



UvA-DARE (Digital Academic Repository)

Reconstructing the fine-scale habitat structure of wetlands for animal ecology using remote sensing

Koma, Z.V.

Publication date
2021

[Link to publication](#)

Citation for published version (APA):

Koma, Z. V. (2021). *Reconstructing the fine-scale habitat structure of wetlands for animal ecology using remote sensing*.

General rights

It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations

If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: <https://uba.uva.nl/en/contact>, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.

REFERENCES

- Alexander, C., Deák, B., Heilmeyer, H., 2016. Micro-topography driven vegetation patterns in open mosaic landscapes. *Ecol. Indic.* 60, 906–920.
<https://doi.org/10.1016/J.ECOLIND.2015.08.030>
- Alexander, C., Deák, B., Kania, A., Mücke, W., Heilmeyer, H., 2015. Classification of vegetation in an open landscape using full-waveform airborne laser scanner data. *Int. J. Appl. Earth Obs. Geoinformation* 41, 76–87.
<https://doi.org/10.1016/j.jag.2015.04.014>
- Anders, K., Winiwarter, L., Mara, H., Lindenbergh, R., Vos, S.E., Höfle, B., 2021. Fully automatic spatiotemporal segmentation of 3D LIDAR time series for the extraction of natural surface changes. *ISPRS J. Photogramm. Remote Sens.* 173, 297–308.
<https://doi.org/10.1016/j.isprsjprs.2021.01.015>
- Andersen, H.-E., Reutebuch, S.E., McGaughey, R.J., 2006. Active remote sensing, in: Shao, G., Reynolds, K.M. (Eds.), *Computer Applications in Sustainable Forest Management: Including Perspectives on Collaboration and Integration*. Springer Netherlands, Dordrecht, pp. 43–66. https://doi.org/10.1007/978-1-4020-4387-1_3
- Araújo, M.B., Anderson, R.P., Barbosa, A.M., Beale, C.M., Dormann, C.F., Early, R., Garcia, R.A., Guisan, A., Maiorano, L., Naimi, B., O'Hara, R.B., Zimmermann, N.E., Rahbek, C., 2019. Standards for distribution models in biodiversity assessments. *Sci. Adv.* 5, 4858–4874. <https://doi.org/10.1126/sciadv.aat4858>
- Awange, J.L., Kyalo Kiema, J.B., 2013. Optical Remote Sensing, in: Awange, J.L., Kyalo Kiema, J.B. (Eds.), *Environmental Geoinformatics: Monitoring and Management, Environmental Science and Engineering*. Springer, Berlin, Heidelberg, pp. 119–132. https://doi.org/10.1007/978-3-642-34085-7_8
- Bae, S., Levick, S.R., Heidrich, L., Magdon, P., Leuther, B.F., Wöllauer, S., Serebryanyk, A., Nauss, T., Krzystek, P., Gossner, M.M., Schall, P., Heibl, C., Bässler, C., Doerfler, I., Schulze, E.-D., Krahe, F.-S., Culmsee, H., Jung, K., Heurich, M., Fischer, M., Seibold, S., Thorn, S., Gerlach, T., Hothorn, T., Weisser, W.W., Müller, J., 2019. Radar vision in the mapping of forest biodiversity from space. *Nat. Commun.* 10, 4757–4757. <https://doi.org/10.1038/s41467-019-12737-x>
- Bae, S., Reineking, B., Ewald, M., Mueller, J., 2014. Comparison of airborne lidar, aerial photography, and field surveys to model the habitat suitability of a cryptic forest species – the hazel grouse. *Int. J. Remote Sens.* 35, 6469–6489.
<https://doi.org/10.1080/01431161.2014.955145>
- Bakx, T.R.M., Koma, Z., Seijmonsbergen, A.C., Kissling, W.D., 2019. Use and categorization of light detection and ranging vegetation metrics in avian diversity and species distribution research. *Divers. Distrib.* 25, 1045–1059.
<https://doi.org/10.1111/ddi.12915>
- Báldi, A., 2006. Factors Influencing Occurrence of Passerines in the Reed Archipelago of Lake Velence (Hungary). *Acta Ornithol.* 41, 1–6.
<https://doi.org/10.3161/068.041.0105>
- Báldi, A., Kisbenedek, T., 1999. Species-specific distribution of reed-nesting passerine birds across reed-bed edges: Effects of spatial scale and edge type. *Acta Zool. Acad. Sci. Hung.* 45, 97–114.
- Barbet-Massin, M., Jiguet, F., Albert, C.H., Thuiller, W., 2012. Selecting pseudo-absences for species distribution models: how, where and how many? *Methods Ecol. Evol.* 3, 327–338. <https://doi.org/10.1111/j.2041-210X.2011.00172.x>
- Barnes, K.W., Islam, K., Auer, S.A., 2016. Integrating LIDAR-derived canopy structure into cerulean warbler habitat models. *J. Wildl. Manag.* 80, 101–116.
<https://doi.org/10.1002/jwmg.995>

