Global Ecology and Biogeography 2021 vol.30 N9, pages 1740-1764

sPlotOpen – An environmentally balanced, open-access, global dataset of vegetation plots

Sabatini F.M., Lenoir J., Hattab T., Arnst E.A., Chytrý M., Dengler J., De Ruffray P., Hennekens S.M., Jandt U., Jansen F., Jiménez-Alfaro B., Kattge J., Levesley A., Pillar V.D., Purschke O., Sandel B., Sultana F., Aavik T., Aćić S., Acosta A.T.R., Agrillo E., Alvarez M., Apostolova I., Arfin Khan M.A.S., Arroyo L., Attorre F., Aubin I., Banerjee A., Bauters M., Bergeron Y., Bergmeier E., Biurrun I., Bjorkman A.D., Bonari G., Bondareva V., Brunet J., Čarni A., Casella L., Cayuela L., Černý T., Chepinoga V., Csiky J., Ćušterevska R., De Bie E., de Gasper A.L., De Sanctis M., Dimopoulos P., Dolezal J., Dziuba T., El-Sheikh M.A.E.R.M., Enquist B., Ewald J., Fazayeli F., Field R., Finckh M., Gachet S., Galán-de-Mera A., Garbolino E., Gholizadeh H., Giorgis M., Golub V., Alsos I.G., Grytnes J.A., Guerin G.R., Gutiérrez A.G., Haider S., Hatim M.Z., Hérault B., Hinojos Mendoza G., Hölzel N., Homeier J., Hubau W., Indreica A., Janssen J.A.M., Jedrzejek B., Jentsch A., Jürgens N., Kącki Z., Kapfer J., Karger D.N., Kavgacı A., Kearsley E., Kessler M., Khanina L., Killeen T., Korolyuk A., Kreft H., Kühl H.S., Kuzemko A., Landucci F., Lengyel A., Lens F., Lingner D.V., Liu H., Lysenko T., Mahecha M.D., Marcenò C., Martynenko V., Moeslund J.E., Monteagudo Mendoza A.

Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

Motivation: Assessing biodiversity status and trends in plant communities is critical for understanding, quantifying and predicting the effects of global change on ecosystems. Vegetation plots record the occurrence or abundance of all plant species co-occurring within delimited local areas. This allows species absences to be inferred, information seldom provided by existing global plant datasets. Although many vegetation plots have been recorded, most are not available to the global research community. A recent initiative, called 'sPlot', compiled the first global vegetation plot database, and continues to grow and curate it. The sPlot database, however, is extremely unbalanced spatially and environmentally, and is not open-access. Here, we address both these issues by (a) resampling the vegetation plots using several environmental variables as sampling strata and (b) securing permission from data holders of 105 local-to-regional datasets to openly release data. We thus present sPlotOpen, the largest open-access dataset of vegetation plots ever released. sPlotOpen can be used to explore global diversity at the plant community level, as ground truth data in remote sensing applications, or as a baseline for biodiversity monitoring. Main types of variable contained: Vegetation plots (n = 95,104) recording cover or abundance of naturally co-occurring vascular plant species within delimited areas. sPlotOpen contains three partially overlapping resampled datasets (c. 50,000 plots each), to be used as replicates in global analyses. Besides geographical location, date, plot size, biome, elevation, slope, aspect, vegetation type, naturalness, coverage of various vegetation layers, and source dataset, plot-level data also include community-weighted means and variances of 18 plant functional traits from the TRY Plant Trait Database. Spatial location and grain: Global, 0.01–40,000 m^2. Time period and grain: 1888–2015, recording dates. Major taxa and level of measurement: 42,677 vascular plant taxa, plot-level records. Software format: Three main matrices (.csv), relationally linked.

http://dx.doi.org/10.1111/geb.13346

Keywords

big data, biodiversity, biogeography, database, functional traits, macroecology, vascular plants, vegetation plots

References

[1] Aćić, S., Petrović, M., Dajić Stevanović, Z., & Šilc, U. (2012). Vegetation Database Grassland Vegetation in Serbia. Biodiversity & Ecology, 4, 418.

[2] Agrillo, E., Alessi, N., Massimi, M., Spada, F., De Sanctis, M., Francesconi, F., & Attorre, F. (2017). Nationwide vegetation plot database—Sapienza University of Rome: State of the art, basic figures and future perspectives. Phytocoenologia, 47, 221–229.

[3] Alvarez, M., Curran, M., & Malombe, I. (2021). SWEA-Dataveg: A vegetation database for sub-Saharan Africa. Vegetation Classification and Survey, 2, 59–63. https://doi.org/10.3897/VCS/2021/64911

[4] Apostolova, I., Sopotlieva, D., Pedashenko, H., Velev, N., & Vasilev, K. (2012). Bulgarian Vegetation Database: Historic background, current status and future prospects. Biodiversity & Ecology, 4, 141–148. https://doi.org/10.7809/b-e.00069

[5] Aubin, I., Cardou, F., Boisvert-Marsh, L., Garnier, E., Strukelj, M., & Munson, A. D. (2020). Managing data locally to answer questions globally: The role of collaborative science in ecology. Journal of Vegetation Science, 31, 509–517. https://doi.org/10.1111/jvs.12864

[6] Aubin, I., Gachet, S., Messier, C., & Bouchard, A. (2007). How resilient are northern hardwood forests to human disturbance? An evaluation using a plant functional group approach. Ecoscience, 14, 259–271.

