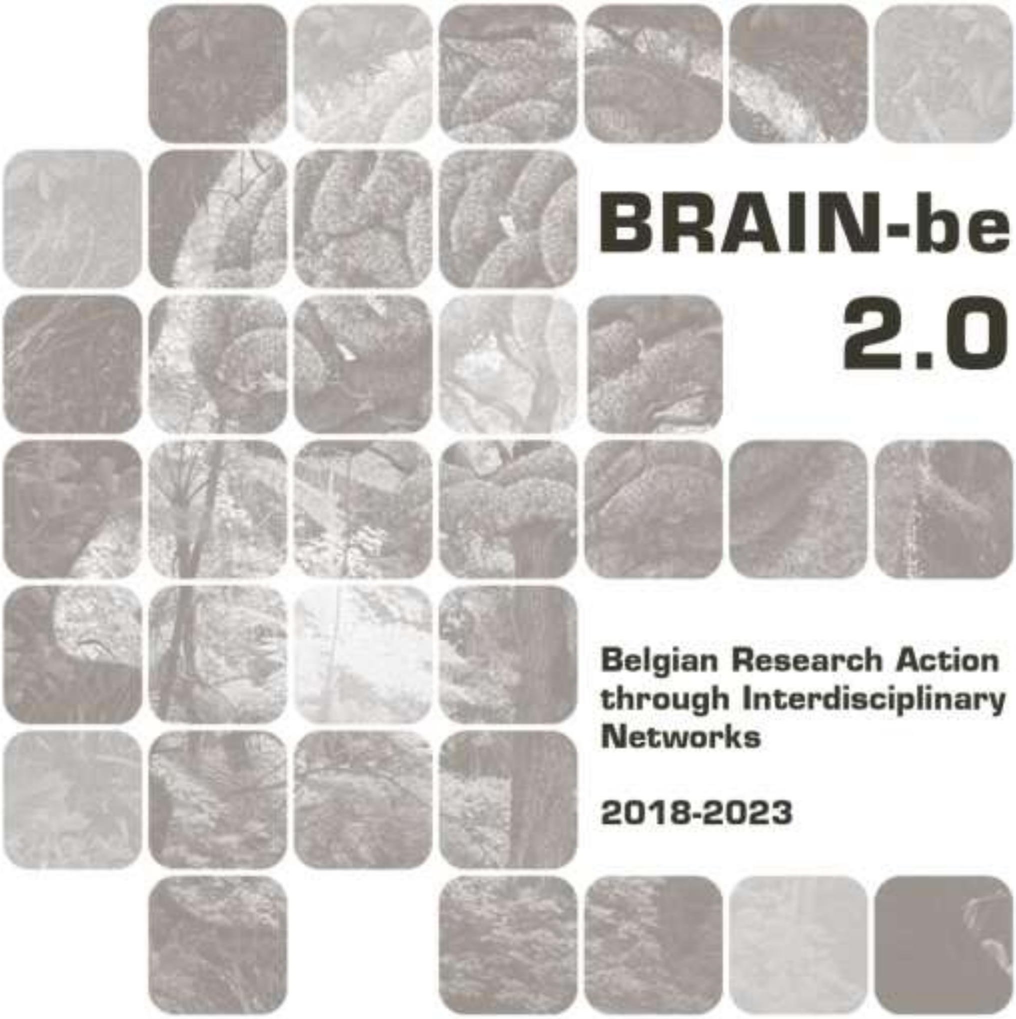

NITROPOL
Impact of Nitrogen Deposition on Pollen Allergy

NITROPOL-BE

Impacts of nitrogen deposition in the natural environment on pollen allergy in Belgium

Aerts Raf (Sciensano) – Bruffaerts Nicolas (Sciensano) – Devleesschauwer Brecht (Sciensano) – Honnay Olivier (KU Leuven) – Linard Catherine (UNamur) – Schrijvers Rik (UZ KU Leuven) – Speybroeck Niko (UCLouvain) (Eds)

Pillar 1: Challenges and knowledge of the living and non-living world

NETWORK PROJECT

NITROPOL-BE

Impacts of nitrogen deposition in the natural environment on pollen allergy in Belgium

Contract - B2/212/P1/NITROPOL-BE

FINAL REPORT

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Submission date: 15 December 2025

Published in 2026 by the Belgian Science Policy Office
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Aerts R., Bruffaerts N., Castin E., Ceulemans T., Charalampous P., Daelemans R., Dendoncker N., Devleeschauwer B., Honnay O., Linard C., Nayani S., Schrijvers R., Smet S., Speybroeck N., Tiwari A., Verscheure P. ***Impacts of nitrogen deposition in the natural environment on pollen allergy in Belgium.*** Final Report. Brussels: Belgian Science Policy Office 2026 – 84 pp. (BRAIN-be 2.0 - (Belgian Research Action through Interdisciplinary Networks))

The NITROPOL logo on the cover was designed by Paulien Verscheure.

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ABSTRACT

Context

Environmental nitrogen pollution is rising globally and alters ecosystems by changing plant communities, productivity, and pollen characteristics. These ecological shifts may increase airborne pollen levels and enhance pollen allergenicity, potentially contributing to the growing burden of allergic diseases. Evidence suggests that nitrogen pollution affects both atmospheric and soil pathways, influencing pollen abundance, structure, and protein composition. Yet its specific impact on human allergy prevalence, severity, and well-being remains poorly quantified. Current environmental policies focus on biodiversity and respiratory health (NO_x) but overlook nitrogen-driven allergy risks.

Objectives

The project aimed to clarify how nitrogen pollution influences pollen exposure, allergenicity, and allergy burden in Belgium. It sought to synthesize existing evidence, quantify ecological and immunological effects of nitrogen pollution on grass and birch pollen, and assess consequences for symptom severity and health-related quality of life. Additional objectives included evaluating nitrogen deposition as a population-level risk factor and exploring whether altered nitrogen availability affects allergenicity of plant-based foods.

Conclusions

Nitrogen enrichment consistently increased pollen abundance, altered pollen traits, and heightened allergenic potential across grass and birch species. High-nitrogen environments yielded more protein-dense pollen with stronger immunoreactivity, and in birch, such pollen were markedly smaller. Pilot food-allergy experiments further indicated nitrogen-driven changes in allergen profiles. A large Belgian survey confirmed substantial health-related quality of life impacts from pollen allergy symptoms, but with nitrogen showing only minimal direct associations. Collectively, the findings provide converging evidence that nitrogen pollution indirectly increases allergy risks, underscoring the need to widen the scope of nitrogen reduction policies beyond biodiversity conservation to explicitly include the protection of public health.

Keywords

Allergic disease, Environmental pollution, Nitrogen deposition, Pollen allergy, Respiratory health

Note

The original project title, as listed in the contract and technical specifications, was ‘Impacts of nitrogen deposition in the natural environment on pollen allergy *and respiratory infection outcomes* in Belgium’. Respiratory infection outcomes were included in the proposal in response to the COVID-19 crisis. As subsequent evidence indicated that COVID-19 infection patterns could not be directly linked to environmental exposures, the performed research activities and therefore the final report focus solely on allergy, and the reference to respiratory infection outcomes has been removed from the title.

MeSH (MEDICAL SUBJECT HEADINGS)

Publication types

Opinion Article
Scoping Review
Comparative Study

MeSH terms

Adult
Air Pollution / adverse effects
Allergens* / adverse effects
Allergens* / immunology
Belgium / epidemiology
Cross-Sectional Studies
Ecosystem
Food hypersensitivity
Grassland
Humans
Hypersensitivity / epidemiology
Hypersensitivity / etiology
Immunoglobulin E*
Nitrogen* / analysis
Pollen*
Pollen* / immunology
Rhinitis, Allergic, Seasonal* / epidemiology
Rhinitis, Allergic, Seasonal / etiology
Rhinitis, Allergic, Seasonal* / immunology

Substances

Nitrogen
Allergens
Immunoglobulin E

1. INTRODUCTION

Allergic diseases represent a growing public health challenge, with their rising burden shaped by complex interactions between environmental change and modern lifestyles. The NITROPOL-BE project was established to investigate whether environmental nitrogen pollution—stemming from atmospheric deposition linked to agricultural emissions, combustion processes, and excessive fertilization—acts as an overlooked driver of increasing pollen allergy prevalence and symptom severity. Nitrogen enrichment can alter plant community composition and productivity, potentially increasing the abundance of allergenic species and airborne pollen. It may also modify the biochemical properties of pollen itself, thereby influencing allergen potency. Together, these pathways could contribute to a heightened allergy burden. The project therefore aimed to quantify how nitrogen pollution affects allergenic plant communities, pollen biochemical traits, and downstream allergenicity and symptoms, providing evidence needed to better understand, prevent, and manage nitrogen-related allergy risks. These insights are intended to inform environmental policies that currently mainly focus on direct respiratory effects of NO and NO_x and/or biodiversity conservation but notyet on allergy, ultimately supporting both ecosystem resilience and the habitability of nitrogen-impacted regions, both major challenges of the living world.

2. STATE OF THE ART AND OBJECTIVES

Main findings of past research

Allergic rhinitis, conjunctivitis, and bronchial asthma are widespread manifestations of allergy (Gilles et al. 2018) and pose a substantial public health burden due to their high prevalence, chronic impact on daily functioning, and effects on mental well-being (Lake et al. 2017). Allergy prevalence has increased globally over recent decades (Brożek et al. 2017; D'Amato et al. 2007; D'Amato et al. 2016; Gilles et al. 2018; Newson et al. 2014). In Belgium, the proportion of individuals aged 15 years and older reporting allergies rose from 12.7% in 1997 to 14.2% in 2013, reaching 20.3% in women and 17.0% in men by 2018. This upward trend is expected to continue as environmental and lifestyle changes intensify (D'Amato and Cecchi 2008; Reinmuth-Selzle et al. 2017; Gilles et al. 2018).

Global environmental change affects aeroallergens and the prevalence of respiratory allergic disease by altering plant distributions, pollen quantities, pollen allergenicity, the timing and duration of pollen seasons, and pollen dispersal patterns (Beggs 2004; D'Amato and Cecchi 2008; Barnes 2018; Demain 2018). Rising temperatures have driven long-term shifts in pollen seasons (Ziello et al. 2012; Bruffaerts et al. 2018; Hoebeke et al. 2018; Ziska et al. 2019), while elevated ozone and CO_2 concentrations have been shown to modify allergenic properties of pollen in grasses and trees (D'Amato et al. 2007; Beck et al. 2013; Buters et al. 2015; Kim et al. 2018). These changes expose individuals with pollen allergy to higher and potentially more potent pollen loads over longer periods, increasing symptom severity and societal costs. Pollen exposure can also heighten susceptibility to respiratory infections by weakening innate antiviral defenses (Gilles et al. 2020), hereby posing secondary health risks by increasing the risk of viral dissemination during uncontrolled hay fever (Scadding et al. 2020).

Existing gaps of past research

Environmental nitrogen pollution represents a potentially important yet underexplored driver of escalating aeroallergen levels and allergy prevalence. Nitrogen inputs from fossil fuel combustion and intensive fertilizer use have enriched terrestrial ecosystems (Galloway et al. 2008; Peñuelas et al. 2012), posing mounting risks to environmental and human health (Kanter et al. 2020). In the Atlantic biogeographic region, chronic atmospheric nitrogen deposition ranges from 2.4 to 43.5 kg N ha^{-1} yr^{-1} (Stevens et al. 2010), with the highest levels typically found near major agricultural and industrial zones (Schaap et al. 2017). In Belgium, exposure to excessive nitrogen loads increases sharply from southeast to northwest. The ecological consequences of nitrogen enrichment include biodiversity loss, altered species distributions, ecosystem simplification, and reduced ecosystem service provision (Tilman et al. 2001; Wang et al. 2018). Enrichment generally increases productivity while reducing plant species richness, favoring dominance by a few competitive species (Bobbink et al. 2010; Damgaard et al. 2011; Ceulemans et al. 2014). Across Atlantic acid grasslands, plant species richness declined by 21.7% per 10 kg additional nitrogen deposition ha^{-1} yr^{-1} (Stevens et al. 2010). These shifts in nitrogen availability, plant community composition, and productivity may influence airborne pollen distributions, abundance, and allergen potency. Consequently, nitrogen deposition may exert both direct and indirect effects on aeroallergens and allergy burden (see Figure 1), yet its health impacts remain poorly understood (Johnson et al. 2010; Erisman et al. 2013; Kanter et al. 2020).

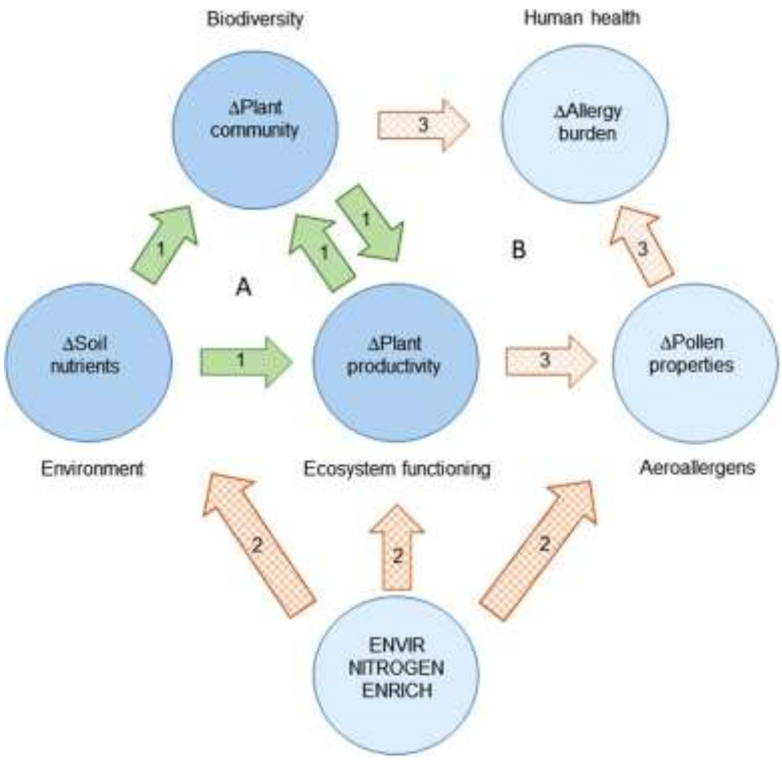

Figure 1*. *Environmental nitrogen pollution and the burden of allergic disease *in the light of environment, biodiversity, and ecosystem functioning. (**A**) Under the present "biodiversity-ecosystem functioning" paradigm, biodiversity and environmental variation drive ecosystem functioning, such as plant productivity (arrow set 1). (**B**) Environmental nitrogen pollution may drive changes in the burden of pollen allergies through a combination of direct changes (arrow set 2) and indirect changes (arrow set 3) in the abiotic environment, plant species composition, plant productivity, airborne pollen species composition and abundance, and, importantly, allergen potency. Adapted from Figure 1 in Ceulemans et al.* Front Allergy. 2023;4:1063982. *Published 2 February 2023. doi:10.3389/falgy.2023.1063982*

Objectives

This project aimed to assess the impact of nitrogen pollution on pollen allergenic properties of grass and birch species, their in-vitro allergenic effect, and the contribution of environmental nitrogen pollution to the burden of respiratory allergic disease in Belgium. The project aimed to inform policy to facilitate the development of measures aimed at reducing nitrogen-related health risks.

The specific objectives were to:

1. Identify the mechanisms through which nitrogen enrichment may affect pollen allergy prevalence along a national nitrogen deposition gradient, focusing on plant community composition, airborne pollen abundance, and pollen species composition.

2. Determine how nitrogen enrichment alters pollen abundance and allergen potency in key allergenic grass and tree species.

3. Assess allergen-specific IgE reactivity to environmentally collected pollen in a cross-sectional sample of allergic patients.

4. Quantify the burden of allergic disease attributable to nitrogen enrichment using validated health status and well-being instruments and a disability-adjusted life year (DALY) framework.

5. Evaluate the health care costs and benefits associated with future nitrogen deposition scenarios under alternative environmental and health policy pathways.

Policy relevance

This project was closely aligned with the overarching objectives of Pillar 1A (thematic part) of the BELSPO call, addressing key research needs in support of biodiversity protection, ecosystem service preservation, natural environment safeguarding, and natural risk assessment. It directly supported the habitability thematic priority by advancing understanding of how people interact with their environment—including biodiversity loss, nutrient-driven soil pollution, and air pollution—and by improving the assessment, evaluation, and management of environmental risks to public health, particularly those related to pollen allergies and respiratory infections. Through its focus on environmental change and human health, the project contributed to sustaining long-term habitability in a context of global change, fully reflecting the thematic priority of the call.

The project also supported several major international biodiversity policies. It contributed to Aichi Target 14 of the Convention on Biological Diversity by strengthening the evidence base on links between biodiversity and health, thereby supporting the health and well-being of communities dependent on local ecosystem goods and services. In addition, it advanced the goals of the EU Biodiversity Strategy, particularly Target 2, Actions 5 and 6, by generating knowledge relevant to mapping health-related ecosystem services and by identifying opportunities to optimize green environments for improved human health outcomes.

Expectations in terms of policy maker recommendations

The NITROPOL-BE project generated robust scientific evidence that may be used to support the development of policy guidance across environmental, health, and land-use domains. By clarifying how nitrogen enrichment alters plant communities, airborne pollen emissions, and pollen allergenicity, the project produced a foundation that may inform evidence-based measures aimed at reducing allergy-related health burdens. The experimental components, which enabled causal inference, strengthened the credibility of this evidence and may allow policymakers to draw on demonstrable mechanisms rather than associations alone. Building on these insights, the project results may be used to inform recommendations for the management of public and private green spaces to better safeguard respiratory health. This includes the identification of biodiversity-oriented land-use practices that may mitigate ecosystem shifts known to exacerbate allergy burdens. Such guidance may support planners, land managers, and environmental authorities in designing green environments that confer health benefits while reducing unintended allergenic impacts. In addition, the project's findings may serve as a basis for integrating allergy-risk considerations into environmental health assessments, enabling health professionals and local authorities to identify higher-risk areas and advise patients and stakeholders accordingly. Enhanced awareness and targeted prevention informed by this evidence may help reduce symptom severity, lower the societal and economic burden of allergic disease, and promote healthier interactions between people and their environments.

3. METHODOLOGY

Work package structure

The project deployed seven work packages to achieve the desired objectives. Each work package accomplished its own specific objectives and generated its own publishable outputs, while also contributing to the achievement of results in downstream work packages (see Fig. 2). The Sciensano Health Impact Assessment team assumed overall responsibility for coordination and data management of the NITROPOL-BE project and fulfilled the roles of project coordinator and data manager (WP0, WP6).

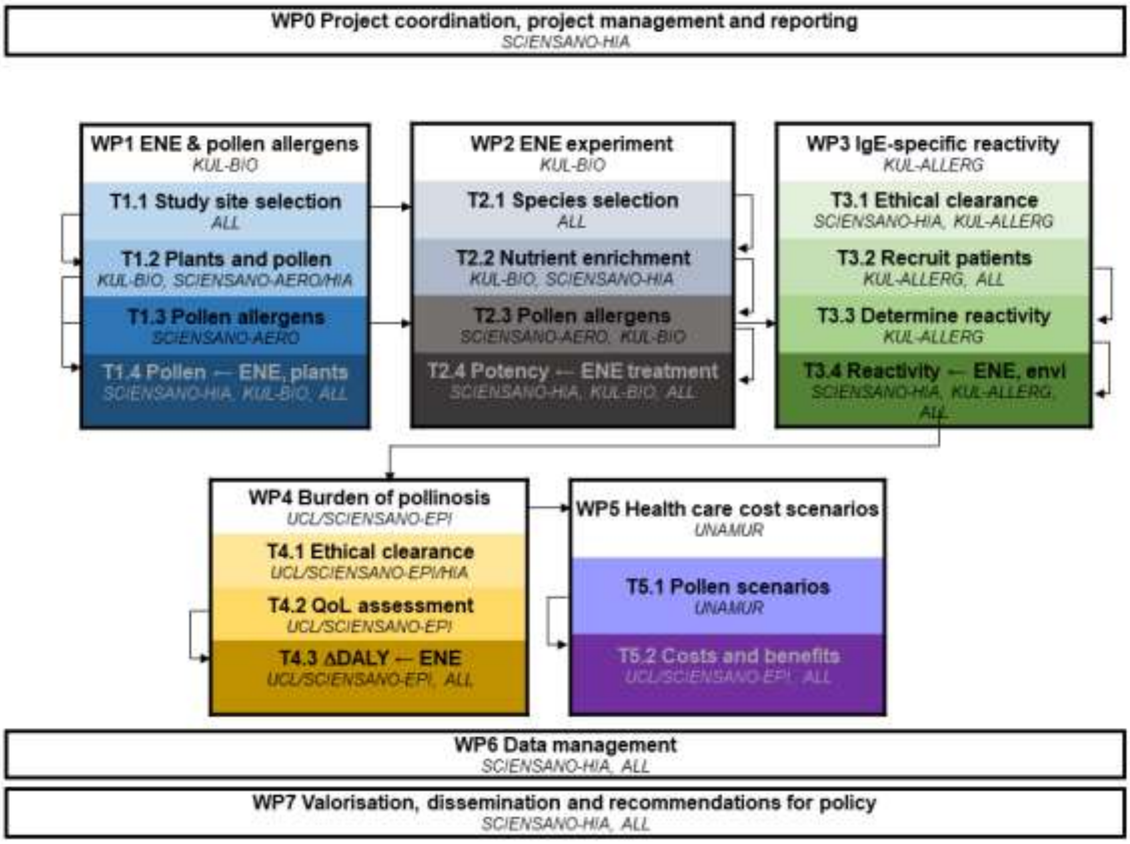

Figure 2. Work packages of the NITROPOL-BE project *(WP), with an indication of individual tasks (T), showing the interrelationships between the work packages and tasks, and responsible WP and T leaders. Tasks with the ← symbol indicate modelling tasks that link work package endpoints (allergy prevalence, pollen abundance and potency, allergen-specific IgE reactivity, and quality of life) to environmental nitrogen enrichment (ENE).*

Materials and methods

To evaluate the impact of nitrogen enrichment on pollen allergy, we integrated evidence from a scoping review, a detailed survey of grasslands in a study area in Flanders, an international birch pollen sampling campaign across Europe, experimental studies in a clinical cohort in a university hospital setting, and a nationwide electronic survey of pollen allergy patients. Grassland sites were selected to span a gradient of fertilized and unfertilized conditions. Birch pollen sampling sites across Europe were selected by expert partners in the European aerobiology community and represented an atmospheric nitrogen deposition gradient. Recruitment for the electronic survey targeted individuals with pollen allergies, although participation ultimately relied on self-selection.

