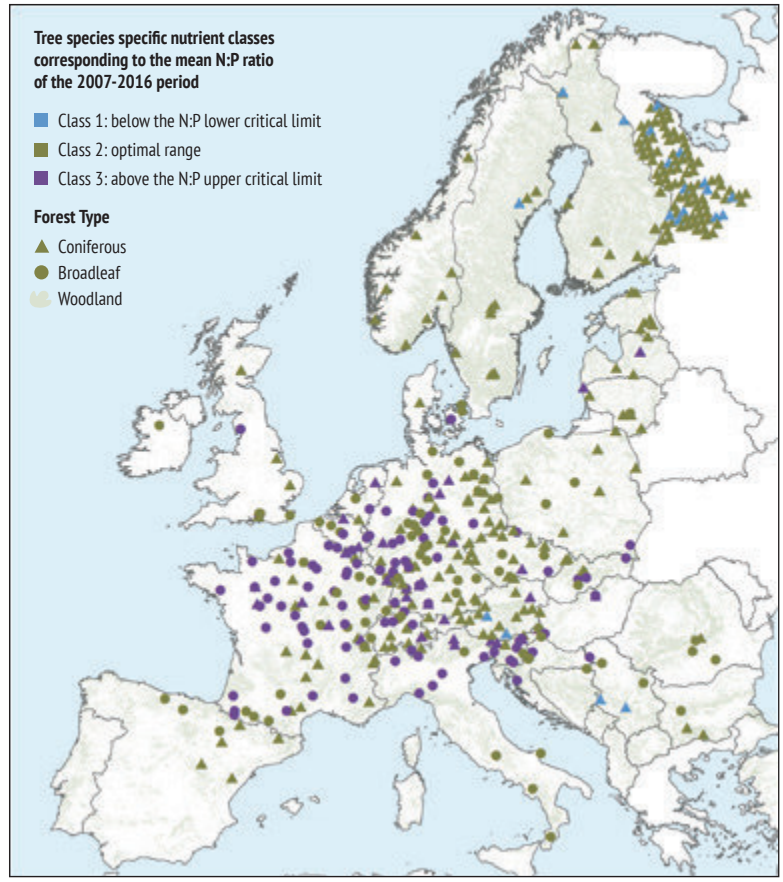


▲ CO_2 enrichment and atmospheric deposition of N to forests can lead to N:P nutrient imbalances in trees, thereby limiting tree growth and C sequestration and decreasing the resilience to drought and insects. Illustrations: Freepik.com

Current status

Foliar N:P ratios in broadleaf forests across Europe for the period 2007-2016 varied between 10.3 and 34.1, with an overall average of 20.2. Ratios at more than half the study sites (56%) were above the critical limit for optimal nutrition. For all sites, this is due to both high foliar N and low foliar P concentrations.

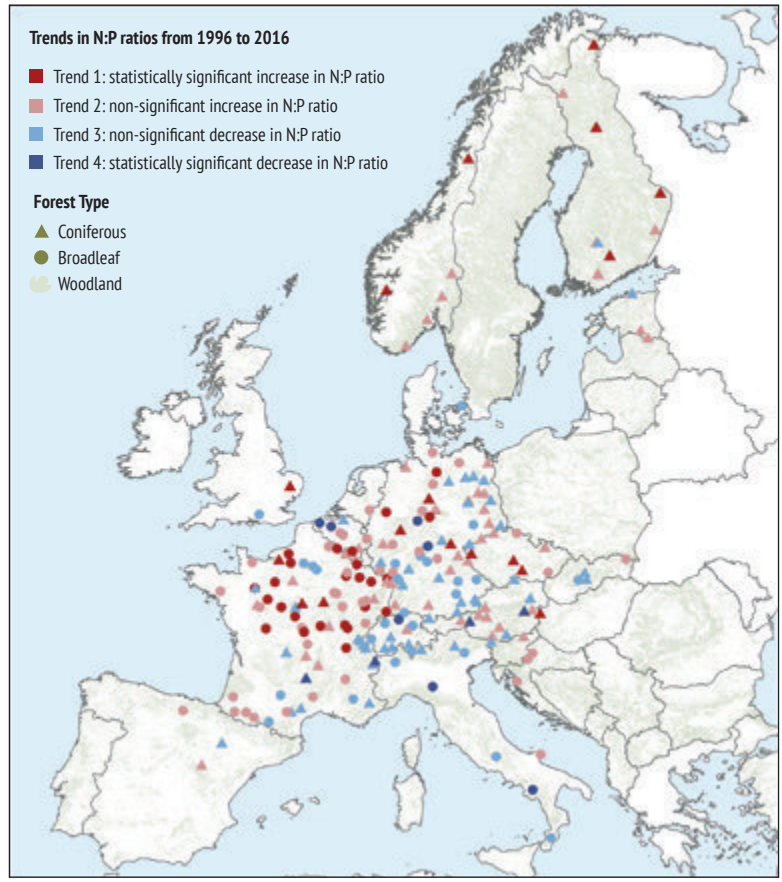
Foliar N:P ratios were lower in coniferous forests, ranging from 5.3 to 20.9, with an average of 9.6. Ratios at over 80% of the study sites were within the optimal nutrition range. The few sites with low N:P ratios, indicating limited availability of N, are mostly in northern Europe or in mountain areas. In contrast, sites with high N:P ratios, indicating low availability of P relative to N, occur all over Europe.