[7] Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. Proceedings of the National Academy of Sciences USA, 115, 6506–6511. https://doi.org/10.1073/pnas.1711842115

[8] Beck, J. J., Larget, B., & Waller, D. M. (2018). Phantom species: Adjusting estimates of colonization and extinction for pseudo-turnover. Oikos, 127, 1605–1618. https://doi.org/10.1111/oik.05114

[9] Biurrun, I., García-Mijangos, I., Campos, J. A., Herrera, M., & Loidi, J. (2012). Vegetation-plot database of the University of the Basque Country (BIOVEG). Biodiversity & Ecology, 4, 328. https://doi.org/10.7809/b-e.00121

[10] Boakes, E. H., McGowan, P. J. K., Fuller, R. A., Chang-qing, D., Clark, N. E., O'Connor, K., & Mace, G. M. (2010). Distorted views of biodiversity: Spatial and temporal bias in species occurrence data. PLoS Biology, 8, e1000385. https://doi.org/10.1371/journal.pbio.1000385

[11] Bonebrake, T. C., Brown, C. J., Bell, J. D., Blanchard, J. L., Chauvenet, A., Champion, C., Chen, I.-C., Clark, T. D., Colwell, R. K., Danielsen, F., Dell, A. I., Donelson, J. M., Evengård, B., Ferrier, S., Frusher, S., Garcia, R. A., Griffis, R. B., Hobday, A. J., Jarzyna, M. A., … Pecl, G. T. (2018). Managing consequences of climate-driven species redistribution requires integration of ecology, conservation and social science. Biological Reviews, 93, 284–305. https://doi.org/10.1111/brv.12344

[12] Boyle, B., Hopkins, N., Lu, Z., Raygoza Garay, J. A., Mozzherin, D., Rees, T., Matasci, N., Narro, M. L., Piel, W. H., McKay, S. J., Lowry, S., Freeland, C., Peet, R. K., & Enquist, B. J. (2013). The taxonomic name resolution service: An online tool for automated standardization of plant names. BMC Bioinformatics, 14, 1–16. https://doi.org/10.1186/1471-2105-14-16

[13] Bruelheide, H., Böhnke, M., Both, S., Fang, T., Assmann, T., Baruffol, M., Bauhus, J., Buscot, F., Chen, X.-Y., Ding, B.-Y., Durka, W., Erfmeier, A., Fischer, M., Geißler, C., Guo, D., Guo, L.-D., Härdtle, W., He, J.-S., Hector, A., … Schmid, B. (2011). Community assembly during secondary forest succession in a Chinese subtropical forest. Ecological Monographs, 81, 25–41. https://doi.org/10.1890/09-2172.1

[14] Bruelheide, H., Dengler, J., Jiménez-Alfaro, B., Purschke, O., Hennekens, S. M., Chytrý, M., Pillar, V. D., Jansen, F., Kattge, J., Sandel, B., Aubin, I., Biurrun, I., Field, R., Haider, S., Jandt, U., Lenoir, J., Peet, R. K., Peyre, G., Sabatini, F. M., … Zverev, A. (2019). sPlot—A new tool for global vegetation analyses. Journal of Vegetation Science, 30, 161–186. https://doi.org/10.1111/jvs.12710

[15] Bruelheide, H., Dengler, J., Purschke, O., Lenoir, J., Jiménez-Alfaro, B., Hennekens, S. M., Botta-Dukát, Z., Chytrý, M., Field, R., Jansen, F., Kattge, J., Pillar, V. D., Schrodt, F., Mahecha, M. D., Peet, R. K., Sandel, B., van Bodegom, P., Altman, J., Alvarez-Dávila, E., … Jandt, U. (2018). Global trait–environment relationships of plant communities. Nature Ecology & Evolution, 2, 1906–1917. https://doi.org/10.1038/s41559-018-0699-8

[16] Cai, Q., Welk, E., Ji, C., Fang, W., Sabatini, F. M., Zhu, J., Zhu, J., Tang, Z., Attorre, F., Campos, J. A., Čarni, A., Chytrý, M., Çoban, S., Dengler, J., Dolezal, J., Field, R., Frink, J. P., Gholizadeh, H., Indreica, A., … Bruelheide, H. (2021). The relationship between niche breadth and range size of beech (Fagus) species worldwide. Journal of Biogeography, 48, 1240–1253. https://doi.org/10.1111/jbi.14074

[17] Cardinale, B. J., Matulich, K. L., Hooper, D. U., Byrnes, J. E., Duffy, E., Gamfeldt, L., Balvanera, P., O'Connor, M. I., & Gonzalez, A. (2011). The functional role of producer diversity in ecosystems. American Journal of Botany, 98, 572–592. https://doi.org/10.3732/ajb.1000364

[18] Casella, L., Bianco, P. M., Angelini, P., & Morroni, E. (2012). Italian national vegetation database (BVN/ISPRA). Biodiversity & Ecology, 4, 404. https://doi.org/10.7809/b-e.00192

[19] Cayuela, L., Gálvez-Bravo, L., Pérez Pérez, R., de Albuquerque, F., Golicher, D., Zahawi, R., Ramírez-Marcial, N., Garibaldi, C., Field, R., Rey Benayas, J., González-Espinosa, M., Balvanera, P., Ángel Castillo, M., Figueroa-Rangel, B., Griffith, D., Islebe, G., Kelly, D., Olvera-Vargas, M., Schnitzer, S., … Zamora, R. (2012). The tree biodiversity network (BIOTREE-NET): Prospects for biodiversity research and conservation in the Neotropics. Biodiversity & Ecology, 4, 211–224. https://doi.org/10.7809/b-e.00078

[20] Černý, T., Kopecký, M., Petřík, P., Song, J.-S., Šrůtek, M., Valachovič, M., Altman, J., & Doležal, J. (2015). Classification of Korean forests: Patterns along geographic and environmental gradients. Applied Vegetation Science, 18, 5–22. https://doi.org/10.1111/avsc.12124

[21] Chabbi, A., & Loescher, H. W. (2017). Terrestrial ecosystem research infrastructures: Challenges and opportunities. CRC Press.