References

- Bazzaz, F.A., 1975. Plant Species Diversity in Old-Field Successional Ecosystems in Southern Illinois. *Ecology* 56, 485–488. <https://doi.org/10.2307/1934981>
- Bechtold, S., Höfle, B., 2016. HELIOS: a multi-purpose lidar simulation framework for research, planning and training of laser scanning operations with airborne, ground-based mobile and stationary platforms, in: ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Presented at the XXIII ISPRS Congress, Commission III (Volume III-3) - 12–19 July 2016, Prague, Czech Republic, Copernicus GmbH, pp. 161–168. <https://doi.org/10.5194/isprs-annals-III-3-161-2016>
- Bijkerk, W., Bakker, R., Buijs, R., 2013. Monitoring effecten van bodemdaling op vegetatie in de Lauwersmeer, Verslag monitoringsperiode 2007 t/m 2012.
- Breiman, L., 2001. Random Forests. *Mach. Learn.* 45, 5–32. <https://doi.org/10.1023/A:1010933404324>
- Broennimann, O., Fitzpatrick, M.C., Pearman, P.B., Petitpierre, B., Pellissier, L., Yoccoz, N.G., Thuiller, W., Fortin, M.-J., Randin, C., Zimmermann, N.E., Graham, C.H., Guisan, A., 2012. Measuring ecological niche overlap from occurrence and spatial environmental data. *Glob. Ecol. Biogeogr.* 21, 481–497. <https://doi.org/10.1111/j.1466-8238.2011.00698.x>
- Brown, J.L., Carnaval, A.C., 2019. A tale of two niches: methods, concepts, and evolution. *Front. Biogeogr.* 11:4. <https://doi.org/10.21425/F5FBG44158>
- Brubaker, K.M., Myers, W.L., Drohan, P.J., Miller, D.A., Byer, E.W., 2013. The use of LiDAR terrain data in characterizing surface roughness and microtopography. *Appl. Environ. Soil Sci.* 2013. <https://doi.org/10.1155/2013/891534>
- Bruggisser, M., Dorigo, W., Dostálová, A., Schlaffer, S., Pfeifer, N., Hollaus, M., Navacchi, C., 2021. Potential of Sentinel-1 C-Band Time Series to Derive Structural Parameters of Temperate Deciduous Forests 1–30.
- Burns, P., Clark, M., Salas, L., Hancock, S., Leland, D., Jantz, P., Dubayah, R., Goetz, S.J., 2020. Incorporating canopy structure from simulated GEDI lidar into bird species distribution models. *Environ. Res. Lett.* 15, 095002. <https://doi.org/10.1088/1748-9326/ab80ee>
- Cao, L., Coops, N.C., Hermosilla, T., Innes, J., Dai, J., She, G., 2014. Using Small-Footprint Discrete and Full-Waveform Airborne LiDAR Metrics to Estimate Total Biomass and Biomass Components in Subtropical Forests. *Remote Sens.* 6, 7110–7135. <https://doi.org/10.3390/rs6087110>
- Chase, J.M., Leibold, M.A., 2003. *Ecological Niches: Linking Classical and Contemporary Approaches*, 1 edition. ed. University of Chicago Press, Chicago.
- Chasmer, L., Hopkinson, C., Montgomery, J., Petrone, R., 2016. A Physically Based Terrain Morphology and Vegetation Structural Classification for Wetlands of the Boreal Plains, Alberta, Canada. *Can. J. Remote Sens.* 42, 521–540. <https://doi.org/10.1080/07038992.2016.1196583>
- Cody, M.L., 1985. *Habitat Selection in Birds*. Academic Press.
- Congalton, R.G., 1991. A review of assessing the accuracy of classifications of remotely sensed data. *Remote Sens. Environ.* 37, 35–46. [https://doi.org/10.1016/0034-4257\(91\)90048-B](https://doi.org/10.1016/0034-4257(91)90048-B)
- Coops, N.C., Tompaski, P., Nijland, W., Rickbeil, G.J.M., Nielsen, S.E., Bater, C.W., Stadt, J.J., 2016. A forest structure habitat index based on airborne laser scanning data. *Ecol. Indic.* 67, 346–357. <https://doi.org/10.1016/j.ecolind.2016.02.057>
- Cord, A.F., Klein, D., Mora, F., Dech, S., 2014. Comparing the suitability of classified land cover data and remote sensing variables for modeling distribution patterns of plants. *Ecol. Model.* 272, 129–140. <https://doi.org/10.1016/j.ecolmodel.2013.09.011>
- Corti Meneses, N., Baier, S., Geist, J., Schneider, T., 2017. Evaluation of Green-LiDAR Data for Mapping Extent, Density and Height of Aquatic Reed Beds at Lake Chiemsee, Bavaria—Germany. *Remote Sens.* 9, 1308. <https://doi.org/10.3390/rs9121308>
- Cramp, the late S. (Ed.), 1992. *Handbook of the Birds of Europe, the Middle East, and*

