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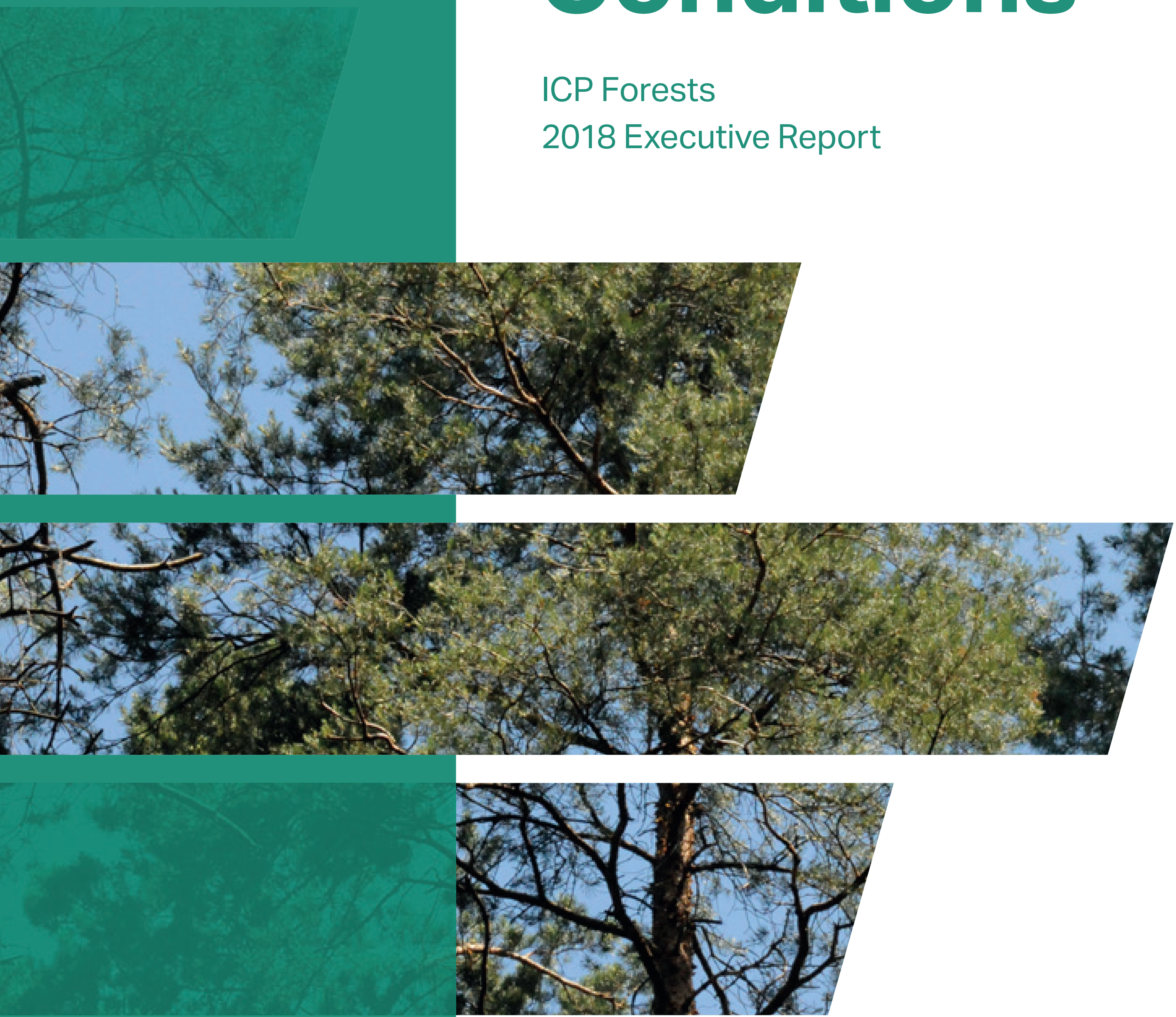
ICP Forests

LRTAP Long-range Transboundary Air Pollution

Forest Conditions

ICP Forests
2018 Executive Report



2018

THÜNEN

ICP Forests

Forest Conditions

ICP Forests 2018 Executive Report

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

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FORESTS FOR ALL FOREVER

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Preface

I am honoured to introduce the 2018 Executive Report of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). Latvia hosted the 34th Task Force Meeting in 2018 and the Ministry of Agriculture of Latvia strongly supports the work of the programme.

Latvia is the fifth most forested country in Europe. In fact, the major part of our country is covered by forests – 54%, if the international forest definition is used. If we compare the situation as it was a century ago, forest cover has almost doubled yet still there is a slight trend of increase in forest cover. The principles of sustainable forest management are followed in our forest policy and legislation. All three functions of forests (economic, ecological and social) are important for our society.

To ensure sustainable forest management it is very important to have knowledge of forests and their health condition. Following substantial and sustained research efforts, Latvia has very precise long-term data available. Latvia has participated in the ICP Forests programme since 1990.

The results of the extensive (Level I) and intensive (Level II) forest health condition monitoring shows that over the past 25 years forest health in Latvia has improved and is today in a pan-European context rather good.

Forest protection is important for all forest-related stakeholders and the amount of damaged forest stands is probably one of the most important indicators for forest owners. Although the amount of damaged forests varies from year to year, the forest damaging agents are more or less the same. But developments are not always so predictable and we still face new challenges. We can share our experience – experts have identified a couple of infestations of Acute Oak Decline which is a new disease for Latvia and therefore existing expert networks such as ICP Forests are invaluable for proper consultations.

I would like to thank everyone involved in the ICP Forests programme for their efforts and wish every success in the future.

Arvids Ozols
Director of Forestry Department
Ministry of Agriculture
Republic of Latvia

Introduction

1

The International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was launched in 1985 under the Convention on Long-range Transboundary Air Pollution (Air Convention; CLRTAP) of the United Nations Economic Commission for Europe (UNECE) in response to wide public and political concern over the extensive forest damage observed in North America and Europe since the end of the 1970s. Together with five other international co-operative programmes and the task force on health, ICP Forests operates under the Working Group on Effects (WGE) to provide scientific information on air pollution effects on ecosystems, plants, materials and human health. ICP Forests is principally concerned with the condition and development of forest ecosystems and increased understanding of cause-effect relationships in forest ecosystem functioning. Owing to the complex structure of forest ecosystems this can only be achieved if all major influences are addressed, including variability in climatic conditions. This means that symptoms of stress in trees or any adverse change in forest ecosystem services must be assessed in relation to primary and secondary causes.

The contributions to this year's report reflect the potential for combining the results of basic monitoring at the long-term monitoring sites maintained by countries cooperating under ICP Forests and the results of cutting-edge research undertaken by specialist institutes able to apply advanced techniques such as DNA sequencing. Taking advantage of such combinations through statistical modelling and opportunities arising from the collocation of various field observations and measurements, yields a unique set of results that could not be achieved through basic monitoring alone. So the reader is encouraged to become inspired by this collection of short articles all linked to the aims of the Air Convention and with special regard to forests.