[22] Chepinoga, V. V. (2012). Wetland Vegetation Database of Baikal Siberia (WETBS). Biodiversity & Ecology, 4, 311. https://doi.org/10.7809/b-e.00107

[23] Chytrý, M. (2012). Database of Masaryk University vegetation research in Siberia. Biodiversity & Ecology, 4, 290.

[24] Chytrý, M., Hennekens, S. M., Jiménez-Alfaro, B., Knollová, I., Dengler, J., Jansen, F., Landucci, F., Schaminée, J. H. J., Aćić, S., Agrillo, E., Ambarlı, D., Angelini, P., Apostolova, I., Attorre, F., Berg, C., Bergmeier, E., Biurrun, I., Botta-Dukát, Z., Brisse, H., … Yamalov, S. (2016). European Vegetation Archive (EVA): An integrated database of European vegetation plots. Applied Vegetation Science, 19, 173–180. https://doi.org/10.1111/avsc.12191

[25] Chytrý, M., & Rafajová, M. (2003). Czech National Phytosociological Database: Basic statistics of the available vegetation-plot data. Preslia, 75, 1–15.

[26] Chytrý, M., Tichý, L., Hennekens, S. M., Knollová, I., Janssen, J. A. M., Rodwell, J. S., Peterka, T., Marcenò, C., Landucci, F., Danihelka, J., Hájek, M., Dengler, J., Novák, P., Zukal, D., Jiménez-Alfaro, B., Mucina, L., Abdulhak, S., Aćić, S., Agrillo, E., … Schaminée, J. H. J. (2020). EUNIS Habitat Classification: Expert system, characteristic species combinations and distribution maps of European habitats. Applied Vegetation Science, 23, 648–675. https://doi.org/10.1111/avsc.12519

[27] De Sanctis, M., & Attorre, F. (2012). Socotra Vegetation Database. Biodiversity & Ecology, 4, 315. https://doi.org/10.7809/b-e.00111

[28] De Sanctis, M., Fanelli, G., Mullaj, A., & Attorre, F. (2017). Vegetation database of Albania. Phytocoenologia, 47, 107–108. https://doi.org/10.1127/phyto/2017/0178

[29] Dengler, J., Jansen, F., Glöckler, F., Peet, R. K., De Cáceres, M., Chytrý, M., Ewald, J., Oldeland, J., Lopez-Gonzalez, G., Finckh, M., Mucina, L., Rodwell, J. S., Schaminee, J. H. J., & Spencer, N. (2011). The Global Index of Vegetation-Plot Databases (GIVD): A new resource for vegetation science. Journal of Vegetation Science, 22, 582–597. https://doi.org/10.1111/j.1654-1103.2011.01265.x

[30] Dengler, J., & Rūsiņa, S. (2012). Database dry grasslands in the Nordic and Baltic region. Biodiversity & Ecology, 4, 319–320. https://doi.org/10.7809/b-e.00114

[31] Dimopoulos, P., & Tsiripidis, I. (2012). Hellenic Natura 2000 Vegetation Database (HelNAtVeg). Biodiversity & Ecology, 4, 388. https://doi.org/10.7809/b-e.00177

[32] Elmendorf, S. C., Henry, G. H. R., Hollister, R. D., Björk, R. G., Boulanger-Lapointe, N., Cooper, E. J., & Wipf, S. (2012). Plot-scale evidence of tundra vegetation change and links to summer warming. Nature Climate Change, 2, 453–457.

[33] El-Sheikh, M. A., Thomas, J., Alfarhan, A. H., Alatar, A. A., Mayandy, S., Hennekens, S. M., Schaminėe, J. H. J., Mucina, L., & Alansari, A. M. (2017). SaudiVeg ecoinformatics: Aims, current status and perspectives. Saudi Journal of Biological Sciences, 24, 389–398. https://doi.org/10.1016/j.sjbs.2016.02.012

[34] Enquist, B. J., Condit, R., Peet, R. K., Schildhauer, M., & Thiers, B. M. (2016). Cyberinfrastructure for an integrated botanical information network to investigate the ecological impacts of global climate change on plant biodiversity. PeerJ, 4, e2615v2.

[35] Enquist, B. J., Norberg, J., Bonser, S. P., Violle, C., Webb, C. T., Henderson, A., Sloat, L. L., & Savage, V. M. (2015). Scaling from traits to ecosystems: Developing a general trait driver theory via integrating trait-based and metabolic scaling theories. In S. Pawar, G. Woodward, & A. I. Dell (Eds.), Advances in ecological research (pp. 249–318). Academic Press.

[36] Ewald, J., May, R., & Kleikamp, M. (2012). VegetWeb—the national online-repository of vegetation plots from Germany. Biodiversity & Ecology, 4, 173–175. https://doi.org/10.7809/b-e.00073

[37] Fazayeli, F., Banerjee, A., Kattge, J., Schrodt, F., & Reich, P. B. (2014). Uncertainty quantified matrix completion using Bayesian hierarchical matrix factorization. In 2014 13th international conference on machine learning and applications (pp. 312–317). https://doi.org/10.1109/ICMLA.2014.56

[38] Finckh, M. (2012). Vegetation database of southern Morocco. Biodiversity & Ecology, 4, 297. https://doi.org/10.7809/b-e.00094

[39] Fotiadis, G., Tsiripidis, I., Bergmeier, E., & Dimopoulos, P. (2012). Hellenic woodland database. Biodiversity & Ecology, 4, 389. https://doi.org/10.7809/b-e.00178

[40] Franklin, J., Serra-Diaz, J. M., Syphard, A. D., & Regan, H. M. (2017). Big data for forecasting the impacts of global change on plant communities. Global Ecology and Biogeography, 26, 6–17. https://doi.org/10.1111/geb.12501

