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## Phenotypic plasticity and genetic adaptation of plant functional traits on global scales

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## References

### A

- Abakumova M, Zobel K, Lepik A, Semchenko M. 2016.** Plasticity in plant functional traits is shaped by variability in neighbourhood species composition. *New Phytologist* **211**: 455–463.
- Abrams MD. 1994.** Genotypic and phenotypic variation as stress adaptations in temperate tree species: a review of several case studies. *Tree Physiology* **14**: 833–842.
- Ackerly DD, Cornwell WK. 2007.** A trait-based approach to community assembly: partitioning of species trait values into within- and among-community components. *Ecology Letters* **10**: 135–145.
- Aitken SN, Yeaman S, Holliday JA, Wang T, Curtis-McLane S. 2008.** Adaptation, migration or extirpation: climate change outcomes for tree populations. *Evolutionary Applications* **1**: 95–111.
- Albert CH, Thuiller W, Yoccoz NG, Soudant A, Boucher F, Saccone P, Lavorel S. 2010a.** Intraspecific functional variability: Extent, structure and sources of variation. *Journal of Ecology* **98**: 604–613.
- Albert CH, Thuiller W, Yoccoz NG, Douzet R, Aubert S, Lavorel S. 2010b.** A multi-trait approach reveals the structure and the relative importance of intra- vs. interspecific variability in plant traits. *Functional Ecology* **24**: 1192–1201.
- Alberti M, Correa C, Marzluff JM, Hendry AP, Palkovacs EP, Gotanda KM, Hunt VM, Apgar TM, Zhou Y. 2017.** Global urban signatures of phenotypic change in animal and plant populations. *Proceedings of the National Academy of Sciences of the United States of America* **114**: 8951–8956.
- Allen CD, Breshears DD. 1998.** Drought-induced shift of a forest-woodland ecotone: Rapid landscape response to climate variation. *Proceedings of the National Academy of Sciences of the United States of America* **95**: 14839–14842.
- Anderegg LDL, Berner LT, Badgley G, Sethi ML, Law BE, HilleRisLambers J. 2018.** Within-species patterns challenge our understanding of the leaf economics spectrum. *Ecology Letters* **21**: 734–744.
- Anderson JT, Gezon ZJ. 2015.** Plasticity in functional traits in the context of climate change: a case study of the subalpine forb *Boechera stricta* (Brassicaceae). *Global Change Biology* **21**: 1689–1703.
- Anderson JT, Wagner MR, Rushworth CA, Prasad KVSK, Mitchell-Olds T. 2013.** The evolution of quantitative traits in complex environments. *Heredity* **2014** *112*:1 **112**: 4–12.
- Auld JR, Agrawal AA, Relyea RA. 2010.** Re-evaluating the costs and limits of adaptive phenotypic plasticity. *Proceedings. Biological sciences* **277**: 503–11.
- Austin AT, Ballaré CL. 2010.** Dual role of lignin in plant litter decomposition in terrestrial ecosystems. *Proceedings of the National Academy of Sciences of the United States of America* **107**: 4618–4622.

### B

- Baudena M, D’Andrea F, Provenzale A. 2010.** An idealized model for tree - grass coexistence in savannas: the role of life stage structure and fire disturbances. *Journal of Ecology* **98**: 74–80.
- Beck PSA, Juday GP, Alix C, Barber VA, Winslow SE, Sousa EE, Heiser P, Herriges JD, Goetz SJ. 2011.** Changes in forest productivity across Alaska consistent with biome shift. *Ecology Letters* **14**: 373–379.
- Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A, Wood EF. 2018.** Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Scientific Data* **5**: 180214.
- de Bello F, Lavorel S, Albert CH, Thuiller W, Grigulis K, Dolezal J, Janeček Š, Lepš J. 2011.** Quantifying the relevance of intraspecific trait variability for functional diversity. *Methods in Ecology and Evolution* **2**: 163–174.
- Benito Garzón M, Robson TM, Hampe A. 2019.**  $\Delta$ TraitSDMs: species distribution models that account for local adaptation and phenotypic plasticity. *New Phytologist* **222**: 1757–1765.
- Bergmann J, Weigelt A, van der Plas F, Laughlin DC, Kuyper TW, Guerrero-Ramirez N, Valverde-Barrantes OJ, Bruelheide H, Fresche GT, Iversen CM, *et al.* 2020.** The fungal collaboration gradient dominates

the root economics space in plants. *Science Advances* 6: eaba3756.

**Blackman CJ, Aspinwall MJ, Tissue DT, Rymer PD. 2017.** Genetic adaptation and phenotypic plasticity contribute to greater leaf hydraulic tolerance in response to drought in warmer climates. *Tree Physiology* 37: 583–592.

**Blair AC, Wolfe LM. 2004.** The Evolution of an invasive plant: an experimental study with *Silene Latifolia*. *Ecology* 85: 3035–3042.

**van Bodegom PM, Douma JC, Verheijen LM. 2014.** A fully traits-based approach to modeling global vegetation distribution. *Proceedings of the National Academy of Sciences of the United States of America* 111: 13733–13738.

**van Bodegom PM, Douma JC, Witte JPM, Ordoñez JC, Bartholomeus RP, Aerts R. 2012.** Going beyond limitations of plant functional types when predicting global ecosystem-atmosphere fluxes: exploring the merits of traits-based approaches. *Global Ecology and Biogeography* 21: 625–636.

**van Bodegom P, Price T. 2015.** A traits-based approach to quantifying ecosystem services. In: Bouma JA, van Beukering PJH, eds. *Ecosystem Services*. Cambridge, UK: Cambridge University Press, 40–64.

**van Boheemen LA, Atwater DZ, Hodgins KA. 2019.** Rapid and repeated local adaptation to climate in an invasive plant. *New Phytologist* 222: 614–627.

**Bolnick DI, Amarasekare P, Araujo MS, Burger R, Levine JM, Novak M, Rudolf VHW, Schreiber SJ, Urban MC, Vasseur DA. 2011.** Why intraspecific trait variation matters in community ecology. *Trends in Ecology and Evolution* 26: 183–192.

**Bone E, Farres A. 2001.** Trends and rates of microevolution in plants. *Genetica* 2001 112:1 112: 165–182.

**Bryant C, Wheeler NR, Rubel F, French RH. 2017.** kgc: Köppen-Geiger Climatic Zones. R package version 1.0.0.2. <https://CRAN.R-project.org/package=kgc>.

**Buswell JM, Moles AT, Hartley S. 2011.** Is rapid evolution common in introduced plant species? *Journal of Ecology* 99: 214–224.

**Buzzard V, Hulshof CM, Birt T, Violle C, Enquist BJ. 2016.** Re-growing a tropical dry forest: functional plant trait composition and community assembly during succession. *Functional Ecology* 30: 1006–1013.