Serina Trotzer

Long-term monitoring of forest ecosystem compartments

2

Long-term observations are crucial for ecosystem monitoring in general and for forest ecosystems in particular, because such systems have high capacities to store atmospheric inputs and feedback loops may be slow. Changes in carbon storage in forest soils are one such example, and can only be directly measured within the multi-annual monitoring activities of ICP Forests. Measurements on various topics have now been performed over a relatively long period – in the case of crown condition, foliar analysis and soil analysis for more than 30 years (Level I monitoring) and for more intensive monitoring activities for more than 20 years (Level II monitoring).

Soil solution chemistry should reflect such long-term changes. However, in the case of carbon, long-term developments are overlaid by cyclic and episodic annual variations, governed by seasonal weather conditions. These complex dynamics make it a challenge to separate the various components: a seasonal short-term component, a long-term development, and variability ('noise') due to undefined influences such as small-scale disturbances or measurement errors. Based on work undertaken at a Swiss monitoring site, Section 2.1 provides an example of how the different components can be analysed. Together with large-scale statistical approaches, this may help to explain the increasing presence of dissolved organic carbon in freshwater bodies in Europe and North America.

Deposition of airborne substances is a process central to the study of air pollution effects on forest ecosystems. To follow these processes at a sufficient level of detail and accuracy is one of the main activities of the monitoring at Level II sites. Examples from six sites in Romania document the amounts of substances being deposited in forest ecosystems and through the declines observed, the success of air pollution abatement policies. The contribution presented in Section 2.2 concerns atmospheric deposition and soil solution measurements.

Nutritional supply of tree foliage is the combined result of many processes, governed by annual weather conditions (especially during spring) with mobilisation from soil, transport within the xylem and finally by becoming part of the foliage where its metabolic role takes place. Collecting samples of leaves or needles provides the opportunity to assess the supply of trees with a wide range of nutrients. To avoid variation due to position effects within crowns, it is important to follow the methodology outlined in the extensive ICP Forests manual. This guarantees a stable signal for the average nutritional status of trees in forests. Section 2.3 demonstrates how subtle changes over time can accumulate to relevant amounts.

2.1 Is dissolved organic carbon in soil solution increasing?

Several studies have shown that dissolved organic carbon (DOC) levels in surface waters across Europe and North America have increased in response to the decline in acidic atmospheric deposition. The response in the soil solution within forest soils across Europe has been less unequivocal due to factors acting at the local (soil and vegetation) and regional (atmospheric deposition of nitrogen and sulphur) scale. The objective of this study was to understand DOC trends in soil solution from 2000 to 2016 at six Swiss Level II plots by analysing the influence of throughfall DOC over this same period and by measuring the distribution of DOC between the hydrophobic and hydrophilic fractions (for the period 2005 to 2012) by means of UV spectroscopy (see 'Terminology' box).

Soil solution DOC time series at the six Swiss sites exhibit both upward and downward monotonic trends (Seasonal Mann-Kendall test) and as such confirm the ambiguous findings of soil solution DOC trends at the European scale. Interestingly, decomposition of the DOC time series shows that the long-term component of both throughfall and soil solution is not monotonic. Instead, irregular patterns with DOC

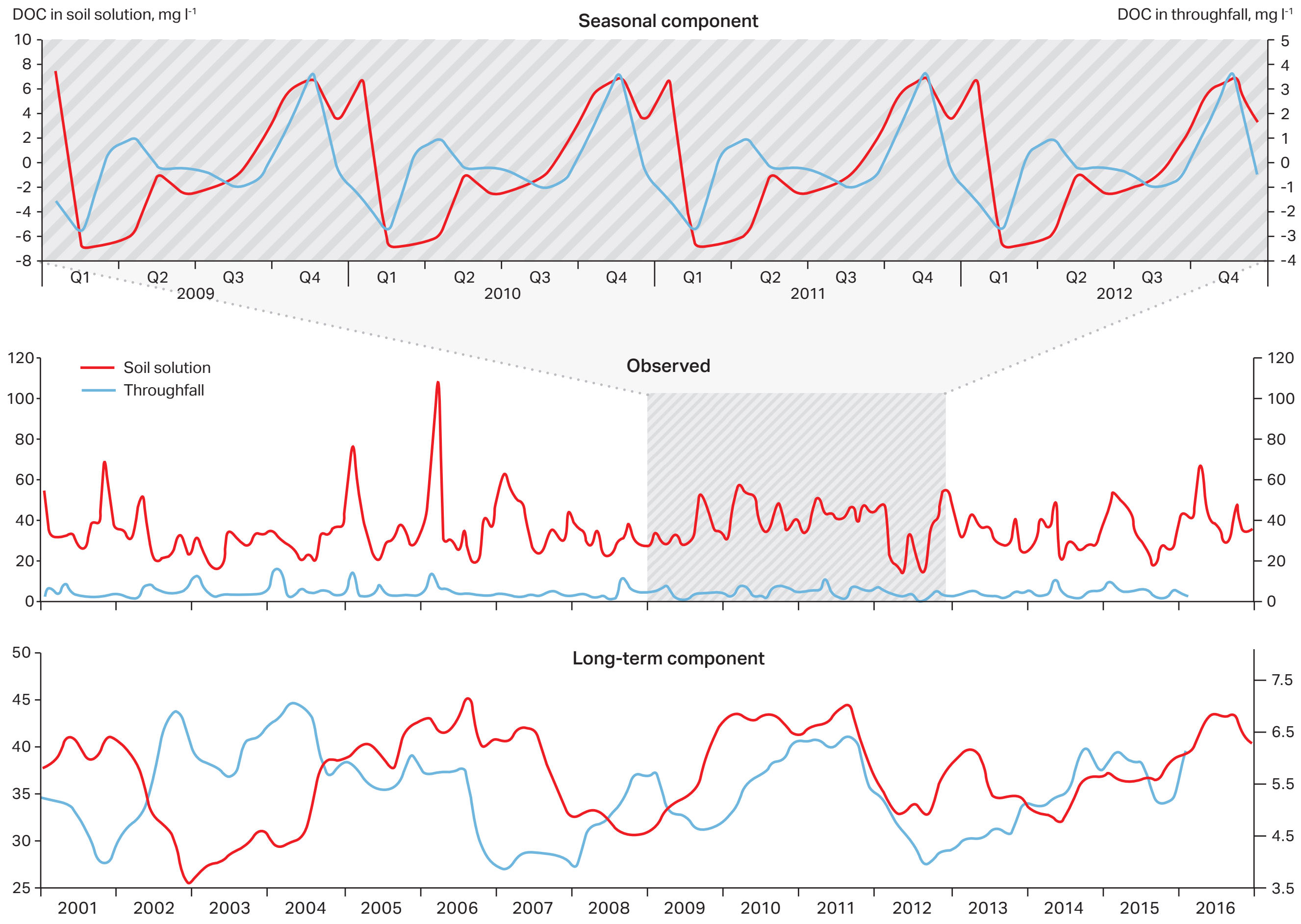

Figure 2-1: Additive time series decomposition of the dissolved organic carbon (DOC) concentration measured in throughfall and soil solution (0 cm depth) at the Swiss Level II plot 'Beatenberg'. The seasonal component is centred at the mean value. The long-term component is extracted by a moving average filter. The remaining random component (not shown) is derived by subtracting the trend and seasonal components from the observed data.