[41] Fricke, E. C., & Svenning, J.-C. (2020). Accelerating homogenization of the global plant–frugivore meta-network. Nature, 585, 74–78. https://doi.org/10.1038/s41586-020-2640-y

[42] Garbolino, E., De Ruffray, P., Brisse, H., & Grandjouan, G. (2012). The phytosociological database SOPHY as the basis of plant socio-ecology and phytoclimatology in France. Biodiversity & Ecology, 4, 177–184. https://doi.org/10.7809/b-e.00074

[43] Golub, V., Sorokin, A., Starichkova, K., Nikolaychuk, L., Bondareva, V., & Ivakhnova, T. (2012). Lower Volga valley phytosociological database. Biodiversity & Ecology, 4, 589.

[44] Harper, K., Boudreault, C., DeGrandpré, L., Drapeau, P., Gauthier, S., & Bergeron, Y. (2003). Structure, composition, and diversity of old-growth black spruce boreal forest of the Clay Belt region in Quebec and Ontario. Environmental Reviews, 11, S79–S98. https://doi.org/10.1139/a03-013

[45] Hatim, M. (2012). Vegetation database of Sinai in Egypt. Biodiversity & Ecology, 4, 303. https://doi.org/10.7809/b-e.00099

[46] Hengl, T., Mendes de Jesus, J., Heuvelink, G. B. M., Ruiperez Gonzalez, M., Kilibarda, M., Blagotić, A., Shangguan, W., Wright, M. N., Geng, X., Bauer-Marschallinger, B., Guevara, M. A., Vargas, R., MacMillan, R. A., Batjes, N. H., Leenaars, J. G. B., Ribeiro, E., Wheeler, I., Mantel, S., & Kempen, B. (2017). SoilGrids250m: Global gridded soil information based on machine learning. PLoS ONE, 12, e0169748. https://doi.org/10.1371/journal.pone.0169748

[47] Hennekens, S. M., & Schaminée, J. H. J. (2001). TURBOVEG, a comprehensive data base management system for vegetation data. Journal of Vegetation Science, 12, 589–591. https://doi.org/10.2307/3237010

[48] Himmelstein, D. S., Rubinetti, V., Slochower, D. R., Hu, D., Malladi, V. S., Greene, C. S., & Gitter, A. (2019). Open collaborative writing with Manubot. PLoS Computational Biology, 15, e1007128. https://doi.org/10.1371/journal.pcbi.1007128

[49] Ibanez, T., Munzinger, J., Dagostini, G., Hequet, V., Rigault, F., Jaffré, T., & Birnbaum, P. (2014). Structural and floristic diversity of mixed rainforest in New Caledonia: New data from the New Caledonian Plant Inventory and Permanent Plot Network (NC-PIPPN). Applied Vegetation Science, 17, 386–397.

[50] Indreica, A., Turtureanu, P. D., Szabó, A., & Irimia, I. (2017). Romanian forest database: A phytosociological archive of woody vegetation. Phytocoenologia, 47, 389–393. https://doi.org/10.1127/phyto/2017/0201

[51] IPBES (Ed.) (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat.

[52] Jaccard, P. (1912). The distribution of the flora in the alpine zone. 1. New Phytologist, 11, 37–50. https://doi.org/10.1111/j.1469-8137.1912.tb05611.x

[53] Jandt, U., & Bruelheide, H. (2012). German Vegetation Reference Database (GVRD). Biodiversity & Ecology, 4, 355. https://doi.org/10.7809/b-e.00146

[54] Jandt, U., von Wehrden, H., & Bruelheide, H. (2011). Exploring large vegetation databases to detect temporal trends in species occurrences. Journal of Vegetation Science, 22, 957–972. https://doi.org/10.1111/j.1654-1103.2011.01318.x

[55] Jansen, F., Dengler, J., & Berg, C. (2012). VegMV—the vegetation database of Mecklenburg-Vorpommern. Biodiversity & Ecology, 4, 149–160. https://doi.org/10.7809/b-e.00070

[56] Kącki, Z., & Śliwiński, M. (2012). The polish vegetation database: Structure, resources and development. Acta Societatis Botanicorum Poloniae, 81, 75–79. https://doi.org/10.5586/asbp.2012.014

[57] Karger, D. N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R. W., Zimmermann, N. E., Linder, H. P., & Kessler, M. (2017). Climatologies at high resolution for the earth's land surface areas. Scientific Data, 4, 170122. https://doi.org/10.1038/sdata.2017.122

[58] Kattge, J., Bönisch, G., Díaz, S., Lavorel, S., Prentice, I. C., Leadley, P., Tautenhahn, S., Werner, G. D. A., Aakala, T., Abedi, M., Acosta, A. T. R., Adamidis, G. C., Adamson, K., Aiba, M., Albert, C. H., Alcántara, J. M., Alcázar C, C., Aleixo, I., Ali, H., … Wirth, C. (2020). TRY plant trait database–enhanced coverage and open access. Global Change Biology, 26, 119–188. https://doi.org/10.1111/gcb.14904

[59] Kearsley, E., de Haulleville, T., Hufkens, K., Kidimbu, A., Toirambe, B., Baert, G., Huygens, D., Kebede, Y., Defourny, P., Bogaert, J., Beeckman, H., Steppe, K., Boeckx, P., & Verbeeck, H. (2013). Conventional tree height–diameter relationships significantly overestimate aboveground carbon stocks in the Central Congo Basin. Nature Communications, 4, 2269. https://doi.org/10.1038/ncomms3269