## C

**Cannone N, Guglielmin M, Casiraghi C, Malfasi F. 2022.** Salix shrub encroachment along a 1000 m elevation gradient triggers a major ecosystem change in the European Alps. *Ecography* 2022: e06007.

**Carmona CP, de Bello F, Mason NWH, Lepš J. 2016.** Traits Without Borders: Integrating Functional Diversity Across Scales. *382 Trends in Ecology & Evolution* 31.

**Carmona CP, Rota C, Azcárate FM, Peco B. 2015.** More for less: sampling strategies of plant functional traits across local environmental gradients. *Functional Ecology* 29: 579–588.

**Cayuela L, Granzow-de la Cerda Í, Albuquerque FS, Golicher DJ. 2012.** taxonstand: An r package for species names standardisation in vegetation databases. *Methods in Ecology and Evolution* 3: 1078–1083.

**Cazzolla Gatti R, Callaghan T, Velichevskaya A, Dudko A, Fabbio L, Battipaglia G, Liang J. 2019.** Accelerating upward treeline shift in the Altai Mountains under last-century climate change. *Scientific Reports* 9: 7678.

**Chave J, Coomes D, Jansen S, Lewis SL, Swenson NG, Zanne AE. 2009.** Towards a worldwide wood economics spectrum. *Ecology Letters* 12: 351–366.

**Chen Q, Hu T, Li X, Song C-P, Zhu J-K, Chen L, Zhao Y. 2022.** Phosphorylation of SWEET sucrose transporters regulates plant root:shoot ratio under drought. *Nature Plants* 8: 68–77.

**Cheng J, Chu P, Chen D, Bai Y. 2016.** Functional correlations between specific leaf area and specific root length along a regional environmental gradient in Inner Mongolia grasslands. *Functional Ecology* 30: 985–997.

**Cieraad E, Mcglone MS, Huntley B. 2014.** Southern Hemisphere temperate tree lines are not climatically depressed. *Journal of Biogeography* 41: 1456–1466.

**Cole TCH, Hilger HH, Stevens PF. 2017.** Angiosperm phylogeny poster (APP) – Flowering plant systematics, 2017. *PeerJ Preprints*: 5:e2320v4.

**Cordell S, Goldstein G, Mueller-Dombois D, Webb D, Vitousek PM. 1998.** Physiological and morphological variation in *Metrosideros polymorpha*, a dominant Hawaiian tree species, along an altitudinal gradient: The role of phenotypic plasticity. *Oecologia* **113**: 188–196.

**Cornelissen JHC, Lavorel S, Garnier E, Díaz S, Buchmann N, Gurvich DE, Reich PB, ter Steege H, Morgan HD, van der Heijden MGA, et al. 2003.** A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. *Australian Journal of Botany* **51**: 335–380.

**Cornwell WK, Ackerly DD. 2009.** Community Assembly and Shifts in Plant Trait Distributions across an Environmental Gradient in Coastal California. *Ecological Monographs* **79**: 109–126.

**Crick JC, Grime JP. 1987.** Morphological plasticity and mineral nutrient capture in two herbaceous species of contrasted ecology. *New Phytologist* **107**: 403–414.

**Crispo E, Dibattista JD, Correa C, Thibert-Plante X, Mckellar AE, Schwartz AK, Berner D, De León LF, Hendry AP. 2010.** The evolution of phenotypic plasticity in response to anthropogenic disturbance. *Evolutionary Ecology Research* **12**: 47–66.

**Cullen AC, Frey HC. 1999.** *Probabilistic Techniques in Exposure Assessment: A Handbook for Dealing with Variability and Uncertainty in Models and Inputs*. New York and London: Plenum Press.

## D

**Darlington PJ. 1977.** The cost of evolution and the imprecision of adaptation. *Proceedings of the National Academy of Sciences* **74**: 1647–1651.

**Davidson AM, Jennions M, Nicotra AB. 2011.** Do invasive species show higher phenotypic plasticity than native species and, if so, is it adaptive? A meta-analysis. *Ecology Letters* **14**: 419–431.

**Dawson TP, Jackson ST, House JI, Prentice IC, Mace GM. 2011.** Beyond predictions: Biodiversity conservation in a changing climate. *Science* **332**: 53–58.

**Delignette-Muller ML, Dutang C. 2015.** fitdistrplus: An R Package for Fitting Distributions. *Journal of Statistical Software* **64**: 1–34.

**Derroire G, Powers JS, Hulshof CM, Cárdenas Varela LE, Healey JR. 2018.** Contrasting patterns of leaf trait variation among and within species during tropical dry forest succession in Costa Rica. *Scientific Reports* **8**: 1–11.

**DeSilva R, Dodd RS. 2020.** Association of genetic and climatic variability in giant sequoia, *Sequoiadendron giganteum*, reveals signatures of local adaptation along moisture-related gradients. *Ecology and Evolution* **10**: 10619–10632.

**DeWitt TJ, Sih A, Wilson DS. 1998.** Cost and limits of phenotypic plasticity. *Trends in Ecology & Evolution* **13**: 77–81.

**Díaz S, Kattge J, Cornelissen JH, Wright IJ, Lavorel S, Dray S, Reu B, Kleyer M, Wirth C, Prentice C, et al. 2016.** The global spectrum of plant form and function. *Nature* **529**: 167–133.

**Dietz H, Köhler A, Ullmann I. 2002.** Regeneration Growth of the Invasive Clonal Forb *Rorippa austriaca* (Brassicaceae) in Relation to Fertilization and Interspecific Competition. *Plant Ecology* **158**: 171–182.

**Donovan LA, Maherali H, Caruso CM, Huber H, de Kroon H. 2011.** The evolution of the worldwide leaf economics spectrum. *Trends in Ecology & Evolution* **26**: 88–95.

**Douma JC, de Haan MWA, Aerts R, Witte JPM, van Bodegom PM. 2012.** Succession-induced trait shifts across a wide range of NW European ecosystems are driven by light and modulated by initial abiotic conditions. *Journal of Ecology* **100**: 366–380.

**Douma JC, Weedon JT. 2019.** Analysing continuous proportions in ecology and evolution: A practical introduction to beta and Dirichlet regression. *Methods in Ecology and Evolution* **10**: 1412–1430.

**Dussault AC. 2019.** Functional Biodiversity and the Concept of Ecological Function. In: Casetta, E., Marques da Silva, J., Vecchi, D, eds. *From Assessing to Conserving Biodiversity. History, Philosophy and Theory of the Life Sciences*. Cham, CH: Springer Press.

**Dwyer JM, Laughlin DC. 2017.** Constraints on trait combinations explain climatic drivers of biodiversity: the importance of trait covariance in community assembly. *Ecology Letters* **20**: 872–882.