peaks in certain years are observed (Figure 2-1). There is little resemblance of the long-term component in throughfall and soil solution. In contrast, except for a small time lag, the seasonal pattern of throughfall and soil solution DOC is very similar with a minor peak in spring and a major peak in October. The spring peak may be related to the start of the growing season with its massive bud burst and the simultaneous snow melt that may lead to a release of DOC. The autumn peak is related to the litterfall and the related increase in canopy leaching. Associating the long-term component peaks with litterfall, mast years and climatic data may help to pinpoint causal relationships in future.

In soil solution the hydrophobic fraction and total DOC are strongly related (both $R^2_{adj.} > 0.79$) with hydrophobic DOC constituting the major share of total DOC (74%), but much less for throughfall (47%; Figure 2-2).

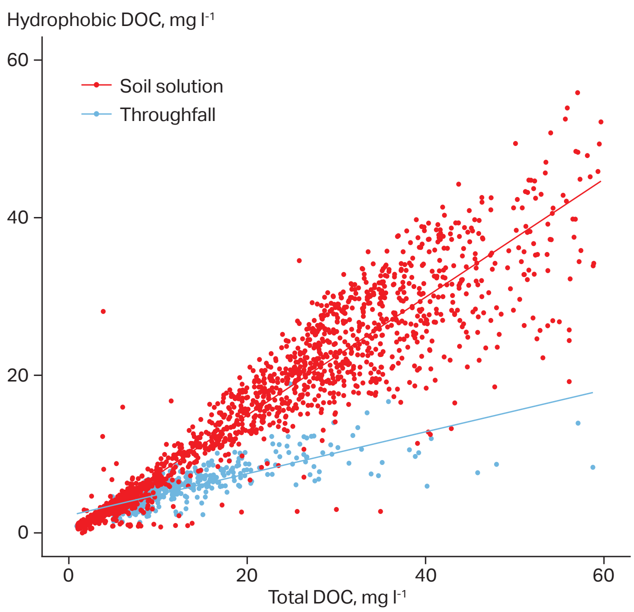

Figure 2-2: Hydrophobic DOC versus total DOC in soil solution and throughfall samples at six Swiss Level II plots.

In contrast to the ambiguous monotonic trends observed for total DOC, the hydrophobic DOC fraction showed consistently decreasing trends at five of the six sites at a significance level of 5% (Seasonal Mann-Kendall test). This is all the more surprising given the large variability in DOC levels and the short time series considered. The trends observed imply that the counterpart, the hydrophilic DOC fraction, is increasing in the soil solution. The low-molecular hydrophilic fraction is more enriched in nutrients, but at the same time more susceptible to microbial degradation and leaching and may eventually contribute to the observed increase in stream water DOC concentrations mentioned at the start of Section 2.1.

Terminology

UV spectroscopy: When a substance absorbs radiation the energy of the photons is transferred to the substance. The amount of radiation absorbed at different wavelengths is characteristic of a particular substance and thus allows its identification. This technique is routinely used in analytical chemistry. UV spectroscopy measures the absorption of ultraviolet radiation (10–400 nm) by different analytes. Absorption at 260 nm was used in this application because absorption is significantly higher for the hydrophobic DOC fraction at this wavelength. By measuring absorption at 260 nm it is therefore possible to distinguish hydrophobic DOC from hydrophilic DOC at different concentrations.

Further reading

Camino-Serrano M et al., 2016: Trends in soil solution dissolved organic carbon (DOC) concentrations across European forests. Biogeosciences 13: 5567-5585.

2.2 Air pollutants in deposition and soil solution

Atmospheric deposition and soil solution are both monitored within the ICP Forests programme in order to investigate trends and correlations with other factors that can affect forest ecosystems. This section reports on concentrations of a range of substances measured at four intensive monitoring (Level II) plots in Romania. Between 1998 and 2016, bulk deposition and throughfall of sulphate decreased significantly

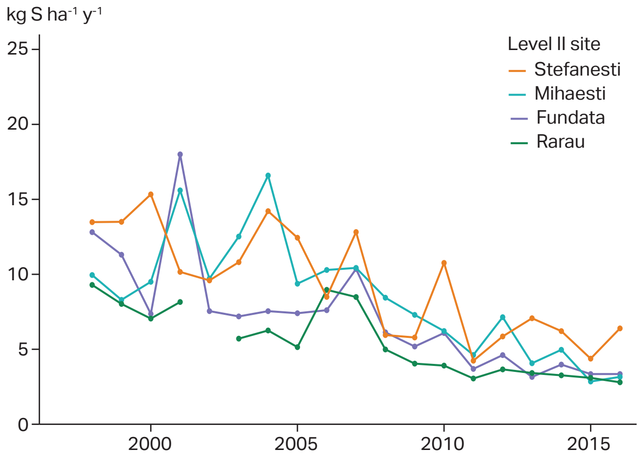

Figure 2-3: Annual deposition of sulphate sulphur with open field total deposition at four Romanian Level II sites.

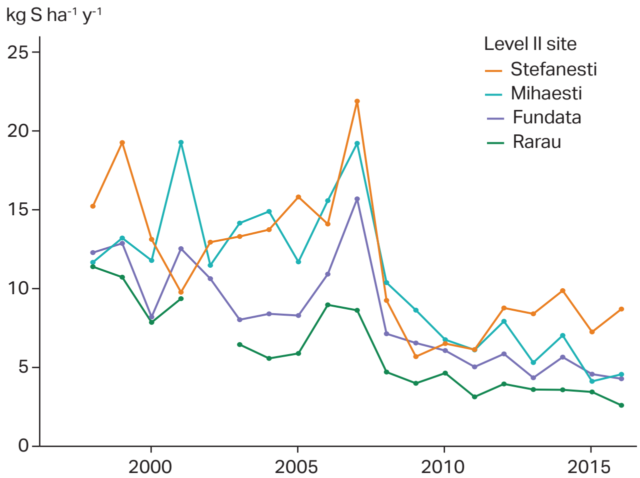

Figure 2-4: Annual deposition of sulphate sulphur with throughfall precipitation at four Romanian Level II sites.

at all plots (Figures 2-3 and 2-4). The same trends were observed for ammonium, except at 'Stefanesti', located near the capital Bucharest, where ammonium fluxes in throughfall still exceeded 8 kg ha^{-1} y^{-1} in 2013 and 2015 (Figure 2-5), values to be considered high in a European context. For the other three plots, throughfall fluxes at least since 2013 have been below or close to 4 kg ha^{-1} y^{-1}, which can be considered low.