[60] Körner, C., Jetz, W., Paulsen, J., Payne, D., Rudmann-Maurer, K., & Spehn, M. E. (2017). A global inventory of mountains for bio-geographical applications. Alpine Botany, 127, 1–15. https://doi.org/10.1007/s00035-01--0182-6

[61] Korolyuk, A. Y., & Zverev, A. (2012). Database of Siberian Vegetation (DSV). Biodiversity & Ecology, 4, 312. https://doi.org/10.7809/b-e.00108

[62] Kühl, H. S., Bowler, D. E., Bösch, L., Bruelheide, H., Dauber, J., Eichenberg, D., Eisenhauer, N., Fernández, N., Guerra, C. A., Henle, K., Herbinger, I., Isaac, N. J. B., Jansen, F., König-Ries, B., Kühn, I., Nilsen, E. B., Pe'er, G., Richter, A., Schulte, R., … Bonn, A. (2020). Effective biodiversity monitoring needs a culture of integration. One Earth, 3, 462–474. https://doi.org/10.1016/j.oneear.2020.09.010

[63] Kuzemko, A. (2012). Ukrainian grasslands database. Biodiversity & Ecology, 4, 430. https://doi.org/10.7809/b-e.00217

[64] Lájer, K., Botta-Dukát, Z., Csiky, J., Horváth, F., Szmorad, F., Bagi, I., Dobolyi, Z. K., Hahn, I., Kovács, J. A., & Rédei, T. (2008). Hungarian phytosociological database (COENODATREF): Sampling methodology, nomenclature and its actual stage. Annali Di Botanica, Nuova Serie, 7, 197–201.

[65] Landucci, F., Acosta, A. T. R., Agrillo, E., Attorre, F., Biondi, E., Cambria, V. E., Chiarucci, A., Del Vico, E., De Sanctis, M., Facioni, L., Geri, F., Gigante, D., Guarino, R., Landi, S., Lucarini, D., Panfili, E., Pesaresi, S., Prisco, I., Rosati, L., … Venanzoni, R. (2012). VegItaly: The Italian collaborative project for a national vegetation database. Plant Biosystems, 146, 756–763. https://doi.org/10.1080/11263504.2012.740093

[66] Landucci, F., Řezníčková, M., Šumberová, K., Chytrý, M., Aunina, L., Biţă-Nicolae, C., Bobrov, A., Borsukevych, L., Brisse, H., Čarni, A., Csiky, J., Cvijanović, D., De Bie, E., De Ruffray, P., Dubyna, D., Dimopoulos, P., Dziuba, T., FitzPatrick, Ú., Font, X., … Willner, W. (2015). WetVegEurope: A database of aquatic and wetland vegetation of Europe. Phytocoenologia, 45, 187–194. https://doi.org/10.1127/phyto/2015/0050

[67] Lengyel, A., Chytrý, M., & Tichý, L. (2011). Heterogeneity-constrained random resampling of phytosociological databases. Journal of Vegetation Science, 22, 175–183. https://doi.org/10.1111/j.1654-1103.2010.01225.x

[68] Lenoir, J., Bertrand, R., Comte, L., Bourgeaud, L., Hattab, T., Murienne, J., & Grenouillet, G. (2020). Species better track climate warming in the oceans than on land. Nature Ecology & Evolution, 4, 1044–1059. https://doi.org/10.1038/s41559-020-1198-2

[69] Lenoir, J., Gégout, J.-C., Guisan, A., Vittoz, P., Wohlgemuth, T., Zimmermann, N. E., Dullinger, S., Pauli, H., Willner, W., Grytnes, J.-A., Virtanen, R., & Svenning, J.-C. (2010). Cross-scale analysis of the region effect on vascular plant species diversity in southern and northern European mountain ranges. PLoS ONE, 5, e15734. https://doi.org/10.1371/journal.pone.0015734

[70] Lenoir, J., Gégout, J. C., Marquet, P. A., de Ruffray, P., & Brisse, H. (2008). A significant upward shift in plant species optimum elevation during the 20th century. Science, 320, 1768–1771. https://doi.org/10.1126/science.1156831

[71] Lenoir, J., Graae, B. J., Aarrestad, P. A., Alsos, I. G., Armbruster, W. S., Austrheim, G., Bergendorff, C., Birks, H. J. B., Bråthen, K. A., Brunet, J., Bruun, H. H., Dahlberg, C. J., Decocq, G., Diekmann, M., Dynesius, M., Ejrnaes, R., Grytnes, J.-A., Hylander, K., Klanderud, K., … Svenning, J.-C. (2013). Local temperatures inferred from plant communities suggest strong spatial buffering of climate warming across Northern Europe. Global Change Biology, 19, 1470–1481. https://doi.org/10.1111/gcb.12129

[72] Lenoir, J., & Svenning, J.-C. (2015). Climate-related range shifts—a global multidimensional synthesis and new research directions. Ecography, 38, 15–28. https://doi.org/10.1111/ecog.00967

[73] Liu, H., Cui, H., Pott, R., & Speier, M. (2000). Vegetation of the woodland-steppe ecotone in southeastern Inner Mongolia, China. Journal of Vegetation Science, 11, 525–532.

[74] Lopez-Gonzalez, G., Lewis, S. L., Burkitt, M., & Phillips, O. L. (2011). ForestPlots.net: A web application and research tool to manage and analyse tropical forest plot data. Journal of Vegetation Science, 22, 610–613. https://doi.org/10.1111/j.1654-1103.2011.01312.x

[75] Lysenko, T., Kalmykova, O., & Mitroshenkova, A. (2012). Vegetation database of the Volga and the Ural rivers basins. Biodiversity & Ecology, 4, 420–421. https://doi.org/10.7809/b-e.00208

[76] Marcenò, C., & Jiménez-Alfaro, B. (2017). The Mediterranean Ammophiletea Database: A comprehensive dataset of coastal dune vegetation. Phytocoenologia, 47, 95–105.