Scoping review

A scoping review was conducted to map existing evidence on nitrogen-driven effects on plant communities, pollen abundance, pollen properties, and allergy outcomes. The protocol was drafted and reported according to PRISMA-ScR guidelines. Literature searches were performed in PubMed, Embase, Web of Science Core Collection, and Scopus, including manuscripts published between January 1, 2001, and August 31, 2022. Search strategies used MeSH or Emtree terms, and results were exported to Endnote for deduplication. Titles and abstracts were screened for relevance, followed by full-text review, with additional publications identified via reference snowballing. Non-English, non-peer-reviewed, inaccessible publications, and review articles (except for reference screening) were excluded. Data were extracted into a pre-designed table including study characteristics, pollen and allergen measures, nitrogen exposure type, population, and outcomes. Nitrogen effects were categorized as impacts on pollen properties, allergenicity, patient responses, symptoms, disease prevalence, or pollen-producing plant taxa. The scoping review provided a comprehensive overview of knowledge gaps and mechanistic hypotheses, informing the field and experimental studies.

Clinical cohort studies

A monocentric, cross-sectional study recruited adult allergic patients and non-allergic controls, confirmed by skin prick testing and clinical ImmunoCAP. Ethical approval was granted by the Ethical Committee Research of UZ/KU Leuven (S65184; Belgian Reg. B3222021000626). Participants provided serum and whole blood for basophil activation testing (BAT) and sIgE measurement against environmental and experimentally enriched pollen. Each participant served as their internal control for comparisons of pollen from different nitrogen environments. Statistical analyses included paired t-tests or Wilcoxon matched-pairs tests and linear mixed models incorporating nitrogen deposition, pollen protein content, pollen size, and random effects for subject and extract IDs.

For grass pollen, a cross-sectional paired comparison study was performed (Fig. 6), examining differences between nitrogen-enriched (fertilized) and non-enriched common semi-natural grasslands in Belgium. Pollen from paired grasslands (n=50, enriched (n=25) vs non-enriched (n=25)) based on their common geography, were sampled following a standardized protocol. Grassland pollen abundance was quantified, and pollen species composition was determined via DNA sequencing. Pollen allergenicity was assessed using basophil activation testing (BAT) and specific IgE (sIgE) measurements in a cross-sectional sample of grass pollen-allergic adult patients (n = 20). BAT outcome measures included area under the curve (AUC), maximal reactivity (CD63max), and half maximal effective concentration (EC50).

For birch pollen, a 3-year cross-sectional study (within-patient comparison) was conducted to evaluate birch pollen and its allergenicity. Paired samples from predicted low (pLow) and high (pHigh) nitrogen sites in Belgium (2022, n=66), and samples across an environmental nitrogen deposition gradient in Europe (2023, n=98; 2024, n=16) were collected (Fig. 9). After quality control, selected samples were extracted and used for further testing. Immunoreactivity was assessed with basophil activation testing, specific IgE measurement, and immunoblotting in birch pollen-allergic adult patients (n=80). Pollen characteristics were assessed with proteomics and digital holography.

Burden of allergy assessment

The burden of allergic disease attributable to eutrophication was analyzed by examining whether indicators of health-related quality of life, psychological well-being, and symptom duration varied across the Belgian nitrogen deposition gradient among adults with pollen allergy symptoms. A cross-sectional, web-based survey was administered between March and September 2023 to individuals aged 18 years or older residing in Belgium who self-reported a pollen allergy. The questionnaire captured demographic, lifestyle, and clinical characteristics, including age, gender, education, smoking status, physical activity, symptom type and severity, medication use, and physician-diagnosed asthma. Atmospheric nitrogen deposition values aggregated at the postal-code level for 2023 were obtained from the European Monitoring and Evaluation Programme. Five severity indicators were evaluated. Quality of life was measured using the EQ-5D-5L, which comprises five dimensions with five response levels. Each dimension was dichotomized into “any problem” versus “no problem” and analysed using logistic regression models. The EQ-5D-5L index, calculated using Belgian population norms, and the EQ-VAS score (0–100) were analysed using linear regression. Psychological well-being was assessed using the GHQ-12, scored with the bi-modal method (0–0–1–1), providing a total score from 0 to 12; GHQ-12 scores were analysed using linear regression. Symptom duration (categorised as <4 days/week, 4 days/week, or >4 days/week) was examined using logistic regression models. All models were adjusted for gender, age, region, educational attainment, employment status, smoking, physical activity, pollen-allergy symptoms, nitrogen deposition, medication use, and physician-diagnosed asthma.

Novelty of the methods

The NITROPOL-BE project introduced a uniquely integrated, multi-scale methodological framework that had not previously been applied to study the links between environmental nitrogen enrichment, airborne allergens, and allergic disease. Its novelty derives from the combination of several methodological advances across ecology, molecular biology, clinical immunology, and epidemiology. The project implemented broad ecological sampling along a quantified nitrogen deposition gradient in Belgium and across the EU, paired with standardized vegetation surveys, enabling the first systematic assessment of how nitrogen enrichment shapes airborne pollen abundance and species composition at the landscape scale. The use of DNA metabarcoding (Illumina ITS2) for airborne pollen identification provided unprecedented taxonomic resolution, allowing detection of nitrogen-related changes in pollen assemblages that are invisible to traditional field work or microscopy. Quantification of allergen proteins, including Bet v 1 and Phl p 5, in environmentally collected pollen via double-sandwich ELISA represented a novel molecular approach to measuring real-world allergen potency in relation to nitrogen deposition.

A further methodological innovation was the combination of environmental sampling with controlled nitrogen-enrichment experiments, which allowed causal inference by isolating nitrogen effects on pollen production and allergenicity and bridging a long-standing gap between observational ecology and mechanistic plant physiology. The project also integrated a monocentric clinical study linking environmental exposures directly to human immunological responses, incorporating allergen-specific IgE quantification, dot/slot blot and immunoblot analyses, basophil activation testing, and standardized skin prick testing, a combination of assays not previously applied to assess nitrogen-related modulation of pollen allergenicity. Clinical immunological data were further combined with population-based health metrics, enabling multi-dimensional assessment of symptom severity, quality-of-life loss, and functional impairment.

Chronology and difficulties encountered

A comprehensive chronology of the activities conducted to achieve the project objectives is provided in Annex 1. As is typical for a complex, multidisciplinary initiative such as NITROPOL, challenges arose despite meticulous planning and the inclusion of contingency measures. The principal problems and difficulties encountered, together with an evaluation of these issues in the context of the a priori identified project risks, are documented in Annex 3.

4. SCIENTIFIC RESULTS AND RECOMMENDATIONS

Synthesis of existing evidence of nitrogen-driven effects on allergy outcomes

A total of 59 studies met the inclusion criteria after screening 14,398 initial records. Most included articles were conducted in Europe, with a clear rise in publications over the past decade, peaking in 2021. Figure 3 shows that the vast majority of studies examined airborne nitrogen pollution (Fig. 3A) and its effects on pollen, pollen allergens, or pollen-allergic patients (Fig. 3B), making this the dominant research focus. In contrast, impacts of soil (6.8%) and water (5.1%) nitrogen pollution on pollen allergy were only marginally represented (Fig. 3A). Several studies assessed multiple pollution types or pollen outcomes. The most frequently investigated pollen taxa, varying by region, included birch, timothy-grass, ragweed, plane, pine, and hop—primarily wind-pollinated species relevant for respiratory allergies (Fig. 3C).

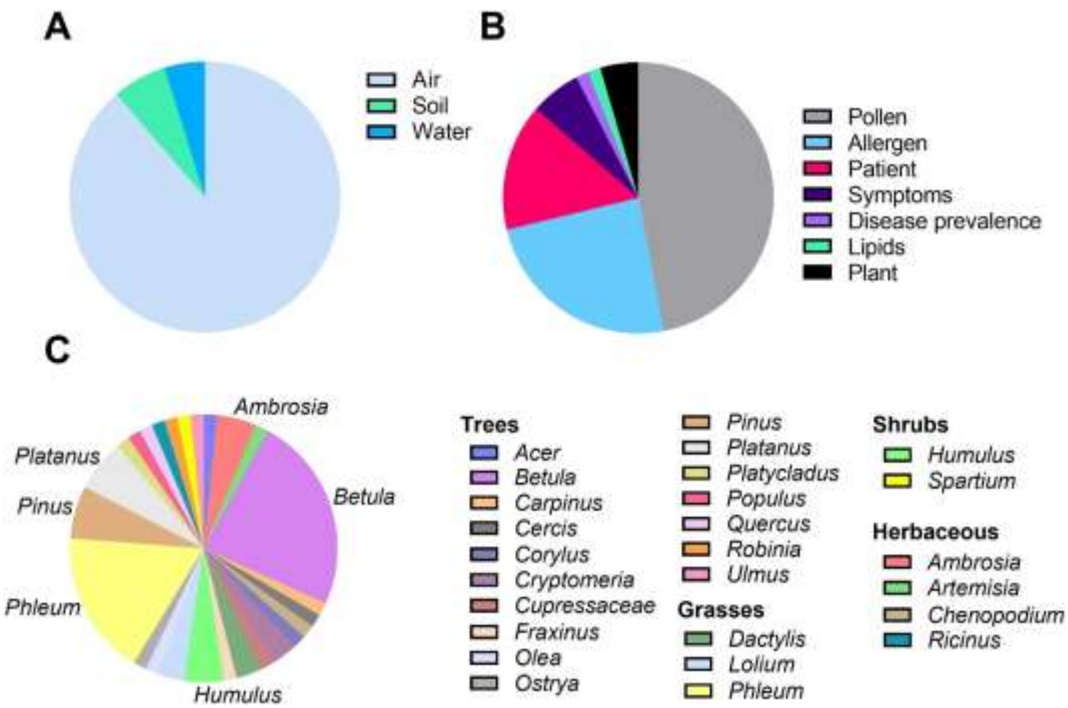

Figure 3. Articles investigating associations between nitrogen pollution, pollen, and allergy *published between 2001 and 2022 in international peer-reviewed journals according to (**A**) the source of nitrogen pollution investigated, (**B**) the parameter used to measure the nitrogen impact, and (**C**) the pollen taxa investigated. Adapted from Figure 4 in Verscheure et al.* Sci Total Environ*. 2023;893:164801. Available online 14 June 2023. doi:[10.1016/j.scitotenv.2023.164801](https://doi.org/10.1016/j.scitotenv.2023.164801)*

Most of the studies that examined airborne nitrogen pollution focused on the effects on pollen (31 studies), followed by research on specific pollen allergens (15 studies) and on patient responses, symptoms, or disease prevalence (14 studies); only a few addressed multiple aspects simultaneously (Fig. 4). Many studies assessed nitrogen pollution within a broader mixture of co-occurring atmospheric pollutants, while others isolated nitrogen compounds experimentally. The nitrogen pollutants most frequently investigated were NOx, particularly NO_2 and NO, alongside additional pollutants such as ozone, sulfur dioxide, and sulfate. Overall, the studies primarily evaluated how atmospheric nitrogen exposure influences pollen characteristics and allergenic potential.

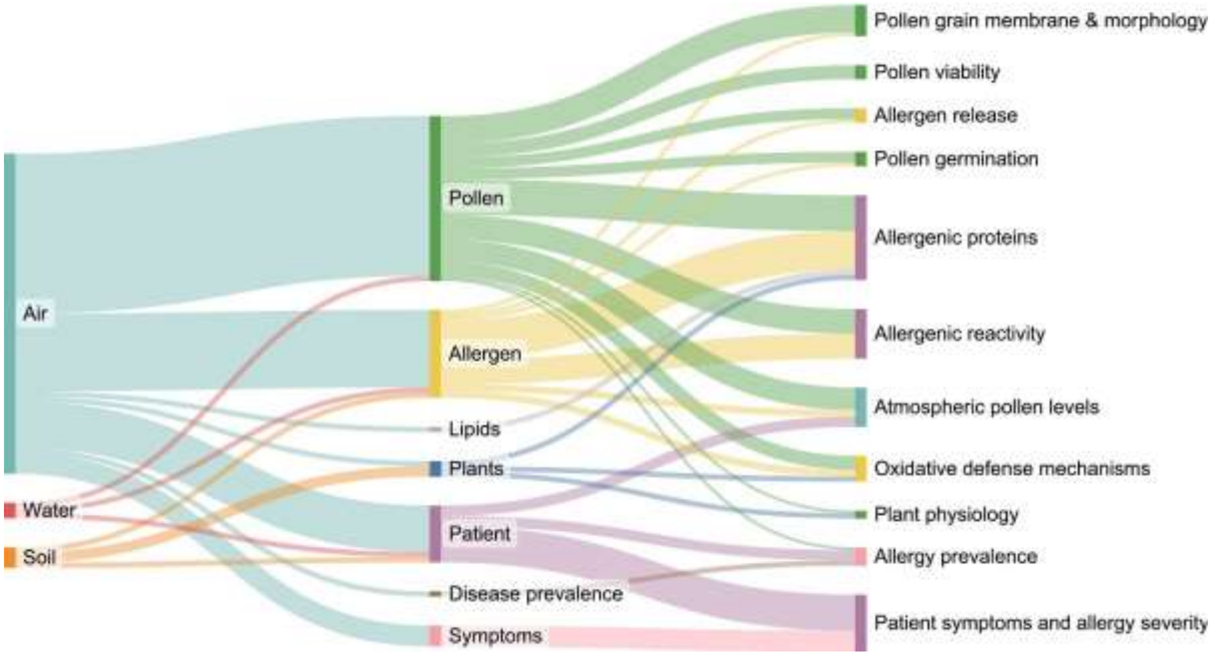

Figure 4. Evidence mapped in the scoping review on plant and human responses to nitrogen pollution*, structured by the environmental compartment affected (air, water, or soil) and the indicators used to quantify nitrogen impacts (pollen, allergen, lipids, etc.); the width of each flow reflects the number of studies contributing to that linkage. Adapted from Figure 5 in Verscheure et al. Sci Total Environ. 2023;893:164801. Available online 14 June 2023. doi:10.1016/j.scitotenv.2023.164801*

Our scoping review demonstrates that atmospheric nitrogen pollution influences multiple mechanisms relevant to pollen allergy (Fig. 5). Evidence across the included studies shows effects on pollen abundance (Fig. 5, top panel), likely linked to shifts in biodiversity and plant productivity, as well as alterations in pollen morphology and membrane integrity, which can modify allergen release and several other processes (Fig. 5, central panel). Nitrogen pollution was also associated with changes in pollen viability and germination. Several studies demonstrated modifications in allergenic properties, including impacts on oxidative defence pathways, allergenic proteins, and immune-modulatory mediators—affecting their structure, expression, and reactivity. These mechanistic changes translated into differences in pollen-allergenic burden, with reported effects on patient symptoms, allergy severity, and allergy prevalence (Fig. 5, bottom panel).

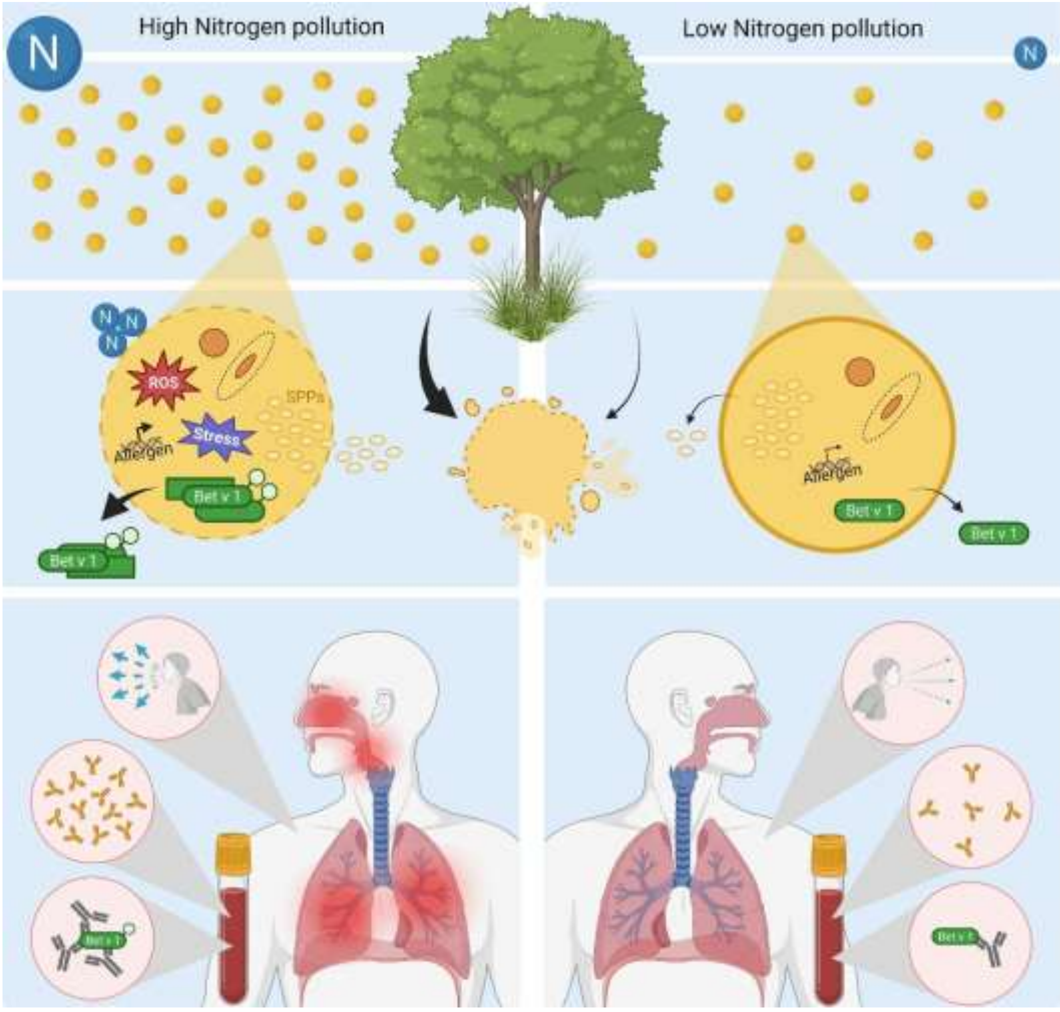

***Figure 5. Potential impact of nitrogen pollution on pollen and their allergenic activity**. High nitrogen pollution concentrations can lead to higher emissions of airborne pollen (**upper panel**), and result in changes such as thinner pollen cell wall, more pollen damage, attachment of pollutant particles on the surface, a greater degree of oxidative stress, increased sub-pollen particle (SPP) release, increased amount of allergenic proteins and increased release of allergenic proteins, post-translational modifications and structural changes of allergenic proteins, upregulation of stress-related genes and proteins, and enhanced allergenic transcript amounts (**middle panel**). These changes can affect the allergenic reactivity in humans via: increased irritation of the airway mucosa which facilitates pollinosis, increased sensitization, and allergic rhinitis prevalence, higher sIgE levels, and higher IgE recognition (**bottom panel**). Adapted from Figure 6 in Verscheure et al.* Sci Total Environ. *2023;893:164801. Available online 14 June 2023. doi:10.1016/j.scitotenv.2023.164801*

Taken together, the evidence reviewed shows that atmospheric nitrogen pollution affects pollen allergy through multiple, interacting pathways. Overall, the most consistently reported effects include increases in airborne pollen emissions, structural and membrane alterations of pollen grains, enhanced allergen expression and release, and greater allergenic reactivity, all of which contribute to heightened symptoms and disease burden in patients. Much of this evidence comes from studies examining nitrogen in combination with other pollutants, reflecting real-world exposure but complicating efforts to isolate nitrogen-specific effects. Experimental work using nitrogen alone provides clearer insights, although exposure levels in some studies exceed typical environmental concentrations, limiting their relevance.

Variability in pollutant mixtures, exposure levels, environmental conditions, and pollen taxa contributes to inconsistent findings, and some evidence suggests species-dependent or region-specific responses. Nitrogen pollution may exert both direct effects on airborne pollen and indirect effects via nitrogen deposition and soil enrichment, with plants responding differently to elevated nitrogen availability. Mechanistic studies also highlight the role of protein nitration, though differences in nitration methods and conditions may lead to divergent allergenic outcomes.

Evidence for the effects of soil and water nitrogen pollution on pollen allergy remains sparse, particularly regarding plant-level (pre-production) processes that precede pollen release. Because of the diversity of pollutants, mechanisms, and study designs, a quantitative synthesis was not feasible, and substantial heterogeneity and background “noise” in the literature remain. Nonetheless, the collective findings demonstrate that nitrogen pollution contributes to pollen allergenicity and related health impacts through multiple, overlapping, and context-dependent mechanisms.

Ecological and clinical evidence of nitrogen enrichment impacts on pollen allergy

Multiple pathways link nitrogen pollution to grass pollen allergy burden

Across 25 paired grassland sites (Fig. 6), nitrogen enrichment produced consistent and marked ecological and aerobiological shifts. Fertilized grasslands exhibited significantly altered plant community composition (Fig. 7A), with grasses nearly doubling in mean cover relative to unfertilized plots and with a concomitant decline in plant species richness, in line with earlier evidence from studies focused on species composition shifts following nitrogen enrichment of habitats (Fig. 7C). Biomass production and nitrogen uptake increased by more than 70% under fertilization, reflecting strong productivity responses (Fig. 7C). Standardized pollen sampling demonstrated that airborne pollen abundance was more than six times higher in fertilized than in unfertilized grasslands (Fig. 7C), and DNA metabarcoding confirmed significant shifts in the taxonomic composition of airborne pollen assemblages (Fig. 7B). These differences were robust across most grassland habitat types, indicating that nitrogen enrichment consistently amplified both vegetation dominance patterns and pollen release dynamics. It must be noted that grasslands under agriculture were not within the scope of this study.

The clinical component included 20 eligible patients with confirmed grass pollen allergy (the sample size constrained by work load per patient, not by the amount of eligible patients recruited and available), the majority of whom were polysensitized and symptomatic during both spring and summer. Basophil activation testing demonstrated dose-dependent responses in all participants, with consistently higher reactivity to pollen derived from nitrogen-enriched grasslands at intermediate and high allergen doses (Fig. 8A, one patient; Fig. 8B, all patients). Compared with unfertilized pollen, fertilized pollen elicited greater basophil activation (higher AUC and maximal CD63 expression) (Fig. 8C), substantially enhanced basophil sensitivity (lower EC50 and higher CDsens) (Fig. 8C), and broader IgE-mediated recognition in immunoblot assays (Fig. 8D). Allergen-specific IgE concentrations were approximately 30% higher for fertilized than for unfertilized pollen extracts, and patients reacted to a wider array of proteins in the enriched samples. Stratified analyses further indicated that these effects were particularly pronounced for fen meadows and grass heaths (Fig. 8E). Together, these results show that nitrogen enrichment intensifies pollen production, alters pollen taxonomic profiles, and increases the allergenic potency of airborne pollen in sensitized individuals.