▶ Mean foliar N:P ratios for the period 2007-2016 period assessed against the critical limit for optimal nutrition for coniferous trees (Scots pine, Norway spruce) and broadleaf trees (European beech, temperate oaks) at ICP Forests Level II intensive monitoring sites across Europe.

Recent trends

Overall, both foliar N and foliar P concentrations have decreased significantly at ICP Forests monitoring sites over the past two decades for both broadleaf and coniferous trees. The rate of decrease in foliar P is more than double that for foliar N, resulting in a shift towards higher N:P ratios. Although certain sites show a trend towards lower N:P ratios, the number of sites with N:P ratios above corresponding, species-specific limit values have increased for both broadleaf and coniferous forests, showing an increasing imbalance in tree nutrition across Europe.



▶ Trends over time (1996-2016) in foliar N:P ratios for coniferous trees (Scots pine, Norway spruce) and broadleaf trees (European beech, temperate oaks) at ICP Forests Level II intensive monitoring sites across Europe.

Future developments

Shifts in the ratio between levels of foliar N and foliar P can be attributed to human emissions of N and carbon. The resulting nutrient imbalance has the potential to limit tree growth, leading to a reduction in wood supply and carbon sequestration by forests, and to decrease the resilience of forest trees to stressors such as drought or insect infestation.

The implications for forest productivity and for the potential of forest ecosystems to respond to global environmental change highlight the importance of monitoring the deposition of N and other elements into forests and their subsequent impacts on the structure and functioning of forest ecosystems.

Counteracting nutrient imbalances in forest trees through P fertilisation of forest soils is not generally considered viable or cost-effective. Instead, and for ecological as well as economic reasons, the nutrient imbalances detected on ICP Forests monitoring plots would perhaps be better addressed through action to further reduce levels of air pollution.

Suggested reading

Jonard et al., 2015. Tree mineral nutrition is deteriorating in Europe. Global Change Biology, 21:418-430.

Mellert KH, Göttlein A, 2012. Comparison of new foliar nutrient thresholds derived from van den Burg's literature compilation with established central European references. European Journal of Forest Research, 131:1461-1472.

Sardans J et al., 2016. Foliar and soil concentrations and stoichiometry of nitrogen and phosphorous across European *Pinus sylvestris* forests: relationships with climate, N deposition and tree growth. Functional Ecology, 30:676-689.

Talkner U et al., 2015. Phosphorus nutrition of beech (*Fagus sylvatica* L.) is decreasing in Europe. Annals of Forest Science, 72:919-928.

This is the forth issue of the ICP Forests Brief series, which aims to provide clear and concise information on the ICP Forests monitoring programme and its latest scientific findings. These short updates are primarily directed at policymakers and the interested public offering them scientific knowledge for an informed debate on key forest-related environmental topics.