[77] Muche, G., Schmiedel, U., & Jürgens, N. (2012). BIOTA Southern Africa Biodiversity Observatories Vegetation Database. Biodiversity & Ecology, 4, 111–123. https://doi.org/10.7809/b-e.00066

[78] Müller, J. (2003). Zur Vegetationsökologie der Savannenlandschaften im Sahel Burkina Fasos. Frankfurt am Main: Goethe Universität Frankfurt am Main.

[79] Nowak, A., Nobis, M., Nowak, S., Nobis, A., Swacha, G., & Kącki, Z. (2017). Vegetation of Middle Asia: The project state of the art after ten years of survey and future perspectives. Phytocoenologia, 47, 395–400.

[80] Pauchard, A., Fuentes, N., Jiménez, A., Bustamante, R., & Marticorena, A. (2013). Alien plants homogenise protected areas: Evidence from the landscape and regional scales in south central Chile. In L. C. Foxcroft, P. Pyšek, D. M. Richardson, & G. Piero (Eds.), Plant invasions in protected areas (pp. 191–208). Springer. https://doi.org/10.1007/978-94-007-7750-7

[81] Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I.-C., Clark, T. D., Colwell, R. K., Danielsen, F., Evengård, B., Falconi, L., Ferrier, S., Frusher, S., Garcia, R. A., Griffis, R. B., Hobday, A. J., Janion-Scheepers, C., Jarzyna, M. A., Jennings, S., … Williams, S. E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science, 355, eaai9214. https://doi.org/10.1126/science.aai9214

[82] Peet, R. K., Lee, M. T., Boyle, M. F., Wentworth, T. R., Schafale, M. P., & Weakley, A. S. (2012). Vegetation-plot database of the Carolina Vegetation Survey. Biodiversity & Ecology, 4, 243–253. https://doi.org/10.7809/b-e.00081

[83] Peet, R. K., Lee, M. T., Jennings, M. D., & Faber-Langendoen, D. (2012). VegBank–a permanent, open-access archive for vegetation-plot data. Biodiversity and Ecology, 4, 233–241. https://doi.org/10.7809/b-e.00080

[84] Perring, M. P., Bernhardt-Römermann, M., Baeten, L., Midolo, G., Blondeel, H., Depauw, L., Landuyt, D., Maes, S. L., De Lombaerde, E., Carón, M. M., Vellend, M., Brunet, J., Chudomelová, M., Decocq, G., Diekmann, M., Dirnböck, T., Dörfler, I., Durak, T., De Frenne, P., … Verheyen, K. (2018). Global environmental change effects on plant community composition trajectories depend upon management legacies. Global Change Biology, 24, 1722–1740. https://doi.org/10.1111/gcb.14030

[85] Peterka, T., Jiroušek, M., Hájek, M., & Jiménez-Alfaro, B. (2015). European Mire Vegetation Database: A gap-oriented database for European fens and bogs. Phytocoenologia, 45, 291–297. https://doi.org/10.1127/phyto/2015/0054

[86] Peyre, G., Balslev, H., Martí, D., Sklenář, P., Ramsay, P., Lozano, P., Cuello, N., Bussmann, R., Cabrera, O., & Font, X. (2015). VegPáramo, a flora and vegetation database for the Andean páramo. Phytocoenologia, 45, 195–201. https://doi.org/10.1127/phyto/2015/0045

[87] Phillips, S. J., Dudík, M., Elith, J., Graham, C. H., Lehmann, A., Leathwick, J., & Ferrier, S. (2009). Sample selection bias and presence-only distribution models: Implications for background and pseudo-absence data. Ecological Applications, 19, 181–197. https://doi.org/10.1890/07-2153.1

[88] Pimm, S. L. (2021). What we need to know to prevent a mass extinction of plant species. Plants, People, Planet, 3, 7–15. https://doi.org/10.1002/ppp3.10160

[89] Prokhorov, V., Rogova, T., & Kozhevnikova, M. (2017). Vegetation database of Tatarstan. Phytocoenologia, 47, 309–313. https://doi.org/10.1127/phyto/2017/0172

[90] Purschke, O. (2017). oliverpurschke/Taxonomic_Backbone: First release of the workflow to generate the taxonomic backbone for sPlot v. 2.1 and TRY v. 3.0. Zenodo. https://doi.org/10.5281/zenodo.845445

[91] Reich, P. B. (2014). The world-wide ‘fast–slow’ plant economics spectrum: A traits manifesto. Journal of Ecology, 102, 275–301. https://doi.org/10.1111/1365-2745.12211

[92] Revermann, R., Gomes, A. L., Gonçalves, F. M., Wallenfang, J., Hoche, T., Jürgens, N., & Finckh, M. (2016). Vegetation database of the Okavango Basin. Phytocoenologia, 46, 103–104. https://doi.org/10.1127/phyto/2016/0103

[93] Ricklefs, R. E. (2008). The economy of nature. Macmillan.

[94] Rūsiņa, S. (2012). Semi-natural grassland vegetation database of Latvia. Biodiversity & Ecology, 4, 409. https://doi.org/10.7809/b-e.00197

[95] R Core Team (2020). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

[96] Samimi, C. (2003). Das Weidepotential im Gutu-Distrikt (Zimbabwe)—Möglichkeiten und Grenzen der Modellierung unter Verwendung von Landsat TM-5. Karlsruher Schriften zur Geographie und Geoökologie, 19, 1–136.

[97] Schaminée, J. H. J., Janssen, J. A. M., Haveman, R., Hennekens, S. M., Heuvelink, G. B. M., Huiskes, H. P. J., & Weeda, E. J. (2006). Schatten voor de natuur. Achtergronden, inventaris en toepassingen van de Landelijke Vegetatie Databank. KNNV Uitgeverij.