References

- North Africa: The Birds of the Western Palearctic Volume VI: Warblers. Oxford University Press, Oxford.
- Davidson, N.C., 2014. How much wetland has the world lost? Long-term and recent trends in global wetland area. *Mar. Freshw. Res.* 65, 934–941.
<https://doi.org/10.1071/MF14173>
- Davies, A.B., Asner, G.P., 2014. Advances in animal ecology from 3D-LiDAR ecosystem mapping. *Trends Ecol. Evol.* 29, 681–691.
<https://doi.org/10.1016/j.tree.2014.10.005>
- Davies, A.B., Gaylard, A., Asner, G.P., 2018. Megafaunal effects on vegetation structure throughout a densely wooded African landscape. *Ecol. Appl.* 28, 398–408.
<https://doi.org/10.1002/eap.1655>
- Di Cola, V., Broennimann, O., Petitpierre, B., Breiner, F.T., D’Amen, M., Randin, C., Engler, R., Pottier, J., Pio, D., Dubuis, A., Pellissier, L., Mateo, R.G., Hordijk, W., Salamin, N., Guisan, A., 2017. *ecospat*: an R package to support spatial analyses and modeling of species niches and distributions. *Ecography* 40, 774–787.
<https://doi.org/10.1111/ecog.02671>
- Ding, Q., Chen, W., King, B.A., Chen, Y., Liu, Y., Zhang, H., 2011. Coastal Wetland Investigations by Airborne LiDAR: A Case Study in the Yellow River Delta, China. *Mar. Technol. Soc. J.* 45, 59–70. <https://doi.org/10.4031/MTSJ.45.5.6>
- Drusch, M., Del Bello, U., Carlier, S., Colin, O., Fernandez, V., Gascon, F., Hoersch, B., Isola, C., Laberinti, P., Martimort, P., Meygret, A., Spoto, F., Sy, O., Marchese, F., Bargellini, P., 2012. Sentinel-2: ESA’s Optical High-Resolution Mission for GMES Operational Services. *Remote Sens. Environ.* 120, 25–36.
<https://doi.org/10.1016/j.rse.2011.11.026>
- Dubayah, R., Blair, J.B., Loetz, S., Fatoyinbo, L., Hansen, M., Healey, S., Hofton, M., Hurtt, G., Kellner, J., Luthcke, S., Armston, J., Tang, H., Duncanson, L., Hancock, S., Jantz, P., Marselis, S., Patterson, P.L., Qi, W., Silva, C., 2020. The Global Ecosystem Dynamics Investigation: High-resolution laser ranging of the Earth’s forests and topography. *Sci. Remote Sens.* 1, 100002–100002.
<https://doi.org/10.1016/j.srs.2020.100002>
- Dunlavy, J.C., 1935. Studies on the Phyto-Vertical Distribution of Birds. *The Auk* 52, 425–431. <https://doi.org/10.2307/4077518>
- Dyrce, A., 1981. Breeding ecology of great reed warbler *Acrocephalus arundinaceus* and reed warbler *Acrocephalus scirpaceus* at fish-ponds in SW Poland and lakes in NW Switzerland.
- Elith, J., Ferrier, S., Huettmann, F., Leathwick, J., 2005. The evaluation strip: A new and robust method for plotting predicted responses from species distribution models. *Ecol. Model.* 186, 280–289. <https://doi.org/10.1016/j.ecolmodel.2004.12.007>
- Elith, J., H. Graham, C., P. Anderson, R., Dudík, M., Ferrier, S., Guisan, A., J. Hijmans, R., Huettmann, F., R. Leathwick, J., Lehmann, A., Li, J., G. Lohmann, L., A. Loiselle, B., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., McC. M. Overton, J., Townsend Peterson, A., J. Phillips, S., Richardson, K., Scachetti-Pereira, R., E. Schapire, R., Soberón, J., Williams, S., S. Wisz, M., E. Zimmermann, N., 2006. Novel methods improve prediction of species’ distributions from occurrence data. *Ecography* 29, 129–151. <https://doi.org/10.1111/j.2006.0906-7590.04596.x>
- Ellenberg, Heinz., 1996. *Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer und historischer Sicht* : 170 Tabellen. Ulmer.
- Ene, L.T., Gobakken, T., Andersen, H.-E., Næsset, E., Cook, B.D., Morton, D.C., Babcock, C., Nelson, R., 2018. Large-area hybrid estimation of aboveground biomass in interior Alaska using airborne laser scanning data. *Remote Sens. Environ.* 204, 741–755. <https://doi.org/10.1016/J.RSE.2017.09.027>
- Farrell, S.L., Collier, B.A., Skow, K.L., Long, A.M., Campomizzi, A.J., Morrison, M.L., Hays, K.B., Wilkins, R.N., 2013. Using LiDAR-derived vegetation metrics for high-resolution, species distribution models for conservation planning. *Ecosphere* 4,

References

- art42. <https://doi.org/10.1890/ES12-000352.1>
- Farwell, L.S., Gudex-Cross, D., Anise, I.E., Bosch, M.J., Olah, A.M., Radeloff, V.C., Razenkova, E., Rogova, N., Silveira, E.M.O., Smith, M.M., Pidgeon, A.M., 2021. Satellite image texture captures vegetation heterogeneity and explains patterns of bird richness. *Remote Sens. Environ.* 253, 112175. <https://doi.org/10.1016/j.rse.2020.112175>
- Ficetola, G.F., Bonardi, A., Mùcher, C.A., Gilissen, N.L.M., Padoa-Schioppa, E., 2014. How many predictors in species distribution models at the landscape scale? Land use versus LiDAR-derived canopy height. *Int. J. Geogr. Inf. Sci.* 28, 1723–1739. <https://doi.org/10.1080/13658816.2014.891222>
- Fliervoet, L.M., Werger, M.J.A., 1984. Canopy Structure and Microclimate of Two Wet Grassland Communities. *New Phytol.* 96, 115–130. <https://doi.org/10.1111/j.1469-8137.1984.tb03548.x>
- Friedman, J.H., 2001. Greedy Function Approximation: A Gradient Boosting Machine. *Ann. Stat.* 29, 1189–1232.
- Ghamisi, P., Rasti, B., Yokoya, N., Wang, Q., Hofle, B., Bruzzone, L., Bovolo, F., Chi, M., Anders, K., Gloaguen, R., Atkinson, P.M., Benediktsson, J.A., 2019. Multisource and Multitemporal Data Fusion in Remote Sensing: A Comprehensive Review of the State of the Art. *IEEE Geosci. Remote Sens. Mag.* 7, 6–39. <https://doi.org/10.1109/MGRS.2018.2890023>
- Gilbert, G., Smith, K.W., 2012. Bird–habitat relationships in reedswamps and fens, in: Fuller, R.J. (Ed.), *Birds and Habitat*. Cambridge University Press, Cambridge, pp. 253–277. <https://doi.org/10.1017/CBO9781139021654.013>
- Gilmore, M.S., Wilson, E.H., Barrett, N., Civco, D.L., Prisloe, S., Hurd, J.D., Chadwick, C., 2008. Integrating multi-temporal spectral and structural information to map wetland vegetation in a lower Connecticut River tidal marsh. *Remote Sens. Environ.*, Applications of Remote Sensing to Monitoring Freshwater and Estuarine Systems 112, 4048–4060. <https://doi.org/10.1016/j.rse.2008.05.020>
- Goodale, R., Hopkinson, C., Colville, D., Amirault-Langlais, D., 2007. Mapping piping plover (*Charadrius melodus melodus*) habitat in coastal areas using airborne lidar data. *Can. J. Remote Sens.* 33, 519–533. <https://doi.org/10.5589/m07-058>
- Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., Moore, R., 2017. Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sens. Environ.*, Big Remotely Sensed Data: tools, applications and experiences 202, 18–27. <https://doi.org/10.1016/j.rse.2017.06.031>
- Graveland, J., 1998. Reed die-back, water level management and the decline of the Great Reed Warbler *Acrocephalus arundinaceus* in the Netherlands. *Ardea* 86, 187–201.
- Grinnell, J., 1917. The niche-relationships of the California Thrasher. *The Auk* 34, 427–433. <https://doi.org/10.2307/4072271>
- Guisan, A., Thuiller, W., 2005. Predicting species distribution: Offering more than simple habitat models. *Ecol. Lett.* 8, 993–1009. <https://doi.org/10.1111/j.1461-0248.2005.00792.x>
- Guisan, A., Zimmermann, N.E., 2000. Predictive habitat distribution models in ecology. *Ecol. Model.* 135, 147–186. [https://doi.org/10.1016/S0304-3800\(00\)00354-9](https://doi.org/10.1016/S0304-3800(00)00354-9)
- Guisan, A., Zimmermann, N.E., Thuiller, W. (Eds.), 2017. *Data Acquisition, Sampling Design, and Spatial Scales*, in: *Habitat Suitability and Distribution Models: With Applications in R, Ecology, Biodiversity and Conservation*. Cambridge University Press, Cambridge, pp. 59–150. <https://doi.org/10.1017/9781139028271.010>
- Guo, M., Li, J., Sheng, C., Xu, J., Wu, L., 2017. A Review of Wetland Remote Sensing. *Sensors* 17, 777. <https://doi.org/10.3390/s17040777>
- Guyon, I., Weston, J., Barnhill, S., Vapnik, V., 2002. Gene Selection for Cancer Classification using Support Vector Machines. *Mach. Learn.* 46, 389–422. <https://doi.org/10.1023/A:1012487302797>
- Hall, F.G., Bergen, K., Blair, J.B., Dubayah, R., Houghton, R., Hurtt, G., Kellendorfer, J.,