A decline in ammonium nitrogen was also measured in the soil solution. A significant decrease of its concentration was observed at 'Fundata' at all four depths of the soil profile. Although nitrate nitrogen concentrations and fluxes also decreased, the trends were not significant at any of the plots.

The level of throughfall deposition of nitrate was below 4 kg N ha^{-1} y^{-1} in 2015 at all four plots, which is considered low.

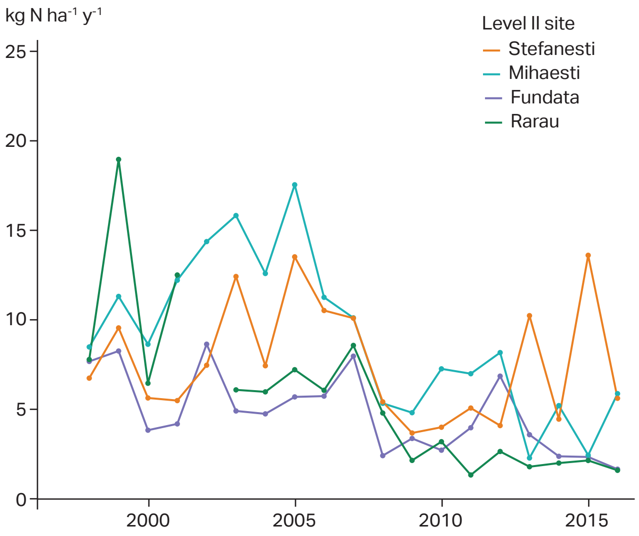

Figure 2-5: Annual deposition of ammonium nitrogen with throughfall precipitation at four Romanian Level II sites.

Fluxes of chloride decreased at three plots, but increased significantly at 'Stefanesti', up to about 50 kg Cl ha^{-1} y^{-1} in the past three years, which is 2.5-fold higher than for 1998.

For calcium, throughfall and open field deposition showed no trend. In 2015, throughfall deposition was high (over 10 kg Ca ha^{-1} y^{-1}) at the three plots in central and southern Romania, possibly due to the influence of Saharan dust transported over these regions. At 'Rarau', in northern Romania, throughfall deposition was below 10 kg Ca ha^{-1} y^{-1}.

Annual mean concentrations and fluxes of magnesium decreased at three plots, but the trend was not significant. In contrast, the mean magnesium concentration increased at 'Rarau', a plot on calcareous soil.

Further reading

Barbu I et al., 2011: Monitoring of atmospheric deposition in the research grid of forest ecosystems selected in the framework of FutMon. Revista Pădurilor 126: 70-84. (In Romanian)

2.3 Tree nutrition trends

Evaluating changes and trends in tree nutrition reflects environmental forces acting at the tree level. The longest uninterrupted time series for ICP Forests Level II plots in Czechia are from two Norway spruce (*Picea abies*) plots (e.g. Figure 2-6), for the

Figure 2-6: Monitoring needle chemistry for a Norway spruce tree; samples are first collected in the forest and then subject to chemical analysis in the laboratory.

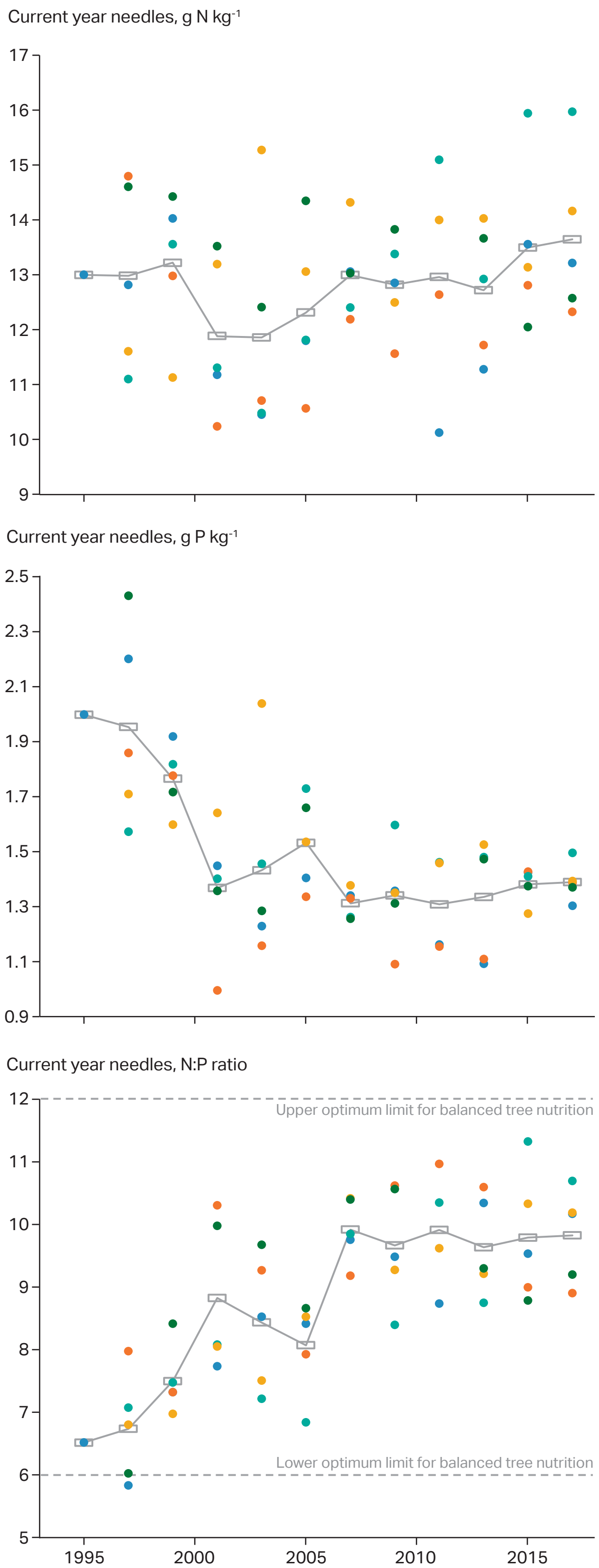

Figure 2-7: Development of total nitrogen, phosphorus, and the nitogen:phosphorus ratio for current-year needles of five specimens of Norway spruce (represented by five different colours) at Plot 2161 in Czechia. Grey lines show average values of all sampled trees. Plot 2161 is located in central Bohemia, 440 m above sea level.

period 1995 to 2017. Other sampled plots differ in the length of sampling period, continuity of data sets and the array of elements analysed. Sampling and analysis are generally performed every two years and in accordance with the designated methodology.

Monitoring data for plot 2161, one of the two long-term monitoring plots in Czechia show a large amount of variability but since around 2005 there appears to be both a slight increase in nitrogen concentration and a slow decrease in phosphorus concentration. This created an imbalance between the two important nutrients, with N:P ratios approaching (Figure 2-7) or even exceeding a value of 12, which is seen as an upper optimum limit for balanced tree nutrition.