[98] Schmidt, M., Janßen, T., Dressler, S., Hahn, K., Hien, M., Konaté, S., Lykke, A. M., Mahamane, A., Sambou, B., Sinsin, B., Thiombiano, A., Wittig, R., & Zizka, G. (2012). The West African vegetation database. Biodiversity and Ecology, 4, 105–110. https://doi.org/10.7809/b-e.00065

[99] Schrodt, F., Kattge, J., Shan, H., Fazayeli, F., Joswig, J., Banerjee, A., Reichstein, M., Bönisch, G., Díaz, S., Dickie, J., Gillison, A., Karpatne, A., Lavorel, S., Leadley, P., Wirth, C. B., Wright, I. J., Wright, S. J., & Reich, P. B. (2015). BHPMF—A hierarchical Bayesian approach to gap-filling and trait prediction for macroecology and functional biogeography. Global Ecology and Biogeography, 24, 1510–1521. https://doi.org/10.1111/geb.12335

[100] Schultz, J. (2005). The ecozones of the world. Springer.

[101] Šibík, J. (2012). Slovak vegetation database. Biodiversity & Ecology, 4, 429. https://doi.org/10.7809/b-e.00216

[102] Sieg, B., Drees, B., & Daniëls, F. J. A. (2006). Vegetation and altitudinal zonation in continental West Greenland. Meddelelser Om Grønland Bioscience, 57, 1–93.

[103] Šilc, U. (2012). Vegetation database of Slovenia. Biodiversity & Ecology, 4, 428. https://doi.org/10.7809/b-e.00215

[104] Stančić, Z. (2012). Phytosociological database of non-forest vegetation in Croatia. Biodiversity & Ecology, 4, 391. https://doi.org/10.7809/b-e.00180

[105] Staude, I. R., Waller, D. M., Bernhardt-Römermann, M., Bjorkman, A. D., Brunet, J., De Frenne, P., Hédl, R., Jandt, U., Lenoir, J., Máliš, F., Verheyen, K., Wulf, M., Pereira, H. M., Vangansbeke, P., Ortmann-Ajkai, A., Pielech, R., Berki, I., Chudomelová, M., Decocq, G., … Baeten, L. (2020). Replacements of small- by large-ranged species scale up to diversity loss in Europe's temperate forest biome. Nature Ecology & Evolution, 4, 802–808. https://doi.org/10.1038/s41559-020-1176-8

[106] Stebler, F., & Schröter, C. (1892). Versuch einer Übersicht über die Wiesentypen der Schweiz. Landwirtschaftl Jahrbuch der Schweiz.

[107] Steinbauer, M. J., Grytnes, J.-A., Jurasinski, G., Kulonen, A., Lenoir, J., Pauli, H., Rixen, C., Winkler, M., Bardy-Durchhalter, M., Barni, E., Bjorkman, A. D., Breiner, F. T., Burg, S., Czortek, P., Dawes, M. A., Delimat, A., Dullinger, S., Erschbamer, B., Felde, V. A., … Wipf, S. (2018). Accelerated increase in plant species richness on mountain summits is linked to warming. Nature, 556, 231–234. https://doi.org/10.1038/s41586-018-0005-6

[108] Synes, N. W., & Osborne, P. E. (2011). Choice of predictor variables as a source of uncertainty in continental-scale species distribution modelling under climate change. Global Ecology and Biogeography, 20, 904–914. https://doi.org/10.1111/j.1466-8238.2010.00635.x

[109] Testolin, R., Attorre, F., Borchardt, P., Brand, R. F., Bruelheide, H., Chytrý, M., De Sanctis, M., Dolezal, J., Finckh, M., Haider, S., Hemp, A., Jandt, U., Kessler, M., Korolyuk, A. Y., Lenoir, J., Makunina, N., Malanson, G. P., Montesinos-Tubée, D. B., Noroozi, J., … Jiménez-Alfaro, B. (2021). Global patterns and drivers of alpine plant species richness. Global Ecology and Biogeography, 30(6), 1218–1231. https://doi.org/10.1111/geb.13297

[110] Testolin, R., Carmona, C. P., Attorre, F., Borchardt, P., Bruelheide, H., Dolezal, J., Finckh, M., Haider, S., Hemp, A., Jandt, U., Korolyuk, A. Y., Lenoir, J., Makunina, N., Malanson, G. P., Mucina, L., Noroozi, J., Nowak, A., Peet, R. K., Peyre, G., … Jiménez-Alfaro, B. (2021). Global functional variation in alpine vegetation. Journal of Vegetation Science, 32, e13000. https://doi.org/10.1111/jvs.13000

[111] Trabucco, A., & Zomer, R. J. (2010). Global soil water balance geospatial database. CGIAR Consortium for Spatial Information. Available from the CGIAR-CSI GeoPortal at: https://cgiarcsi.community/

[112] van der Sande, M. T., Bruelheide, H., Dawson, W., Dengler, J., Essl, F., Field, R., Haider, S., van Kleunen, M., Kreft, H., Pagel, J., Pergl, J., Purschke, O., Pyšek, P., Weigelt, P., Winter, M., Attorre, F., Aubin, I., Bergmeier, E., Chytrý, M., … Knight, T. M. (2020). Similar factors underlie tree abundance in forests in native and alien ranges. Global Ecology and Biogeography, 29, 281–294. https://doi.org/10.1111/geb.13027

[113] Vanselow, K. A. (2016). Eastern Pamirs—A vegetation-plot database for the high mountain pastures of the Pamir Plateau (Tajikistan). Phytocoenologia, 46, 105. https://doi.org/10.1127/phyto/2016/0122