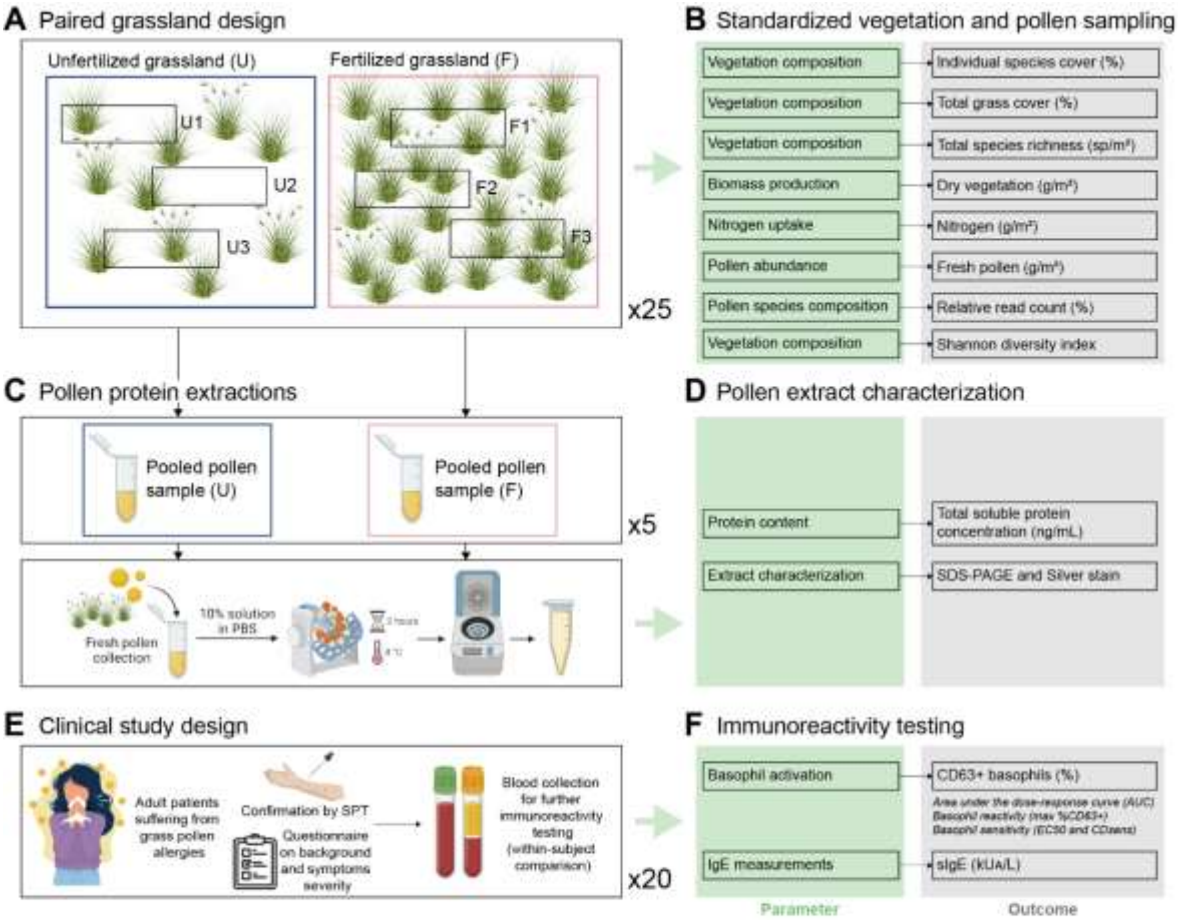

Figure 6. *Schematic presentation of the grass pollen study design. (**A**) Paired pollen sampling design. U1-U2-U3 and F1-F2-F3 represent the three transects in each unfertilized (U) or fertilized (F) grassland. In total, 25 grassland sites were sampled, each containing one pair of grasslands (n=50), including Fen Meadows (n=18), Grass heaths (n=16), and Hay Meadows (n=16). (**B**) Different parameters derived from each sampled transect and their outcome variable (**C**) A subset of pollen samples (n=10) was processed for inclusion in the clinical study. Pollen samples from all transects were pooled per grassland and a standardized extraction protocol was used to make total soluble protein extracts. (**D**) Protein concentration was used for sample normalization and Sodium Dodecyl Sulfate Polyacrylamide Gel Electrophoresis for extract characterization. (**E**) Clinical study design, and (**F**) derived immunoreactivity parameters on extracts normalized for protein content. Abbreviations: SPT, skin prick test; sIgE, specific Immunoglobulin E; PBS, phosphate buffered saline. Adapted from Figure 1 in Daelemans, Verscheure et al.* Lancet Planet Health *2025;9: e294–303. Available online April 2025. doi:10.1016/S2542-5196(25)00060-9*

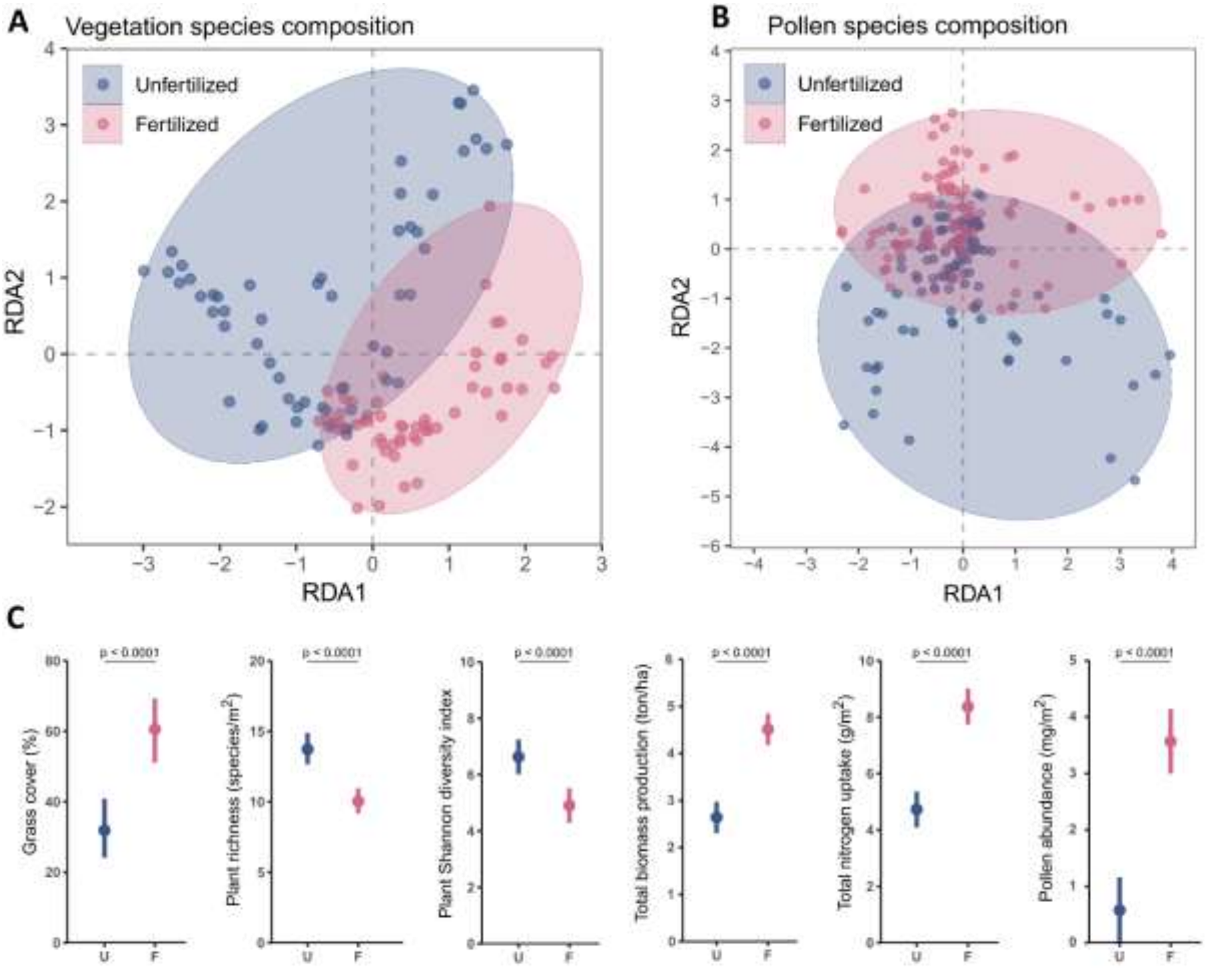

Figure 7. *Grassland vegetation and pollen characteristics**.** Redundancy analysis (RDA) biplots visualizing the plant species composition of the grasslands (**A**) and pollen samples (**B**). Points illustrate individual vegetation surveys or pollen samples, respectively. Points that are closer together are characterized by a more similar plant species composition. Colors and ellipses depict the fertilization status of the grasslands where samples were collected. (**C**) Estimated marginal means for grass cover (%), plant richness (species/m^2), plant Shannon diversity index, total biomass production (ton/ha), total nitrogen uptake (g/m^2), and pollen abundance (mg/m^2) for unfertilized (U) and fertilized (F) grasslands. Error bars show 95% CI. Adapted from Figure 2 in Daelemans, Verscheure et al.* Lancet Planet Health *2025;9: e294–303. Available online April 2025. doi:10.1016/S2542-5196(25)00060-9*

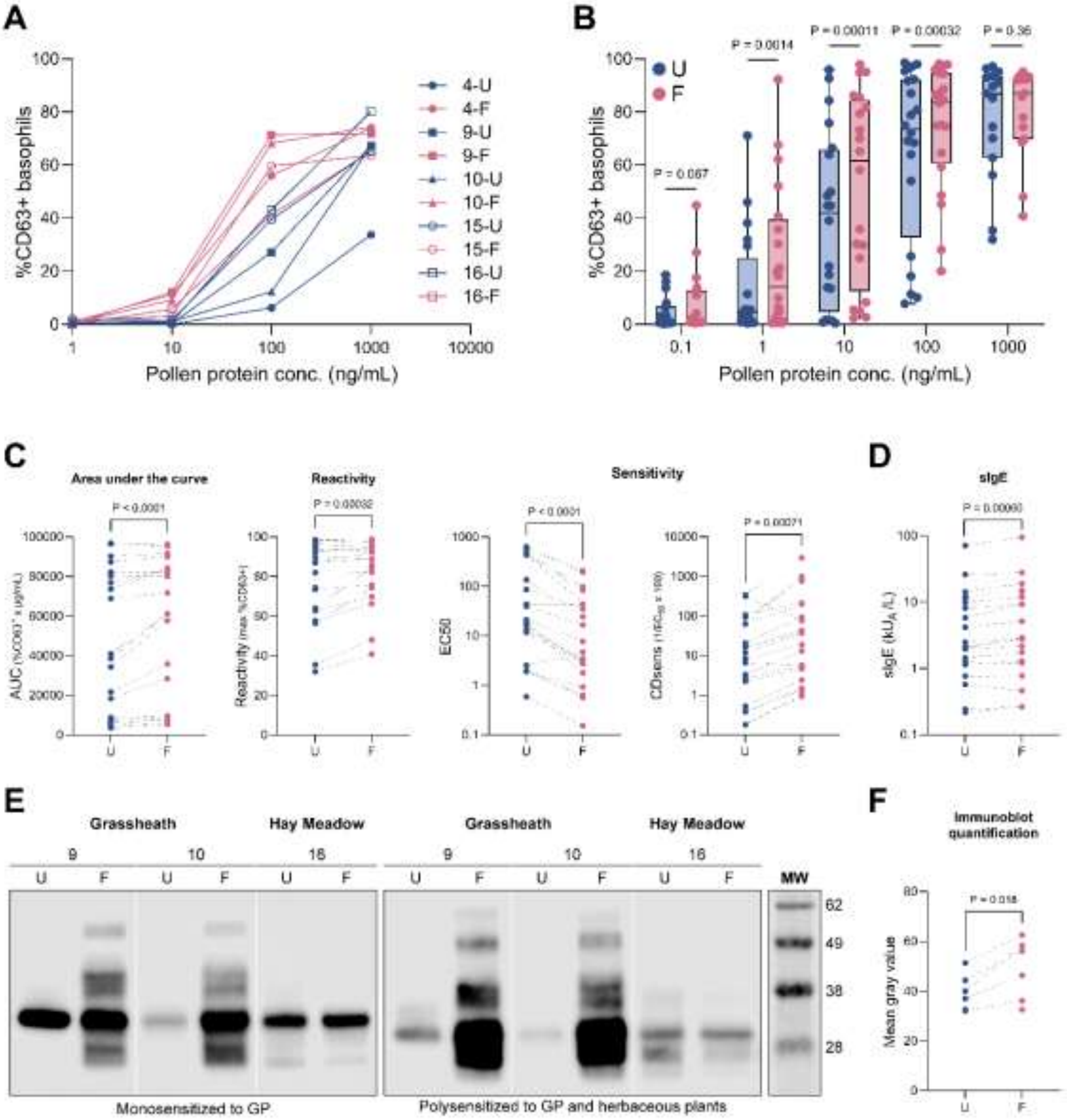

Figure 8. *Immunoreactivity of grassland pollen samples. (**A**) Exemplary dose-response basophil activation of all pollen samples tested on 1 patient included in the study, and (**B**) basophil activation of all included patients, measured as %CD63+ basophils (CD123+HLA-DR-; y-axis) and pollen protein concentration (ng/mL; x-axis) (0·1 ng/mL: p=0·067, 1 ng/mL: p=0·0014, 10 ng/mL: p=0·00011, 100 ng/mL: p=0·00032, 1000 ng/mL: p=0·36). Data is shown with boxplots showing median, interquartile range, and whiskers extending to the minimum and maximum values. (**C**) Area under the curve (AUC; p<0·0001), basophil reactivity (max %CD63+; p=0·0003), effective concentration 50% activation (EC50; p<0·0001), and CDsens (1/EC50*100; p=0·00071), between the unfertilized (U) and fertilized (F) group. (**D**) sIgE values in the U and F group (log10-transformed scale of the y-axis; p=0·00060; paired t-test of log_{10}-transformed data). (**E**) Comparison of allergenicity of two selected patients sensitized to grass pollen (GP) via immunoblot. (**F**) Immunoblot quantification shows mean gray values. Graph shows mean value of two (n=4) or three (n=2) pollen extracts. Differences between U and F groups were compared via a paired t-test. Dotted lines represent coupled measurements per patient. Wilcoxon matched-pairs signed rank test was used to determine significance unless stated otherwise. Adapted from Figure 3 in Daelemans, Verscheure et al.* Lancet Planet Health *2025;9: e294–303. Available online April 2025. doi:[10.1016/S2542-5196(25)00060-9](10.1016/S2542-5196(25)00060-9)*

BOX 1. Nitrogen enrichment intensifies grass pollen production, alters grass pollen taxonomic profiles, and increases the allergenic potency of airborne grass pollen in sensitized individuals (in vitro).

Key evidence:

Nitrogen-enriched grasslands produced significantly more pollen, with a 6·2-fold increase compared to their unfertilized counterparts. When normalized to protein content, pollen from these enriched grasslands showed increased allergenic potential, with 5·1 times higher BAT sensitivity and a 1·3-fold increase in sIgE titers compared with their unfertilized counterparts.

Interpretation:

Nitrogen enrichment substantially increased pollen abundance and allergenicity, indicating a heightened allergy burden in nitrogen-rich environments. These findings underscore the need for policies addressing nitrogen pollution to mitigate its public health impacts.

Implications for policy:

Evidence emphasizes the need for updated environmental and public health policies to address the growing issue of pollen allergy as a major public health concern. Together with atmospheric nitrogen pollution, ubiquitous ecosystem nitrogen enrichment can significantly worsen pollen allergies. To mitigate these health impacts, nitrogen emission regulations should not only take into account the direct ecological consequences of nitrogen pollution (biodiversity loss) but also its indirect health impacts (e.g. allergy DALYs). Future research should prioritize evaluating the effects of nitrogen pollution on the disease burden across entire populations on a larger spatial scale, assessing the healthcare costs and benefits of various nitrogen reduction scenarios within regional and national policy frameworks. Simultaneously, it is crucial to deepen our mechanistic understanding by further investigating the biochemical mechanisms linking nitrogen enrichment to pollen allergenicity. By integrating ecological changes with public health outcomes, this study provides crucial guidance for future research and policy actions.

Multiple pathways link nitrogen pollution to birch pollen allergy burden

Across three birch pollen seasons, the project enrolled 97 clinically confirmed birch-allergic patients, of whom 80 constituted the final analytic cohort, complemented by seven skin-test–negative controls. Participants were predominantly young to middle-aged adults with typical seasonal symptomatology (birch-pollen induced allergic rhinitis) and robust sensitization profiles. Pairwise field sampling in 2022 established controlled contrasts between predicted low- and high-nitrogen sites (Fig. 9A,C). Although these paired samples showed no differences in total or soluble protein content (Fig. 10A) or pollen size (Fig. 10B), functional assays revealed consistently heightened basophil reactivity and sensitivity to pollen from high-nitrogen environments (Fig. 10C, one patient; Fig. 10D, all patients), paralleled by elevated sIgE binding and increased abundance of the highly allergenic Bet v 1-A isoform (Fig. 10F).

Sampling across a broader European nitrogen deposition gradient in 2023–2024 (Fig. 9B) demonstrated systematic nitrogen-dependent shifts in birch pollen biochemistry (Fig. 11A), morphology (Fig. 11B-D), and immunogenicity (Fig. 11E). Increasing atmospheric nitrogen deposition was associated with reduced total protein content (Fig. 11A, left panel) but increased soluble protein fractions (Fig. 11A, central panel), enhanced protein releasability (Fig. 11A, right panel), and smaller pollen grains (Fig. 11B), with grain size inversely related to protein release capacity (Fig. 11C). Basophil activation outcomes and sIgE responses rose significantly with nitrogen deposition, an effect only partly attenuated by adjustments for soluble protein concentration. Interaction analyses indicated that nitrogen-driven reductions in pollen size and concomitant increases in protein releasability jointly amplified pollen allergenicity. Proteomic profiling further showed marked increases in total Bet v 1 with nitrogen deposition and selective enrichment of Bet v 1 isoforms with high or intermediate IgE reactivity (Fig. 11F). Nitrogen deposition was also strongly associated with greater catkin density (Fig. 11D), implying substantially higher landscape-level pollen production potential in more nitrogen-enriched regions. Collectively, these findings provided mechanistic evidence that atmospheric nitrogen deposition modifies birch pollen output, composition, and functional allergenicity in ways that may increase exposure and symptomatic burden for sensitized individuals.

BOX 2. Nitrogen enrichment intensifies birch pollen production, alters birch pollen grain size, and increases the concentration of potent allergenic proteins, triggering stronger immune responses in sensitized individuals (in vitro).

Key evidence:

Birch pollen from pHigh nitrogen sites showed increased immunoreactivity (EC5: pLow 181·2 ng/mL vs pHigh 177·6 ng/mL) and more Bet v 1-A compared with pollen from pLow nitrogen sites (pLow 10,387 vs pHigh 1,692). Pollen collected across high nitrogen deposition sites was associated with stronger immunoreactivity, higher catkin density, higher protein releasability, and smaller pollen size. A positive correlation between nitrogen deposition levels and Bet v 1 (r=048), and predominantly reactive isoforms, was observed.

Interpretation:

Our results demonstrate that pollen from high-nitrogen areas was more abundant, smaller, and contained more potent allergenic proteins, triggering stronger immune responses. These findings add to the evidence of nitrogen pollution's environmental impact by demonstrating it can also affect public health through increased allergenicity of airborne pollen.

Implications for policy:

Given the increasing global prevalence of pollen allergies, our findings highlight the urgent need for public health policies to address nitrogen pollution as an emerging environmental health threat. Further studies should investigate population-level impacts through large-scale epidemiological research, quantifying associated healthcare burdens and costs, and evaluating benefits from policy-driven nitrogen reduction. This research underlines the necessity of integrating ecological research into public health frameworks to better manage and mitigate allergy-related health outcomes. Additionally, studies are needed to further investigate the mechanism by which environmental nitrogen pollution can impact pollen allergenicity. This study is a crucial starting point to guide future research and policy actions and shows the importance of integrating ecological changes with public health outcomes.

