Global distribution patterns of mycorrhizal associations: abundance, environmental drivers and ecological impacts

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Summary

Mycorrhizas are symbiotic associations between soil fungi and most vascular plant species, where the plant hosts provide carbohydrates to the associated fungi, which in exchange supply soil nutrients and water to the plant. Besides the implications of these associations for plant fitness and productivity, mycorrhizas have a profound impact on ecosystem functioning, influencing plant community composition, soil structure and soil biogeochemical cycles.

Depending on the identity of the plant and fungal partners, four mycorrhizal types have been described. Among them, arbuscular mycorrhiza (AM), ectomycorrhiza (EcM) and ericoid mycorrhiza (ErM) are the most taxonomically and geographically widespread mycorrhizal types, being present in approximately 80% of the plant species. Due to significant differences in morphology, physiology and nutrient uptake strategies of the fungal partners, the consequence of mycorrhizal mediation on ecosystem processes greatly depends on the predominant mycorrhizal types. Despite its recognized ecological relevance, quantitative information about the abundance patterns of distinct mycorrhizal plants and fungal types and their environmental drivers and ecological implications across different biomes is incomplete. This thesis quantitatively explores the aboveground and belowground abundance patterns of arbuscular mycorrhiza, ectomycorrhiza and ericoid mycorrhiza and the ecosystem properties derived from these patterns.

In Chapter 2 I assessed the climatic and edaphic factors that better predict the global distribution patterns of distinct types of mycorrhizal vegetation. Based on a gridded dataset that includes 39 soil and climatic parameters and the relative abundance of AM, EcM and ErM plants at a global scale, I showed that the distribution of mycorrhizal host plants is mainly driven by temperature-related factors. These findings contradict the predominant view that, at global scale, distinct types of mycorrhizal plants distribute according to the competitive advantage that specific mycorrhizal fungal traits provide to colonize areas with beneficial edaphic conditions. The results of this chapter highlight the role of climate as the main driving force shaping the mycorrhizal global distribution and suggest that climate change can significantly alter

the distribution of mycorrhizal host plants, with a subsequent impact on the functioning of terrestrial ecosystems.

Given the major uncertainties that exist in tropical areas regarding mycorrhizal types distribution and their environmental preferences and ecosystem impacts, Chapter 3 examines the relationship along a gradient from AM- to EcM-dominated tropical forests. Along that gradient, different topsoil properties, climatic conditions, and microbial abundance proxies were evaluated. This chapter reveals consistent differences in biogeochemical proxies between AM and EcM-dominated tropical stands, indicating lower soil fertility and lower carbon (C) and nutrient transformation rates in EcM forests. Moreover, in contrast to the patterns reported in temperate forests, EcM- dominated stands tended to accumulate less topsoil C than AM stands. A different impact of microbial residues on the formation of stable topsoil organic matter between EcM tropical and temperate forests may explain the contrasting impacts on topsoil C accumulation.

Chapter 4 focuses on the belowground mycorrhizal distribution by creating the first high-resolution global maps of fine root biomass colonized by AM and EcM fungi. This information is key for better quantification of mycorrhizal impacts on ecosystem processes and to incorporate mycorrhizal pathways into global biogeochemical models. To build these maps, I combined multiple datasets including aboveground and belowground plant biomass, plot-level plant species abundance, plant traits and mycorrhizal intensity of colonization. The maps revealed the highest AM abundances in the (sub-)tropics and the highest EcM abundances in the taiga regions. This chapter does not provide an ecological analysis of the resulting maps but serves as a basis for future research where quantitative data on mycorrhizal distribution belowground is needed.

Finally, to gain insights into the mechanisms of belowground C flow and allocation through mycorrhiza, Chapter 5 explores the existence of a relationship between the total fine root length root colonized by AM fungi and the AM extraradical mycelium at plant community level. I found that, while different colonization strategies were present in the studied AM community, the AM biomass in the soil was generally positively correlated with the AM biomass within the plant roots. I suggest that the proportional biomass allocation between intra-and extraradical AM fungal mycelium (i.e. the AM fungal biomass that develops inside and outside the host plant roots) is made possible by compensation between different AM fungal colonization strategies to maximize plant productivity and fitness. The result of Chapter 5 opens the possibility of using AM fungal total root colonization as a proxy for soil AM fungal abundances. This proxy will help to estimate AM fungal abundance in soils, which is key to a better understanding of terrestrial ecosystems functioning in present and future climates.

Taken all together, the chapters of this thesis highlight the need of considering the specific environmental context when assessing mycorrhizal impacts on ecosystem functioning. Evaluating mycorrhizal-mediated ecosystem processes based solely on the abundance of AM, EcM and ErM plants may be misrepresentative. Specific climatic conditions, the abundances of the fungal partners, the microbial community composition or species-specific plant and fungal traits should also be taken into account. New theoretical frameworks need to be developed that allow more accurate predictions on mycorrhizal influence on biogeochemical cycles.