[114] Vassilev, K., Pedashenko, H., Alexandrova, A., Tashev, A., Ganeva, A., Gavrilova, A., Gradevska, A., Assenov, A., Vitkova, A., Grigorov, B., Gussev, C., Filipova, E., Aneva, I., Knollová, I., Nikolov, I., Georgiev, G., Gogushev, G., Tinchev, G., Pachedjieva, K., … Vulchev, V. (2016). Balkan vegetation database: Historical background, current status and future perspectives. Phytocoenologia, 46, 89–95. https://doi.org/10.1127/phyto/2016/0109

[115] Vassilev, K., Ruprecht, E., Alexiu, V., Becker, T., Beldean, M., Biță-Nicolae, C., Csergő, A. M., Dzhovanova, I., Filipova, E., Frink, J. P., Gafta, D., Georgieva, M., Germany, M. S., Goia, I., Gumus, M., Hennekens, S. M., Janišová, M., Knollová, I., Koleva, V., … Dengler, J. (2018). The Romanian Grassland Database (RGD): Historical background, current status and future perspectives. Phytocoenologia, 48, 91–100. https://doi.org/10.1127/phyto/2017/0229

[116] Vassilev, K., Stevanović, Z. D., Cušterevska, R., Bergmeier, E., & Apostolova, I. (2012). Balkan dry grasslands database. Biodiversity & Ecology, 4, 330. https://doi.org/10.7809/b-e.00123

[117] Vibrans, A. C., Gasper, A. L. D., Moser, P., Oliveira, L. Z., Lingner, D. V., & Sevegnani, L. (2020). Insights from a large-scale inventory in the southern Brazilian Atlantic Forest. Scientia Agricola, 77, e20180036. https://doi.org/10.1590/1678-992x-2018-0036

[118] von Wehrden, H., Wesche, K., & Miehe, G. (2009). Plant communities of the southern Mongolian Gobi. Phytocoenologia, 39, 331–376. https://doi.org/10.1127/0340-269X/2009/0039-0331

[119] Wagner, V. (2009). Eurosiberian meadows at their southern edge: Patterns and phytogeography in the NW Tien Shan. Journal of Vegetation Science, 20, 199–208. https://doi.org/10.1111/j.1654-1103.2009.01032.x

[120] Wagner, V., Spribille, T., Abrahamczyk, S., & Bergmeier, E. (2014). Timberline meadows along a 1000 km transect in NW North America: Species diversity and community patterns. Applied Vegetation Science, 17, 129–141. https://doi.org/10.1111/avsc.12045

[121] Walker, D. A., Breen, A. L., Druckenmiller, L. A., Wirth, L. W., Fisher, W., Raynolds, M. K., Šibík, J., Walker, M. D., Hennekens, S., Boggs, K., Boucher, T., Buchhorn, M., Bültmann, H., Cooper, D. J., Daniëls, F. J. A., Davidson, S. J., Ebersole, J. J., Elmendorf, S. C., Epstein, H. E., … Zona, D. (2016). The Alaska Arctic Vegetation Archive (AVA-AK). Phytocoenologia, 46, 221–229.

[122] Wana, D., & Beierkuhnlein, C. (2011). Responses of plant functional types to environmental gradients in the south-west Ethiopian highlands. Journal of Tropical Ecology, 27, 289–304.

[123] Wang, Y., Heberling, G., Görzen, E., Miehe, G., Seeber, E., & Wesche, K. (2017). Combined effects of livestock grazing and abiotic environment on vegetation and soils of grasslands across Tibet. Applied Vegetation Science, 20, 327–339.

[124] Weigand, A., Abrahamczyk, S., Aubin, I., Bita-Nicolae, C., Bruelheide, H., I. Carvajal-Hernández, C., Cicuzza, D., Nascimento da Costa, L. E., Csiky, J., Dengler, J., Gasper, A. L. D., Guerin, G. R., Haider, S., Hernández-Rojas, A., Jandt, U., Reyes-Chávez, J., Karger, D. N., Khine, P. K., Kluge, J., … Kessler, M. (2020). Global fern and lycophyte richness explained: How regional and local factors shape plot richness. Journal of Biogeography, 47, 59–71.

[125] Weigelt, P., König, C., & Kreft, H. (2020). GIFT—A global inventory of floras and traits for macroecology and biogeography. Journal of Biogeography, 47, 16–43.

[126] Westoby, M. (1998). A leaf-height-seed (LHS) plant ecology strategy scheme. Plant and Soil, 199, 213–227.

[127] Whitfeld, T. J. S., Lasky, J. R., Damas, K., Sosanika, G., Molem, K., & Montgomery, R. A. (2014). Species richness, forest structure, and functional diversity during succession in the New Guinea lowlands. Biotropica, 46, 538–548.

[128] Whittaker, R. H. (1975). Communities and ecosystems (2nd ed.). Macmillan.

[129] Willner, W., Berg, C., & Heiselmayer, P. (2012). Austrian vegetation database. Biodiversity & Ecology, 4, 333.

[130] Wiser, S. K. (2016). Achievements and challenges in the integration, reuse and synthesis of vegetation plot data. Journal of Vegetation Science, 27, 868–879.

[131] Wiser, S. K., Bellingham, P. J., & Burrows, L. E. (2001). Managing biodiversity information: Development of New Zealand's National Vegetation Survey databank. New Zealand Journal of Ecology, 25, 1–17.

[132] Wohlgemuth, T. (2012). Swiss forest vegetation database. Biodiversity & Ecology, 4, 340.

[133] WWF (2020). Living Planet Report 2020-Bending the curve of biodiversity loss. R. Almond, M. Grooten, & T. Peterson (Eds.). World Wildlife Fund.