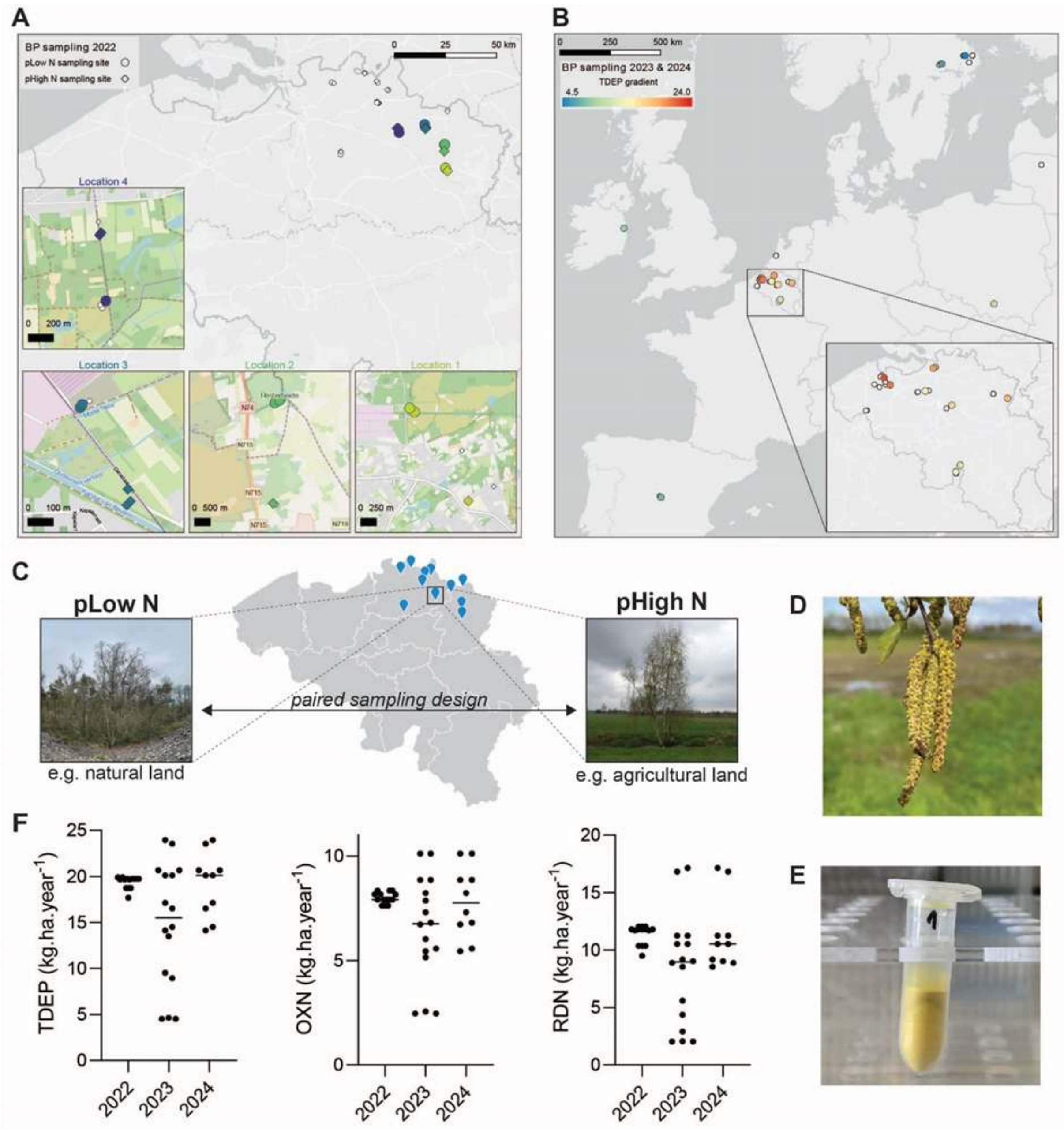

Figure 9. Birch pollen sampling design and sample characteristics of the birch pollen study. *Map showing the sampling locations of all paired sampling sites in Belgium (**A**) and all nitrogen gradient sampling sites along the European nitrogen deposition gradient (**B**). White dots indicate sampling sites that were not used for experimental testing. (**C**) Schematic representation of the paired sampling design of a predicted low nitrogen site (pLow nitrogen, e.g., unfertilized semi-natural land) and a predicted high nitrogen site (pHigh nitrogen, e.g., fertilized agricultural land). (**D**) Birch catkins used for pollen collection. (**E**) Eppendorf tube containing collected pollen grains for further experimental testing. (**F**) Nitrogen deposition gradient across the three consecutive pollen sampling seasons. TDEP = total deposition of nitrogen = OXN + RDN, OXN = total deposition of oxidized nitrogen, RDN = total deposition of reduced nitrogen. Adapted from Figure 1 in Chapter5 of Verscheure 2025, available via repository: https://lirias.kuleuven.be/4249128&lang=en*

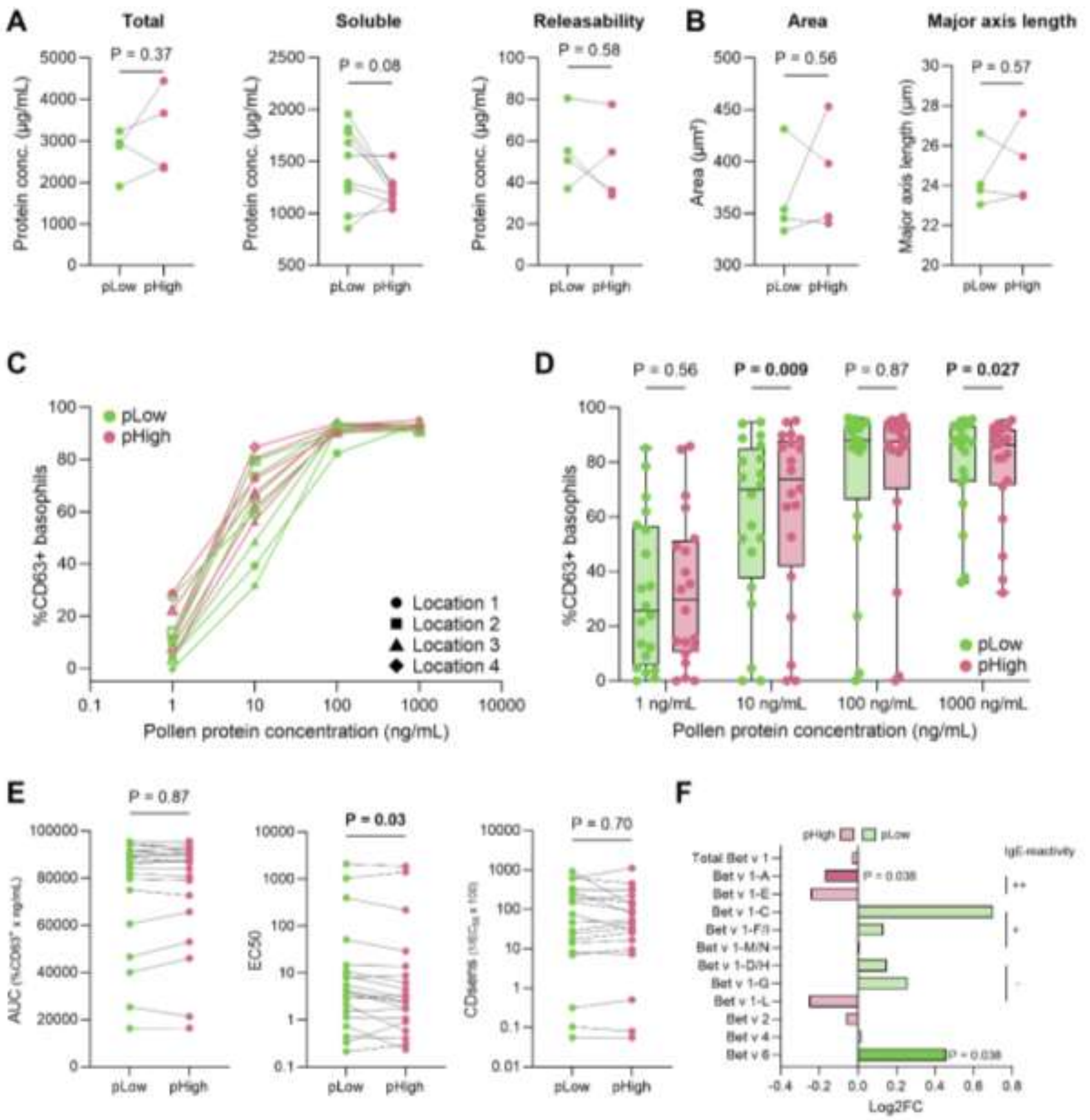

Figure 10. Paired birch pollen sampling and immunoreactivity testing *(**A**) Comparison of soluble (samples: n=48, sampling pairs: n=9) and total (samples: n=14, sampling pairs: n=4) protein concentrations, and protein releasability (samples: n=14, sampling pairs: n=4) of extracted birch pollen samples between pollen from predicted low nitrogen sites (pLow nitrogen) and predicted high nitrogen sites (pHigh nitrogen), using a paired t-test. (**B**) Comparison of pollen size characteristics, including area and major axis length, between pLow nitrogen and pHigh nitrogen samples, using a paired t-test. (**C**) Exemplary dose-response basophil activation test of all pollen samples (n=13) tested in one patient included in the study. (**D**) Basophil activation of all patients (n=20) tested with selected pollen samples from the paired collection (n=13). Data are presented using boxplots, which display the median, interquartile range (IQR), and whiskers extending to the minimum and maximum values. (**E**) Area under the dose-response curve (AUC), half maximal effective concentration (EC50), and CDsens (1/EC50 * 100), between pLow nitrogen and pHigh nitrogen samples. (**D, E**) The Wilcoxon matched pairs signed-rank test was used to determine significance. (**F**) Log2 fold change (Log2FC) values of known birch pollen allergens in the pLow nitrogen samples compared to the pHigh nitrogen samples. Comparison between groups are presented with the Mann-Whitney test; p-values are shown for significant changes. IgE-reactivity for Bet v 1 isoforms is indicated as high (++), intermediate (+), or low (-). Adapted from Figure 2 in Chapter5 of Verscheure 2025, available via repository: https://lirias.kuleuven.be/4249128&lang=en*

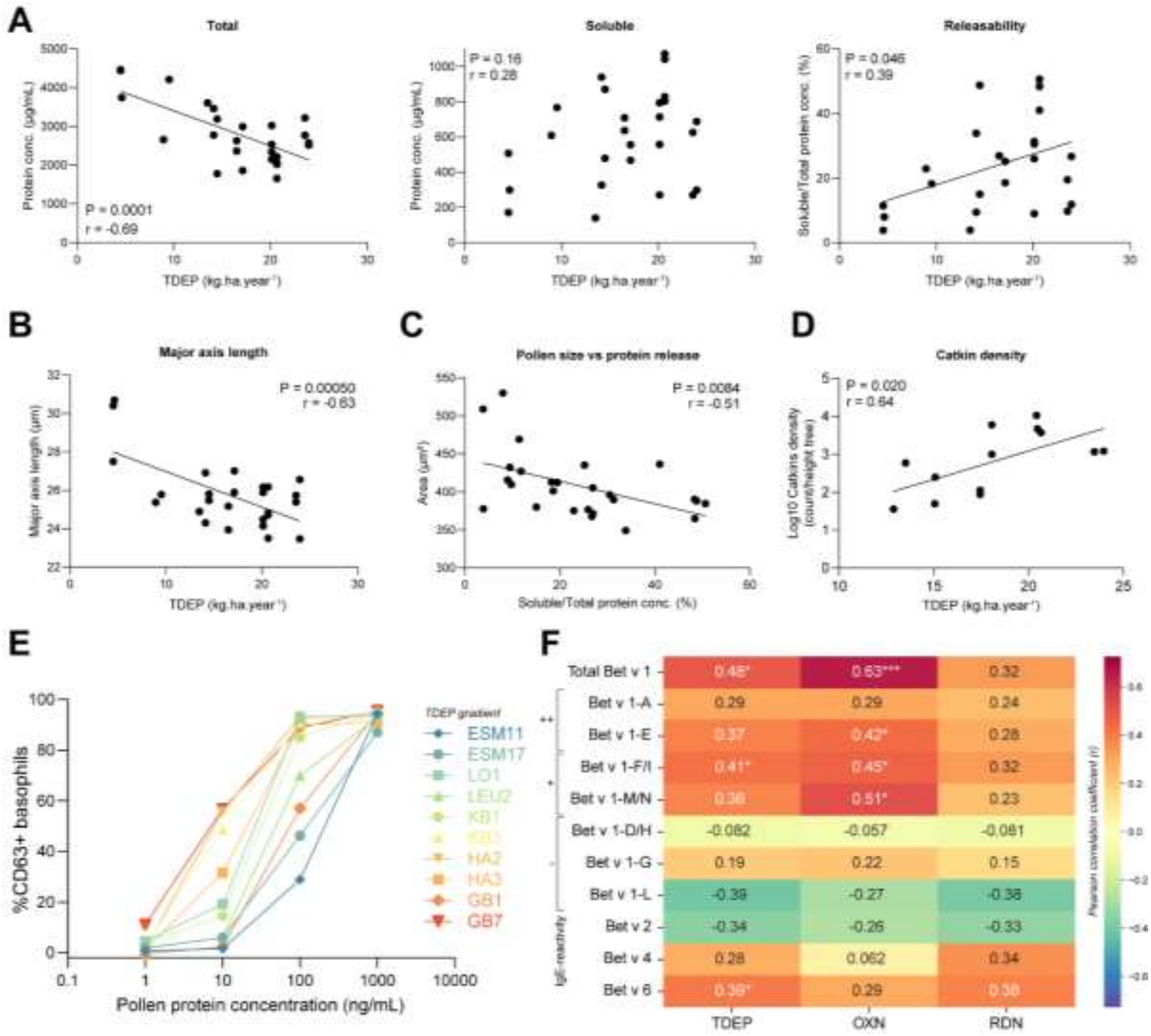

Figure 11. Birch pollen samples along a nitrogen deposition gradient and their immunoreactivity testing. *(**A**) Pearson correlation between total nitrogen deposition (TDEP) and soluble protein concentration (r=0·28), total protein concentration (r=-0·69), and protein releasability (r=0·39). (**B**) Pearson correlation between TDEP and major axis length (r=-0·63). (**C**) Pearson correlation between pollen area and pollen protein releasability (r=-0·51). (**D**) Pearson correlation between TDEP and estimated catkin density (r=0·64). Simple linear regression analysis of the estimated catkin density for the pollen samples collected in 2024 presents a slope of 0·15, indicating a 30-fold increase for every increase of 10 kg.ha.year^{-1} TDEP. (**E**) Exemplary dose-response basophil activation test of pollen samples from one patient included in the study. Pollen sample IDs and detailed sample information can be found in table S10. (**F**) Pearson correlation matrix between nitrogen deposition (TDEP, OXN, RDN) and birch pollen allergen content. Adapted from Figure 3 in Chapter5 of Verscheure 2025, available via repository: https://lirias.kuleuven.be/4249128&lang=en*

Nitrogen enrichment and soybean allergenicity in birch pollen-associated food allergy

Soybean plants grown under contrasting fertilization regimes yielded similar harvest quantities, yet individual beans showed marked morphological differences: unfertilized beans were consistently larger, whereas fertilized beans were significantly smaller and visibly shriveled. Despite this size reduction, fertilized beans exhibited a trend toward higher soluble protein concentrations, although differences were not statistically significant. SDS-PAGE profiling revealed condition-specific protein patterns, with unfertilized beans displaying additional bands in the ~30 kDa and ~8 kDa range. Basophil activation testing in five birch pollen–allergic patients with soybean-related oral allergy syndrome showed no significant differences in basophil reactivity or sensitivity between extracts from unfertilized and fertilized beans. Overall, this pilot suggested that nitrogen enrichment may alter soybean morphology and protein composition, but its impact on functional allergenicity in this cross-reactive context remained inconclusive.

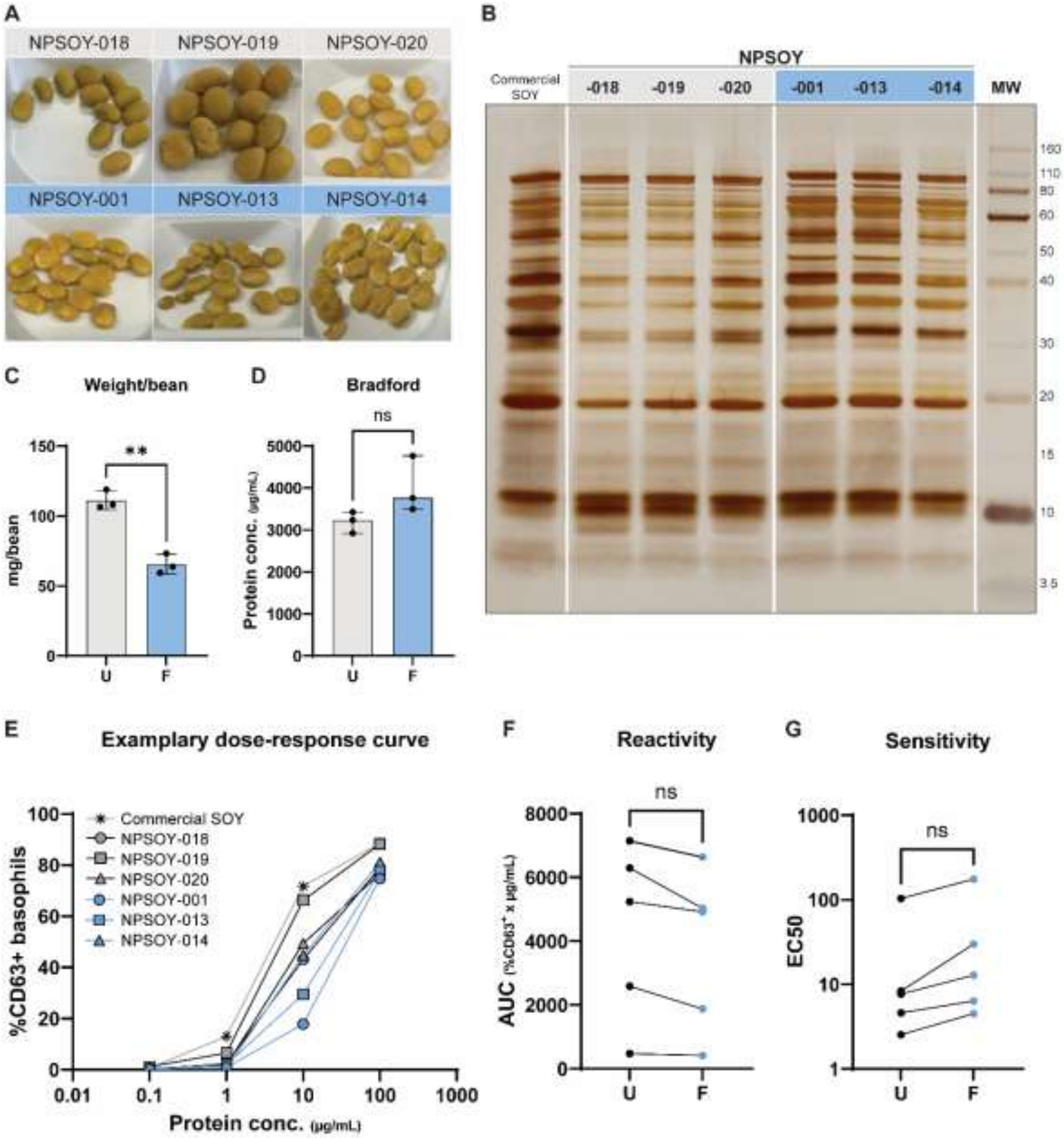

Figure 12. Soybean fertilization and impact on allergenicity in birch pollen-associated food allergy *(**A**) Pictures of soybeans used for total soluble protein extracts. (**B**) SDS-PAGE and silver stain of the soybean extracts. The white lines indicate where the original images were digitally sectioned and reassembled. (**C**) Weight (mg) per bean between the unfertilized (U) and fertilized (F) group (p=0.0013, unpaired t-test). (**D**) Total soluble protein concentration (Bradford) between the U and F group (p=0.1211, Unpaired t-test). (**E**) Exemplary dose-response curve of basophil activation of 1 patient included in the study (NP164), measured as %CD63+ basophils ($CD123^{+}HLA\text{-}DR^{-}$; y-axis) for different protein concentrations of the soybean extracts (µg/mL; x-axis). (**F**) Basophil reactivity (AUC) and sensitivity (EC50) between the U and F groups. Wilcoxon test was used to determine significance unless stated otherwise; **p<0.01. Adapted from Figure 4 in Verscheure et al.* Frontiers Allergy *6:1650232. Published 23 September 2025. doi:[10.3389/falgy.2025.1650232](https://doi.org/10.3389/falgy.2025.1650232)*

Quantification of the burden of disease attributable to nitrogen pollution

A total of 4,692 individuals completed the survey, with a mean age of 39.9 years and a predominance of adults aged 26–45. Women represented 46.3% of respondents, half of the participants resided in Wallonia, and 53.9% reported a high educational level. Most respondents had never smoked, and three-quarters experienced pollen-allergy symptoms more than four days per week. Mean values for the EQ-5D-5L level sum, EQ-VAS, and GHQ-12 scores were 8.33, 73.5, and 7.59, respectively.

Across the EQ-5D-5L dimensions, nitrogen deposition showed statistically significant but negligible associations, with odds ratios extremely close to unity for anxiety/depression and usual activities, and no significant associations for mobility, pain/discomfort, or self-care. Several allergy symptoms—particularly sleep disturbance and coughing—were consistently associated with impaired functioning and poorer quality-of-life outcomes, including higher odds of reporting problems in mobility and anxiety/depression, and lower EQ-5D-5L index and EQ-VAS scores. Nitrogen deposition showed no significant association with EQ-VAS scores, and only a minimal inverse association with GHQ-12, suggesting slightly better psychological well-being. Nitrogen deposition and coughing were both associated with slightly higher odds of experiencing symptoms more than four days per week.

Scenario analysis

Scenario-development encompassed structuring a modelling framework that can incorporate the integrated results of the other work packages. The team prepared multiple future land-use projections aligned with established climate and nitrogen deposition scenarios and organized these within a GIS environment to allow simulation of policy-relevant changes at urban and rural scales. At the urban level, the framework enables adjustment of parameters such as greenspace density, biodiversity, and mowing frequency, while in rural areas it accommodates variation in grassland diversity and land-use planning constraints. Procedures were outlined to assess how climate change and nitrogen deposition may influence birch abundance in forested and non-forested areas and alter grassland species composition, providing the structural basis for subsequent pollen abundance and allergenicity scenario modelling.

Recommendations

Drawing on the most consistent findings across the ecological, clinical, and population-level components of NITROPOL, the results support a set of mutually reinforcing recommendations that focus on reducing nitrogen inputs, managing green spaces to limit allergy burden, strengthening clinical preparedness, and improving environmental health surveillance.

Across ecosystems dominated by grasses and birch, the project demonstrated that even moderate nitrogen enrichment alters plant community structure, increases pollen output, and enhances allergen potency. These ecological shifts translated into measurably stronger basophil reactivity, higher sIgE responses, and broader IgE-binding profiles in sensitized patients. Although the burden-of-disease analyses did not reveal large direct associations between nitrogen deposition and health-related quality of life, symptom severity remained high in the population, and nitrogen deposition was associated with a higher probability of experiencing symptoms on more than four days per week. Together, these findings provide a clear rationale for reducing nitrogen emissions at the source, as lowering atmospheric inputs is the only structural way to limit the upstream drivers of allergenic pollen proliferation. Concrete actions include strengthening agricultural and industrial nitrogen-reduction measures, accelerating implementation of ammonia mitigation techniques, and aligning emission targets with ecological and epidemiological thresholds.

Because nitrogen enrichment increases both pollen quantity and potency, improved management of urban and peri-urban vegetation is warranted to mitigate local allergy risks while safeguarding biodiversity goals. The results show that nitrogen-driven shifts in species composition promote high-emitting, high-allergenicity taxa. Consequently, municipalities may reduce allergenic exposure by prioritizing diverse plantings, limiting the dominance of nitrogen-responsive grasses and birches in high-use public spaces, and optimizing mowing regimes to reduce grass flowering peaks without compromising ecological quality. In rural areas, sustaining grassland heterogeneity and preventing excessive fertilization can help maintain lower biomass production and pollen output and higher ecological quality and integrity.

The evidence that nitrogen-enriched pollen elicits stronger immunological responses underscores the need for enhanced clinical preparedness. Allergy diagnostics and management guidelines may benefit from incorporating environmental context, for example by alerting clinicians that patients may experience stronger reactions during high-nitrogen years or in nitrogen-rich regions. These findings justify continued investment in aerobiological monitoring and forecasting, including systematic tracking of allergen content rather than pollen counts alone.