## E

**Edwards EJ, Chatelet DS, Sack L, Donoghue MJ. 2014.** Leaf life span and the leaf economic spectrum in the context of whole plant architecture. *102*: 328–336.

**Eichenberg D, Purschke O, Ristok C, Wessjohann L, Bruelheide H. 2015.** Trade-offs between physical and chemical carbon-based leaf defence: of intraspecific variation and trait evolution. *Journal of Ecology* **103**: 1667–1679.

## F

**Fajardo A, Siefert A. 2019.** The interplay among intraspecific leaf trait variation, niche breadth and species abundance along light and soil nutrient gradients. *Oikos* **128**: 881–891.

**Fisher RA, Koven CD, Anderegg WRL, Christoffersen BO, Dietze MC, Farrior CE, Holm JA, Hurtt GC, Knox RG, Lawrence PJ, et al. 2018.** Vegetation demographics in Earth System Models: A review of progress and priorities. *Global Change Biology* **24**: 35–54.

**Flower H, Rains M, Carl Fitz H, Orem W, Newman S, Osborne TZ, Ramesh Reddy K, Obeysekera J. 2019.** Shifting Ground: Landscape-Scale Modeling of Biogeochemical Processes under Climate Change in the Florida Everglades. *Environmental Management* **64**: 416–435.

**Foden WB, Young BE, Akçakaya HR, Garcia RA, Hoffmann AA, Stein BA, Thomas CD, Wheatley CJ, Bickford D, Carr JA, et al. 2019.** Climate change vulnerability assessment of species. *Wiley Interdisciplinary Reviews: Climate Change* **10**: e551.

**Franklin O, Harrison SP, Dewar R, Farrior CE, Brännström Å, Dieckmann U, Pietsch S, Falster D, Cramer W, Loreau M, et al. 2020.** Organizing principles for vegetation dynamics. *Nature Plants* **6**: 444–453.

**Fréjaville T, Vizcaíno-Palomar N, Fady B, Kremer A, Benito Garzón M. 2020.** Range margin populations show high climate adaptation lags in European trees. *Global Change Biology* **26**: 484–495.

**Freschet GT, Cornelissen JHC, van Logtestijn RSP, Aerts R. 2010.** Evidence of the ‘plant economics spectrum’ in a subarctic flora. *Journal of Ecology* **98**: 362–373.

**Freschet GT, Dias ATC, Ackerly DD, Aerts R, van Bodegom PM, Cornwell WK, Dong M, Kurokawa H, Liu G, Onipchenko VG, et al. 2011.** Global to community scale differences in the prevalence of convergent over divergent leaf trait distributions in plant assemblages. *Global Ecology and Biogeography* **20**: 755–765.

**Fujita Y, Venterink HO, van Bodegom PM, Douma JC, Heil GW, Hölzel N, Jabłońska E, Kotowski W, Okruszko T, Pawlikowski P, et al. 2013.** Low investment in sexual reproduction threatens plants adapted to phosphorus limitation. *Nature* **505**: 82–86.

**Fukami T, Bezemer TM, Mortimer SR, van der Putten WH. 2005.** Species divergence and trait convergence in experimental plant community assembly. *Ecology Letters* **8**: 1283–1290.

## G

**García Criado M, Myers-Smith IH, Bjorkman AD, Lehmann CER, Stevens N. 2020.** Woody plant encroachment intensifies under climate change across tundra and savanna biomes. *Global Ecology and Biogeography* **29**: 925–943.

**Gazol A, Camarero JJ, Igual JM, González de Andrés E, Colangelo M, Valeriano C. 2022.** Intraspecific trait variation, growth, and altered soil conditions at tree species distribution limits: From the alpine treeline to the rear edge. *Agricultural and Forest Meteorology* **315**: 108811.

**Ghalambor CK, Mckay JK, Carroll SP, Reznick DN. 2007.** Adaptive versus non-adaptive phenotypic plasticity and the potential for contemporary adaptation in new environments. *Functional Ecology* **21**: 394–407.

- Gibson-Reinemer DK, Sheldon KS, Rahel FJ. 2015.** Climate change creates rapid species turnover in montane communities. *Ecology and Evolution* **5**: 2340–2347.
- Gienapp P, Teplitsky C, Alho JS, Mills JA, Merilä J. 2008.** Climate change and evolution: Disentangling environmental and genetic responses. *Molecular Ecology* **17**: 167–178.
- Gonzalez P, Neilson RP, Lenihan JM, Drapek RJ. 2010.** Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography* **19**: 755–768.
- Gorné LD, Díaz S. 2019.** Meta-analysis shows that rapid phenotypic change in angiosperms in response to environmental change is followed by stasis. *American Naturalist* **194**: 840–853.
- Götmark F, Götmark E, Jensen AM. 2016.** Why Be a Shrub? A Basic Model and Hypotheses for the Adaptive Values of a Common Growth Form. *Frontiers in Plant Science* **7**: 1095.
- Grassein F, Till-Bottraud I, Lavorel S. 2010.** Plant resource-use strategies: the importance of phenotypic plasticity in response to a productivity gradient for two subalpine species. *Annals of botany* **106**: 637–45.
- Grime JP. 1977.** Evidence for the Existence of Three Primary Strategies in Plants and Its Relevance to Ecological and Evolutionary Theory. *The American Naturalist* **111**: 1169–1194.
- Grubb PJ. 2016.** Trade-offs in interspecific comparisons in plant ecology and how plants overcome proposed constraints. *Plant Ecology and Diversity* **9**: 3–33.