Potassium behaves differently in mountainous areas: decreasing at altitudes over 800 m above sea level, especially in one-year old needles, while at lower altitudes concentrations fluctuate or even increase slightly.

The annual average magnesium concentration at two plots of European beech (*Fagus sylvatica*) decreased between 2001 and 2015; one from 2.3 to 1.5 g Mg kg^{-1} dry matter and the other from 1.4 to 0.9 g Mg kg^{-1} dry matter. A decrease in magnesium of about 25% was found on a Scots pine plot between 2005 and 2015.

Sulphur concentrations were higher in the 1990s, with present-day levels around 1.0–1.3 g S kg^{-1} dry matter within coniferous plots and about 1.6 g S kg^{-1} dry matter for broadleaved plots. This suggests that in Czechia sulphur should no longer be considered a contaminant, but rather a nutrient.

Overall, it seems that nutrition levels are changing slightly, with an imbalance often observed in the ratio between nitrogen and other important nutrients, especially between nitrogen and phosphorus. This indicates the importance of controlling emissions and monitoring immissions of nitrogen.

Further reading

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

Organism responses to environmental stress

3

Organisms are adapted to their specific environment as a result of processes that have taken place over evolutionary time scales. Present-day changes in environmental conditions can thus affect local performance, especially for sessile organisms such as plants or fungi, for example in terms of growth reduction or the amount of foliage in tree crowns or even single tree death. Observing tree performance and changes in the abundance of other forest organisms (e.g. fungi) is a task directly related to the aims of ICP Forests.

Observing or measuring changes in tree performance such as the visually recognisable amount of foliage in tree crowns was one of the earliest activities of ICP Forests. Crown condition has been assessed on an annual basis since 1985 in many European countries. However, it is now clear that crown condition is a relatively non-specific symptom and can be an indicator of climate stress, especially drought, as well as the direct or indirect influence of air pollutants. In the 1980s, high immissions of sulphur dioxide were the main concern while the focus has now switched to the still high immissions of nitrogen. In large parts of Europe, high ground-level ozone concentrations are also considered a causal agent of leaf or needle damage. Meteorological phenomena such as hail, storms or late frosts can likewise cause leaf or needle losses and may also foster mass reproduction of herbivorous insects or phytopathogenic fungi. Section 3.1 addresses long-term changes in crown condition in oak and beech stands and examines the extent to which diversity of forest stands influences the condition of tree crowns over time.

Fungi living in close symbiosis with forest trees and forming the so-called ectomycorrhiza results in mutual benefits: fungi obtain carbohydrates from their tree partners and trees get better access to nutrients and water from soils. It has long been suspected that the fungal partner of this symbiosis may be adversely affected by environmental change, especially enhanced inputs of reactive nitrogen. Section 3.2 reports on a long-term collaboration between ICP Forests, Imperial College London and the Royal Botanic Gardens Kew, to substantiate such claims and deliver a solid basis for future research activities.

3.1 Does tree diversity influence defoliation trends?

Climate change is increasingly understood to affect the composition, structure and function of forest ecosystems. In particular, extreme or prolonged periods of drought are a major cause of concern for forest health. Drought can trigger a series of plant responses, such as reduced radial growth and increased crown defoliation potentially leading to elevated tree mortality. Recent ecosystem research suggests that higher diversity in tree species is associated with stronger resistance of forest trees to disturbance. Thus, it was hypothesised that maintenance of forest ecosystem condition is enhanced by species diversity, especially over the longer term. This was tested by revisiting recent trends in defoliation at Belgian Level I and Level II plots for three deciduous tree species: common beech (*Fagus sylvatica*), sessile oak (*Quercus petraea*) and pedunculate oak (*Q. robur*), growing in pure and mixed stands. This made it possible to test for species-diversity and species-specific effects in terms of the forest defoliation response to drought.

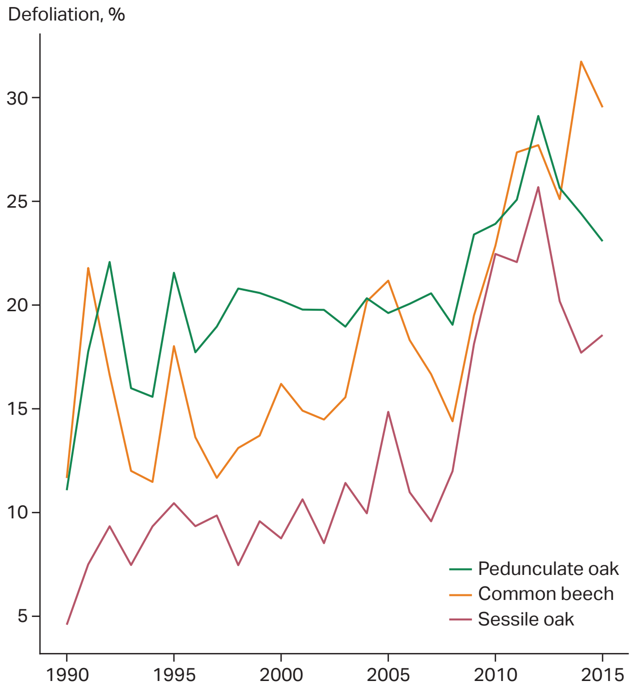

Figure 3-1: Crown defoliation since 1990 for three deciduous tree species at Level I and II sites in Belgium. Defoliation severity is expressed as the proportion of leaf loss (0–100%, with intervals of 5%), and a mean annual value was calculated for each species. n = 37,800 observations.

