

PROJECT INFORMATION

---

**Project title:** Mycorrhizas, alternative stable states, and landscape partitioning in south-temperate forests

**Project ID:** 253

**Contact person:** Xiaobin Hua // [xhua@waikato.ac.nz](mailto:xhua@waikato.ac.nz)  
Christopher Lusk // [chris.lusk@waikato.ac.nz](mailto:chris.lusk@waikato.ac.nz)

PROJECT DESCRIPTION

---

An emblem of the Gondwanan legacy, southern beech trees (Nothofagaceae) dominate the biomass of the southern hemisphere's temperate forests (1), and have been at the heart of debates about the origins of the biota of the southern continents (2-5). Although Nothofagaceae are often associated with cool temperatures (6, 7), their distributions within the various southern continents are rather poorly explained by climate (6, 8). Enigmatic disjunctions ("beech gaps") have been variously attributed to geographic variation in disturbance regimes (9), or to the supposedly poor dispersal of beech impeding recovery after removal by glaciation or volcanism (7). Conversely, beeches show an unexplained ability to displace a range of other tree species from climatically suitable sites (10).

The ectomycorrhizal (EM) condition of beeches has been viewed mainly as a constraint on their dispersal because of the presumed difficulties in finding suitable fungal symbionts in landscapes otherwise largely populated by arbuscular mycorrhizal (AM) trees (11). Recent advances by us and others (12-14) suggest we might better understand landscape partitioning between beeches and AM trees by focusing instead on the implications of mycorrhizal symbioses for nutrition and nutrient cycling. Mycorrhizas are now known to underlie the formation of alternative stable states in tropical rainforests: short-circuiting of the nitrogen (N) cycle by EM fungi gives rise to monodominant EM stands that form a stable alternative to more diverse AM-dominated forests (12). EM fungi can obtain N directly from organic sources (15), enhancing N supply to their host trees but suppressing N mineralization and thus starving AM plants that are unable to utilize organic N sources (12, 16, 17). This raises the question: are southern beech stands a temperate analogue of the monodominant EM stands that arise as an alternative stable state in tropical rainforests?

We will use a chronosequence approach to test hypotheses about landscape partitioning between beeches and AM trees, comparing trajectories of understorey light and soil C, N and P along beech-dominant and AM-dominant chronosequences in NZ, Chile and Tasmania. Wherever possible, we will pair sites colonized by beech vs. AM trees on the same parent material. We will then model the successional trajectories of mycorrhizal associations in south temperate forests as a function of soil parent material, climate, and seed sources, incorporating feedbacks on light and nutrient availability. We will also use natural ecotones and pre-existing paired plantations in Chile and NZ to compare the influences on beeches and AM trees on soil chemistry. Lastly, we will use a global dataset to review environmental partitioning worldwide between AM and EM trees.

Capitalizing on recent advances in the fast-moving field of mycorrhizal ecology (12, 13, 18), this work has the potential to unify our understanding of the dynamics and distribution of beech forests, reconciling disparate interpretations that have developed in New Zealand, Chile and Tasmania (1), and resolving the puzzle of beech disjunctions. Our proposal also

breaks new ground internationally by jointly addressing both above- and belowground feedback loops associated with different mycorrhizal associations, and their consequences for forest development.

### References

1. Veblen, TT, RS Hill, J Read (1996) The Ecology and Biogeography of Nothofagus forests. Yale University Press.
2. Cook, LG & MD Crisp (2005) Not so ancient: the extant crown group of Nothofagus represents a post-Gondwanan radiation. *Proceedings of the Royal Society B: Biological Sciences* 272: 2535-2544. <https://doi.org/10.1098/rspb.2005.3219>.
3. van Steenis, CGJ (1971) Nothofagus, key genus of plant geography, in time and space, living and fossil, ecology and phylogeny. *Blumea* 19: 65-98.
4. Knapp, M, K Stöckler, D Havell, F Delsuc, F Sebastiani, PJ Lockhart (2005) Relaxed molecular clock provides evidence for long-distance dispersal of Nothofagus (southern beech). *PLoS biology* 3:e14-e14. <http://10.1371/journal.pbio.0030014>.
5. Swenson, U, RS Hill, S McLoughlin (2001) Biogeography of Nothofagus supports the sequence of Gondwana break-up. 50: 1025-1041. [10.2307/1224719](http://10.2307/1224719).
6. Busby, JR (1986) A biogeoclimatic analysis of Nothofagus cunninghamii (Hook.) Oerst. in southeastern Australia. *Australian Journal of Ecology* 11: 1-7. <http://10.1111/j.1442-9993.1986.tb00912.x>.
7. Wardle, P (1991) *Vegetation of New Zealand*. Cambridge, Cambridge University Press. 672.
8. Leathwick, JR (1998) Are New Zealand's Nothofagus species in equilibrium with their environment? *Journal of Vegetation Science* 9: 719-732. <https://doi.org/10.2307/3237290>.
9. Veblen, TT, C Donoso, FM Schlegel, BR Escobar (1981) Forest dynamics in south-central Chile. *Journal of Biogeography* 8: 211-247. <http://DOI:10.2307/2844678>.
10. Leathwick, J & M Austin (2001) Competitive interactions between tree species in New Zealand's old-growth indigenous forests. *Ecology* 82: 2560-2573. [https://doi.org/10.1890/0012-9658\(2001\)082\[2560:CIBTSI\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2001)082[2560:CIBTSI]2.0.CO;2).
11. Baylis, GT (1980) Mycorrhizas and the spread of beech. *New Zealand Journal of Ecology* 3: 151-153.
12. Corrales, A, SA Mangan, BL Turner, JW Dalling (2016) An ectomycorrhizal nitrogen economy facilitates monodominance in a neotropical forest. *Ecology Letters* 19: 383-392. <http://doi:10.1111/ele.12570>.
13. Lu, M & LO Hedin (2019) Global plant-symbiont organization and emergence of biogeochemical cycles resolved by evolution-based trait modelling. *Nature Ecology & Evolution* 3: 239-250. <http://10.1038/s41559-018-0759-0>.
14. Fritz, RA & CH Lusk (2020) Determinants of leaf area index and understory light availability in New Zealand old-growth forests. *Journal of Biogeography* 47: 941-954. <https://doi.org/10.1111/jbi.13781>.
15. Hobbie, EA & P Högberg (2012) Nitrogen isotopes link mycorrhizal fungi and plants to nitrogen dynamics. *New Phytologist* 196: 367-382. <https://doi.org/10.1111/j.1469-8137.2012.04300.x>.
16. Orwin, KH, MUF Kirschbaum, MG St John, IA Dickie (2011) Organic nutrient uptake by mycorrhizal fungi enhances ecosystem carbon storage: a model-based assessment. *Ecology Letters* 14: 493-502. <http://10.1111/j.1461-0248.2011.01611.x>.
17. Dickie, IA, N Koele, JD Blum, JD Gleason, MS McGlone (2014) Mycorrhizas in changing ecosystems. *Botany* 92: 149-160. <http://10.1139/cjb-2013-0091>.
18. Lin, G, ML McCormack, C Ma, D Guo (2017) Similar below-ground carbon cycling dynamics but contrasting modes of nitrogen cycling between arbuscular mycorrhizal and ectomycorrhizal forests. *New Phytologist* 213: 1440-1451. <https://doi.org/10.1111/nph.14206>