References

- Lefsky, M., Ranson, J., Saatchi, S., Shugart, H.H., Wickland, D., 2011. Characterizing 3D vegetation structure from space: Mission requirements. *Remote Sens. Environ.*, DESDynI VEG-3D Special Issue 115, 2753–2775. <https://doi.org/10.1016/j.rse.2011.01.024>
- He, K.S., Bradley, B.A., Cord, A.F., Rocchini, D., Tuanmu, M.N., Schmidtlein, S., Turner, W., Wegmann, M., Pettorelli, N., 2015. Will remote sensing shape the next generation of species distribution models? *Remote Sens. Ecol. Conserv.* 1, 4–18. <https://doi.org/10.1002/rse2.7>
- Hill, R.A., Hinsley, S.A., Broughton, R.K., 2014. Assessing habitats and organism-habitat relationships by Airborne Laser Scanning, in: Maltamo, M., Næsset, E., Vauhkonen, J. (Eds.), *Forestry Applications of Airborne Laser Scanning: Concepts and Case Studies, Managing Forest Ecosystems*. Springer Netherlands, Dordrecht, pp. 335–356. https://doi.org/10.1007/978-94-017-8663-8_17
- Hinsley, S.A., Hill, R.A., Gaveau, D.L.A., Bellamy, P.E., 2002. Quantifying woodland structure and habitat quality for birds using airborne laser scanning. *Funct. Ecol.* 16, 851–857. <https://doi.org/10.1046/j.1365-2435.2002.00697.x>
- Hirano, A., Madden, M., Welch, R., 2003. Hyperspectral image data for mapping wetland vegetation. *Wetlands* 23, 436–448. <https://doi.org/10.1672/18-20>
- Hladik, C., Alber, M., 2012. Accuracy assessment and correction of a LIDAR-derived salt marsh digital elevation model. *Remote Sens. Environ.* 121, 224–235. <https://doi.org/10.1016/j.rse.2012.01.018>
- Hoffmeister, D., Waldhoff, G., Korres, W., Curdt, C., Bareth, G., 2016. Crop height variability detection in a single field by multi-temporal terrestrial laser scanning. *Precis. Agric.* 17, 296–312. <https://doi.org/10.1007/s11119-015-9420-y>
- Höfle, B., Pfeifer, N., 2007. Correction of laser scanning intensity data: Data and model-driven approaches. *ISPRS J. Photogramm. Remote Sens.* 62, 415–433. <https://doi.org/10.1016/j.isprsjprs.2007.05.008>
- Holt, R.D., 2009. Bringing the Hutchinsonian niche into the 21st century: Ecological and evolutionary perspectives. *Proc. Natl. Acad. Sci.* 106, 19659–19665. <https://doi.org/10.1073/pnas.0905137106>
- Hopkinson, C., 2007. The influence of flying altitude, beam divergence, and pulse repetition frequency on laser pulse return intensity and canopy frequency distribution. *Can. J. Remote Sens.* 33, 312–324. <https://doi.org/10.5589/m07-029>
- Hopkinson, C., Chasmer, L.E., Sass, G., Creed, I.F., Sitar, M., Kalbfleisch, W., Treitz, P., 2005. Vegetation class dependent errors in lidar ground elevation and canopy height estimates in a boreal wetland environment. *Can. J. Remote Sens.* 31, 191–206. <https://doi.org/10.5589/m05-007>
- Hopkinson, C., Lim, K., Chasmer, L.E., Treitz, P., Creed, I.F., Gynan, C., 2004. Wetland grass to plantation forest—estimating vegetation height from the standard deviation of lidar frequency distributions. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* 36.
- Howland, W.G., 1980. Multispectral aerial photography for wetland vegetation mapping. *Photogramm. Eng. Remote Sens.* 46, 87–99.
- Hutchinson, G.E., 1957. Concluding Remarks. *Cold Spring Harb. Symp. Quant. Biol.* 22, 415–427. <https://doi.org/10.1101/SQB.1957.022.01.039>
- Hyypä, J., Hyypä, H., Leckie, D., Gougeon, F., Yu, X., Maltamo, M., 2008. Review of methods of small-footprint airborne laser scanning for extracting forest inventory data in boreal forests. *Int. J. Remote Sens.* 29, 1339–1366. <https://doi.org/10.1080/01431160701736489>
- James, G., Witten, D., Hastie, T., Tibshirani, R., 2013. Linear Regression, in: James, G., Witten, D., Hastie, T., Tibshirani, R. (Eds.), *An Introduction to Statistical Learning: With Applications in R*, Springer Texts in Statistics. Springer, New York, NY, pp. 59–126. https://doi.org/10.1007/978-1-4614-7138-7_3
- Jonckheere, I., Fleck, S., Nackaerts, K., Muys, B., Coppin, P., Weiss, M., Baret, F., 2004.