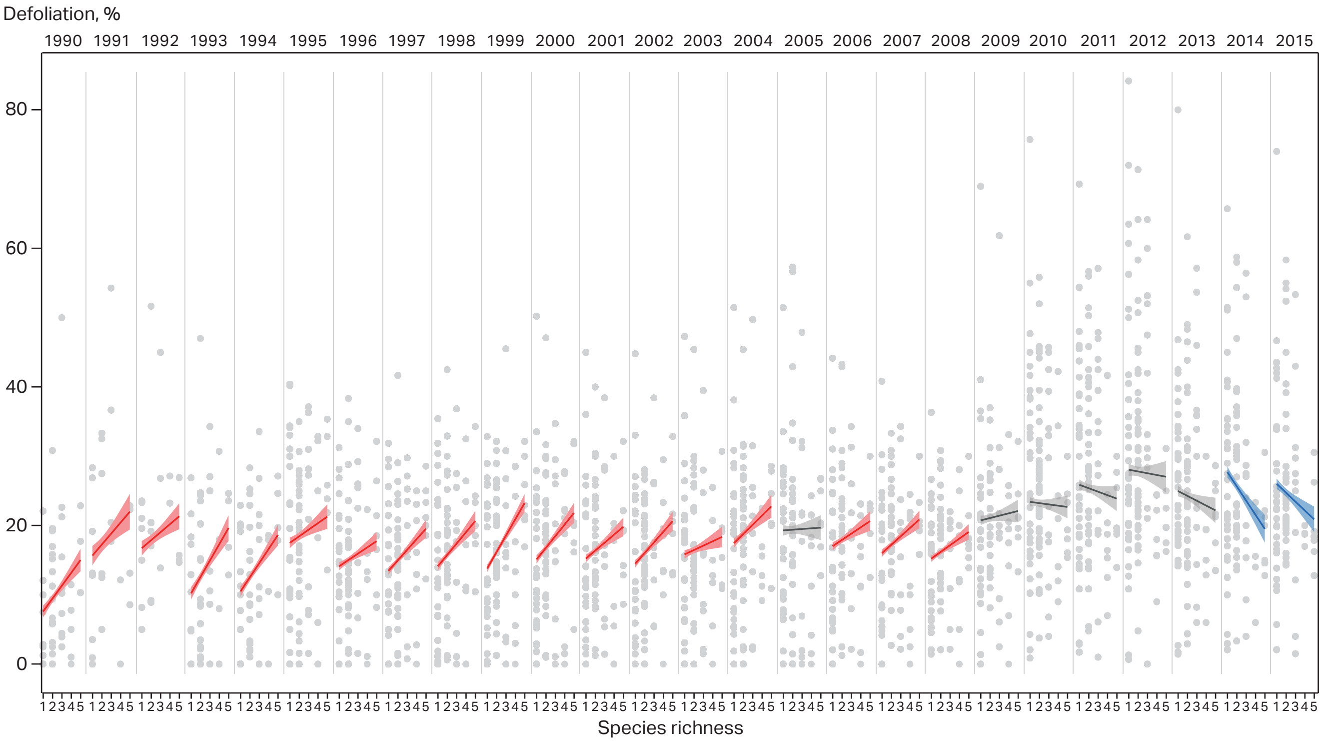

Figure 3-2: Trends in plot-averaged tree defoliation along a tree species richness gradient in temperate deciduous forests. Defoliation severity is expressed as the proportion of leaf loss (0–100%, with intervals of 5%). Grey dots indicate annual defoliation averaged over all trees of a monitoring plot. Solid lines and shaded areas represent the mean and 95% confidence intervals for each year of the study. Positive slopes (red) indicate an increase in defoliation with increased species richness (ranging from 1 to 5), whereas negative slopes (blue) denote a decrease in defoliation in more diverse stands. Non-significant slopes are shaded grey ($p \geq 0.05$). n = 37,800 observations.

Although the three tree species showed different individual responses, the general pattern was similar. Overall, defoliation increased steadily, particularly in recent years, with peak defoliation observed in 2012 for sessile and pedunculate oak and 2014 for beech (Figure 3-1). A smaller peak is evident between 2003 and 2005, probably linked to the hot dry summer of 2003. However, the most striking result to emerge from the data is that, over time, the effect of tree species diversity on crown defoliation shifted from negative to positive. Defoliation was initially higher in mixed stands than pure stands, but following a period of steady increase in defoliation this trend progressively shifted towards lower defoliation at higher species richness (Figure 3-2). This finding appears to confirm the stress gradient hypothesis, which predicts that interactions between species shift from competition (negative effect) to facilitation (positive effect) with increasing stress (e.g. in water deficit conditions). Under drought stress, water uptake efficiency is likely to increase in mixed forests because a greater volume of soil can be exploited in space and time by species with complementary root characteristics. In fact, some tree species are able to transport water from deeper, moister soil layers to upper, drier soil layers, a mechanism known as 'hydraulic lift'. This is driven by roots and gradients in soil water potential, from the least negative water potentials (usually the deepest soil layers) to the most negative water potentials (usually the shallowest soil layers). Trees and other plants benefit not only from increased water availability but also indirectly by higher nutrient availability related to this.

Although support for the importance of mixed forests is implicit in the vast body of research on forest disturbances, the relationship between tree diversity and the stability of forest ecosystems has never been directly observed in real forests. This study provides evidence that species-diverse forests are an important management option for adapting forests to the changing climate, such that the effects of drought are minimised and the dynamics and functioning of forests continue under minimum disturbance.

Further reading

Sousa-Silva R et al., 2018: Tree diversity mitigates defoliation after a drought-induced tipping point. Global Change Biology 24: 4304-4315.

3.2 Nitrogen deposition changes ectomycorrhizal fungi

The mycorrhizal symbiosis between plants and fungi (Figure 3-3) evolved at the plant root-soil interface to play a crucial functional role. The fungi maximize plant access to soil nutrients and water, while the plants provide carbohydrates to fungi. In boreal and temperate regions, which were originally nitrogen-limited, ectomycorrhizas specialised on inorganic or organic nitrogen uptake enabling trees to succeed in developing forest biomes.

Anthropogenic nitrogen input to forest ecosystems has long been assumed to influence the composition of tree mycorrhizas at the large scale. To investigate this, a series of studies were conducted as a cooperative project between ICP Forests, Imperial College London, and the Royal Botanic Gardens Kew. Soil samples were obtained across Europe from the ICP Forests long-term monitoring sites. The first study focused on Scots pine (*Pinus sylvestris*), the second on pedunculate oak (*Quercus robur*) and sessile oak (*Q. petraea*), and the third on common beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) as well as Scots pine and the two oak species. In total, 39,621 ectomycorrhizas from 13,152 soil cores from 137 sites across 20 countries were analysed individually using DNA techniques. Environmental data on 38 soil, tree host, deposition, and climate variables were extracted from the ICP Forests database.

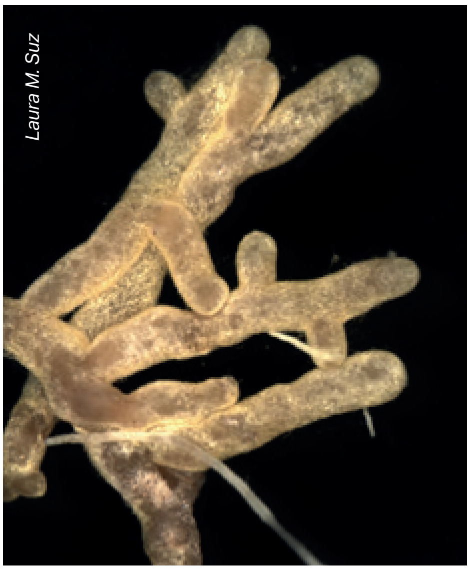

Figure 3-3: Ectomycorrhizal root tips of the yellow cracking bolete (*Xerocomellus subtomentosus*) on sessile oak (*Quercus petraea*).

