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Editorial: Interactions Between Ozone Pollution and Forest Ecosystems

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Editorial on the Research Topic

Interactions between Ozone Pollution and Forest Ecosystems

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INTRODUCTION

Forests are a key element of landscape, carbon sink, biodiversity conservation, and human well-being. The major air pollutant nowadays affecting forest health and biodiversity worldwide is tropospheric ozone (O_3) (Li et al., 2017; Feng et al., 2019; Agathokleous et al., 2020). Progress has been achieved by controlling the emission of O_3 precursors in some areas of the world (Sicard et al., 2013; Paoletti et al., 2014). However, O_3 levels still reach potentially phytotoxic thresholds in many areas (Mills et al., 2018a; Sicard et al., 2020). Major gaps of knowledge in our understanding of O_3 and forest interactions exist. In particular, risk assessment, multifactorial responses, detoxification mechanisms, and the role of forest vegetation in cleaning urban air require further investigation (Paoletti et al., 2020).

This Research Topic of *Frontiers in Forests and Global Change*, Interactions between Ozone Pollution and Forest Ecosystems, presents eight original research articles that span the field of O_3 research on forests and give new insights based on novel results, thus providing a basis for further studies and potential reduction of the severity of O_3 impacts on forests.

Hoshika et al. developed stomatal-flux and exposure-based critical levels for O_3 risk assessment of biomass losses in two larch species (*Larix*), a genus of high forest value. They found that the critical levels for the larches were smaller than those for other forest tree species, suggesting a relatively high susceptibility of these larches. This research also revealed that the use of stomatal fluxes as the metric of dose resulted in no species-specific differences that were found using an exposure-based metric. Protection of forest productivity from negative impacts of O_3 requires species-specific critical levels that may be based on either O_3 concentrations or stomatal uptake accumulation over the growing season (Moura et al., 2018). Even though O_3 concentrations are more easily available, stomatal uptake, more biologically meaningful, is recommended in spite of the more complex calculation (Emberson et al., 2000; Paoletti and Manning, 2007). Stomatal-flux risk assessment may be carried out at different scales, e.g., leaf (Shang et al., 2017), ecosystem (Fares et al., 2013; Hoshika et al., 2017), regional (Anav et al., 2016; De Marco et al., 2020), or global (Mills et al., 2018b). Savi et al. investigated the relationship between stomatal O_3 fluxes and net ecosystem productivity (NEP), measured directly at the ecosystem level in a network of forest experimental sites with the eddy covariance technique, by the means of artificial neural networks. The analysis highlighted that O_3 effects over NEP are highly non-linear and site-specific. By isolating O_3 effects from other covarying environmental factors, negative effect on NEP were found in the order of 1 percent. These low but significant effects were correlated with meteorological variables showing that O_3 damage depends on weather conditions.

For a proper risk assessment, it is important to evaluate all environmental factors that may affect the ecosystem responses to O_3, such as nutrient (Zhang et al., 2018) and water availability (Hoshika et al., 2018). Hunová et al. evaluated O_3 concentrations, ambient NOx concentrations and meteorology in Czech mountain forests over the period 1992–2018. They found that both meteorology and air pollution are highly important in affecting day-to-day variability in O_3 concentrations in Czech forests. They applied a generalized additive model with semiparametric (penalized-spline-based) components to properly capture the non-linear responses that are typical of O_3 studies (Agathokleous et al., 2019) and are not captured by traditional linear regression approaches. Overall, there is an urgent need of using sophisticated statistical approaches for untangling the effects of O_3 from those of the co-occurring environmental factors. Multifactorial experiments will help to clarify the contribution of each factor. Sugai et al. investigated O_3 responses of larch in combination with soil salinization, an interaction that represents a potential concern for vegetation in many coastal areas (Calzone et al., 2019), and found that the responses were additive and did not exhibit significant interactive effects. Such additive responses are common in experiments where elevated O_3 is combined with other factors (e.g., Carriero et al., 2016; Yuan et al., 2017), and their identification and understanding may help developing a conceptual model of plant response to O_3 in a multi-factorial world.

Integrating plant detoxification processes into O_3 risk assessment is still a major challenge for O_3 research. Dusart et al. reviewed the great diversity of antioxidative systems, scattered in different cellular compartments, that are involved in foliar responses to O_3, in particular the Halliwell Asada Foyer cycle and phenolic compounds in cell wall, vacuole and chloroplasts. They pointed out that a better understanding of subcellular localization and transport would allow a more precise identification of the respective contribution of each compartment to the foliar defense system, and recommended more detoxification modeling efforts, similar to Tuzet et al. (2011).

The relevance of urban forests for human well-being and other services is continuously rising, and the selection of plant species that may improve air quality is thus of great interest (Samson et al., 2019). Plants may uptake Volatile Organic Compounds (VOC) emitted by anthropogenic activities. Araya et al. found several anthropogenic VOCs (e.g., toluene, styrene, xylenes, naphthalene, benzenes, and trichloroethene) in the leaves of two tree species in Santiago city (Chile), and *Liriodendron tulipifera* was more efficient than *Platanus* × *acerifolia* in the O_3 uptake. However, plants may also emit biogenic VOCs, e.g., isoprene and monoterpenes, which affect air quality and may contribute to O_3 formation (Sicard et al., 2018). Fitzky et al. reviewed the interplay of O_3 and urban vegetation shedding light on the complex photochemistry leading to O_3 production. BVOCs emitted by vegetation can be considered O_3 precursors especially in presence of anthropogenically emitted NO_X. The authors highlight differences along the rural-urban gradient affecting tropospheric O_3 concentrations. Grote et al. developed a new modeling approach for estimating abiotic and biotic stress-induced *de novo* emissions of BVOCs from plants. A function is proposed that describes the production of all stress-induced biogenic VOCs and scales with stress intensity. It is hypothesized that the response delay and the form of the function are specific for the production pathway and valid for stress induced by O_3 as well as wounding (herbivory). These results will help including biogenic VOC responses to stressors into modeling.

These articles were presented at the 2nd International Conference on "Ozone and Plant Ecosystems" that was held in Florence (Italy) in 2018. The next conference of this series was planned in 2020 but was postponed to May 2021 due to the COVID-19 pandemic (https://cyprus2021.com/). Interestingly, the lockdown following the pandemic resulted in a drastic improvement of the air quality, especially nitrogen dioxide (NO_2) levels, in many world areas (Zhang et al., 2020), while O_3 levels tended to increase in the cities (Sicard et al., 2020). Ozone is a unique air pollutant due to its high reactivity and the fact that is formed by reactions of precursors, including NO_2. This is why controlling O_3 pollution has resulted to be a serious challenge and justify why more research is still needed about the Interactions between Ozone Pollution and Forest Ecosystems.

AUTHOR CONTRIBUTIONS

EP, ZF, SF, PS, EA, and AD contributed to writing this Editorial of the Research Topic on Interactions between Ozone Pollution and Forest Ecosystems that they edited in 2019–2020. All authors contributed to the article and approved the submitted version.

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