## H

- Habibullah MS, Din BH, Tan S-H, Zahid H. 2022.** Impact of climate change on biodiversity loss: global evidence. *Environmental Science and Pollution Research* **29**: 1073–1086.
- Hacke UG, Sperry JS, Pockman WT, Davis SD, McCulloh KA. 2001.** Trends in wood density and structure are linked to prevention of xylem implosion by negative pressure. *Oecologia* **126**: 457–461.
- Haldane JBS. 1949.** Suggestions as to Quantitative Measurement of Rates of Evolution. *Evolution* **3**: 51–56.
- Haldane JBS. 1957.** The cost of natural selection. *Journal of Genetics* **55**: 511–524.
- Hansen AJ, Phillips LB. 2015.** Which tree species and biome types are most vulnerable to climate change in the US Northern Rocky Mountains? *Forest Ecology and Management* **338**: 68–83.
- Hardin G. 1960.** The competitive exclusion principle. *Science* **131**: 1292–1297.
- Harrison SP, Cramer W, Franklin O, Prentice IC, Wang H, Brännström Å, de Boer H, Dieckmann U, Joshi J, Keenan TF, et al. 2021.** Eco-evolutionary optimality as a means to improve vegetation and land-surface models. *New Phytologist* **231**: 2125–2141.
- Hartmann H, Bastos A, Das AJ, Esquivel-Muelbert A, Hammond WM, Martínez-Vilalta J, McDowell NG, Powers JS, Pugh TAM, Ruthrof KX, et al. 2022.** Climate Change Risks to Global Forest Health: Emergence of Unexpected Events of Elevated Tree Mortality Worldwide. *Annual Review of Plant Biology* **73**: 673–702.
- Hautier Y, Tilman D, Isbell F, Seabloom EW, Borer ET, Reich PB. 2015.** Anthropogenic environmental changes affect ecosystem stability via biodiversity. *Science* **348**: 336–340.
- Hendry AP, Kinnison MT. 1999.** The Pace of Modern Life: Measuring Rates of Contemporary Microevolution. *Evolution* **53**: 1637.
- Henn JJ, Buzzard V, Enquist BJ, Halbritter AH, Klanderud K, Maitner BS, Michaletz ST, Pötsch C, Seltzer L, Telford RJ, et al. 2018.** Intraspecific trait variation and phenotypic plasticity mediate alpine plant species response to climate change. *Frontiers in Plant Science* **871**: 1548.
- Hereford J. 2009.** A quantitative survey of local adaptation and fitness trade-offs. *American Naturalist* **173**: 579–588.
- Herz K, Dietz S, Haider S, Jandt U, Scheel D, Bruelheide H. 2017.** Drivers of intraspecific trait variation of grass and forb species in German meadows and pastures. *Journal of Vegetation Science* **28**: 705–716.
- Hickling R, Roy DB, Hill JK, Fox R, Thomas CD. 2006.** The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology* **12**: 450–455.

**Hierro JL, Eren Ö, Khetsuriani L, Diaconu A, Török K, Montesinos D, Andonian K, Kikodze D, Janoian L, Villarreal D, et al. 2009.** Germination responses of an invasive species in native and non-native ranges. *Oikos* **118**: 529–538.

**Hill MO, Preston CD, Roy DB. 2004.** PLANTATT – Attributes of British and Irish plants: Status, size, life history, geography and habitats. Abbotts Ripton, UK: Centre for Ecology & Hydrology.

**Hoffmann AA, Sgró CM. 2011.** Climate change and evolutionary adaptation. *Nature* **470**: 479–485.

**Holling CS. 1973.** Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* **4**: 1–23.

## I

**IPCC. 2021.** Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, et al., eds. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK & New York, NY, USA: Cambridge University Press.

**IPCC. 2007.** Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, eds. *Climate change 2007: the physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Cambridge, UK & New York, NY, USA: Cambridge University Press.

**Isbell F, Calcagno V, Hector A, Connolly J, Harpole WS, Reich PB, Scherer-Lorenzen M, Schmid B, Tilman D, VanRuijven J, et al. 2011.** High plant diversity is needed to maintain ecosystem services. *Nature* **477**: 199–202.

## J

**Jager MM, Richardson SJ, Bellingham PJ, Clearwater MJ, Laughlin DC. 2015.** Soil fertility induces coordinated responses of multiple independent functional traits. *Journal of Ecology* **103**: 374–385.

**Jump AS, Peñuelas J. 2005.** Running to stand still: adaptation and the response of plants to rapid climate change. *Ecology Letters* **8**: 1010–1020.

## K

**Karcher DE, Richardson MD, Hignight K, Rush D. 2008.** Drought Tolerance of Tall Fescue Populations Selected for High Root/Shoot Ratios and Summer Survival. *Crop Science* **48**: 771–777.

**Kattge J, Bönisch G, Díaz S, Lavorel S, Prentice IC, Leadley P, Tautenhahn S, Werner GDA, Aakala T, Abedi M, et al. 2020.** TRY plant trait database – enhanced coverage and open access. *Global Change Biology* **26**: 119–188.

**Kattge J, Díaz S, Lavorel S, Prentice IC, Leadley P, Bönisch G, Garnier E, Westoby M, Rrich PB, Wright IJ, et al. 2011.** TRY - a global database of plant traits. *Global Change Biology* **17**: 2905–2935.

**Katul GG, Oren R, Manzoni S, Higgins C, Parlange MB. 2012.** Evapotranspiration: A process driving mass transport and energy exchange in the soil-plant-atmosphere-climate system. *Reviews of Geophysics* **50**: RG3002, doi:10.1029/2011RG000366.

**Keddy PA. 1992.** Assembly and response rules: two goals for predictive community ecology. *Journal of Vegetation Science* **3**: 157–164.

**Kembel SW, Cahill JF. 2011.** Independent evolution of leaf and root traits within and among temperate grassland plant communities. *PLoS ONE* **6**: e19992.

**Kichenin E, Wardle DA, Peltzer DA, Morse CW, Freschet GT. 2013.** Contrasting effects of plant inter- and intraspecific variation on community-level trait measures along an environmental gradient. *Functional Ecology* **27**: 1254–1261.

**van Kleunen M, Weber E, Fischer M. 2010.** A meta-analysis of trait differences between invasive and non-invasive plant species. *Ecology Letters* **13**: 235–245.

**Kleyer M, Bekker RM, Knevel IC, Bakker JP, Thompson K, Sonnenschein M, Poschlod P, van Groenendael JM, Klimeš L, Klimešová J, et al. 2008.** The LEDA Traitbase: a database of life-history traits of the Northwest European flora. *Journal of Ecology* **96**: 1266–1274.

**Knapp S. 2019.** The Link Between Diversity, Ecosystem Functions, and Ecosystem Services. In: Schröter M. et al., eds. *Atlas of Ecosystem Services*. Cham, CH: Springer International Publishing AG, 13–15.

**Kooyman R, Cornwell W, Westoby M. 2010.** Plant functional traits in Australian subtropical rain forest: partitioning within-community from cross-landscape variation. *Journal of Ecology* **98**: 517–525.

**Körner C. 2018.** Concepts in empirical plant ecology. *Plant Ecology & Diversity* **11**: 405–428.

**Kraft NJB, Ackerly DD. 2014.** Assembly of Plant Communities. In: Monson RK, eds. *Ecology and the Environment, The Plant Sciences 8*. New York, US: Springer New York Press, 68–85.

**Kremer A, Ronce O, Robledo-Arnuncio JJ, Guillaume F, Bohrer G, Nathan R, Bridle JR, Gomulkiewicz R, Klein EK, Ritland K, et al. 2012.** Long-distance gene flow and adaptation of forest trees to rapid climate change. *Ecology Letters* **15**: 378–392.

## L

**Lajoie G, Vellend M. 2018.** Characterizing the contribution of plasticity and genetic differentiation to community-level trait responses to environmental change. *Ecology and Evolution* **8**: 3895–3907.