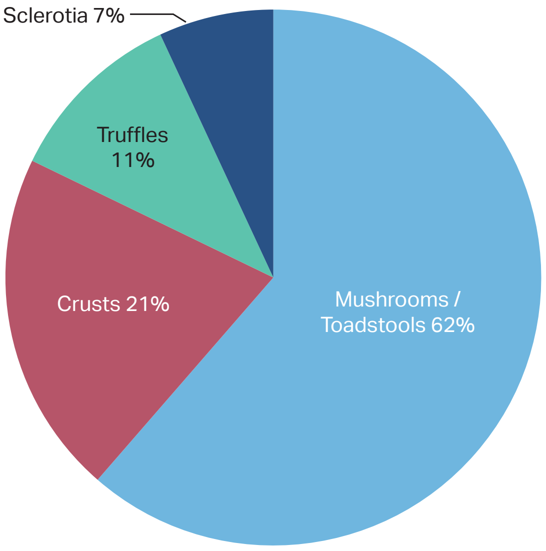

Figure 3-4: Reproductive structure by type in the ectomycorrhizal fungi identified. n = 1406.

Brittlegill (*Russula* sp.) in a Scots pine (*Pinus sylvestris*) forest.

A total of 1406 ectomycorrhizal fungi were identified. Of these, 62% form aboveground fruitbodies (mushrooms and toadstools, see Figure 3-4), while the rest produce crusts, subterranean fruitbodies (truffles) or sclerotia (resistant propagules). Over half the ectomycorrhizal fungi were associated with broadleaf or conifer trees only, and 7% were specialised to one particular tree species.

Analyses revealed that 38% of the variation in mycorrhizal diversity can be explained by the variables considered in this study, with tree host variables the most important, followed by atmospheric deposition and soil variables, geographic distance, and climate variables (Figure 3-5). The rest may be attributed to factors such as forest management and stochasticity. Multi-dimensional scaling revealed the key environmental variables to be nitrogen throughfall deposition, followed by forest floor pH, mean annual air temperature, potassium throughfall deposition and the foliar nitrogen:phosphorus ratio. Sensitive fungi with regard to nitrogen deposition include darkening brittlegill (*Russula vinosa*), red hot milkcap (*Lactarius rufus*) and gypsy mushroom (*Cortinarius caperatus*); most of the sensitive fungi are conifer-associates and specialise on organic nitrogen uptake. Further analysis revealed a new critical value of 5.8 kg N ha^{-1} y^{-1}. Above this level, sensitive mycorrhizal species respond with sharp declines or may disappear entirely. This should be considered in future specifications of critical loads for eutrophying nitrogen in forests, especially forests dominated by conifers.

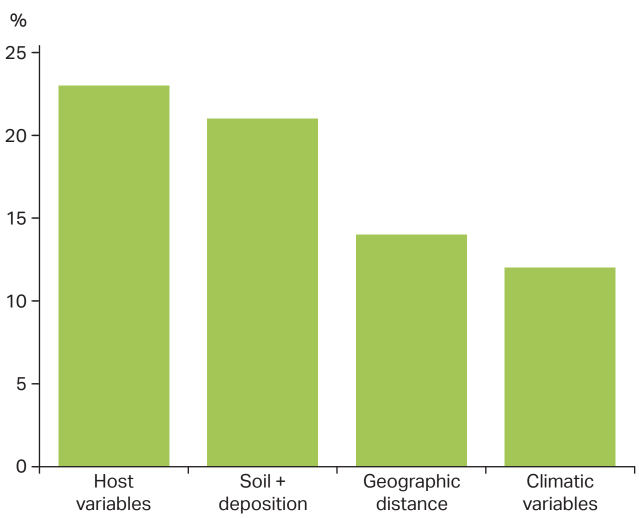

Figure 3-5: Explained variance in ectomycorrhizal community composition by parameter group.

Having linked environmental conditions with mycorrhizal diversity across Europe, it should now be possible to link them with forest condition and to use this first-ever baseline to assess future large-scale mycorrhizal changes over time.

Further reading

Van der Linde S et al., 2018: Environment and host as large-scale controls of ectomycorrhizal fungi. Nature 558: 243-248.

Modelling environmental stress in forest ecosystems

4

Many ecosystem processes cannot be directly measured, such as the rate of water seepage in soils or the ecosystem respiration rate. One factor of high interest that cannot be directly measured is the total quantity of nitrogen deposited in forest ecosystems. Atmospheric nitrogen compounds enter forest ecosystems through two main pathways: wet deposition and dry deposition. In terms of wet deposition, nitrogen compounds (mainly nitrate and ammonium) are deposited dissolved in rainfall and this is easily measured. The other pathway is dry deposition in which nitrogen attached to aerosols is trapped by canopy forests, while gaseous forms are adsorbed onto vegetation surfaces (mainly ammonia and nitric acid vapour) or are taken up by leaves directly from ambient air (mainly ammonia and nitrogen dioxide). Dry deposition of particulate and gaseous nitrogen cannot be directly measured and must be estimated using models.

Section 4.1 describes an approach to optimise the modelling of dry deposition under Mediterranean conditions (i.e. long dry summers). This is important because most modelling approaches have been developed under the more Atlantic (i.e. wetter) climate condition of central Europe. Achieving better estimates of nitrogen input to forests is essential because these inputs have far-reaching effects on forest ecosystems, with implications for nature protection. Comprehensive measures for preventing the adverse effects of nitrogen on forests can only be developed from a full and accurate assessment of inputs. This study should be seen as an example that is probably also applicable to areas under the more continental (i.e. drier) conditions of eastern Europe or other areas under future scenarios of drier climate.

4.1 Dry nitrogen deposition in Mediterranean forests

The Mediterranean Basin presents an extraordinary biological richness, but more information is needed on the threat that atmospheric deposition of nitrogen can pose to biodiversity and ecosystem functioning. A first approach to assess the risk of nitrogen enrichment on Spanish ecosystems within the Natura 2000 network showed that some of the most endangered forests (i.e. risk of forest damage in more than 50% of the assessed areas) were habitats with relict or endemic tree species.

In Mediterranean areas, dry deposition represents a major component of the total nitrogen input to natural habitats, especially forest ecosystems. Studies show that using the standard approach for determining total nitrogen input could significantly underestimate the dry deposition input to Mediterranean forests and, therefore, the risk of nitrogen enrichment and other negative effects of excess nitrogen.

Figure 4-1: Collectors for wet deposition under the canopy (throughfall) of a holm oak forest near Madrid, Spain (Área Forestal de Tres Cantos, Ayto. Madrid).

Figure 4-2: Open-field site for monitoring wet deposition, gaseous pollutants and meteorology in a holm oak forest near Madrid, Spain (Área Forestal de Tres Cantos, Ayto. Madrid).