Finally, the project demonstrates the value of integrating ecological measurements, clinical physiology, and population health data into environmental health decision-making. Routine surveillance systems may therefore incorporate nitrogen-exposure indicators, pollen allergenicity metrics, and symptom-tracking tools to support anticipatory public health responses. Strengthening these systems will allow policy makers to monitor the effectiveness of nitrogen-reduction strategies and to tailor health communication, such as warnings during periods of high allergenic potency.

5. DISSEMINATION AND VALORISATION

Data availability

The de-identified data used in the analyses of the clinical research papers will be made available upon reasonable request from 30 days after the finish date of the NITROPOL-BE project. The data can be obtained from the corresponding author (rik.schrijvers@uzleuven.be). Data will be shared after the approval of a proposal with a signed data access agreement. The data sources analysed in the scoping review are published as supplementary information with the article.

Scientific outreach (scientific conferences)

Aerts, R. (presenting author) & Van Gucht, S. (2022). Biodiversity in the OH programme: (un)healthy nature? Invited lecture presented on 8 December 2022 at *Health challenges of the 21st century symposium*. Brussels.

Aerts, R. (2023). Green space and airway diseases. Invited lecture presented on 6 May 2023 at *CHILDHOOD IMMUNOLOGY "Can we influence external triggers in order to prevent airway diseases?"*. Leuven.

Bruffaerts, N. (2025) "Changements climatiques et saisons polliniques: Quels enjeux pour la pratique clinique?". Invited lecture presented on 13 September 2025 at the Annual Congress of the ABEFORCAL (Association BElge de FORmation Continue en ALlergologie).

Daelemans, R., Verscheure, P. (presenting author), Rombouts, T., Keysers, S., Devriese, A., Peeters, G., . . . Schrijvers, R. (2024). Soil nitrogen enrichment of grasslands increases pollen allergenicity: a cross-sectional paired comparison study. Presented on 30 November 2024 at *BelSACI Annual Symposium*, 2024, Brussels.

🎖 **BelSACI Best Oral Abstract Presentation Award (first prize), Paulien Verscheure**

Daelemans, R., Verscheure, P. (presenting author), Rombouts, T., Keysers, S., Coorevits, L., Frans, G., . . . Aerts, R. (2025). Soil nitrogen enrichment of grasslands increases pollen allergenicity: a cross-sectional paired comparison study. Presented on 2 March 2025 at 2025 AAAAI / WAO Joint Congress, 2025, San Diego. Abstract published in *Journal Of Allergy And Clinical Immunology* 155(2 S2):AB282. doi:10.1016/j.jaci.2024.12.871

Smet, S. (presenting author), Dendoncker, N. & Linard, C. (2024). Impacts of nitrogen deposition in the natural environment on pollen allergy in Belgium: exploration of land use change and biodiversity scenarios. Presented on 15 March 2024 at Belgian Geographers Day. Namur, Belgium.

Smet, S. (presenting author) (2024). Use of scenarios to evaluate the impacts of nitrogen deposition on pollen allergy prevalence in Belgium through the lens of biodiversity losses. Presented on 19 November 2024 at 5th ESP Europe Conference – Ecosystem services: One planet, One Health. Wageningen, The Netherlands.

Verscheure, P. (presenting author), Daelemans, R., Keysers, S., Coorevits, L., Honnay, O., Van Gerven, L., . . . Schrijvers, R. (2024). Impact of environmental nitrogen enrichment on birch pollen allergy. Presented on 3 July 2024 at *World Aerobiology Conference 2024*, Vilnius, Lithuania.

🎖 **Best Oral Abstract Presentation Award, Paulien Verscheure**

Verscheure, P. (presenting author), Bruffaerts, N., Daelemans, R., Keysers, S., Verbeek, M., Galicia, G., . . . Schrijvers, R. (2025). The impact of Nitrogen Pollution on Birch Pollen Allergy: Insights from a Multi-Year cross-sectional study across Europe. Presented on 29 April 2025 at *yBIS Annual Meeting*. Leuven.

Verscheure, P. (presenting author), Daelemans, R., Keysers, S., Coorevits, L., Breynaert, C., Bullens, D., Van Gerven, L., Frans, G., Honnay, O., Ceulemans, T., Bruffaerts, N., Aerts, R., Schrijvers, R. (2025). The Impact of Environmental Soil Nitrogen Pollution on Birch Pollen Allergy: Insights from a Multi-Year Study across Europe. Presented on 16 Jun 2025 at *EAACI Annual Congress*, Glasgow, 2025, abstract published in *Allergy*.

🎖 **EACCI Outstanding Flash Talk Presentation Award, Paulien Verscheure**

Scientific outreach (media and press)

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Contribution to public debate and policy making

Vraag om uitleg over de gezondheidsimpact van stikstofbemesting van Bieke Verlinden aan minister Jo Brouns. VOU 2861 (2024-2025), Commissie voor Leefmilieu, Natuur en Ruimtelijke Ordening van het Vlaams Parlement, 6 mei 2025.
URL (verslag): https://www.vlaamsparlement.be/nl/parlementair-werk/commissies/commissievergaderingen/1898950/verslag/1900711 (and see Annex 4)

Summary of the project results presented at the annual meeting for the AirAllergy activity report, to the Cellule Permanente Environnement-Santé (CPES), Service Public de Wallonie, 3 décembre 2025.

Hoorzitting over de gezondheidsimpact van stikstofbemesting. HZ 25 (2025-2026), Commissie Leefmilieu, Natuur en Ruimtelijke Ordening van het Vlaams Parlement, 9 december 2025. URL (verslag en video-opname): https://www.vlaamsparlement.be/nl/parlementair-werk/commissies/commissievergaderingen/1971333 (and see Annex 5)

6. PUBLICATIONS

Published (A1)

Verscheure P., Daelemans R., Coorevits L., Van Gerven L., Honnay O., Aerts R., Schrijvers R. (2025) Comparison of food extraction techniques and impact of nitrogen fertilization on the potential allergenicity of soybean related to birch pollen-food allergy syndrome. ***Frontiers in Allergy*** 6:1650232. PMID: 41064229 (IF 3.1)
https://doi.org/10.3389/falgy.2025.1650232 (Open Access)
OA via repository: https://lirias.kuleuven.be/handle/20.500.12942/773133

Daelemans R., Verscheure P., Rombouts T., Keysers S., Devriese A., Peeters G., Coorevits L., Frans G., Van Gerven L., Bruffaerts N., Honnay O., Ceulemans T., Aerts R., Schrijvers R. (2025) The impact of ecosystem nitrogen enrichment on pollen allergy: a cross-sectional paired comparison study. ***The Lancet Planetary Health*** 9(4): e294–e303. PMID: 40252676 (IF 24.2)
https://doi.org/10.1016/S2542-5196(25)00060-9 (Open Access) See **Fig. 13.**
OA via repository: https://lirias.kuleuven.be/handle/20.500.12942/773133

Verscheure P., Honnay O., Speybroek N., Daelemans R., Bruffaerts N., Devleesschauwer B., Ceulemans T., Van Gerven L., Aerts R., Schrijvers R. 2023. Impact of airborne, soil, and water nitrogen pollution on pollen allergy: a scoping review. ***Science of the Total Environment*** 893:164801. PMID: 37321510 (IF 10.8)
https://doi.org/10.1016/j.scitotenv.2023.164801
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Ceulemans T., Verscheure P., Shadouh C., Van Acker K., Devleesschauwer B., Linard C., Dendoncker N., Speybroeck N., Bruffaerts N., Honnay O., Schrijvers R., Aerts R. 2023. Environmental degradation and the increasing burden of allergic disease: The need to determine the impact of nitrogen pollution. ***Frontiers in Allergy*** 4:1063982. PMID: 36819832 (IF 3.1)
https://doi.org/10.3389/falgy.2023.1063982 (Open Access)
OA via repository: https://lirias.kuleuven.be/handle/20.500.12942/713374

In preparation (A1)

Verscheure P., Bruffaerts N., Daelemans R., Coorevits L., Ieven T., Galicia G., Tiwari A., Van Gerven L., Glynis F., Smet S., Speybroeck N., Boeraeve M., Damialis A., De Weger L.A., Fernández-González D., Rodriguez-Fernández A., Pace L.G., Grinn-Grofoń A., Markey E., Martínez-Bracero M., Myszkowska D., O'Connor D., Peres Badia R., Rodinkova V., Rojo Ubeda J., Sozinova O., Honnay O., Ceulemans T., Schrijvers R., Aerts R. (under review) Environmental nitrogen pollution intensifies birch pollen allergenicity across Europe.

Charalampous P., Castin E., Nayani S., Aerts R., Bruffaerts N., Verscheure P., Speybroeck N., Devleesschauwer B. Impact of pollen allergy symptoms on quality of life and psychological well-being: the role of nitrogen deposition. (manuscript in preparation)

Other publications

Aerts R. (2024). Klimaat, milieu en allergie (editoriaal). *Medi-Sfeer*, *752*, 3-3. (URL)

PhD thesis

Verscheure P., Schrijvers R. (sup.), Van Gerven L. (cosup.) (2025). The impact of environmental nitrogen pollution on pollen allergy. 244 pp.
OA via repository: https://lirias.kuleuven.be/4249128&lang=en

Figure 13. *Cover of* The Lancet Planetary Health *(Vol. 9, Issue 4, April 2025), featuring Timothy grass (Phleum pratense) spreading pollen from spikes (Norway, July), highlighting the issue's focus on green space and health and linking to our article on page e294 examining the impact of nitrogen fertilization on grass pollen allergens.*

Cover image by Pal Hermansen/Nature Picture Library/Science Photo Library (F042/7536 Royalty Free)

7. ACKNOWLEDGEMENTS

The NITROPOL-BE project gratefully acknowledges the patients who participated in the clinical study for their time and for providing blood samples. Appreciation is also extended to colleagues from the European aerobiology community for supplying birch pollen samples from across Europe; their contributions were essential to the research. Support from Thomas Vandendriessche, Anouck D'Hont, and Eline Vancoppernolle of the KU Leuven Libraries in conducting the systematic literature search is duly acknowledged. The Agency for Nature and Forest and Natuurpunt vzw are thanked for granting permission to collect grass pollen in their nature reserves. Acknowledgement is given to the clinical staff of the UZ KU Leuven allergy and ENT departments for facilitating the project's clinical activities. Dr. Paulien Verscheure acknowledges the dedicated efforts of master students Sien Keysers and Miel Verbeek for their assistance with practical work, and expresses gratitude to laboratory technicians, particularly Kasper Van Acker for support in the field, L. Coorevits for training and acquisition of BAT data, and J. Cremer and E. Dilissen for general guidance. The KU Leuven SyBioMa Proteomics Core is thanked for processing proteomics data.

Rik Schrijvers and Laura Van Gerven, academic promotors of Dr. Paulien Verscheure, received support from FWO senior clinical investigator fellowships 1805523N and 18B2222N. The jury members for Dr. Verscheure's examination were Prof. Christine Breynaert (chair), Prof. Helena Ribeiro, Dr. Letty A. De Weger, Prof. Martine Grosber, with assessors Prof. Jeroen Vanoirbeek and Prof. Ben Somers. Prof. Tatiana Kouznetsova served as chair of the reading committee.

Follow-up committee

The authors would like to acknowledge the members of the Follow-up Committee for their advice at various stages of the project (Fig. 14).

	Sex		Language			Discipline							
Name	F	M	NL	FR	E	Ecology	Environmental Science	Aerobiology	Medicine	Public Health	Geography	Greenspace Mgt	Nature Conservation
Dominique Bullens	●		●						●				
Jeroen Buters		●			●			●		●			
Athanasios Damialis		●			●			●		●			
David De Pue		●	●				●						
Hans De Wandeler		●	●			●	●					●	
Letty de Weger	●		●					●	●	●			
Antoine Froidure		●		●					●				
Benno Geertsma		●	●			●							●
Sarah Habran	●			●		●	●			●			
Eric Hallot		●		●			●				●		
Hans Keune		●	●						●	●			
Gudrun Koppen†	●		●				●			●			
Dorota Myszkowska	●				●			●		●			
Erik Smolders		●	●				●						
Ben Somers		●	●				●				●	●	●
Hans Van Calster		●	●			●							●
Karen Van de Vel	●		●				●			●			

Figure 14. *Members of the follow-up committee of the NITROPOL-BE project (listed in alphabetical order), reflecting the project's commitment to balanced gender representation and multidisciplinary expertise across language communities and scientific domains—key requirements for effective oversight of a project of this scope and complexity.*

We respectfully commemorate dr. ir. Gudrun Koppen (1969–2024), who passed away during the course of this project. A pioneering molecular epidemiologist and internationally recognised expert in human biomonitoring, she devoted her career at VITO to advancing scientific understanding of environmental health risks and to fostering the next generation of researchers. Her commitment to rigorous science, interdisciplinary collaboration, and a healthier environment continues to inspire all who had the privilege to work with her.

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ANNEXES

Annex 1: Chronological overview of activities

WP1 — Identify mechanisms that drive the impact of nitrogen enrichment on pollen allergy

Year 1

- Protocol development and stratified sampling design
  • A pan-European protocol was drafted to sample birch pollen, soil and fresh leaves across a modeled atmospheric nitrogen-deposition gradient (EMEP), stratified by four environment types (urban, semi-urban, rural, natural).
  • This protocol established standardized field procedures used across partner aerobiology networks (Annex 2)
  Feeds to: WP3 (clinical immunoassays), WP4 (exposure mapping and survey linkage), WP5 (scenario inputs).
  Concrete outputs: standardized sampling protocol; an assembled network of 19 aerobiologists in 16 countries.

- Field sampling — birch and grass pollen collection across Europe and in Belgium
  • March–May 2021: collection of catkins/pollen, soil and branch material at 69 sites across Europe (via partners).
  • June 2021: pilot grass pollen sampling at 12 paired grassland sites in Belgium (paired neighbouring fertilized vs unfertilized plots); transect vacuum protocol used to quantify pollen productivity and to collect biomass samples for above-ground productivity estimates.
  • Commercial pollen was procured to optimise laboratory immunological protocols.
  Feeds to: laboratory allergen quantification, WP3 immunoassays, WP2 comparisons with experimental material.
  Concrete outputs: primary environmental sample repository (birch & grass pollen, soils, vegetation biomass); optimized lab extraction protocols using commercial pollen.

- Environmental chemistry baseline
  • May 2021: leaf and soil samples analysed for nitrogen (and C) and soil mineral content to characterise site nutrient status.
  Feeds to: validation of nitrogen exposure gradients for WP1 analyses and selection criteria for WP3 sample subsets.
  Concrete outputs: chemical datasets (leaf N, soil nitrate/ammonium, soil organic matter).

Year 2

- Strategic refocus of field sampling
  • Given setbacks in the first year (some pollen quality issues), pan-European resampling was not repeated; instead sampling focused on paired plots within the Belgian Campine region using the established paired-plot approach.
  Feeds to: provision of higher-quality, regionally consistent samples to WP3 and WP2 experimental comparisons.
  Concrete outputs: refined Belgian sampling frames and higher-quality local samples.

Year 3

- Expanded sampling and sample processing (Belgium + Europe)
  • March 2023: a new round of birch pollen sampling produced 82 site samples across six countries (Belgium, Netherlands, Poland, Spain, Sweden, Ireland), with selection of 16 samples earmarked for clinical assays (10 Belgian, 6 low-deposition European).
  • March 2024: resampling of the 10 Belgian locations used for immunoreaction assays to obtain fresh material for additional BAT, proteomics and amino-acid profiling.
  • May–June 2023: intensive grassland campaign at 50 paired grassland sites (three 2 m × 20 m transects per grassland, two sampling rounds in May and June). Vegetation surveys (three per grassland), biomass sampling and elemental analyses were performed; pollen productivity per hectare was calculated.
  • DNA metabarcoding (ITS2) was performed on grass pollen samples to link plant community composition to pollen composition and productivity.
  Feeds to: WP3 (selection of samples for BAT and sIgE), WP2 (comparisons with experimental treatments), WP4 (exposure metrics used in health models), WP5 (spatial data for scenarios).
  Concrete outputs: expanded environmental sample set (birch & grass), processed metabarcoding data, vegetation and biomass datasets, pollen abundance estimates; pollen aliquots stored at −80°C ready for proteomics and immunoassays.

- Continued chemical characterisation
  • April 2023: tree leaves and pollen analysed for N and C content; July 2023: grass biomass analysed for N and C.
  Feeds to: covariates and mechanistic variables for statistical models in WP1, and explanatory variables used in WP3 and WP5.
  Concrete outputs: leaf and biomass N datasets linked to sample metadata.

Cross-WP linkages & key WP1 deliverables

- WP1 produced the principal environmental exposure datasets (pollen abundance, species composition by metabarcoding, vegetation composition, biomass, leaf/soil nitrogen metrics) that served as core inputs for: WP2 (experimental comparisons), WP3 (selection and interpretation of pollen used in immunoassays), WP4 (linking exposure to population surveys and DALY estimation), and WP5 (spatial scenario development).

- Concrete outcomes from WP1 included the pan-European and national sample collections, processed metabarcoding results, and chemical characterisation tables that underpinned subsequent analyses and manuscript preparation.

WP2 — Experimental determination of nitrogen effects on pollen abundance and allergen potency

Year 1

- Species selection and initiation of field experiment
  • Established birch (*Betula pendula*) as the focal tree model and grasses as a focal group (single-species grass pollen collection is impractical in mixed grasslands).

• April 2021: started a common-garden field fertilization experiment at a nutrient-poor state reserve (Beninksberg, Holsbeek) with 10 birch trees; half were fertilized to simulate elevated rural nutrient input (~100 kg N ha^{-1} yr^{-1}), half used as controls.
Feeds to: WP3 (experimental pollen used in immunoassays), WP1 (comparative inference with environmental samples).
Concrete outputs: experimental birch trees under controlled fertilization; baseline measurements of tree condition and leaf chemistry.

Year 2

- Continued monitoring of field experiment
  • The Beninksberg experiment continued; some trees were lost/cut by maintenance activities, which affected sample numbers. Leaf and growth measurements continued where possible.
  Feeds to: adjusted expectations for experimental pollen yield, informed design of greenhouse follow-ups.
  Concrete outputs: continued time series of tree response data and lessons on field-experiment vulnerability.

Year 3

- Greenhouse experiments and diversifying experimental species
  • March 2023: started a soybean greenhouse fertilization experiment (40 plants; four N treatments: control, 25, 50, 75 kg N ha^{-1} equivalents). Beans and leaves were analysed for N and C content; seed/bean yield was low.
  • Because bean yield proved insufficient for downstream work, a new experiment was initiated in March 2024.
  • March 2024 (initiated in Year 3 activities): started a greenhouse fertilization experiment with five grass species (*Holcus lanatus*, *Poa annua*, *Lolium multiflorum*, *Dactylis glomerata*, *Anthoxanthum odoratum*) — 50 pots per species with half the pots fertilized to simulate high N (≈100 kg N ha^{-1} yr^{-1}) and half controls.
  Feeds to: WP3 (experimental pollen and plant tissue for immunoassays and proteomics), WP1 (mechanistic comparison between field and controlled treatments), WP5 (parameter values for scenario modelling).
  Concrete outputs: greenhouse pollen and plant tissue collections (birch experimental material, soybean/grass experimental samples), N/C datasets for experimental plants; initiation of a second greenhouse experiment to increase sample yield.

Cross-WP linkages & key WP2 deliverables

- WP2 generated experimentally controlled pollen/plant material that was directly used in WP3 immunoreactivity assays (BAT, ImmunoCAP, immunoblots) to disentangle effects of nitrogen per se from co-occurring field confounders.

- Experimental data (leaf N, pollen productivity, allergen release per grain) were used to parameterise mechanistic interpretations in WP1 and to inform exposure-response relationships needed by WP5.

WP3 — Clinical immunoprofiling: allergen-specific IgE reactivity to environmental & experimental pollen

Year 1

- Project staffing, registration and ethics
  • Recruitment process and a 4-yr PhD position were launched; a candidate (PV) was appointed.
  • The clinical study protocol was registered (CTC S65184) and received ethical approval from the UZ/KU Leuven Ethics Committee (favourable decision 25 March 2022; Belgian Reg. B3222021000626).
  Feeds to: enabled recruitment and all human participant work across Years 2–4.
  Concrete outputs: ethics approval and clinical trial registration.

- Methods development and pilot work
  • Optimised extraction protocols for pollen proteins and standardised immunoassay protocols (ImmunoCAP, immunoblot, BAT).
  • Conducted pilot experiments to gauge sample reactivity and explore potential nitrogen-related effects on allergenicity.
  Feeds to: informed the large-scale BAT and sIgE testing design in Years 2–4.
  Concrete outputs: validated lab methods and pilot data informing sample selection and power calculations.

Year 2

- Continued optimisation and pilot extension
  • Further refinement of extraction and immunoassay methods; continuation of pilot experiments and initial application to early environmental samples.
  Feeds to: improved assay robustness used in Year 3 full analyses.
  Concrete outputs: finalised SOPs for BAT, ImmunoCAP loading and immunoblotting.

Year 3

- Execution of immunoreactivity assays on environmental samples
  Birch pollen analyses
  • Completed immunoreactivity analysis (NPB22) on an initial subset of 20 patients with modest differences between high/low environmental N conditions.
  • Processed new 2023 birch samples (NPB23-BE and NPB23-EU) and produced protein extracts for a subset (n=41). Selected 10 BE and 10 EU samples representing the deposition gradient and tested them in BAT on two patient cohorts (20 patients each; total 40). Results were mixed: marginally higher estimated basophil reactivity in lower predicted deposition regions (contrary to hypothesis) but lower sIgE in lower deposition EU samples (consistent with hypothesis); significant positive effect of initial pollen protein concentration on BAT reactivity was observed, prompting additional protein-content investigations.
  Grass pollen analyses
  • Processed Belgian environmental grass pollen (selection n=10: 5 fertilized, 5 unfertilized paired sites). Conducted BAT on these extracts with 20 patients and observed a significant increase in basophil reactivity toward pollen from fertilized grasslands. sIgE comparisons were pending at the time. Additional patient recruitment and testing were ongoing.
  Feeds to: WP1 (interpretation of field patterns), WP2 (confirmatory assessment with

experimental material), WP4 (linking immunoreactivity to symptom data).
Concrete outputs: BAT and sIgE datasets on birch and grass environmental samples; detection of a clear fertilization signal in grass pollen BAT; operational decisions to undertake further protein-content analyses.