References

- Review of methods for in situ leaf area index determination: Part I. Theories, sensors and hemispherical photography. *Agric. For. Meteorol.* 121, 19–35. <https://doi.org/10.1016/j.agrformet.2003.08.027>
- Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., Jepsen, M.R., Kuemmerle, T., Meyfroidt, P., Mitchard, E.T.A., Reiche, J., Ryan, C.M., Waske, B., 2016. A Review of the Application of Optical and Radar Remote Sensing Data Fusion to Land Use Mapping and Monitoring. *Remote Sens.* 8, 70. <https://doi.org/10.3390/rs8010070>
- Keränen, J., Maltamo, M., Packalen, P., 2016. Effect of flying altitude, scanning angle and scanning mode on the accuracy of ALS based forest inventory. *Int. J. Appl. Earth Obs. Geoinformation* 52, 349–360. <https://doi.org/10.1016/j.jag.2016.07.005>
- Kerr, J.T., Ostrovsky, M., 2003. From space to species: ecological applications for remote sensing. *Trends Ecol. Evol.* 18, 299–305. [https://doi.org/10.1016/S0169-5347\(03\)00071-5](https://doi.org/10.1016/S0169-5347(03)00071-5)
- Kissling, W.D., Seijmonsbergen, A., Foppen, R., Bouten, W., 2017. eEcoLiDAR, eScience infrastructure for ecological applications of LiDAR point clouds: reconstructing the 3D ecosystem structure for animals at regional to continental scales. *Res. Ideas Outcomes* 3, e14939. <https://doi.org/10.3897/rio.3.e14939>
- Kleefstra, R., de Boer, P., Kampichler, C., 2016. Broedvogelmonitoring in het Lauwersmeer in 2016. Sovon-rapport 2016/44, Sovon Vogelonderzoek, Nederland, Nijmegen.
- Koma, Z., Grootes, M.W., Meijer, C.W., Nattino, F., Seijmonsbergen, A.C., Sierdsema, H., Foppen, R., Kissling, W.D., 2021a. Niche separation of wetland birds revealed from airborne laser scanning. *Ecography* 44, 907–918. <https://doi.org/10.1111/ecog.05371>
- Koma, Z., Seijmonsbergen, A.C., Kissling, W.D., 2021b. Classifying wetland-related land cover types and habitats using fine-scale lidar metrics derived from country-wide Airborne Laser Scanning. *Remote Sens. Ecol. Conserv.* 7, 80–96. <https://doi.org/10.1002/rse2.170>
- Koma, Zs., Koenig, K., Höfle, B., 2016. URBAN TREE CLASSIFICATION USING FULL-WAVEFORM AIRBORNE LASER SCANNING. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.* III–3, 185–192. <https://doi.org/10.5194/isprs-annals-III-3-185-2016>
- Kopec, D., Michalska-Hejduk, D., Sfawik, S., Berezowski, T., Borowski, M., Rosadzifski, S., Chormafski, J., 2016. Application of multisensoral remote sensing data in the mapping of alkaline fens Natura 2000 habitat. *Ecol. Indic.* 70, 196–208. <https://doi.org/10.1016/J.ECOLIND.2016.06.001>
- Korpela, I., Hovi, A., Morsdorf, F., 2012. Understorey trees in airborne LiDAR data — Selective mapping due to transmission losses and echo-triggering mechanisms. *Remote Sens. Environ.* 119, 92–104. <https://doi.org/10.1016/j.rse.2011.12.011>
- Lang, M., McCarty, G., Oesterling, R., Yeo, I.-Y., 2013. Topographic Metrics for Improved Mapping of Forested Wetlands. *Wetlands* 33, 141–155. <https://doi.org/10.1007/s13157-012-0359-8>
- Lefsky, M.A., Cohen, W.B., Parker, G.G., Harding, D.J., 2002. Lidar Remote Sensing for Ecosystem Studies Lidar, an emerging remote sensing technology that directly measures the three-dimensional distribution of plant canopies, can accurately estimate vegetation structural attributes and should be of particular interest to forest, landscape, and global ecologists. *BioScience* 52, 19–30. [https://doi.org/10.1641/0006-3568\(2002\)052\[0019:LRSFES\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2002)052[0019:LRSFES]2.0.CO;2)
- Leisler, B., Schulze-Hagen, K., 2011. The reed warblers: Diversity in a uniform bird family. *BRILL*.
- Lindsay, J.B., Creed, I.F., Beall, F.D., 2004. Drainage basin morphometrics for depressional landscapes. *Water Resour. Res.* 40, W09307–W09307. <https://doi.org/10.1029/2004WR003322>
- Liu, J., Pattey, E., 2010. Retrieval of leaf area index from top-of-canopy digital photography