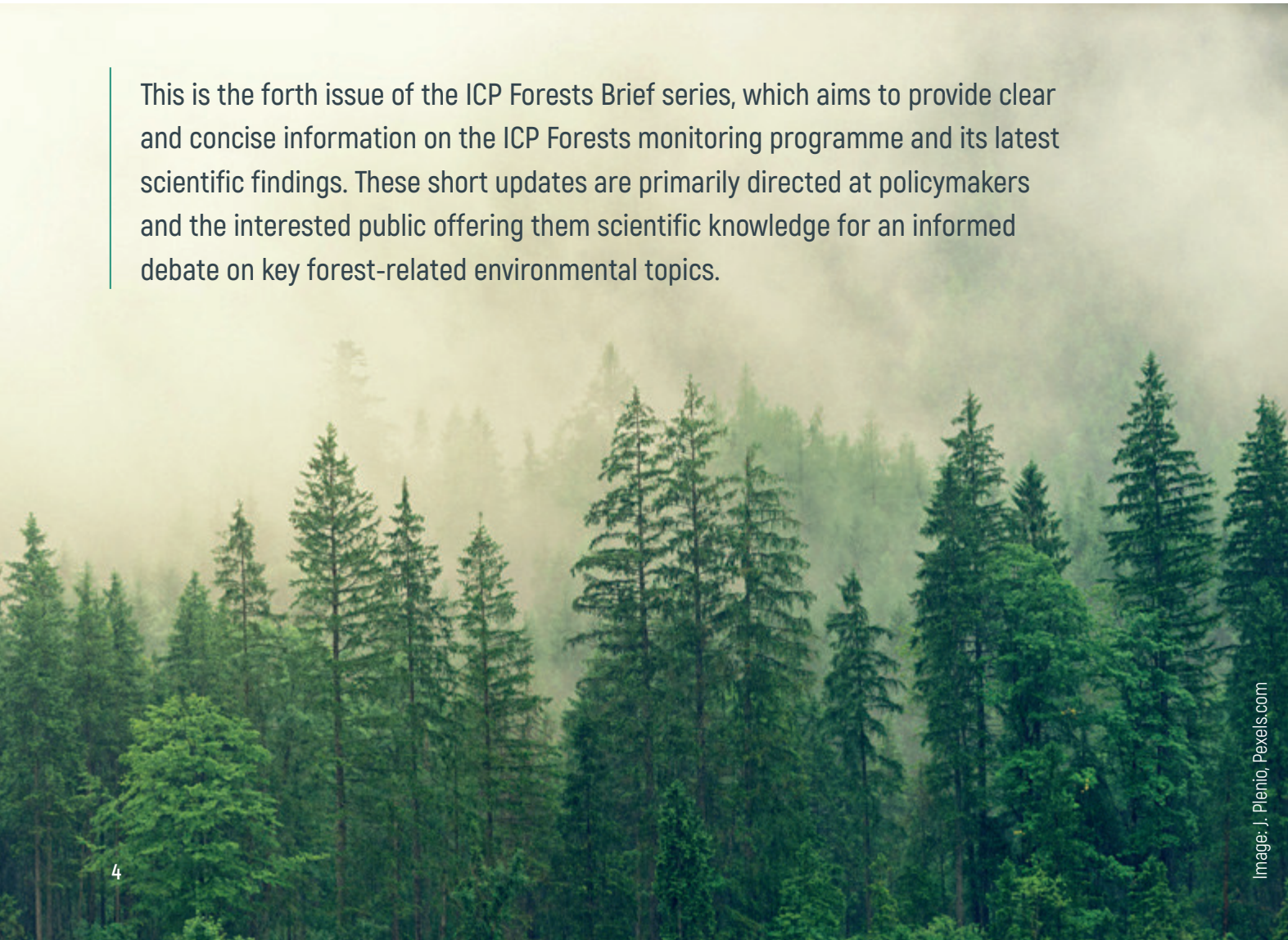


Image: J. Plenio, Pexels.com

United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (Air Convention) International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

The data underlying this Brief were collected through ICP Forests. Monitoring sites are maintained by the ICP Forests member states and a wide range of environmental parameters and ecosystem responses are regularly assessed. See ICP Forests Brief #1 for further details.

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