Year 4

- Completion, analysis and dissemination (grass) / proteomics & holography (birch)
  Grass pollen
  • Finalised all experimental work for grass pollen including last sIgE measurements and immunoblots. Analysed and combined data into an original manuscript. Manuscript submitted to *The Lancet Planetary Health* in December 2024; minor revisions were addressed in February 2025; manuscript accepted March 2025 and published on 16 April 2025. Results had already been presented at AAAAI/WAO Joint Congress (San Diego) and BelSACI annual congress (Brussels). The manuscript received significant attention and broad scientific outreach in national and international media (see 5, Dissemination).
  Birch pollen
  • Collected 2024 resamples from previously sampled trees and completed BAT on a further 20 patients. Prepared 40 selected birch pollen extracts for proteomics; optimized extraction for recalcitrant tissues and submitted samples to the KU Leuven Symbioma proteomics core. Conducted pollen-grain size analysis via digital holography (SwisensPoleno Jupiter) in collaboration with Sciensano. Intermediate birch results were presented at the World Aerobiology Meeting (Vilnius).

- In the final months of the project (extension of Year 4), completing the birch pollen project and finalizing the manuscript of the birch pollen was the priority. Data from the proteomics experiment were analyzed to assess protein content across different birch pollen samples. All results were evaluated and compiled into an original research article. Additionally, a final sequencing experiment was initiated to verify the proteomics findings at the genomic level. DNA from 12 birch pollen samples (collected in 2022) was extracted and submitted for whole-genome PacBio sequencing. At the time of reporting, results were being evaluated to be incorporated into the birch pollen manuscript or submitted separately as a letter.
  Feeds to: WP1 (interpretation of field gradients), WP5 (parameter and hazard information for scenario building), WP4 (triangulation with population-level burden data).
  Concrete outputs: *Lancet Planetary Health* grass paper, conference presentations (AAAI/WAO, BelSACI, World Aerobiology, EAACI), completed proteomics sample set and holography dataset for birch, finalized BAT and sIgE datasets feeding manuscripts in preparation.

WP4 — Quantify the burden of disease attributable to eutrophication

Year 1

- Project setup and PhD recruitment
  • PhD position advertised and candidate appointed; thesis proposal approved by UCLouvain doctoral school.

Feeds to: capacity to perform survey design, DALY calculations and economic analyses.
Concrete outputs: PhD appointment and approved research plan.

- Preparatory work for non-interventional study and burden estimation
  • Drafted the ethics submission file for the cross-sectional HRQoL survey; requested access to relevant databases; performed literature reviews on DALYs for allergy and EQ-5D in allergy populations.
  Feeds to: survey instrument design and analytic plan for DALY/QALY estimation.
  Concrete outputs: ethics submission drafts, database access requests, literature synthesis.

Year 2

- Ethical clearance and survey launch (first edition)
  • Obtained ethical approval for the cross-sectional survey.
  • Launched the web-based survey on 21 March 2023 (run through end September 2023 with monthly reminders). Logistical adjustments were made after a PhD candidate departure and tasks were redistributed.
  Feeds to: WP3 (subject recruitment overlap), WP1 (linking exposure by postcode), WP5 (health impact inputs for scenarios).
  Concrete outputs: active survey platform and initial respondent accrual.

Year 3

- Survey execution and dissemination (first edition)
  • Ran the first edition of the multilingual (Dutch, French, German) survey over the birch and grass pollen seasons; dissemination through Sciensano channels and project communications.
  • Survey content included EQ-5D-5L, EQ VAS, WPAI-AS, GHQ-12, and socio-demographic/lifestyle items; recruitment included participants from WP1 study areas and clinical cohorts.
  Feeds to: derivation of QALY and DALY estimates, covariate adjustment for epidemiological models in WP4 analyses.
  Concrete outputs: a completed dataset from thousands of respondents (analysis results reported in the project interim materials — see earlier interim summary describing n=4,692 respondents and association findings).

Year 4

- Second survey edition and ongoing analysis
  • Launched a second edition of the survey on 21 March 2024 (again at the start of the birch season), which remained active into Year 4. Analyses of HRQoL, GHQ-12 and productivity outcomes were undertaken, with regression models adjusted for potential confounders.
  Feeds to: DALY/QALY calculations for WP4 deliverables and to economic modelling in WP5.
  Concrete outputs: two survey waves (2023, 2024), analysed associations between symptoms and HRQoL (summarised in interim results), datasets supporting DALY/QALY estimation and cost-benefit inputs.

Cross-WP linkages & key WP4 deliverables

- WP4 generated the population-level health impact evidence (survey datasets, QALY and DALY estimates) that were combined with exposure data from WP1 and immunoreactivity outputs from WP3 to estimate attributable burden and to parameterise economic assessments in WP5.

- Concrete outputs included the large survey dataset (n≈4,692) and analytic results linking symptom profiles to EQ-5D/GHQ-12 outcomes.

WP5 — Evaluate health care costs and benefits of nitrogen deposition scenarios & policy interventions

Year 3

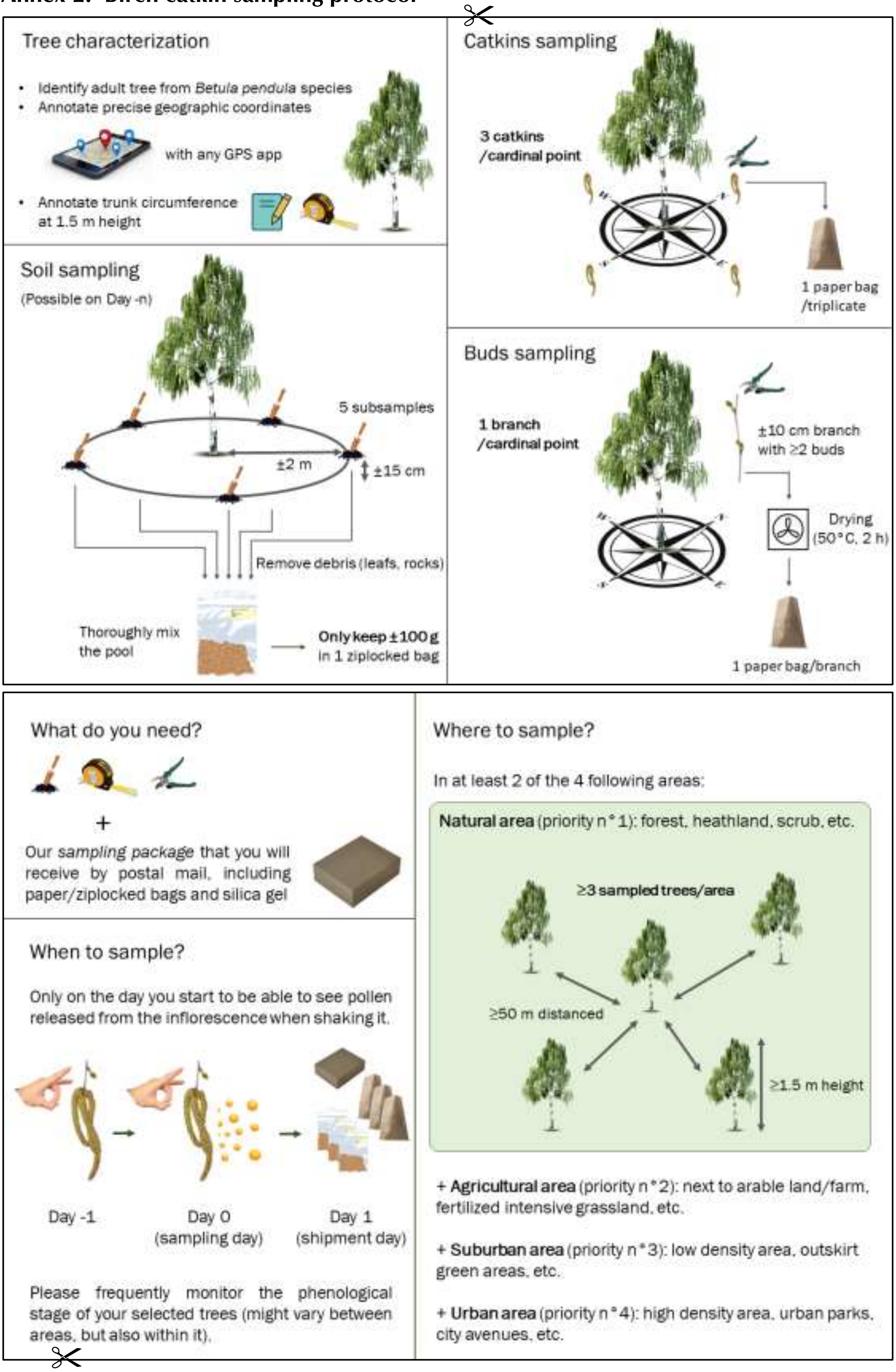
- Project initiation and data compilation
  • UNamur joined active contributions (from Sept 2023) and undertook literature review, stakeholder contacts and database gathering. Compiled multiple future N-deposition projection datasets, national observations of grass/tree species distributions, and updated forest inventories; integrated related datasets from external projects (e.g., RespirIT).
  Feeds to: development of scenario inputs for hazard/exposure modelling and risk mapping.
  Concrete outputs: assembled spatial datasets and bibliographic inventory for scenario building

Year 4

- Re-framing and methodological development for scenarios and risk maps
  • Recognising uncertainties in direct relationships between nitrogen and allergenicity/abundance, the team pivoted toward building risk maps that integrate exposure and hazard components. They operationalised the geon concept to construct hazard maps: (1) indicator selection, (2) data normalisation, (3) weighting (expert-based), and (4) multi-resolution segmentation/regionalisation. Spatial indicators were selected across urban and rural variables expected to change under climate and nitrogen scenarios; expert weighting provided a policy-relevant hazard weighting scheme. Geons were framed as homogeneous spatial objects responsive to land-management and policy interventions.
  Feeds to: targeted mitigation mapping, prioritisation of areas for management interventions, and the economic cost-benefit modelling work
  Concrete outputs: geon-based hazard mapping methodology and preliminary geon maps; inputs for the forthcoming deliverable and foundation for scenario-based QALY/QALY and cost-benefit calculations.

- Scenario-to-impact translation
  • Using geons and compiled spatial datasets, scenario prototypes were being linked to potential changes in pollen abundance/allergenicity and thus to population exposure and health impact. This work is the basis for quantifying QALY losses/gains and estimating healthcare costs and benefits under alternative nitrogen and land-use policies.
  Feeds to: policy recommendations and WP4 DALY/QALY cost translations.
  Concrete outputs: draft hazard/exposure mapping products and scenario prototypes; methodological framework for subsequent economic evaluation (final quantitative cost-benefit outputs and recommended baselines pending completion of model parameterisation from WP1–WP3 results).

Annex 2. Birch catkin sampling protocol



Annex 3: Main problems and difficulties encountered

List of problems and difficulties

1. Field sampling challenges

1.1. Poor-quality pollen samples (Year 1)

- Several birch pollen samples collected across Europe arrived with insufficient pollen quantity or compromised integrity.
- Causes included inconsistent collection methods and varying expertise among partners in the aerobiology network.
- This necessitated revisions to the pan-European sampling protocol and increased communication with partner laboratories.

1.2. Sub-optimal birch pollen yields (Years 1–2)

- Despite protocol improvements, some sampling rounds still yielded low-quality or low-quantity material, especially from urban trees exposed to harsh conditions.
- As a consequence, the consortium cancelled the planned second pan-European sampling in Year 2 and instead shifted to a Belgian paired-plot sampling approach in the Campine region.

1.3. Loss of experimental trees (Year 2)

- In the WP2 nitrogen-enrichment experiment, some birch trees in the common-garden experiment were accidentally cut by green-space workers, reducing replication and lowering the power of experimental comparisons.

1**.4. Insufficient pollen yield in greenhouse experiments (Year 3)**

- Initial soybean fertilization trials produced insufficient bean material, requiring repetition of the experiment in 2024.
- This caused delays in downstream analyses (protein extraction, IgE reactivity testing).

2. Laboratory and analytical difficulties

2.1. Need for extensive optimization of immunological protocols (Years 1–2)

- Pollen extract formation, ImmunoCAP procedures, immunoblots, and basophil activation tests required substantial optimization, delaying the start of large-scale testing.
- For grass pollen, extracting sufficient high-quality protein proved challenging due to complex matrices and mixture of species.

2.2. Strong influence of pollen protein content on basophil activation (Year 3)

- During the WP3 immunoreactivity analyses, unexpectedly strong correlations between initial protein concentration and basophil reactivity remained even after methodological corrections.

- This created doubt about initial interpretations and required additional protein quantification and re-analysis, delaying clinical interpretation.

2.3. Complexities in DNA metabarcoding (Year 3)

- Linking grassland species composition to pollen composition required careful optimization of bioinformatic pipelines and troubleshooting of low DNA yields in some samples, prolonging processing time.

3. Data governance, GDPR & ethical oversight

3.1. Delays caused by GDPR Joint Controllership Agreement (Year 1)

- A GDPR-compliant Joint Controllership Agreement between Sciensano and UZ Leuven required multiple rounds of negotiation, due to differing interpretations of Article 26 and related responsibilities.
- This resulted in significant delays in ethical approval (EC Research), which cascaded into delays in the clinical cohort work.

3.2. Slow progress on ethical approval for WP4 (Year 1)

- WP4 required a complex ethical submission for a nationwide patient survey. Drafting the file was time-consuming due to cross-institutional input requirements and alignment with GDPR obligations.

4. Human resources and project continuity issues

4.1. Unexpected departure of WP1 postdoc (Year 2)

- Dr. Tobias Ceulemans was replaced by Robin Daelemans for the lab tasks associated with WP1+2 after his promotion to ZAP at the University of Antwerp.
- Prof. Ceulemans stayed involved in the project but no longer on a full-time basis.

4.2. Missing PhD candidate for WP3 (Year 2)

- A second PhD candidate for the clinical study decided not to pursue a PhD.
- All clinical tasks were combined within the PhD of Paulien Verscheure.

4.3. Unexpected departure of WP4 PhD student (Year 2)

- The initial WP4 PhD candidate, Caroline Shadouh, ended her PhD prematurely.
- This disrupted the work package at a critical moment (ethical approval, survey launch, burden-of-disease modeling).
- Responsibilities were transferred to Sarah Nayani, supported by a Master’s student (Catherine Magérus).

- The transition required onboarding time and led to delays in data analysis and survey continuity.

4.4. Unexpected departure of Sciensano pollen expert (Year 2)

- The contract of Lucie Hoebeke at Sciensano was not prolonged.
- At Sciencano, the vacant position was filled by Astha Tiwari, who took over the aerobiological tasks in the NITROPOL project.

5. Coordination across international partners

5.1. Variability in sampling capacity across countries

- In the pan-European sampling campaigns, partners differed in their:
  - technical experience,
  - availability to sample within the required temporal windows,
  - ability to adhere strictly to standardized protocols.
- This caused variation in pollen quantity/quality and required additional follow-up and quality checks.

5.2. Reduced participation in Year 3 European sampling

- Compared with Year 1, fewer countries contributed samples in Year 3.
- This reduced the breadth of the nitrogen deposition gradient and required strategic selection of Belgian and low-deposition European samples for clinical testing.

6. Challenges in linking ecological and clinical data

6.1. Limited nitrogen gradient in Belgian birch samples

- The Belgian nitrogen deposition gradient was narrower than expected, making it difficult to detect differences in IgE reactivity or basophil activation.
- As a result, environmental–clinical correlations were weaker for Belgian samples than for European low-nitrogen samples.

6.2. Complex multi-step data integration

- Linking nitrogen deposition, plant physiological indicators (C:N ratios), allergen potency, IgE reactivity, and patient-reported health outcomes required major coordination and multiple rounds of data harmonization.
- Some steps (e.g., proteomics) were delayed due to upstream bottlenecks.

7. Modeling and scenario development difficulties (WP5)

7.1. Uncertainty in mechanistic relationships

- Because nitrogen–allergenicity mechanisms were less clear than anticipated, the WP5 team had to change their conceptual approach – shifting from mechanistic scenario modeling to risk mapping using geons.

7.2. Large heterogeneity in spatial datasets

- Integrating multiple land-use maps, nitrogen deposition scenarios, forest inventories, and RespirIT data required substantial preprocessing and expert-based indicator weighting.
- As a result, WP5 output remained limited.

Evaluation of difficulties in the context of a-priori identified risks

The project's risk assessment, as formulated in the proposal, emphasized that the modular design—where each work package could progress semi-independently—would minimize the impact of non-performance in any single component. The most prominent scientific risk identified at project outset was the possibility that Belgium's generally high nitrogen deposition levels would yield only limited contrast between "high" and "low" deposition sites, potentially reducing statistical power to detect nitrogen-related changes in pollen abundance, composition, or allergen potency. This risk was intentionally mitigated through a parallel, multi-layered design combining observational field gradients, controlled experimental manipulations (WP2), clinical IgE reactivity assays using both environmental and experimental pollen (WP3), and additional sampling in European low-nitrogen sites.

Against this backdrop, the operational difficulties encountered during project execution can be evaluated as follows:

1. Poor-quality pollen samples in Year 1

The initial receipt of suboptimal pollen samples represented a technical challenge that could have jeopardized analyses in WP1 and WP2. However, this issue was rapidly identified and resolved through refinement of the pollen sampling protocol in collaboration with partners. Given the project's design—including redundancy through experimental manipulations and the use of multiple sampling sites including those outside of Belgium—this problem did not materially elevate the principal scientific risk (insufficient deposition gradient contrast). Instead, it represented a correctable procedural issue with limited downstream impact.

2. Delays due to GDPR Joint Controllership Agreement negotiations

The protracted drafting of the Joint Controllership Agreement (JCA), required to comply with GDPR Article 26, delayed ethical approval and initiation of activities involving personal health data (particularly WP3 and WP4). While time-consuming and resource-intensive, this difficulty did not fundamentally threaten the project's ability to answer its scientific questions. The primary risk mitigation—having parallel components not dependent on patient data—effectively absorbed some of this delay (resulting in a hypothesis paper and substantial work done for the scoping review).

Nevertheless, the JCA negotiations introduced administrative risk not explicitly foreseen in the initial risk assessment, particularly regarding timelines for clinical and health-data components.

3. Personnel changes in Year 2 (including a PhD student withdrawal)

The unexpected discontinuation of the PhD student primarily responsible for WP4 posed a risk to continuity in the socioeconomic and DALY-based modelling. This risk was partly mitigated through reassignment of responsibilities. Because WP4 relied on analytical rather than experimental continuity, staffing flexibility helped sustain progress without compromising the broader project. Importantly, this challenge did not interact with the main scientific risk but did require internal reorganization to maintain workflow and analytical output.

Overall assessment relative to a-priori risks

The encountered difficulties were primarily administrative and operational rather than scientific. None of them critically interacted with the central scientific risk identified at project outset—that the national nitrogen deposition gradient might be too narrow to detect effects in environmental pollen. The study's multi-pronged design (observational + experimental + clinical + modelling) effectively safeguarded progress and analytical robustness despite these challenges.

Annex 4: Request for clarification about the health impact of nitrogen fertilization (in Dutch)

Verslag vergadering

Commissie voor Leefmilieu, Natuur en Ruimtelijke Ordening

dinsdag 6 mei 2025

URL: https://www.vlaamsparlement.be/nl/parlementair-werk/commissies/commissievergaderingen/1898950/verslag/1900711

Vraag om uitleg

Vraag om uitleg over de gezondheidsimpact van stikstofbemesting

2861 (2024-2025)

van Bieke Verlinden aan minister Jo Brouns

Bekijk documentenfiche

Verslag

De voorzitter

Mevrouw Verlinden heeft het woord.

Bieke Verlinden (Vooruit)

We weten al langer dat de hoge stikstofuitstoot onze natuur en biodiversiteit aantast, maar nu blijkt uit een nieuwe studie van de KU Leuven[1] dat die uitstoot ook rechtstreeks schadelijk is voor onze gezondheid. Dat maakt ons ernstig ongerust. De onderzoekers tonen aan dat bemeste graslanden tot zes keer meer graspollen produceren dan niet-bemeste graslanden. Die pollen veroorzaken bovendien een veel sterkere allergische reactie.

De boosdoener is stikstof. Het is voor het eerst dat er zo'n duidelijke en concrete link wordt gelegd. De stikstofuitstoot leidt dus niet alleen tot ecologische schade, maar ook tot concrete gezondheidsklachten bij een grote groep Vlamingen, want zo'n 15 à 20 procent van de mensen lijdt aan hooikoorts. Voor sommigen beperkt het zich tot niezen en tranende ogen, maar voor anderen, en zeker kinderen, is het veel ernstiger, met astmatische klachten tot gevolg. Sommige mensen durven in het pollenseizoen zelfs nauwelijks buiten te komen. We mogen de maatschappelijke kosten van dit probleem absoluut niet onderschatten. Denk maar aan het

[1] The 'KU Leuven study' referred to in the Request for Clarification is the NITROPOL paper published in *The Lancet Planetary Health*. The question was raised following the extensive media coverage of this article.
Daelemans R., Verscheure P., Rombouts T., Keysers S., Devriese A., Peeters G., Coorevits L., Frans G., Van Gerven L., Bruffaerts N., Honnay O., Ceulemans T., Aerts R., Schrijvers R. (2025) The impact of ecosystem nitrogen enrichment on pollen allergy: a cross-sectional paired comparison study. ***The Lancet Planetary Health*** 9(4): e294–e303. PMID: 40252676 (IF 24.2) https://doi.org/10.1016/S2542-5196(25)00060-9

toenemende aantal ziektedagen, de druk op de gezondheidszorg, maar ook de terugbetaling van medicatie. Dat alles komt boven op de schade aan onze natuur.

Minister, hoe kijkt u naar die studie? Ziet u misschien de noodzaak om, vanuit het voorzorgsprincipe, maatregelen te nemen om de gezondheidsschade door stikstof maximaal te voorkomen? Zult u de resultaten meenemen bij het vormgeven van het stikstofbeleid na 2030?

Tot slot heb ik misschien eerder een vraag voor de collega's die hier aanwezig zijn: zou het geen goede zaak zijn om de onderzoekers uit te nodigen voor een hoorzitting?[2] Zij hebben toch een publicatie kunnen doen in The Lancet [Planetary Health, ed.], dat is een toonaangevend internationaal wetenschappelijk tijdschrift. Het zou misschien niet slecht zijn om hun bevindingen beter te kunnen begrijpen en hun aanbevelingen daaromtrent te kunnen aanhoren. Ik snap dat we vandaag daarover niet kunnen beslissen, maar bij een volgende regeling der werkzaamheden kunnen we agenderen om te beslissen om daarvoor een hoorzitting te organiseren.