**Laughlin DC, Joshi C, vanBodegom PM, Bastow ZA, Fulé PZ. 2012.** A predictive model of community assembly that incorporates intraspecific trait variation. *Ecology Letters* **15**: 1291–1299.

**Laughlin DC, Lusk CH, Bellingham PJ, R P Burslem DF, Simpson AH, Kramer-Walter KR, Daniel Laughlin CC, Burslem DFRP, Simpson AH, Kramer-Walter KR. 2017.** Intraspecific trait variation can weaken interspecific trait correlations when assessing the whole-plant economic spectrum. *7*: 8936–8949.

**Leger EA, Rice KJ. 2003.** Invasive California poppies (*Eschscholzia californica* Cham.) grow larger than native individuals under reduced competition. *Ecology Letters* **6**: 257–264.

**Leites L, Benito Garzón M. 2023.** Forest tree species adaptation to climate across biomes: Building on the legacy of ecological genetics to anticipate responses to climate change. *Global Change Biology* **00**: 1–20.

**Lepš J, de Bello F, Šmilauer P, Doležal J. 2011.** Community trait response to environment: disentangling species turnover vs intraspecific trait variability effects. *Ecography* **34**: 856–863.

**Levin SA. 1998.** Ecosystems and the biosphere as complex adaptive systems. *Ecosystems* **1**: 431–436.

**Lenth RV, Buerkner P, Herve M, Jung M, Love J, Miguez F, Riebl H, Singmann H. 2022.** emmeans: Estimated Marginal Means, aka Least-Squares Means. <https://CRAN.Rproject.org/package=emmeans>.

**Li Y, Shipley B, Price JN, de L Dantas V, Tamme R, Westoby M, Siefert A, Schamp BS, Spasojevic MJ, Jung V, et al. 2018.** Habitat filtering determines the functional niche occupancy of plant communities worldwide. *Journal of Ecology* **106**: 1001–1009.

**Lind BM, Friedline CJ, Wegrzyn JL, Maloney PE, Vogler DR, Neale DB, Eckert AJ. 2017.** Water availability drives signatures of local adaptation in whitebark pine (*Pinus albicaulis* Engelm.) across fine spatial scales of the Lake Tahoe Basin, USA. *Molecular Ecology* **26**: 3168–3185.

**Liu Y, Dawson W, Prati D, Haeuser E, Feng Y, van Kleunen M. 2016.** Does greater specific leaf area plasticity help plants to maintain a high performance when shaded? *Annals of Botany* **118**: 1329–1336.

**Lloyd J, Bloomfield K, Domingues TF, Farquhar GD. 2013.** Photosynthetically relevant foliar traits correlating better on a mass vs an area basis: of ecophysiological relevance or just a case of mathematical imperatives and statistical quicksand? *New Phytologist* **199**: 311–321.

**Loarie SR, Duffy PB, Hamilton H, Asner GP, Field CB, Ackerly DD. 2009.** The velocity of climate change. *Nature* **462**: 1052–1055.

**Lu X, Liang E, Wang Y, Babst F, Camarero JJ. 2021.** Mountain treelines climb slowly despite rapid climate warming. *Global Ecology and Biogeography* **30**: 305–315.

**Lusk CH, Reich PB, Montgomery RA, Ackerly DD, Cavender-Bares J. 2008.** Why are evergreen leaves so



contrary about shade? *Trends in Ecology and Evolution* **23**: 299–303.

## M

**MacBean N, Scott RL, Biederman JA, Peylin P, Kolb T, Litvak ME, Krishnan P, Meyers TP, Arora VK, Bastrikov V, et al. 2021.** Dynamic global vegetation models underestimate net CO<sub>2</sub> flux mean and inter-annual variability in dryland ecosystems. *Environmental Research Letters* **16**: 094023.

**Maestre FT, Quero JL, Gotelli NJ, Escudero A, Ochoa V, Delgado-Baquerizo M, García-Gómez M, Bowker MA, Soliveres S, Escobar C, et al. 2012.** Plant species richness and ecosystem multifunctionality in global drylands. *Science* **335**: 214–218.

**Mahecha MD, Bastos A, Bohn FJ, Eisenhauer N, Feilhauer H, Hartmann H, Hickler T, Kalesse-Los H, Migliavacca M, Otto FEL, et al. 2022.** Biodiversity loss and climate extremes — study the feedbacks. *Nature* **612**: 30–32.

**Maire V, Gross N, Hill D, Martin R, Wirth C, Wright IJ, Soussana J-F. 2013.** Disentangling Coordination among Functional Traits Using an Individual-Centred Model: Impact on Plant Performance at Intra- and Inter-Specific Levels. *PLoS ONE* **8**: e77372.

**Malyshev AV., Arfin Khan MASS, Beierkuhnlein C, Steinbauer MJ, Henry HAL, Jentsch A, Dengler J, Willner E, Kreyling J. 2016.** Plant responses to climatic extremes: within-species variation equals among-species variation. *Global Change Biology* **22**: 449–464.

**Mammola S, Carmona CP, Guillerme T, Cardoso P. 2021.** Concepts and applications in functional diversity. *Functional Ecology* **35**: 1869–1885.

**Marks CO, Lechowicz MJ. 2006.** Alternative designs and the evolution of functional diversity. *The American Naturalist* **167**: 55–66.

**Martin AR, Rapidel B, Rouspard O, van den Meersche K, de Melo Virginio Filho E, Barrios M, Isaac ME. 2017.** Intraspecific trait variation across multiple scales: the leaf economics spectrum in coffee. *Functional Ecology* **31**: 604–612.

**de Mazancourt C, Isbell F, Larocque A, Berendse F, De Luca E, Grace JB, Haegeman B, Wayne Polley H, Roscher C, Schmid B, et al. 2013.** Predicting ecosystem stability from community composition and biodiversity. *Ecology Letters* **16**: 617–625.

**McGill BJ, Enquist BJ, Weiher E, Westoby M. 2006.** Rebuilding community ecology from functional traits. *Trends in Ecology and Evolution* **21**: 178–185.

**Mclean EH, Prober SM, Stock WD, Steane DA, Potts BM, Vaillancourt RE, Byrne M. 2014.** Plasticity of functional traits varies clinally along a rainfall gradient in *Eucalyptus tricarpa*. *Plant, Cell and Environment* **37**: 1440–1451.

**Messier J, McGill BJ, Lechowicz MJ. 2010.** How do traits vary across ecological scales? A case for trait-based ecology. *Ecology Letters* **13**: 838–848.

**Molina-Montenegro MA, Naya DE. 2012.** Latitudinal Patterns in Phenotypic Plasticity and Fitness-Related Traits: Assessing the Climatic Variability Hypothesis (CVH) with an Invasive Plant Species. *PLoS ONE* **7**: e47620.

