Climatic controls of decomposition drive the global biogeography of forest-tree symbioses

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Abstract

The identity of the dominant root-associated microbial symbionts in a forest determines the ability of trees to access limiting nutrients from atmospheric or soil pools[1,2], sequester carbon[3,4] and withstand the effects of climate change[5,6]. Characterizing the global distribution of these symbioses and identifying the factors that control this distribution are thus integral to understanding the present and future functioning of forest ecosystems. Here

we generate a spatially explicit global map of the symbiotic status of forests, using a database of over 1.1 million forest inventory plots that collectively contain over 28,000 tree species. Our analyses indicate that climate variables—in particular, climatically controlled variation in the rate of decomposition—are the primary drivers of the global distribution of major symbioses. We estimate that ectomycorrhizal trees, which represent only 2% of all plant species[7], constitute approximately 60% of tree stems on Earth. Ectomycorrhizal symbiosis dominates forests in which seasonally cold and dry climates inhibit decomposition, and is the predominant form of symbiosis at high latitudes and elevation. By contrast, arbuscular mycorrhizal trees dominate in aseasonal, warm tropical forests, and occur with ectomycorrhizal trees in temperate biomes in which seasonally warm-and-wet climates enhance decomposition. Continental transitions between forests dominated by ectomycorrhizal or arbuscular mycorrhizal trees occur relatively abruptly along climate-driven decomposition gradients; these transitions are probably caused by positive feedback effects between plants and microorganisms. Symbiotic nitrogen fixers—which are insensitive to climatic controls on decomposition (compared with mycorrhizal fungi)—are most abundant in arid biomes with alkaline soils and high maximum temperatures. The climatically driven global symbiosis gradient that we document provides a spatially explicit quantitative understanding of microbial symbioses at the global scale, and demonstrates the critical role of microbial mutualisms in shaping the distribution of plant species.

Fig. 1: The global distribution of GFBi training data.Fig. 2: A small number of environmental variables predict the majority of global turnover in forest symbiotic status.Fig. 3: The distribution of forest symbiotic status across biomes is related to climatic controls over decomposition.Fig. 4: Global maps of predicted forest-tree symbiotic state.

Data availability

Information regarding symbiotic guild assignments, model selection (including global rasters of our model projections for ectomycorrhizal, arbuscular mycorrhizal and N-fixer proportion of tree basal area) and analyses is available as Supplementary Data. The GFBi database is available upon

written request at https://www.gfbinitiative.org/datarequest. Any other relevant data are available from the corresponding authors upon reasonable request.

Change history

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  In this Letter, a middle initial and additional affiliation have been added for author G. J. Nabuurs; two statements have been added to the Supplementary Acknowledgements; and a citation to the French National Institute has been added to the Methods; see accompanying Author Correction for further details.

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K.G.P. and T.W.C. conceived the study; T.W.C., J.L., P.B.R., G.J.N., S.d.-M., M.Z., N.P., B.H., X.Z. and C.Z. conceived and organized the GFBi database; K.G.P., B.S.S., G.D.A.W. and M.E.V.N. compiled the symbiosis database; B.S.S. carried out the primary data analysis; M.E.V.N. and D.R. contributed to data compilation and analysis; B.S.S., T.W.C., M.E.V.N. and K.G.P. wrote the initial manuscript; B.S.S., T.W.C., J.L., M.E.V.N., G.D.A.W., P.B.R., G.J.N., S.d.-M., M.Z., N.P., B.H., X.Z., C.Z. and K.G.P. made substantial revisions to all versions of the manuscript; all other named authors provided forest inventory data and commented on the manuscript.

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Ethics declarations

Competing interests

The authors declare no competing interests.

Additional information

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Supplementary information

Supplementary Information

This file contains Supplementary Tables 1–8 and Supplementary Figures 1–26.

Reporting Summary

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This file contains Supplementary Acknowledgments.

Supplementary Data

This zip folder contains Supplementary Data files and a guide showing the climatic controls of decomposition drive the global biogeography of forest tree symbioses.

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