Mijn concrete vraag aan u, minister, is dus hoe u naar de resultaten kijkt en of het voorzorgsprincipe moet worden gehanteerd.

De voorzitter

Minister Brouns heeft het woord.

Minister Jo Brouns

Collega, de studie werd uitgevoerd door wetenschappers verbonden aan verschillende Vlaamse universiteiten en Sciensano. Ikzelf heb de studie nog niet in detail kunnen bestuderen. Ik moet me baseren op wat erover werd vermeld in verschillende artikelen en opinies.

Een van onze diensten, het Instituut voor Landbouw-, Visserij- en Voedingsonderzoek (ILVO), gaf in een persreactie aan dat het onderzoek onvoldoende rekening zou houden met de courante landbouwpraktijk. In Vlaanderen, zoals u weet, worden de meeste percelen waarop bemesting plaatsvindt, vroeg gemaaid om een hoog proteïnegehalte in het gras te hebben en het gemakkelijk in te kunnen kuilen. Met andere woorden, collega's: een slimme boer laat zijn gras niet in bloei komen. Iedereen die de landbouw een beetje kent, zal dat beamen. Het gras wordt dus gemaaid voordat er een bloem op komt en voordat de pollen kunnen ontstaan. Dat is toch wel een heel belangrijk antwoord vanuit de landbouwpraktijk.

Conclusies trekken uit dit onderzoek voor het omgevingsbeleid is sowieso moeilijk en bovendien onwenselijk. Dat werd ook door een van de onderzoekers zelf gezegd. De studie focust immers hoofdzakelijk op één aspect, namelijk de productie van pollen. Daarnaast spelen ook andere aspecten, zoals de landbouwopbrengst en de waterkwaliteit, een belangrijke rol. In elk geval ben ik van mening dat we beter spaarzaam omgaan met termen als gezondheidsschade.

[2] Following this Request for Clarification, a Hearing was indeed organised in the Committee on Environment, Nature and Spatial Planning of the Flemish Parliament on 9 December 2025 (Annex 5).

Los van de sterktes en zwaktes van dat specifieke onderzoek doet het hier wel een uitspraak over de productie van pollen. Ik begrijp dat veel pollen in de lucht – het seizoen is weer gestart – enorm veel hinder en last veroorzaken voor mensen met hooikoorts. Maar het gaat hier over stuifmeel, en dat is natuurlijk niet vergelijkbaar met een of andere chemische stof die door fabrieken wordt uitgestoten.

Ten slotte wat uw vraag over het stikstofbeleid betreft, wil ik verduidelijken dat de atmosferische toediening van stikstof gaat over de uitstoot van ammoniak en stikstofoxiden die neerslaan op de gevoelige natuur in de buurt. Dat is eerder beperkt in relatie tot de stikstofaanbreng via bemesting op landbouwpercelen. Een focus op de effecten bij niet-bemeste natuur lijkt me in dezen ook minder relevant.

De voorzitter

Mevrouw Verlinden heeft het woord.

Bieke Verlinden (Vooruit)

Minister, ik begrijp dat u het onderzoek nog niet helemaal in detail hebt kunnen bekijken. Wie zijn wij om daar vanop afstand en vanuit opinies en gedachten een oordeel over te vormen, of om het onderzoek meteen al in vraag te stellen?

Ik denk dat het belangrijk is om de bevindingen en de kijk te verbreden, en om de onderzoekers te horen, om een beter begrip te krijgen van hoe ze tot die bevindingen komen en wat hun eventuele aanbevelingen kunnen zijn. Ik denk dat we met deze commissie de onderzoekers hier misschien eens moeten uitnodigen voor een gesprek.

De voorzitter

Ik zou even willen stellen dat de vraag over een bespreking met de collega's om een eventuele hoorzitting te organiseren, niet in een openbare zitting hoort plaats te vinden. Dat moeten we straks in de regeling der werkzaamheden doen.

De heer Pieters heeft het woord.

Andy Pieters (N-VA)

Ik denk inderdaad dat het gezondheidsaspect heel weinig aandacht kreeg in het hele stikstofuitstootbeleid van de voorbije jaren. Ik denk dat het op zich belangrijk is, ook los van deze studie, dat we dat blijven meenemen. Als dat inderdaad tot optimalisaties van het beleid kan leiden, moeten we dat maximaal doen. Ik denk ook dat het de afspraak is dat we, in die geest, telkens alle wetenschappelijke inzichten meenemen. Maar zoals de minister ook zegt, en zoals de onderzoekers aangeven, is dit nog maar een eerste vaststelling en zal er vervolgonderzoek nodig zijn.

Het enige wat ik toch nog zou willen aankaarten, is dat er direct kritiek kwam op het onderzoek omdat het te weinig rekening zou houden met de courante landbouwpraktijken. Ook dat hebben de onderzoekers geprobeerd te weerleggen, om te duiden dat dat toch wel het geval was. In die zin is het misschien een idee om hen te ontvangen.

Minister, ik weet niet of het gepland is dat het Instituut voor Natuur- en Bosonderzoek (INBO) of ILVO een analyse gaat maken van de studie en daar conclusies uit gaat trekken, maar zou dat dan eventueel met ons kunnen worden gedeeld? Ik denk dat hun expertise op dat vlak wel belangrijk is.

De voorzitter

Minister Brouns heeft het woord.

Minister Jo Brouns

Ik heb vanochtend toevallig zowel ILVO als het INBO gezien, die de handen in elkaar slaan om nog meer samen te werken. Daar vertelde men mij dat we in Vlaanderen 300.000 hectare aan grasland hebben, en dat we op ongeveer 2500 van die 300.000 hectare het gras laten groeien, waar dan bloemen kunnen komen en pollen kunnen ontstaan. Al de rest wordt gemaaid, omdat het natuurlijk moet dienen als voeder voor de dieren. Die proteïnen moeten optimaal kunnen worden ingezet, daarom wordt het gras gemaaid.

Dat is geen miskenning van het onderzoek, helemaal niet. Daar gaat het niet over. Het gaat alleen over wat de praktijk is en over wat de realiteit is. Dat staat in contrast met het idee dat we alle bemeste grassen zouden laten staan, tot bloei zouden laten komen, zodat er pollen kunnen komen die sterker zouden zijn qua allergene karakteristieken dan wanneer we minder bemesten. Dat is toch wel een heel belangrijke nuance die de studie niet in vraag stelt, die alleen de reële landbouwpraktijk in Vlaanderen op het areaalniveau verder nuanceert. Dat is niet onbelangrijk.

Wat jullie hier verder willen afspreken om daar kennis van te krijgen, is natuurlijk aan jullie, aan het parlement. Ik heb daar geen enkel probleem mee.

De voorzitter

Mevrouw Verlinden heeft het woord.

Bieke Verlinden (Vooruit)

Ik denk dat het aan ons is om daar verdere uitspraken over te doen. Ik begrijp ook dat dat niet tijdens deze zitting kan, maar dat dat in de regeling der werkzaamheden moet, zoals ik ook heb aangegeven. Dat zullen we zeker kunnen doen.

Ik denk wel dat het de eerste keer is dat er een heel concrete link wordt gelegd tussen gezondheid en stikstof, dat dat belangrijke signalen zijn die we echt ernstig moeten nemen en dat we hopelijk enkele concrete aanbevelingen kunnen krijgen over hoe we daar beter mee kunnen omgaan.

De voorzitter

De vraag om uitleg is afgehandeld.

Annex 5: Report of the Hearing in the Committee on Environment, Nature and Spatial Planning of the Flemish Parliament on 9 December 2025

Verslag hoorzitting

Commissie voor Leefmilieu, Natuur en Ruimtelijke Ordening

dinsdag 9 december 2025

URL (verslag en video-opname): https://www.vlaamsparlement.be/nl/parlementair-werk/commissies/commissievergaderingen/1971333

Hoorzitting

Hoorzitting over de gezondheidsimpact van stikstofbemesting

25 (2025-2026)

Naar aanleg van vraag om uitleg 2861 (2024-2025)

van Bieke Verlinden aan minister Jo Brouns

At the time of submission of the final report, the official report of the hearing was still being prepared by the Committee on Environment, Nature and Spatial Planning of the Flemish Parliament. The transcript and final report of the hearing—comprising the presentation of study findings, reflections from representatives of the agricultural sector, questions from committee members, and responses provided by the panel including members of the NITROPOL-BE team—are available at the URL provided above. A concise English summary of the presentation and the questions that were asked, recorded by the coordinator, is included below.

A hearing was held in the Flemish Parliament to present the results of the NITROPOL-BE project, which investigates the health impacts of nitrogen pollution on pollen allergy in Belgium. Prof. Raf Aerts introduced the scientific, financial, and policy framework of the federally funded BELSPO BRAIN-be 2.0 project, explaining that NITROPOL-BE examines how nitrogen enrichment in the environment affects allergic disease as part of Belgium's contribution to federal "global change" and "habitability" priorities. The scientific presentations were delivered by Prof. Tobias Ceulemans (ecology), Dr. Paulien Verscheure (biomedical allergy research), and Prof. Rik Schrijvers (clinical immunology).

The background and research hypothesis highlighted that allergy prevalence has increased and that environmental nitrogen pollution may contribute by altering both plant communities and pollen biology. Findings from the scoping review of the existing literature showed that while nitrogen-related air pollution is well documented, nitrogen in soil and water has been much less studied. Nevertheless, existing evidence suggests that nitrogen enrichment can increase pollen production and modify allergenic protein content. Nitrogen pollution arises from direct inputs such as fertilizers and from atmospheric deposition, leading to ecological changes—reduced plant diversity and dominance of highly productive, high-pollen species—as well as direct biological changes in pollen grains that increase allergenicity.

The ecological component of the NITROPOL study, presented by Prof. Ceulemans, used paired fertilized and unfertilized permanent grasslands in the Hageland region. Historical land-use data supported site selection. Results showed that fertilized grasslands had lower biodiversity, higher biomass, higher nitrogen uptake, and much higher pollen production; notably, the increase in pollen quantity was disproportionate to the increase in biomass, suggesting strong nitrogen-driven amplification effects.

The clinical component, presented by Dr. Verscheure, demonstrated that patients' immune cells showed stronger activation when exposed to pollen from fertilized grasslands. Specific IgE antibodies also reacted more strongly to extracts from nitrogen-enriched pollen, indicating higher allergenic potency.

Sciensano's aerobiology team added context on rising allergy prevalence and long-term trends in pollen concentrations measured across Belgium.

Agricultural sector representatives (not involved in NITROPOL-BE) explained different grassland management systems and emphasized that nitrogen fertilization is essential for producing protein-rich fodder for cattle. They noted that farmers typically prevent grass from flowering to maintain feed quality; flowering and pollen production mainly occur in non-mown buffer strips and biodiversity conservation areas, which are often situated on nitrogen-rich soils. They estimated that the crude protein content of the experimental grasslands (~11%) would be too low for fodder production and more typical of extensive, wet meadows.

Committee members raised questions on the broader health burden of nitrogen pollution, possible policy measures, the mechanisms behind increased allergenicity, the role of road verges and reduced mowing regimes (e.g., "maai-mei-niet"), the predictability of hay fever episodes, and the impact of nitrogen on vegetation types beyond grasses. Additional questions addressed pollen transport distances, the design of green spaces in residential areas, and how mowing strategies in urban green zones may influence exposure. Responses to these questions can be found in the official transcript and video recording of the hearing.

Annex 6: Network

Prof. dr. ir. **Raf Aerts**, PhD, PhD, served as project coordinator for NITROPOL-BE (P1) at **Sciensano**, within the **Risk and Health Impact Assessment** unit of the SD Chemical and Physical Health Risks. He is a bioengineer in land and forest management (MSc and PhD, KU Leuven) and an environmental epidemiologist (PhD, Biomedical Sciences, UHasselt) whose research focuses on elucidating the links between environmental exposures and human health outcomes, with the aim of advancing both biodiversity conservation and public health. In the decade preceding the completion of the NITROPOL project, he held a work leadership role at Sciensano (SW21), collaborating closely with Prof. dr. ir. Eva Declercq, a spatial analyst, and dr. Claire Demoury, a biostatistician, on multiple BELSPO-funded studies investigating the health impacts of green space. He currently holds a part-time associate professorship in Biodiversity and Health at KU Leuven's Department of Biology. As of 26 November 2025, he has supervised over 20 PhD students (including 9 co-promotorships) and more than 30 MSc students, and has (co-)authored 121 peer-reviewed A1 journal articles, 43 of which are first-author publications, with an h-index of 43 (Web of Science) and 49 (Google Scholar).

Relevant international peer-reviewed publications before NITROPOL

Aerts R., Dujardin S., Nemery B., Van Nieuwenhuyse A., Van Orshoven J., Aerts J.M., Somers B., Hendrickx M., Bruffaerts N., Bauwelinck M., Casas L., Demoury C., Plusquin M., Nawrot T.S. 2020. Residential green space and medication sales for childhood asthma: a longitudinal ecological study in Belgium. *Environmental Research* 189:109914 (IF_{2019} 5.7)

Aerts R., Stas M., Vanlessen N., Hendrickx M., Bruffaerts N., Hoebeke L., Dendoncker N., Dujardin S., Saenen N.D., Van Nieuwenhuyse A., Aerts J.-M., Van Orshoven J., Nawrot T.S., Somers B. 2020. Residential green space and seasonal distress in a cohort of tree pollen allergy patients. *International Journal of Hygiene and Environmental Health* 223:71-79 (IF_{2018} 4.4)

Aerts R., Nemery B., Bauwelinck M., Trabelsi S., Deboosere P., Van Nieuwenhuyse A., Nawrot T.S., Casas L. 2020. Residential green space, air pollution, socio-economic deprivation and cardiovascular medication sales in Belgium: a nationwide ecological study. *Science of the Total Environment* 712:136426 (IF_{2018} 5.6)

Stas M., **Aerts R.**, Hendrickx M., Dendoncker N., Dujardin S., Linard C., Nawrot T.S., Van Nieuwenhuyse A., Aerts J.M., Van Orshoven J., Somers B. 2020. An evaluation of species distribution models to estimate tree diversity at genus level in a heterogeneous urban-rural landscape. *Landscape and Urban Planning* 198:103770 (IF_{2018} 5.1)

Aerts R., Honnay O., Van Nieuwenhuyse A. 2018. Biodiversity and human health: mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin*, 127:5-22 (IF_{2018} 2.8) (*invited review*)

Related projects

- Biodiversity at School Environments Benefits for ALL (B@SEBALL) – BELSPO-BRAIN (2019-2024) (postdoctoral researcher)
- Impact of green and blue spaces on specific morbidity and mortality in Belgium (GRESP-HEALTH) – BELSPO-BRAIN (2018-2019) (postdoctoral researcher)
- Assessing spatio-temporal relationships between respiratory health and biodiversity using individual wearable technology (RESPIRIT) – BELSPO-BRAIN (2016-2019) (postdoctoral researcher)
- The Urban Heath Island Effect and heat-related mortality in the urban and peri-urban area of Antwerp – WIV-ISP and VITO (2017) (postdoctoral researcher)
- Detection of plant invasive species and assessment of their impact on ecosystem properties through remote sensing (DIARS-BE) – EU BiodivERsA (2014-2016) (postdoctoral researcher)

Relevant (inter)national contacts

Raf Aerts is member of the Belgian Community of Practice on Biodiversity and Health and contributes to the Superior Health Council project Green and Blue Cities.

Weblinks

https://orcid.org/0000-0003-4018-0790 (ORC-ID publication record)

http://lirias.kuleuven.be/cv?Username=U0019879 (Lirias verified publication record and OA papers)

Dr. ir. **Nicolas Bruffaerts**, PhD (M) (P2, **Sciensano, research group Mycology and Aerobiology**) leads the Aerobiology unit at Sciensano and is the scientific manager of the Belgian aerobiological surveillance network, which he has been coordinating since 2015. He is the main scientific contact person for the Belgian media regarding topics related to allergenic bioaerosols and their impacts on health. With his immediate colleague and pollen specialist dr. Lucie Hoebeke (F), he has been involved in several research projects funded by the Belgian Federal Scientific Policy (RespirIT, RETROPOLLEN). He has also been actively collaborating with the Research institute for Nature & Forest (INBO) to study the role of pollen in the nitrogen fluxes in forest throughfall. Nicolas Bruffaerts is a committee member of the European Aerobiology Society, member the International Aerobiology Association and of the European Association of Allergy and Clinical Immunology. He holds a bioengineering degree (ULB) and did a PhD in Biological Sciences at the Immunology service of Sciensano.

Relevant international peer-reviewed publications before NITROPOL

Aerts R., Dujardin S., Nemery B., Van Nieuwenhuyse A., Van Orshoven J., Aerts J.M., Somers B., Hendrickx M., **Bruffaerts N.**, Bauwelinck M., Casas L., Demoury C., Plusquin M., Nawrot T.S. 2020. Residential green space and medication sales for childhood asthma: a longitudinal ecological study in Belgium. *Environmental Research* 189:109914 (IF_{2019} 5.7)

Aerts R., Stas M., Vanlessen N., Hendrickx M., **Bruffaerts N.**, Hoebeke L., Dendoncker N., Dujardin S., Saenen N.D., Van Nieuwenhuyse A., Aerts J.-M., Van Orshoven J., Nawrot T.S., Somers B. 2020. Residential green space and seasonal distress in a cohort of tree pollen allergy patients. *International Journal of Hygiene and Environmental Health* 223:71-79 (IF_{2018} 4.4)

Ziska L.H., Makra L., Harry S.K., **Bruffaerts N.**, Hendrickx M., Coates F., Saarto A., Thibaudon M., Oliver G., Damialis A., Charalampopoulos A., Vokou D., Heiđmarsson S., Guđjohnsen E., Bonini M., Oh J.W., Sullivan K., Ford L., Brooks G.D., Myszkowska D., Severova E., Gehrig R., Ramón G.D., Beggs P.J., Knowlton K., Crimmins A.R. 2019. Temperature-related changes in airborne allergenic pollen abundance and seasonality across the northern hemisphere: a retrospective data analysis. *Lancet Planetary Health* 3(3):e124-e131. (IF_{2018} 10.7)

Verstraeten W.W., Dujardin S., Hoebeke L., **Bruffaerts N.**, Kouznetsov R., Dendoncker N., Hamdi R., Linard C., Hendrickx M., Sofiev M., Delcloo A.W. 2019. Spatio-temporal monitoring and modelling of birch pollen levels in Belgium. *Aerobiologia* 35:703-717 (IF_{2019} 2.7)

Bruffaerts N., De Smedt T., Delcloo A., Simons K., Hoebeke L., Verstraeten C., Van Nieuwenhuyse A., Packeu A., Hendrickx M. 2018. Comparative long-term trend analysis of daily weather conditions with daily pollen concentrations in Brussels, Belgium. *International Journal of Biometeorology* 62(3):483-491. (IF_{2019} 2.7)

Related projects

- Study on the role of pollen in forest throughfall biochemistry – ICP-Forests (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests) (2018-) (third party collaborator)
- Reconstructing four decades of spatio-temporal airborne pollen levels for Belgium to assess the health impact (RETROPOLLEN) – BELSPO-BRAIN2.0 (2020-2024) (principal investigator)
- COST Action CA18226 New approaches in detection of pathogens and aeroallergens (ADOPT; https://www.cost.eu/actions/CA18226/) – COST (2019-2023) (MC member)
- AutoPollen programme – EIG EUMETNET (2018-2022) (participant)
- Assessing spatio-temporal relationships between respiratory health and biodiversity using individual wearable technology (RespirIT) – BELSPO-BRAIN (2016-2019) (principal investigator)

Weblinks

https://orcid.org/0000-0001-6310-9140 (ORC-ID publication record)

https://airallergy.sciensano.be (Belgian aerobiological surveillance network)

Mrs. **Lucie Hoebeke**, MSc (F) (P2, **Sciensano, research group Mycology and Aerobiology**), has been working as aerobiologist at the *Mycology & Aerobiology* service of Sciensano since 2012. She is actively involved in the routine activities of the Belgian aerobiological surveillance network. She has also been participating as scientific collaborator in several research projects funded by the Belgian Federal Scientific Policy (RespirIT, RETROPOLLEN). Lucie Hoebeke is member of the European Aerobiology Society and of the International Aerobiology Association. She holds two Master degrees in Biological Sciences and in Environmental Science and Management (ULB). Following her departure from the institute, her responsibilities within NITROPOL-BE were assumed by Ms. **Astha Tiwari**.

Relevant international peer-reviewed publications before NITROPOL

Aerts R., Stas M., Vanlessen N., Hendrickx M., Bruffaerts N., **Hoebeke L.**, Dendoncker N., Dujardin S., Saenen N.D., Van Nieuwenhuyse A., Aerts J.-M., Van Orshoven J., Nawrot T.S., Somers B. 2020. Residential green space and seasonal distress in a cohort of tree pollen allergy patients. *International Journal of Hygiene and Environmental Health* 223:71-79 (IF_{2018} 4.4)

Verstraeten W.W., Dujardin S., **Hoebeke L.**, Bruffaerts N., Kouznetsov R., Dendoncker N., Hamdi R., Linard C., Hendrickx M., Sofiev M., Delcloo A.W. 2019. Spatio-temporal monitoring and modelling of birch pollen levels in Belgium. *Aerobiologia* 35:703-717 (IF_{2019} 2.7)

Bruffaerts N., De Smedt T., Delcloo A., Simons K., **Hoebeke L.**, Verstraeten C., Van Nieuwenhuyse A., Packeu A., Hendrickx M. 2018. Comparative long-term trend analysis of daily weather conditions with daily pollen concentrations in Brussels, Belgium. *International Journal of Biometeorology* 62(3):483-491 (IF_{2019} 2.7)

Guilbert A., Cox B., Bruffaerts N., **Hoebeke L.**, Packeu A., Hendrickx M., De Cremer K., Bladt S., Brasseur O., Van Nieuwenhuyse A. 2018. Relationships between aeroallergen levels and hospital admissions for asthma in the Brussels-Capital Region: a daily time series analysis. *Environmental Health* 17(1):35 (IF_{2018} 4.4)

Hoebeke L., Bruffaerts N., Verstraeten C., Delcloo A., De Smedt T., Packeu A., Detandt M., Hendrickx M. 2018. Thirty-four years of pollen monitoring: an evaluation of the temporal variation of pollen seasons in Belgium. *Aerobiologia* 34(2):139 (IF_{2019} 2.7)

Related projects

- Reconstructing four decades of spatio-temporal airborne pollen levels for Belgium to assess the health impact (RETROPOLLEN) – BELSPO-BRAIN2.0 (2020-2024) (scientific collaborator)
- Assessing spatio-temporal relationships between respiratory health and biodiversity using individual wearable technology (RespirIT) – BELSPO-BRAIN (2016-2019) (scientific collaborator)

Weblinks

https://orcid.org/0000-0002-0483-1632 (ORC-ID publication record)

https://airallergy.sciensano.be (Belgian aerobiological surveillance network)

Prof. dr. ir. **Olivier Honnay**, PhD (M) (P3, **KU Leuven, Biology Department**) obtained his PhD in applied biological sciences in 2000 and he currently is a full professor of Conservation Biology at the Biology Department of KU Leuven. He teaches in the Master of Biology and the Master of Sustainable Development at KU Leuven. His research group mainly studies the effects of anthropogenic disturbances such as nutrient pollution, forest management and habitat fragmentation on plant species richness and plant genetic diversity. The objective is to understand the mechanisms behind the worldwide decline of plant (genetic) diversity, and to provide practical, science-based guidelines regarding its conservation and sustainable use. Another part of his research is aiming at identifying microbial communities from the soils of natural and agricultural ecosystems using DNA-barcoding and metagenomics approaches. Olivier Honnay is (co-) author of 243 peer reviewed articles (h-index (GS)= 62) and (co-) advisor of 19 completed PhDs and 8 ongoing PhDs. He is associated editor of *Annals of Botany*.