**Moran EV., Hartig F, Bell DM. 2016.** Intraspecific trait variation across scales: Implications for understanding global change responses. *Global Change Biology* **22**: 137–150.

## N

**Nicotra AB, Atkin OK, Bonser SP, Davidson AM, Finnegan EJ, Mathesius U, Poot P, Purugganan MD, Richards CL, Valladares F, et al. 2010.** Plant phenotypic plasticity in a changing climate. *Trends in Plant Science* **15**: 684–692.

**Niinemets Ü. 2015.** Is there a species spectrum within the world-wide leaf economics spectrum? Major variations in leaf functional traits in the Mediterranean sclerophyll *Quercus ilex*. *New Phytologist* **205**: 79–96.

**Niu K, Zhang S, Lechowicz MJ. 2020.** Harsh environmental regimes increase the functional significance of intraspecific variation in plant communities. *Functional Ecology* **00**: 1–12.

## O

**Oliver TH, Heard MS, Isaac NJB, Roy DB, Procter D, Eigenbrod F, Freckleton R, Hector A, David C, Orme L, et al. 2015.** Biodiversity and Resilience of Ecosystem Functions. *Trends in Ecology & Evolution* **30**: 673–684.

**Onoda Y, Wright IJ, Evans JR, Hikosaka K, Kitajima K, Niinemets U, Poorter H, Tosens T, Westoby M. 2017.** Physiological and structural tradeoffs underlying the leaf economics spectrum. *New Phytologist* **214**: 1447–1463.

**Ordoñez JC, van Bodegom PM, Witte JPM, Bartholomeus RP, van Dobben HF, Aerts R. 2010.** Leaf habit and woodiness regulate different leaf economy traits at a given nutrient supply. *Ecology* **91**: 3218–3228.

**Ordoñez JC, van Bodegom PM, Witte J-PM, Wright IJ, Reich PB, Aerts R. 2009.** A global study of relationships between leaf traits, climate and soil measures of nutrient fertility. *Global Ecology and Biogeography* **18**: 137–149.

**Osnas JLD, Lichstein JW, Reich PB, Pacala SW. 2013.** Global leaf trait relationships: Mass, area, and the leaf economics spectrum. *Science* **340**: 741–744.

## P

**Pal RW, Maron JL, Nagy DU, Waller LP, Tosto A, Liao H, Callaway RM. 2020.** What happens in Europe stays in Europe: apparent evolution by an invader does not help at home. *Ecology* **101**: e03072.

**Pausas JG, Bond WJ. 2020.** Alternative Biome States in Terrestrial Ecosystems. *Trends in Plant Science* **25**: 250–263.

**Pavlick R, Drewry DT, Bohn K, Reu B, Kleidon A. 2013.** The Jena Diversity-Dynamic Global Vegetation Model (JeDi-DGVM): a diverse approach to representing terrestrial biogeography and biogeochemistry based on plant functional trade-offs. *Biogeosciences* **10**: 4137–4177.

**Peacock JA. 1983.** Two-dimensional goodness-of-fit testing in astronomy. *Monthly Notices of the Royal Astronomical Society* **202**: 615–627.

**Pearson RG, Phillips SJ, Lorant MM, Beck PSA, Damoulas T, Knight SJ, Goetz SJ. 2013.** Shifts in Arctic vegetation and associated feedbacks under climate change. *Nature Climate Change* **3**: 673–677.

**Pedlar JH, McKenney DW. 2017.** Assessing the anticipated growth response of northern conifer populations to a warming climate. *Scientific Reports* **7**: 1–10.

**Peñuelas J, Poulter B, Sardans J, Ciais P, van der Velde M, Bopp L, Boucher O, Godderis Y, Hinsinger P, Llusia J, et al. 2013.** Human-induced nitrogen–phosphorus imbalances alter natural and managed ecosystems across the globe. *Nature Communications* **4**: 2934–2943.

**Pérez-Harguindeguy N, Díaz S, Garnier E, Lavorel S, Poorter H, Jaureguiberry P, Bret-Harte MS, Cornwell WK, Craine JM, Gurvich DE, et al. 2013.** New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany* **61**: 167–234.

**Petchey OL, Gaston KJ. 2006.** Functional diversity: back to basics and looking forward. *Ecology Letters* **9**: 741–758.

**Pfennigwerth AA, Bailey JK, Schweitzer JA. 2017.** Trait variation along elevation gradients in a dominant woody shrub is population-specific and driven by plasticity. *AoB PLANTS* **9**: plx027.

**Pierce S, Negreiros D, Cerabolini BEL, Kattge J, Díaz S, Kleyer M, Shipley B, Wright SJ, Soudzilovskaia NA, Onipchenko VG, et al. 2017.** A global method for calculating plant CSR ecological strategies applied across biomes world-wide. *Functional Ecology* **31**: 444–457.

**Pluess AR, Frank A, Heiri C, Lalagüe H, Vendramin GG, Oddou-Muratorio S. 2016.** Genome-environment association study suggests local adaptation to climate at the regional scale in *Fagus sylvatica*. *New Phytologist* **210**: 589–601.

**Poorter H, Lambers H, Evans JR. 2014.** Trait correlation networks: a whole-plant perspective on the recently criticized leaf economic spectrum. *New Phytologist* **201**: 378–382.

**Purugganan MD, Fuller DQ. 2011.** Archaeological data reveal slow rates of evolution during plant domestication. *Evolution* **65**: 171–183.

## R

**R Development Core Team. 2019.** R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

**R Development Core Team. 2020.** R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

**R Development Core Team. 2022.** R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

**Raffard A, Santoul F, Cucherousset J, Blanchet S. 2019.** The community and ecosystem consequences of intraspecific diversity: a meta-analysis. *Biological Reviews* **94**: 648–661.

**Reich PB. 2014.** The world-wide ‘fast-slow’ plant economics spectrum: A traits manifesto. *Journal of Ecology* **102**: 275–301.

**Relyea RA. 2002.** Costs of Phenotypic Plasticity. *The American Naturalist* **159**: 272–282.

**Ren L, Guo X, Liu S, Yu T, Guo W, Wang R, Ye S, Lambertini C, Brix H, Eller F. 2020.** Intraspecific variation in *Phragmites australis*: Clinal adaptation of functional traits and phenotypic plasticity vary with latitude of origin. *Journal of Ecology* **108**: 2531–2543.

**Ren Y, Wang H, Harrison SP, Prentice IC, Atkin OK, Smith NG, Mengoli G, Stefanski A, Reich PB. 2023.** Reduced global plant respiration due to the acclimation of leaf dark respiration coupled with photosynthesis. *New Phytologist* **241**: 578–591.