References

- over agricultural crops. *Agric. For. Meteorol.* 150, 1485–1490.
<https://doi.org/10.1016/j.agrformet.2010.08.002>
- Lucas, C., Bouten, W., Koma, Z., Kissling, W.D., Seijmonsbergen, A.C., 2019. Identification of linear vegetation elements in a rural landscape using LiDAR point clouds. *Remote Sens.* 11, 292. <https://doi.org/10.3390/rs11030292>
- Luo, S., Wang, C., Pan, F., Xi, X., Li, G., Nie, S., Xia, S., 2015. Estimation of wetland vegetation height and leaf area index using airborne laser scanning data. *Ecol. Indic.* 48, 550–559. <https://doi.org/10.1016/j.ecolind.2014.09.024>
- Luo, S., Wang, C., Xi, X., Pan, F., Qian, M., Peng, D., Nie, S., Qin, H., Lin, Y., 2017. Retrieving aboveground biomass of wetland *Phragmites australis* (common reed) using a combination of airborne discrete-return LiDAR and hyperspectral data. *Int. J. Appl. Earth Obs. Geoinformation* 58, 107–117.
<https://doi.org/10.1016/j.jag.2017.01.016>
- MacArthur, R.H., MacArthur, J.W., 1961. On Bird Species Diversity. *Ecology* 42, 594–598.
<https://doi.org/10.2307/1932254>
- Mallet, C., Bretar, F., 2009. Full-waveform topographic lidar: State-of-the-art. *ISPRS J. Photogramm. Remote Sens.* 64, 1–16.
<https://doi.org/10.1016/j.isprsjprs.2008.09.007>
- Meijer, C., Grootes, M.W., Koma, Z., Dzigan, Y., Gonçalves, R., Andela, B., van den Oord, G., Rangelova, E., Renaud, N., Kissling, W.D., 2020. Laserchicken—A tool for distributed feature calculation from massive LiDAR point cloud datasets. *SoftwareX* 12, 100626. <https://doi.org/10.1016/j.softx.2020.100626>
- Millard, K., Richardson, M., 2013. Wetland mapping with LiDAR derivatives, SAR polarimetric decompositions, and LiDAR–SAR fusion using a random forest classifier. *Can. J. Remote Sens.* 39, 290–307. <https://doi.org/10.5589/m13-038>
- Mitchley, J., Willems, J.H., 1995. Vertical canopy structure of Dutch chalk grasslands in relation to their management. *Vegetatio* 117, 17–27.
<https://doi.org/10.1007/BF00033256>
- Mitsch, W.J., Bernal, B., Hernandez, M.E., 2015. Ecosystem services of wetlands. *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* 11, 1–4.
<https://doi.org/10.1080/21513732.2015.1006250>
- Mod, H.K., Scherrer, D., Luoto, M., Guisan, A., 2016. What we use is not what we know: environmental predictors in plant distribution models. *J. Veg. Sci.* 27, 1308–1322.
<https://doi.org/10.1111/jvs.12444>
- Moeslund, J.E., Ziinszky, A., Ejrnæs, R., Brunbjerg, A.K., Bøcher, P.K., Svenning, J.-C., Normand, S., 2019. Light detection and ranging explains diversity of plants, fungi, lichens, and bryophytes across multiple habitats and large geographic extent. *Ecol. Appl.* 29, e01907. <https://doi.org/10.1002/eap.1907>
- Montgomery, J., Brisco, B., Chasmer, L., Devito, K., Cobbaert, D., Hopkinson, C., 2019. SAR and Lidar Temporal Data Fusion Approaches to Boreal Wetland Ecosystem Monitoring. *Remote Sens.* 11, 161–161. <https://doi.org/10.3390/rs11020161>
- Müller, J., Bae, S., Röder, J., Chao, A., Didham, R.K., 2014. Airborne LiDAR reveals context dependence in the effects of canopy architecture on arthropod diversity. *For. Ecol. Manag.* 312, 129–137. <https://doi.org/10.1016/j.foreco.2013.10.014>
- Muro, J., Canty, M., Conradsen, K., Hüttich, C., Nielsen, A.A., Skriver, H., Remy, F., Strauch, A., Thonfeld, F., Menz, G., 2016. Short-Term Change Detection in Wetlands Using Sentinel-1 Time Series. *Remote Sens.* 8, 795.
<https://doi.org/10.3390/rs8100795>
- Mutanga, O., Adam, E., Cho, M.A., 2012. High density biomass estimation for wetland vegetation using WorldView-2 imagery and random forest regression algorithm. *Int. J. Appl. Earth Obs. Geoinformation* 18, 399–406.
<https://doi.org/10.1016/j.jag.2012.03.012>
- Næsset, E., 2005. Assessing sensor effects and effects of leaf-off and leaf-on canopy conditions on biophysical stand properties derived from small-footprint airborne