Relevant international peer-reviewed publications before NITROPOL

Van Geel, M., Jacquemyn, H., Peeters, G., van Acker, K., **Honnay, O**., Ceulemans, T. (joint last author) (2020). Diversity and community structure of ericoid mycorrhizal fungi in European bogs and heathlands across a gradient of nitrogen deposition. *New Phytologist*, published online: doi: 10.1111/nph.16789

Ceulemans, T., Van Geel, M., Jacquemyn, H., Boeraeve, M., Plue, J., Saar, L., Kasari, L., Peeters, G., Van Acker, K., Crauwels, S., Lievens, B., **Honnay, O.** (2019). Arbuscular mycorrhizal fungi in European grasslands under nutrient pollution. *Global Ecology and Biogeography*, (28), 1796-1805.

Ceulemans, T., Hulsmans, E., Van den Ende, W., **Honnay, O.** (2017). Nutrient enrichment is associated with altered nectar and pollen chemical composition in *Succisa pratensis* Moench and increased larval mortality of its pollinator *Bombus terrestris* L. *PLoS One*, 12 (4), Art.No. ARTN e0175160.

Ceulemans, T., Bode, S., Bollyn, J., Harpole, S., Coorevits, K., Peeters, G., Van Acker, K., Smolders, E., Boeckx, P., **Honnay, O.** (2017). Phosphorus resource partitioning shapes phosphorus acquisition and plant species abundance in grasslands. *Nature Plants*, 3 (16224), Art.No. 16224.

Ceulemans, T., Merckx, R., Hens, M., **Honnay, O**. (2013). Plant species loss from European semi-natural grasslands following nutrient enrichment - Is it nitrogen or is it phosphorus. *Global Ecology and Biogeography*, 22, 73-82.

Promoter or co-promoter of following ongoing projects

- PolyTree: Academic capacity building in taxonomy and phylogenetics for the conservation and restoration of threatened Andean plant species and ecosystems – The case of *Polylepis* woodlands. (VLIR IUC, 2020-2021)
- Effects of tropical rainforest disturbance on gene flow, genomic diversity and introgression in understory trees: the case of *Coffea canephora* in the Congo basin. (FWO-Bio3, 2019-2022)
- Evaluating ecosystem services provisioning in apple farming landscapes under different scenarios of land sharing and land sparing. (KU Leuven BOF, 2018-2021)
- Greening intensive farming landscapes: evaluating land use strategies in terms of biodiversity and ecosystem service provisioning and their trade-offs with production and farmer income (FWO-SB, 2018-2021)
- Incidence and Ecology of Rust Disease (*Hemileia vastatrix*) on Wild *Coffea arabica* L. in Moist Ethiopian Mountain Forest. (VLIR UOS, 2017-2021)
- Effects of coffee forest management intensification on Arabica coffee genetic resources (*Coffea arabica* L.). (FWO-Bio4, 2017-2020)
- Understanding and Managing Urban Ectomycorrhizal Fungi Communities to Increase the Health and Ecosystem Service Provisioning of Urban Trees. BiodivERsA ERA-Net - BelSPo Brain (2017-2020)
- Vegetation characterization and evaluation of ecosystem function and plant diversity impacts of *Dichrostachys cinerea* encroachment in Nech Sar national Park, Ethiopia. (VLIR, 2018-2021)
- Diversity and community composition of Arbuscular Mycorrhizal Fungi (AMF) in Bangladeshi rice varieties and their contribution to stress tolerance. (KU Leuven IRO, 2017-2020)

- Linking root functioning and rhizosphere associations to drought tolerance in cassava by using stable isotope techniques. (KU Leuven IRO, 2020-2023)
- Improving Productivity of Enset Based-Farming Systems Through Nutrient Optimization in the Gamo Highland, Southern Ethiopia. (VLIR IUC, 2019-2022)

Relevant international contacts

- Prof. Martin Diekmann, Working Group Vegetation Ecology & Conservation Biology, University of Bremen, Germany (expertise: eutrophication responses of plant communities).
- Prof. Martin Zobel, Plant Ecology laboratory, University of Tartu, Estonia (expertise: global change impacts on plant communities and metabarcoding).

Weblink

http://lirias.kuleuven.be/cv?Username=U0012061 (Lirias verified publication list)

Prof. dr. **Rik Schrijvers**, PhD, MD (M) (P4, **KU Leuven Allergy and Clinical Immunology research group**) is an internal medicine specialist, staff member at the division of allergy and clinical immunology at the University Hospitals Leuven, Belgium (Oct/2014). He is an assistant professor at the KU Leuven (Oct/2014) and the former head of the Allergy and Clinical Immunology Research group (Oct/2015-Dec/2018). He is responsible for the medical care-paths on anaphylaxis, drug allergy and adults with primary immunodeficiency at UZ Leuven. He holds a senior clinical investigator fellowship of the Research Foundation – Flanders (FWO) enabling him to dedicate 50% of his time to scientific research where he mostly focusses on translational scientific research on anaphylaxis and primary immunodeficiency. The Allergy and Clinical Immunology Research group (encompassing 3 shared full-time technicians, 3 post-docs, 10 PhD students) provides access to a wide array of laboratory techniques (e.g. flow cytometry, ELISA, immunoblotting, molecular cloning, genomics) and is well-integrated with the other immunology labs at the KU Leuven. Rik Schrijvers is PI in various investigator-driven translational (in vitro diagnosis of anaphylaxis; epidemiology of molecular determinants of delayed type hypersensitivities, drug allergy; optimization of labeling and delabeling strategies in drug allergy; molecular determinants of primary immunodeficiency) and commercial studies (e.g. PEARL-2, OPuS-2, APEX-2). He is (co-) author of 47 peer reviewed articles (h-index (GS)= 15), with mostly first- or shared first- (n=16) or last-author (n=7) positions. He is supervisor of 2 and co-supervisor of 3 ongoing PhDs. He is a frequent reviewer for journals, awarded with the outstanding reviewer award of the Journal of Allergy and Clinical Immunology, In Practice (IF_{2019} 7.5) in 2019, and an editorial board member of the International Archives of Allergy and Immunology.

Prior funding includes King Baudouin Foundation Fund for medical scientific research (2014, co-PI), KU Leuven C1 grant (2016, PI), FWO researchers fund (2018, PI), VIB grant challenges (2019, co-PI), UZ Leuven KOOR advanced research grant (2020, PI). He teaches allergy (master in medicine), immunopharmacology (master after master hospital pharmacy), physiopathology (bachelor in dentistry) along with scientific reading and reporting (bachelor in medicine).

Relevant international peer-reviewed publications before NITROPOL

Tuyls S, … , **Schrijvers R**. 2016. Subgroups in cephalosporin allergy, making a patient-tailored approach redundant? J Allergy Clin Immunol. 137:331 (IF 11.5)

Schrijvers R, …, Chiriac AM. 2018. Skin Testing for Suspected Iodinated Contrast Media Hypersensitivity. J Allergy Clin Immunol Pract. 6:1246-1254. (IF 7.5)

Renier R, …, **Schrijvers R**. Allergic reactions to polyethoxylated castor oil derivatives: A guide to decipher confusing names on pharmaceutical labels. J Allergy Clin Immunol Pract. 2020 Mar;8(3):1136-1138.e2. (IF 7.5).

Schrijvers R, … , Chiriac AM. Delayed positive skin tests in patients with immediate hypersensitivity reactions to beta-lactams. J Allergy Clin Immunol Pract. 2020 Jul-Aug;8(7):2431-2433. (IF 7.5).

Giovannozzi S, … , **Schrijvers R**. Live Cell Imaging Demonstrates Multiple Routes Toward a STAT1 Gain-of-Function Phenotype. Front Immunol. 2020 Jun 9;11:1114. (IF 6.4).

Relevant projects

- Epidemiology and molecular determinants of delayed type hypersensitivity reactions (2015, ongoing, UZ/KU Leuven funding).
- In vitro diagnosis of rare causes of anaphylaxis (2017, ongoing, UZ Leuven fund) - the proposed techniques are well in line with this ongoing project with most being currently performed routinely.
- Penicillin allergy labeling and delabeling (2018, ongoing, UZ Leuven funding)

Relevant international contacts

- UEMS representative for BelSACI, UEMS treasurer.
- Member of BelSACI, EAACI, AAAAI
- Prof. Dr. Pascal Demoly, Dr. Anca Chiriac (CHU Montpellier, Inserm Paris, France)

Weblink

https://www.ncbi.nlm.nih.gov/pubmed/?term=schrijvers+r

Prof. dr. **Catherine Linard**, PhD (F) and Prof. dr. **Nicolas Dendoncker**, PhD (M) (P5, **U Namur, Department of Geography**) are geographers with PhDs in spatial epidemiology (CL) and land use modelling (ND), with expertise in the production of biodiversity maps to predict the prevalence of respiratory allergies.

Prof. Catherine Linard is Professor in the UNamur's department of Geography. Her research team is currently composed of two post-doctoral researchers and two PhD students. She developed an expertise in health geography and spatial epidemiology. Her research focuses on the combination of different methods and tools – especially Geographical Information Systems, high resolution remote sensing, and spatial models and statistics – for a spatial and integrated approach to various disease systems, including pollen allergy and respiratory disease. She has a solid experience in the production of health risk maps using machine-learning techniques that combine various covariates (e.g. climate, land cover and land use, socio-economic characteristics), most of them being derived from remote sensing. Results of Prof. Linard are published in high impact factors peer-reviewed international journals. To date, she has published 66 papers in peer-reviewed journals, for a total of 2451 citations and an h-index of 22 (source: Scopus).

Prof. Nicolas Dendoncker is Director of the University of Namur's Geography Department. His research builds on a strong expertise in knowledge, modelling techniques and methods revolving around the concepts of landscape and land use dynamics, biodiversity, ecosystem services and sustainable development. In particular, Prof. Dendoncker has worked extensively with biologists and ecologists in linking land use (change) analyses to biodiversity (species and habitat) data, including prospective analyses and modelling of species, habitat and land use change in Europe and Belgium. This reflects in his projects (including several BELSPO-funded projects) and research networks involvement. He is also Lead Author of the IPBES Values assessment. Results of Prof. Dendoncker are published in high impact factors peer-reviewed international journals. To date, he has published 62 papers in peer-reviewed journals, for a total of 1512 citations and an h-index of 20.

Prof. Linard and Prof. Dendoncker recently worked together on the production of biodiversity maps using machine-learning methods and crowd-sourced data. These biodiversity maps were used to predict the prevalence of respiratory allergies in Belgium.

Relevant international peer-reviewed publications before NITROPOL

Stas, M, Aerts, R, Hendrickx, M, **Dendoncker, N**, Dujardin, S, **Linard, C**, Nawrot, T, Van Nieuwenhuyse, A, Aerts, JM, Van Orshoven, J & Somers, B 2020, 'An evaluation of species distribution models to estimate tree diversity at genus level in a heterogeneous urban-rural landscape', *Landscape and Urban Planning*, vol. 198, 103770.

Verstraeten, WW, Dujardin, S, Hoebeke, L, Bruffaerts, N, Kouznetsov, R, **Dendoncker, N**, Hamdi, R, **Linard, C**, Hendrickx, M, Sofiev, M & Delcloo, AW 2019, 'Spatio-temporal monitoring and modelling of birch pollen levels in Belgium', *Aerobiologia*, vol. 35, no. 4, pp. 703-717.

Vanwambeke, S.O., **Linard, C.**, Gilbert, M., 2019. Emerging challenges of infectious diseases as a feature of land systems. Curr. Opin. Environ. Sustain. 38, 31–36.

Martin Y., Van Dyck, H., **Dendoncker N.** et al. 2013. Testing instead of assuming the importance of land use change scenarios to model species distributions under climate change. Global Ecology and Biogeography, 22: 1204-1216.

Berckmans, J., Hamdi, R., **Dendoncker, N.**, 2019. Bridging the Gap Between Policy-Driven Land Use Changes and Regional Climate Projections. J. Geophys. Res. Atmospheres 124, 5934–5950.

Relevant projects

- Multisectoral analysis of climate and land use change impacts on pollinators, plant diversity and crops yields (MAPPY). Axis-JPI climate. (2019-2022)
- Impacts of land use and climate change on the migration of European Nightjars. UNamur-UHasselt BOF (2019-2022).
- The effect of proximity to nature, biodiversity and climate change on the spread of tick-borne diseases and associated health costs. UNamur-UHasselt BOF (2018-2020)
- RespirIT: Assessing spatio-temporal relationships between respiratory health and biodiversity using individual wearable technology. BELSPO (2016-2021)
- Remote sensing for epidemiology in African Cities (REACT). BELSPO (2016-2021)
- Modelling and forecasting African Urban Population Patterns for vulnerability and health assessments (MAUPP). BELSPO (2014 – 2018).
- Modelling and Assessing Surface Change impacts on Belgian and Western European climate (MASC). BELSPO (2014 – 2017).
- Multidiciplinary assessment of BELgian wild BEE decline to adapt mitigation management policy (BELBEES). BELSPO (2014 – 2017).

Relevant international contacts

- EDENext network on biology and control of vector-borne infections in Europe.
- Member of the Ecosystem Services Partnership (ESP) – expert in the mapping and valuation groups
- Evaluator of the BIODIVERSA proposals
- Speaker and tutor at the ALTERNET summer-school on biodiversity and ecosystem services

Weblinks

https://researchportal.unamur.be/fr/persons/catherine-linard/projects/
https://researchportal.unamur.be/fr/persons/nicolas-dendoncker/projects/

Prof. Dr. **Brecht Devleesschauwer**, DVM, PhD (M) (P6, **Sciensano, Epidemiology and public health**), is a senior epidemiologist at Sciensano and visiting professor in Risk Analysis at Ghent University, Belgium. He conducts policy-driven public health research in the domain of composite measures of population health and health inequalities. At Sciensano, he is coordinating the Belgian National Burden of Disease Study , and is involved in several national projects aiming to valorize and strengthen the Belgian health information system (often including linkages between different data sources). He is also chairing the European Burden of Disease Network (COST Action CA18218). Brecht holds PhD degrees in Public Health (UCLouvain) and Veterinary Sciences (UGent), and MSc degrees in Biostatistics (KU Leuven) and Veterinary Medicine (UGent). To date, Brecht Devleesschauwer supervised 3 PhD students and 43 MSc students and has published 149 peer reviewed journal articles and book chapters (h-index (GS) = 32).

Relevant international peer-reviewed publications before NITROPOL

McDonald SA, Haagsma JA, Cassini A, **Devleesschauwer B** (2020) Adjusting for comorbidity in incidence-based DALY calculations: an individual-based modeling approach. BMC Med Res Methodol 20:100.

Otavova M, Van Oyen H, Yokota RTC, Charafeddine R, Joossens L, Molenberghs G, Nusselder WJ, Boshuizen HC, **Devleesschauwer B** (2020) Potential impact of reduced tobacco use on life and health expectancies in Belgium. Int J Public Health 65:129-138.

Devleesschauwer B (2020) European burden of disease network: strengthening the collaboration. Eur J Public Health 30:2-3.

Devleesschauwer B, Maertens de Noordhout C, Smit GSA, Duchateau L, Dorny P, Stein C, Van Oyen H, Speybroeck N (2014) Quantifying burden of disease to support public health policy in Belgium: opportunities and constraints. BMC Public Health 14:1196.

Devleesschauwer B, Havelaar AH, Maertens de Noordhout C, Haagsma JA, Praet N, Dorny P, Duchateau L, Torgerson PR, Van Oyen H, Speybroeck N (2014) DALY calculation in practice: a stepwise approach. Int J Public Health 59:571-574.

Relevant projects

- COST Action CA18218 European Burden of Disease Network (burden-eu; www.burden-eu.net) – COST (2019-2023) (Action Chair)
- Monitoring and mitigating environmental health inequalities in Belgium (ELLIS; www.brain-ellis.be) – BELSPO-BRAIN (2019-2023) (principal investigator)
- Contribution of excessive weight status to the social impact of non-communicable diseases, multimorbidity and disability in Belgium: past, present, and future (WaIST) – Sciensano internal funding (2019-2023) (principal investigator)

- Belgian Health Status Report (HSR; www.healthybelgium.be) – (2017-) (project manager)
- Belgian National Burden of Disease Study (BeBOD) – (2016-) (project manager)

Weblinks

https://orcid.org/0000-0002-2867-6892 (ORC-ID publication record)

https://scholar.google.com/citations?user=AFSxtd0AAAAJ&hl=en (Google Scholar profile)

Prof. **Niko Speybroeck** (PhD MSc MSc) (M) (P7, **UC Louvain, Institut de recherche santé et société**) is Professor at the Institute of Health and Society (IRSS) and the Faculty of Public Health at the Université Catholique de Louvain, with responsibility for teaching epidemiology and statistics. Between 2004 and 2006, he was a Data Team Coordinator at the World Health Organization (WHO) in Geneva, where he contributed to building up country-level capacities to collect and analyse data relevant to public health and to use these data to design and implement effective health policies. Before that, he worked in projects for the African Union and for the Institute of Tropical Medicine in Belgium (1993-2003). The main research interests of Prof. Speybroeck are quantitative epidemiology and the study of infectious diseases. The expertise can be summarized with following key words: Biostatistics, Epidemiology, Modelling, Health and economic burden, Global Health, and Infectious diseases. Prof. Speybroeck has published numerous scientific papers on global and national burden estimations as well as papers on the economic burden due to health problems (h-index (GS) = 58). He used to be a chair of an international task force within the WHO Food borne Disease Burden Epidemiology Reference Group (FERG), comprising the world's leading experts in the area of food safety, with the aim to estimate the Global Burden of Foodborne Diseases and was member of the BIOHAZ panel at the European Food Safety Authority. He was also involved in research towards better understanding the role of possible interventions towards health problems such as malaria. In countries like Peru, the most cost-effective malaria surveillance system is being developed, with the aim to measure progress towards eliminating malaria. N. Speybroeck is also member of the scientific council of Sciensano, and is collaborating in various Sciensano research projects, such as the work on the "post-treatment Lyme disease syndrome" clarifying some of the controversies surrounding Lyme borreliosis. In order to improve the rigor of its estimations, advanced Bayesian approaches are used, as illustrated by our work on malaria and mortality during humanitarian crises. The project at hand offers a good opportunity to do this, bringing advanced methodological tools together with good quality data.

Relevant publications before NITROPOL

Cès S, Lambert A, De Almeida Mello J, Declercq A, **Speybroeck N**, Annemans L, Macq J. The direct cost of disability of community-dwelling older persons in Belgium. Ageing Soc. 2020; in press. doi: 10.1017/S0144686X20000045

Henrard S, Devleesschauwer B, Beutels P, Callens M, De Smet F, Hermans C, **Speybroeck N**. The health and economic burden of haemophilia in Belgium: a rare, expensive and challenging disease. Orphanet J Rare Dis. 2014:9:39. doi: 10.1186/1750-1172-9-39

Maertens de Noordhout C, Devleesschauwer B, Haagsma J, Havelaar A, Bertrand S, Vandenberg O, Quoilin S, Brandt P, **Speybroeck N**. Burden of salmonellosis, campylobacteriosis and listeriosis: a time series analysis, Belgium, 2012 to 2020. Euro Surveill. 2017;22:30615. doi: 10.2807/1560-7917.ES.2017.22.38.30615

Smit G, Apers L, Arrazola de Onate W, Beutels P, Dorny P, Forier A, Janssens K, Macq J, Mak R, Schol S, Wildemeersch D, **Speybroeck N**, Devleesschauwer B. Cost-effectiveness of screening for active cases of tuberculosis in Flanders, Belgium. Bull World Health Organ. 2017;95:27-35. doi: 10.2471/BLT.16.169383

Tromme I, Legrand C, Devleesschauwer B, Leiter U, Suciu S, Eggermont A, Sacré L, Baurain J, Thomas L, Beutels P, **Speybroeck N**. Cost-effectiveness analysis in melanoma detection: A transition model applied to dermoscopy. Eur J Cancer. 2016;67:38-45. doi: 10.1016/j.ejca.2016.07.020

Relevant projects

- Fonds de la Recherche Scientifique (FNRS) Post-doc-scholarship. Targeting co-endemic Plasmodium vivax and Plasmodium falciparum infections for malaria elimination through longitudinal studies & mathematical models (2018-2021).
- Fonds spécial de recherche (FSR) Project. Creating synergy: Linking resources for harnessing the multidisciplinary competitiveness of UCLouvain to disentangle complexities of health in society (2018-2021).
- Bourse de développement UCLouvain PhD - scholarship. Spatio-temporal Modelling of Malaria in Burkina Faso (2016-2020).
- ARES Project, CIUF-CUD - Commission universitaire pour le Développement. Mise en place d'un système de surveillance de la résistance de Plasmodium falciparum aux antipaludéens par marqueurs moléculaires en République Démocratique du Congo (2016-2021).
- ERANet-LAC Project (7th Framework Program funded European Research and Technological Development, FP7). Sero-surveillance tools for targeting Plasmodium vivax infections and monitoring malaria control and elimination efforts in Amazonian countries (2016-2020).
- Sciensano project with PhD-scholarship. Hum Tick: Tick-borne diseases in Belgium: identifying and communicating disease burden (2015-2020).

(Inter)national network

- Member of the Sciensano scientific council
- Member of the Scientific Committee of the Belgian Food Safety Agency
- Member of the Flemish Population Screening Working Group
- Member of the BIOHAZ panel of the European Food Safety Authority

Weblinks

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