**de la Riva EG, Pérez-Ramos IM, Tosto A, Navarro-Fernández CM, Olmo M, Marañón T, Villar R. 2016.** Disentangling the relative importance of species occurrence, abundance and intraspecific variability in community assembly: a trait-based approach at the whole-plant level in Mediterranean forests. *Oikos* **125**: 354–363.

**Des Roches S, Post DM, Turley NE, Bailey JK, Hendry AP, Kinnison MT, Schweitzer JA, Palkovacs EP. 2018.** The ecological importance of intraspecific variation. *Nature Ecology & Evolution* **2**: 57–64.

## S

**Sáenz-Romero C, Lamy JB, Ducouso A, Musch B, Ehrenmann F, Delzon S, Cavers S, Chalupka W, Dağdaş S, Hansen JK, et al. 2017.** Adaptive and plastic responses of *Quercus petraea* populations to climate across Europe. *Global Change Biology* **23**: 2831–2847.

**Sakschewski B, von Bloh W, Boit A, Rammig A, Kattge J, Poorter L, Peñuelas J, Thonicke K. 2015.** Leaf and stem economics spectra drive diversity of functional plant traits in a dynamic global vegetation model. *Global Change Biology* **21**: 2711–2725.

**Salamin N, Wüest RO, Lavergne S, Thuiller W, Pearman PB. 2010.** Assessing rapid evolution in a changing environment. *Trends in Ecology & Evolution* **25**: 692–698.

**Scheepens JF, Deng Y, Bossdorf O. 2018.** Phenotypic plasticity in response to temperature fluctuations is genetically variable, and relates to climatic variability of origin, in *Arabidopsis thaliana*. *AOB PLANTS* **10**: ply043.

**Schneider HM. 2022.** Characterization, costs, cues and future perspectives of phenotypic plasticity. *Annals of Botany* **130**: 131–148.

**Schulze CH, Waltert M, Kessler PJA, Pitopang R, Shahabuddin, Veddeler D, Mühlberg M, Gradstein SR, Leuschner C, Steffan-Dewenter I, et al. 2004.** Biodiversity indicator groups of tropical land-use systems: Comparing plants, birds, and insects. *Ecological Applications* **14**: 1321–1333.

**Shi H, Zhou Q, He R, Zhang Q, Dang H. 2022.** Climate warming will widen the lagging gap of global treeline shift relative to densification. *Agricultural and Forest Meteorology* **318**: 108917.

**Shipley B, Lechowicz MJ, Wright I, Reich PB. 2006.** Fundamental trade-offs generating the worldwide leaf economics spectrum. *Ecology* **87**: 535–541.

- Shirk RY, Hamrick JL. 2014.** Multivariate adaptation but no increase in competitive ability in invasive geranium carolinianum L. (Geraniaceae). *Evolution* **68**: 2945–2959.
- Siebenkäs A, Schumacher J, Roscher C. 2015.** Phenotypic plasticity to light and nutrient availability alters functional trait ranking across eight perennial grassland species. *AoB PLANTS* **7**: plv029.
- Siefert A, Fridley JD, Ritchie ME. 2014.** Community Functional Responses to Soil and Climate at Multiple Spatial Scales: When Does Intraspecific Variation Matter? *PLoS ONE* **9**: e111189.
- Siefert A, Violle C, Chalmandrier L, Albert CH, Taudiere A, Fajardo A, Aarssen LW, Baraloto C, Carlucci MB, Cianciaruso MV., et al. 2015.** A global meta-analysis of the relative extent of intraspecific trait variation in plant communities. *Ecology Letters* **18**: 1406–1419.
- Spasojevic MJ, Suding KN. 2012.** Inferring community assembly mechanisms from functional diversity patterns: The importance of multiple assembly processes. *Journal of Ecology* **100**: 652–661.
- Spasojevic MJ, Turner BL, Myers JA. 2016.** When does intraspecific trait variation contribute to functional beta-diversity? *Journal of Ecology* **104**: 487–496.
- Sperry JS, Hacke UG, Pittermann J. 2006.** Size and function in conifer tracheids and angiosperm vessels. *American Journal of Botany* **93**: 1490–1500.
- Stahl U, Kattge J, BjöB, R, Voigt W, Ogle K, Dickie J, Wirth C, Stahl C., Kattge J, et al. 2013.** Whole-plant trait spectra of North American woody plant species reflect fundamental ecological strategies. *Ecosphere* **4**: 1–28.
- Stasinopoulos DM, Rigby RA. 2007.** Generalized additive models for location scale and shape (GAMLSS) in R. *Journal of Statistical Software* **23**: 1–46.
- Stott P. 2016.** How climate change affects extreme weather events: Research can increasingly determine the contribution of climate change to extreme events such as droughts. *Science* **352**: 1517–1518.
- Stotz GC, Salgado-Luarte C, Escobedo VM, Valladares F, Gianoli E. 2021.** Global trends in phenotypic plasticity of plants. *Ecology Letters* **24**: 2267–2281.
- Sultan SE, Bazzaz FA. 1993.** Phenotypic Plasticity in *Polygonum persicaria*. III. The Evolution of Ecological Breadth for Nutrient Environment. *Evolution* **47**: 1050–1071.
- Svenning JC, Sandel B. 2013.** Disequilibrium vegetation dynamics under future climate change. *American Journal of Botany* **100**: 1266–1286.
- Syed I, Fatima H, Mohammed A, Siddiqui MA. 2018.** *Ceratophyllum demersum* a Free-floating Aquatic Plant: A Review. *Indian Journal of Pharmaceutical and Biological Research* **6**: 10–17.

## T

- Thomas CD. 2010.** Climate, climate change and range boundaries. *Diversity and Distributions* **16**: 488–495.
- Thomas CD. 2015.** Rapid acceleration of plant speciation during the Anthropocene. *Trends in Ecology and Evolution* **30**: 448–455.
- Thuiller W, Lavorel S, Araujo MB, Sykes MT, Prentice IC. 2005.** Climate change threats to plant diversity in Europe. *Proceedings of the National Academy of Sciences* **102**: 8245–8250.
- Tilman D. 2001.** Functional Diversity. *Encyclopedia of Biodiversity* **3**: 109–120.
- Tilman D, Reich PB, Knops JMH. 2006.** Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature* **441**: 629–632.
- Tjoelker MG, Oleksyn J, Reich PB. 1999.** Acclimation of respiration to temperature and CO<sub>2</sub> in seedlings of boreal tree species in relation to plant size and relative growth rate. *Global Change Biology* **5**: 679–691.

## U

- Umaña MN, Swenson NG. 2019.** Does trait variation within broadly distributed species mirror patterns across species? A case study in Puerto Rico. *Ecology* **100**: e02745.