References

- laser data. *Remote Sens. Environ.* 98, 356–370.
<https://doi.org/10.1016/j.rse.2005.07.012>
- Naimi, B., 2015. Uncertainty Analysis for Species Distribution Models. R Software Package.
- Naimi, B., Araújo, M.B., 2016. sdm: a reproducible and extensible R platform for species distribution modelling. *Ecography* 39, 368–375. <https://doi.org/10.1111/ecog.01881>
- Naimi, B., Hamm, N.A.S., Groen, T.A., Skidmore, A.K., Toxopeus, A.G., 2014. Where is positional uncertainty a problem for species distribution modelling? *Ecography* 37, 191–203. <https://doi.org/10.1111/j.1600-0587.2013.00205.x>
- Nasset, E., 2004. Effects of different flying altitudes on biophysical stand properties estimated from canopy height and density measured with a small-footprint airborne scanning laser. *Remote Sens. Environ.* 91, 243–255.
<https://doi.org/10.1016/j.rse.2004.03.009>
- Navarro, L.M., Fernández, N., Guerra, C., Guralnick, R., Kissling, W.D., Londoño, M.C., Muller-Karger, F., Turak, E., Balvanera, P., Costello, M.J., Delavaud, A., El Serafy, G., Ferrier, S., Geijzendorffer, I., Geller, G.N., Jetz, W., Kim, E.-S., Kim, H., Martin, C.S., McGeoch, M.A., Mwampamba, T.H., Nel, J.L., Nicholson, E., Pettorelli, N., Schaepman, M.E., Skidmore, A., Sousa Pinto, I., Vergara, S., Vihervaara, P., Xu, H., Yahara, T., Gill, M., Pereira, H.M., 2017. Monitoring biodiversity change through effective global coordination. *Curr. Opin. Environ. Sustain.* 29, 158–169.
<https://doi.org/10.1016/J.COSUST.2018.02.005>
- Nayegandhi, A., Brock, J.C., Wright, C.W., O'Connell, M.J., 2006. Evaluating A Small Footprint, Waveform-resolving Lidar Over Coastal Vegetation Communities. *Photogramm. Eng. Remote Sens.* 72, 1407–1417.
<https://doi.org/10.14358/PERS.72.12.1407>
- Neto, J.M., 2006. Nest-site selection and predation in Savi's Warblers *Locustella luscinioides*. *Bird Study* 53, 171–176. <https://doi.org/10.1080/00063650609461430>
- Nie, S., Wang, C., Xi, X., Luo, S., Li, S., Tian, J., 2018. Estimating the height of wetland vegetation using airborne discrete-return LiDAR data. *Opt. - Int. J. Light Electron Opt.* 154, 267–274. <https://doi.org/10.1016/j.ijleo.2017.10.016>
- O'Dea, A., Brodie, K.L., Hartzell, P., 2019. Continuous Coastal Monitoring with an Automated Terrestrial Lidar Scanner. *J. Mar. Sci. Eng.* 7, 37.
<https://doi.org/10.3390/jmse7020037>
- Oeser, J., Heurich, M., Senf, C., Pflugmacher, D., Belotti, E., Kuemmerle, T., 2020. Habitat metrics based on multi-temporal Landsat imagery for mapping large mammal habitat. *Remote Sens. Ecol. Conserv.* 6, 52–69. <https://doi.org/10.1002/rse2.122>
- Onojeghuo, A.O., Blackburn, G.A., 2013. Characterising Reedbeds Using LiDAR Data: Potential and Limitations. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* 6, 935–941. <https://doi.org/10.1109/JSTARS.2012.2212235>
- Onojeghuo, A.O., Blackburn, G.A., 2011. Optimising the use of hyperspectral and LiDAR data for mapping reedbed habitats. *Remote Sens. Environ.* 115, 2025–2034.
<https://doi.org/10.1016/j.rse.2011.04.004>
- Onojeghuo, A.O., Blackburn, G.A., Latif, Z.A., 2010. Characterising Reedbed habitat quality using Leaf-off LiDAR Data, in: 2010 6th International Colloquium on Signal Processing Its Applications. Presented at the 2010 6th International Colloquium on Signal Processing its Applications, pp. 1–5.
<https://doi.org/10.1109/CSPA.2010.5545322>
- Ørka, H.O., Næsset, E., Bollandsås, O.M., 2010. Effects of different sensors and leaf-on and leaf-off canopy conditions on echo distributions and individual tree properties derived from airborne laser scanning. *Remote Sens. Environ.* 114, 1445–1461.
<https://doi.org/10.1016/j.rse.2010.01.024>
- Ostendorp, W., 1989. 'Die-back' of reeds in Europe — a critical review of literature. *Aquat. Bot., Reed and Reed Decline in Europe* 35, 5–26. [https://doi.org/10.1016/0304-3770\(89\)90063-6](https://doi.org/10.1016/0304-3770(89)90063-6)
- Pearman, P.B., Guisan, A., Broennimann, O., Randin, C.F., 2008. Niche dynamics in space

