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# Editorial: Forest pathology in changing climate

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Editorial on the Research Topic
Forest pathology in changing climate

Forests cover over 31% of the earth's surface and are vital to our existence. They provide essential ecosystem services by reducing society's carbon footprint and fostering biodiversity. They also provide important societal and economic benefits: the economic value of forest ecosystem services is estimated to contribute between $125 and 145 trillion per year (Costanza et al., 2014). Currently, forests and forest health are in global decline from natural pressures and human-induced threats. Healthy forests are not necessarily pristine and disease-free, but stable and resilient ecosystems that are ecologically dynamic with evolutionary adaptive responses to different stressors (Hadziabdic et al.). However, with globalization and changes in climate patterns, both natural and planted forests are at risk from invasive exotic insect pests and pathogens, climate-induced wildfires, wind disturbance, extended drought cycles or extreme precipitation events, and air pollution. In this special issue of *Forest pathology in changing climate*, nine articles discuss current major forest diseases affecting different tree species, modeling to predict their epidemics, and the current state of forest pathology and related careers in North America.

The first manuscript is a review article focusing on the future of forest pathology in North America. Hadziabdic et al. are a group of researchers, scientists, academics, and administrators from across the United States (U.S.) and Canada working in the field of Forest Health and Forest Pathology. The authors discuss how the Anthropocene is disrupting the current, natural balance and the effect of globalization on invasive exotic insect pests and pathogens that affect historically, culturally, and economically significant tree species. Climate change will have a compounding effect on forest health by changing rainfall patterns, prolonging and intensifying periods of drought or rainfall, increasing temperatures, and shifting seasonal weather patterns that will increase abiotic stressors, making tree hosts more vulnerable to both insect pests and pathogens. Combined, these effects could result in economic losses between $4.3 and 20.2 trillion per year in ecosystem services (Costanza et al., 2014). The authors offer solutions and suggestions, including establishing forest pathology research consortia with multidisciplinary training, approaches, and resources to illuminate society's path forward to protecting and managing our natural resources.

A research area that is still fairly unexplored, but gaining growing attention, involves the role of the host-associated microbiome in tree diseases. Tree endophytes might display diverging roles that span from modulating resistance to exacerbating disease outcomes and could also be affected by climate. Morrison et al. propose the need for considering species composition within pathogen complexes, as well as the broader endophytic community when assessing disease progression and its outcome. In the beech bark disease pathosystem, two different pathogens, *Neonectria faginata* and *N. ditissima*, are broadly co-occurring, but have opposite climate adaptations and are likely associated with different stages of tree decline. The authors indicate that other fungal taxa associated with the system may have a contributing role in driving disease outcomes.

With a similar focus on the role of the microbiome in plant-microbe interactions, but with an emphasis on their beneficial effects, Blumenstein et al. screen Scots pine endophytes for their potential use as control agents against *Diplodia* tip blight disease caused by the fungus *Sphaeropsis sapinea*. They find some promising candidate species that do not change their behavior toward the host plant during drought conditions, which notoriously can trigger a lifestyle switch from endophytes to pathogens in opportunistic species.

Chahal et al.'s study focuses on Thousand Cankers Disease (TCD) in black walnut trees. The TCD complex involves the walnut twig beetle (*Pityophthorus juglandis*) and the fungal pathogen *Geosmithia morbida*. TCD symptoms, incidence, and severity differ between eastern and western U.S. outbreak localities, resulting in high host mortality rates, mainly in the western U.S. The authors report differential virulence among genetic clusters of *G. morbida* isolates and reject the hypothesis that *G. morbida* is less virulent in its native region, the eastern U.S. The authors indicate that both eastern and western isolates can induce cankers, given favorable conditions.

Within the TCD pathosystem, Williams and Ginzel demonstrate how wood moisture content influences the fungal competition of *G. morbida* and model predictions regarding pathogen survival and potential future outbreaks. The authors indicate that the process of fungal competition and distribution involves not only a combination of different abiotic conditions that limit competitive success, sporulation, and dispersal of the fungus, but that the host microbiome plays a crucial role in lowering the severity of TCD in the native range of black walnut. The authors predict that the survival of *G. morbida* was highest in historical epicenters of TCD in the western U.S., which is expected as *G. morbida* is evolutionarily adapted to drier climatic conditions. Future climate scenarios indicate that TCD will expand into the native range of black walnut, threatening their long-term sustainability.

Ash dieback caused by the invasive fungus *Hymenoscyphus fraxineus* has been causing massive mortality of European ash (*Fraxinus excelsior*) populations across Europe. Klesse et al. provide a comprehensive overview of the landscape features that determine ash mortality rates in Switzerland over a 10-year period. Using data from long-term forest monitoring programs in Switzerland, the authors indicate that ash mortality increased significantly since the first discovery of *H. fraxineus* in 2008, especially among the smaller diameter, or slower growing, trees and stands with increased humidity. Climate-change-induced warming may reduce the virulence of the pathogen and, combined with host-induced resistance and different elevation gradients, could improve the long-term conservation of ash in Europe.

Characterizing changes in root pathogens as western forests become drier is vital to making future management decisions. Using Maximum Entropy (MaxEnt) analyses, Kim et al. use contemporary climate space of the root pathogen *Armillaria solidipes* and a common host, Douglas-fir (*Pseudotsuga menziezii*), to predict how the pathogen will move in association to this host based on two future climate scenarios. The authors predict that the range of *A. solidipes* will increase in more northern areas of western North America. These movements follow the trends of the predicted geographic movement of Douglas-fir and suggest that *A. solidipes* could become more prevalent where Douglas-fir becomes maladapted on sites. Using MaxEnt to extrapolate new host and pathogen geographic ranges can be used as an important tool to help manage future forests, giving insights into how our forest will change in future climate scenarios.

Genomic approaches are providing novel ways to understand the impact climate change will have on tree-pathogen interactions and possibly help improve predictions under future climates. Variability within species is generally not considered in prediction models. This may be significant as lineages and genetic variants sometimes exhibit different environmental tolerance ranges which may impact disease severity and climate adaptation. Herpin-Saunier et al. discover that this is the case for the lineages of the Swiss needle cast pathogen, *Nothophaeocryptopus gaeumannii.* The authors use PCR assays to identify two lineages of *N. gaeumannii* in Douglas-fir and included lineage identification in prediction models. Results predict the expansion of one lineage that has a broader environmental tolerance range, which could potentially increase its spread.

Ghosh et al. utilize genomics for a different approach as the novelty of their work disentangles the metabolic host response to pathogens of variable virulence. They experimentally simulate drought and high-temperature conditions and perform inoculations using the aggressive pine pathogen *Diplodia sapinea* and the less virulent *D. scrobiculata*. Their results confirm that under warmer and drier conditions, Austrian pines are hindered by weaker host defense systems that increase susceptibility to less aggressive pathogens. Transcriptome analyses reveal that the climate-change-simulated environment result in a critical change in the expression of genes in the host carbon and nitrogen metabolism and host-defense-associated pathways. These studies indicate that not only pathogen lineages could gain fitness benefits from climate change, but also those host defense reactions could become compromised, which could open the door to even weak pathogen infections.

This special issue highlights the importance of considering climate change in forest disease outbreaks. It also shows that common approaches, such as genomics and modeling, can be applied to different forest pathosystems. We forecast a need in understanding how climate change will affect forest health issues that should be an essential part of future research on forest health.

## Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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