**Urban MC, De Meester L, Vellend M, Stoks R, Vanoverbeke J. 2012.** A crucial step toward realism: responses to climate change from an evolving metacommunity perspective. *Evolutionary Applications* **5**: 154–167.

## V

**Valladares F, Martínez-Ferri E, Balaguer L, Perez-Corona E, Manrique E. 2000.** Low leaf-level response to light and nutrients in Mediterranean evergreen oaks: A conservative resource-use strategy? *New Phytologist* **148**: 79–91.

**Verheijen LM, Aerts R, Bönisch G, Kattge J, van Bodegom PM. 2016.** Variation in trait trade-offs allows differentiation among predefined plant functional types: implications for predictive ecology. *New Phytologist* **209**: 563–575.

**Verheijen LM, Aerts R, Brovkin V, Cavender-Bares J, Cornelissen JHC, Kattge J, van Bodegom PM. 2015.** Inclusion of ecologically based trait variation in plant functional types reduces the projected land carbon sink in an earth system model. *Global Change Biology* **21**: 3074–3086.

**Verheijen LM, Brovkin V, Aerts R, Bönisch G, Cornelissen JHC, Kattge J, Reich PB, Wright IJ, van Bodegom PM. 2013.** Impacts of trait variation through observed trait–climate relationships on performance of an Earth system model: a conceptual analysis. *Biogeosciences* **10**: 5497–5515.

**de Villemereuil P, Gaggiotti OE, Mouterde M, Till-Bottraud I. 2015.** Common garden experiments in the genomic era: new perspectives and opportunities. *Heredity* **116**: 249–254.

**Vinton AC, Gascoigne SJJ, Sepil I, Salguero-Gómez R. 2022.** Plasticity’s role in adaptive evolution depends on environmental change components. *Trends in Ecology and Evolution* **37**: 1067–1078.

**Violle C, Enquist BJ, McGill BJ, Jiang L, Albert CH, Hulshof C, Jung V, Messier J. 2012.** The return of the variance: Intraspecific variability in community ecology. *Trends in Ecology and Evolution* **27**: 244–252.

**Violle C, Navas M-L, Vile D, Kazakou E, Fortunel C, Hummel I, Garnier E. 2007.** Let the concept of trait be functional! *Oikos* **116**: 882–892.

## W

**Wang H, Prentice IC, Wright IJ, Warton DI, Qiao S, Xu X, Zhou J, Kikuzawa K, Stenseth NC. 2023.** Leaf economics fundamentals explained by optimality principles. *Science Advances* **9**: eadd5667.

**Wang C, He J, Zhao TH, Cao Y, Wang G, Sun B, Yan X, Guo W, Li MH. 2019.** The smaller the leaf is, the faster the leaf water loses in a temperate forest. *Frontiers in Plant Science* **10**: 421159.

**Wang B, Li W, Wang J. 2005.** Genetic diversity of *Alternanthera philoxeroides* in China. *Aquatic Botany* **81**: 277–283.

**Warton DI, Duursma RA, Falster DS, Taskinen S. 2012.** smatr 3- an R package for estimation and inference about allometric lines. *Methods in Ecology and Evolution* **3**: 257–259.

**Webb CT, Hoeting JA, Ames GM, Pyne MI, LeRoy Poff N. 2010.** A structured and dynamic framework to advance traits-based theory and prediction in ecology. *Ecology Letters* **13**: 267–283.

**Weemstra M, Freschet GT, Stokes A, Roumet C. 2021.** Patterns in intraspecific variation in root traits are species-specific along an elevation gradient. *Functional Ecology* **35**: 342–356.

**Weng E, Farris CE, Dybzinski R, Pacala SW. 2017.** Predicting vegetation type through physiological and environmental interactions with leaf traits: evergreen and deciduous forests in an earth system modeling framework. *Global Change Biology* **23**: 2482–2498.

**Westerband AC, Funk JL, Barton KE. 2021.** Intraspecific trait variation in plants: a renewed focus on its role in ecological processes. *Annals of Botany* **127**: 397–410.

**Westley PAH. 2011.** What invasive species reveal about the rate and form of contemporary phenotypic change in nature. *American Naturalist* **177**: 496–509.

**Westoby M, Falster DS, Moles AT, Vesk PA, Wright IJ. 2002.** Plant Ecological Strategies: Some Leading Dimensions of Variation Between Species. *Annual Review of Ecology and Systematics* **33**: 125–159.

**Westoby M, Reich PB, Wright IJ. 2013.** Understanding ecological variation across species: area-based vs mass-based expression of leaf traits. *New Phytologist* **199**: 322–323.

**Westoby M, Wright IJ. 2006.** Land-plant ecology on the basis of functional traits. *Trends in Ecology & Evolution* **21**: 261–268.

**Whitham TG, DiFazio SP, Schweitzer JA, Shuster SM, Allan GJ, Bailey JK, Woolbright SA. 2008.** Extending genomics to natural communities and ecosystems. *Science* **320**: 492–495.

**Wielgolaski F, Hofgaard A, Holtmeier F. 2017.** Sensitivity to environmental change of the treeline ecotone and its associated biodiversity in European mountains. *Climate Research* **73**: 151–166.

**Wright IJ, Dong N, Maire V, Prentice IC, Westoby M, Díaz S, Gallagher RV, Jacobs BF, Kooyman R, Law EA, et al. 2017.** Global climatic drivers of leaf size. *Science* **357**: 917–921.

**Wright IJ, Reich PB, Westoby M, Ackerly DD, Baruch Z, Bongers F, Cavender-Bares J, Chapin T, Cornelissen JHC, Diemer M, et al. 2004.** The worldwide leaf economics spectrum. *Nature* **428**: 821–827.

**Wullschleger SD, Epstein HE, Box EO, Euskirchen ES, Goswami S, Iversen CM, Kattge J, Norby RJ, van Bodegom PM, Xu X. 2014.** Plant functional types in Earth system models: past experiences and future directions for application of dynamic vegetation models in high-latitude ecosystems. *Annals of Botany* **114**: 1–16.

## X

**Xiao Y. 2016.** Peacock.test: Two and Three Dimensional Kolmogorov-Smirnov Two-Sample Tests. <https://CRAN.R-project.org/package=Peacock.test>.

## Y

**Yang J, Lu J, Chen Y, Yan E, Hu J, Wang X, Shen G. 2020.** Large Underestimation of Intraspecific Trait Variation and Its Improvements. *Frontiers in Plant Science* **11**: 53.

## Z

**Zeballos SR, Giorgis MA, Cabido M, Gurvich DE. 2017.** Unravelling the coordination between leaf and stem economics spectra through local and global scale approaches. *Austral Ecology* **42**: 394–403.