Methodologies based on a combination of modelled and empirical approximations can improve estimates of the dry atmospheric input. An innovative empirical inferential method coupled with the modelling of stomatal conductance was recently used to estimate dry deposition of nitrogen compounds to four holm oak (*Quercus ilex*) forests under Mediterranean conditions (Figures 4-1 and 4-2). On average, dry deposition of gaseous and particulate atmospheric nitrogen accounted for 77 ± 2% of the total deposition. Surface and stomatal deposition averaged 10.0 ± 2.9 kg N ha^{-1} y^{-1} and 3.3 ± 0.8 kg N ha^{-1} y^{-1}, respectively (Figures 4-3 and 4-4). Dry deposition of oxidised forms (mainly from combustion processes) predominated accounting for 58% of the total atmospheric input of inorganic nitrogen, while the reduced nitrogen compounds (mainly from crop fertilisation and livestock farming) accounted for the rest. The empirical approximation to inferential deposition modelling proved to be an easy-to-apply methodology that generates site-specific results. The importance of having reliable measures of leaf area index and nitric acid vapour in forest monitoring networks cannot be overstated. To achieve better approximations of stomatal conductance will require enhanced parametrisation of a well-known stomatal conductance model for different Mediterranean tree species.

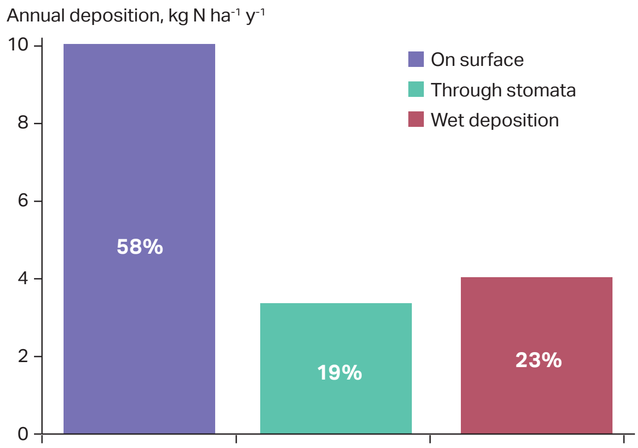

Figure 4-3: Pathways for atmospheric inorganic nitrogen deposition to Mediterranean holm oak forests. Average values for 2011–2013 at four Level II-like sites.

Interestingly, relatively large but short-lived pulses of nitrogen into the soil were found to occur with the first rains of autumn. These ephemeral inputs were related to the dry deposition accumulated over the summer drought being washed out over relatively short periods as the rainwater associated with these transient rainfall events passed through the canopy. Plants and soil communities are unable to use these early autumn pulses of dissolved nitrogen because they are still under drought stress and so these inputs can generate a flush of nitrogen to ground- or stream waters in the form of nitrate. This lixiviation effect, related to the Mediterranean asynchrony hypothesis, was corroborated in the most arid forest, with an increase in nitrates within the soil solution of up to 5 mg N l^{-1} at 40 cm depth.

Finally, a below-canopy reduction in the concentration of gaseous air pollutants was attributed to dry deposition, particularly for ammonia which showed a 40 ± 6% decrease. This measurable improvement in air quality indicates that forests could be used to reduce air pollution exposure for urban populations.

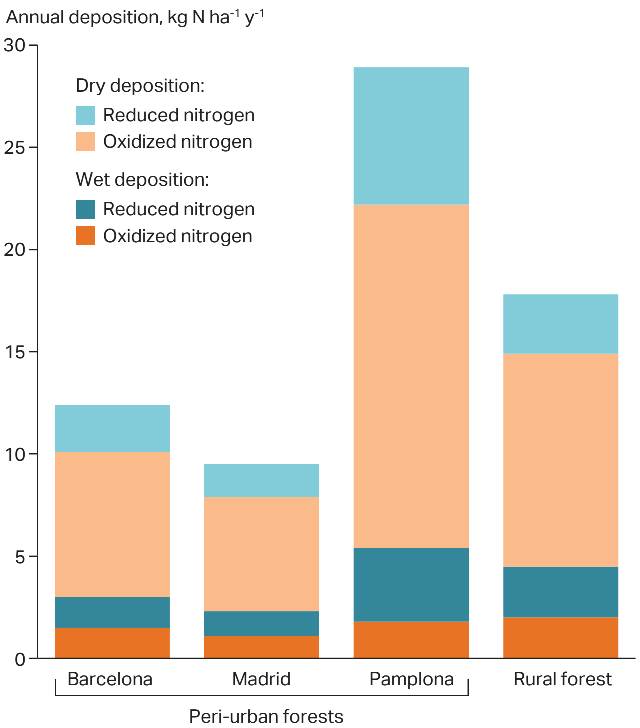

Figure 4-4: Mean annual deposition at three peri-urban forests and a forest at a rural site in Spain. High nitrogen deposition at the site near Pamplona is mainly related to a high leaf area index and a large site-specific deposition velocity for nitric acid.

Further reading

García-Gómez H et al., 2018: Joining empirical and modelling approaches to estimate dry deposition of nitrogen in Mediterranean forests. Environmental Pollution 243: 427-436.

Closing comments

As in earlier years, this Executive Report of ICP Forests highlights examples from both basic monitoring activities and advanced research performed at particular sites within the monitoring network. Both types of activity are mutually beneficial in that better general knowledge of ecological relationships in forests may cause a change in routine monitoring procedures and more importantly evaluation approaches. At the same time, routine monitoring and evaluations deliver the basis for advanced research that is eventually published in top scientific journals. Both must be seen as two sides of the same coin.

To achieve success in routine monitoring and advanced research, organisational structures must be continuously adapted and optimised to help interactions between the various groups, bodies and players involved. The Scientific Conferences, the seventh of which took place in May 2018 at Riga in Latvia, have proven an excellent forum to bring both sides together, as well as to stimulate the exchange of ideas and approaches. An increasing number of presentations at scientific conferences such as those of the International Union of Forest Research Organizations (IUFRO) can be seen as a direct result of these increased scientific activities. The contribution of many ICP Forest members to a recent publication in the highly regarded journal *Nature* is another indication of the growing awareness of the role of scientific research within the ICP Forests programme.

In terms of organisational issues, it is necessary to highlight the important role of the Working Group on Effects (WGE) and the other bodies under the Air Convention. Even if air pollution issues have priority, the structure and programmatic orientation of ICP Forests provides the possibility for wider thematic approaches in order to disentangle causal relationships in forest ecosystems. An ecosystem-related orientation provides the basis for collaboration not only within the WGE, but also beyond. This guarantees progress in both the basic monitoring activities and in advanced forest ecosystem research, which should include options based on remote sensing techniques. Such options could be taken up by members of ICP Forests as well as collaborators, thus enabling more inspiring Executive Reports in the future.

Credits

As editor, Walter Seidling would like to thank all those who directly and indirectly contributed to this 2018 Executive Report. The efforts of the ICP Forests Chairperson, and the National Focal Centres, Expert Panels and Committees are indispensable to the success and outcome of such a programme. Members of the UNECE Working Group on Effects, the Air Convention Secretariat and the Executive Body also deserve a particular mention in this respect. Last but not least, cordial thanks are extended to the host of the 34th Task Force Meeting and the 7th Scientific Conference: namely, Uldis Zvirbulis and Zane Lībiete, and all their supporters.

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