References

- and time. *Trends Ecol. Evol.* 23, 149–158. <https://doi.org/10.1016/j.tree.2007.11.005>
- Pearson, R.G., Dawson, T.P., Liu, C., 2004. Modelling species distributions in Britain: a hierarchical integration of climate and land-cover data. *Ecography* 27, 285–298. <https://doi.org/10.1111/j.0906-7590.2004.03740.x>
- Pereira, H.M., Ferrier, S., Walters, M., Geller, G.N., Jongman, R.H.G., Scholes, R.J., Bruford, M.W., Brummitt, N., Butchart, S.H.M., Cardoso, A.C., Coops, N.C., Dulloo, E., Faith, D.P., Freyhof, J., Gregory, R.D., Heip, C., Höft, R., Hurtt, G., Jetz, W., Karp, D.S., McGeoch, M.A., Obura, D., Onoda, Y., Pettorelli, N., Reyers, B., Sayre, R., Scharlemann, J.P.W., Stuart, S.N., Turak, E., Walpole, M., Wegmann, M., 2013. Essential Biodiversity Variables. *Science* 339, 277 LP – 278. <https://doi.org/10.1126/science.1229931>
- Petitpierre, B., Kueffer, C., Broennimann, O., Randin, C., Daehler, C., Guisan, A., 2012. Climatic niche shifts are rare among terrestrial plant invaders. *Science* 335, 1344–1348. <https://doi.org/10.1126/science.1215933>
- Pettorelli, N., Laurance, W.F., O'Brien, T.G., Wegmann, M., Nagendra, H., Turner, W., 2014a. Satellite remote sensing for applied ecologists: opportunities and challenges. *J. Appl. Ecol.* 51, 839–848. <https://doi.org/10.1111/1365-2664.12261>
- Pettorelli, N., Laurance, W.F., O'Brien, T.G., Wegmann, M., Nagendra, H., Turner, W., 2014b. Satellite remote sensing for applied ecologists: Opportunities and challenges. *J. Appl. Ecol.* 51, 839–848. <https://doi.org/10.1111/1365-2664.12261>
- Pettorelli, N., Ryan, S., Mueller, T., Bunnefeld, N., Jędrzejewska, B., Lima, M., Kausrud, K., 2011. The Normalized Difference Vegetation Index (NDVI): unforeseen successes in animal ecology. *Clim. Res.* 46, 15–27. <https://doi.org/10.3354/cr00936>
- Pettorelli, N., Vik, J.O., Mysterud, A., Gaillard, J.-M., Tucker, C.J., Stenseth, N.Chr., 2005. Using the satellite-derived NDVI to assess ecological responses to environmental change. *Trends Ecol. Evol.* 20, 503–510. <https://doi.org/10.1016/j.tree.2005.05.011>
- Pettorelli, N., Wegmann, M., Skidmore, A., Múcher, S., Dawson, T.P., Fernandez, M., Lucas, R., Schaepman, M.E., Wang, T., O'Connor, B., Jongman, R.H.G., Kempeneers, P., Sonnenschein, R., Leidner, A.K., Böhm, M., He, K.S., Nagendra, H., Dubois, G., Fatoyinbo, T., Hansen, M.C., Paganini, M., de Klerk, H.M., Asner, G.P., Kerr, J.T., Estes, A.B., Schmeller, D.S., Heiden, U., Rocchini, D., Pereira, H.M., Turak, E., Fernandez, N., Lausch, A., Cho, M.A., Alcaraz-Segura, D., McGeoch, M.A., Turner, W., Mueller, A., St-Louis, V., Penner, J., Vihervaara, P., Belward, A., Reyers, B., Geller, G.N., 2016. Framing the concept of satellite remote sensing essential biodiversity variables: challenges and future directions. *Remote Sens. Ecol. Conserv.* 2, 122–131. <https://doi.org/10.1002/rse.2.15>
- Puttonen, E., Briese, C., Mandlbürger, G., Wieser, M., Pfennigbauer, M., Zlinszky, A., Pfeifer, N., 2016. Quantification of Overnight Movement of Birch (*Betula pendula*) Branches and Foliage with Short Interval Terrestrial Laser Scanning. *Front. Plant Sci.* 7. <https://doi.org/10.3389/fpls.2016.00222>
- Rapinel, S., Clément, B., Dufour, S., Hubert-Moy, L., 2018. Fine-Scale Monitoring of Long-term Wetland Loss Using LiDAR Data and Historical Aerial Photographs: the Example of the Couesnon Floodplain, France. *Wetlands* 38, 423–435. <https://doi.org/10.1007/s13157-017-0985-2>
- Rebala, G., Ravi, A., Churiwala, S., 2019. An Introduction to Machine Learning. Springer International Publishing. <https://doi.org/10.1007/978-3-030-15729-6>
- Reutebuch, S.E., Andersen, H.-E., McGaughey, R.J., 2005. Light Detection and Ranging (LiDAR): An Emerging Tool for Multiple Resource Inventory. *J. For.* 103, 286–292. <https://doi.org/10.1093/jof/103.6.286>
- Riegel, J.B., Bernhardt, E., Swenson, J., 2013. Estimating Above-Ground Carbon Biomass in a Newly Restored Coastal Plain Wetland Using Remote Sensing. *PLoS ONE* 8, 68251–68251. <https://doi.org/10.1371/journal.pone.0068251>
- Rolando, A., Palestini, C., 1989. Habitat selection and interspecific territoriality in sympatric

References

- warblers at two Italian marshland areas Habitat selection and interspecific territoriality. *Ethol. Ecol. Evol.* 169–183.
<https://doi.org/10.1080/08927014.1989.9525521>
- Roussel, J.-R., Auty, D., Coops, N.C., Tompalski, P., Goodbody, T.R.H., Meador, A.S., Bourdon, J.-F., de Boissieu, F., Achim, A., 2020. lidR: An R package for analysis of Airborne Laser Scanning (ALS) data. *Remote Sens. Environ.* 251, 112061.
<https://doi.org/10.1016/j.rse.2020.112061>
- Schaminée, J., Hennekens, S., Chytry, M., Rodwell, J., 2009. Vegetation-plot data and databases in Europe: An overview. *Preslia -Praha-* 81, 173–185.
- Schulte to Bühne, H., Pettorelli, N., 2018. Better together: Integrating and fusing multispectral and radar satellite imagery to inform biodiversity monitoring, ecological research and conservation science. *Methods Ecol. Evol.* 9, 849–865.
<https://doi.org/10.1111/2041-210X.12942>
- Schurr, F.M., Pagel, J., Cabral, J.S., Groeneveld, J., Bykova, O., O'Hara, R.B., Hartig, F., Kissling, W.D., Linder, H.P., Midgley, G.F., Schröder, B., Singer, A., Zimmermann, N.E., 2012. How to understand species' niches and range dynamics: a demographic research agenda for biogeography. *J. Biogeogr.* 39, 2146–2162.
<https://doi.org/10.1111/j.1365-2699.2012.02737.x>
- Serbin, S.P., Townsend, P.A., 2020. Scaling Functional Traits from Leaves to Canopies, in: Cavender-Bares, J., Gamon, J.A., Townsend, P.A. (Eds.), *Remote Sensing of Plant Biodiversity*. Springer International Publishing, Cham, pp. 43–82.
https://doi.org/10.1007/978-3-030-33157-3_3
- Shadaydeh, M., Zlinszky, A., Manno-Kovacs, A., Sziranyi, T., 2017. Wetland mapping by fusion of airborne laser scanning and multi-temporal multispectral satellite imagery. *Int. J. Remote Sens.* 38, 7422–7440.
<https://doi.org/10.1080/01431161.2017.1375614>
- Shan, J., Toth, C.K., 2018. *Topographic Laser Ranging and Scanning: Principles and Processing*, Second Edition. Taylor & Francis.
- Simpson, E.H., 1949. Measurement of Diversity. *Nature* 163, 688–688.
<https://doi.org/10.1038/163688a0>
- Sinha, S., Jeganathan, C., Sharma, L.K., Nathawat, M.S., 2015. A review of radar remote sensing for biomass estimation. *Int. J. Environ. Sci. Technol.* 12, 1779–1792.
<https://doi.org/10.1007/s13762-015-0750-0>
- Skidmore, A.K., Coops, N.C., Neinavaz, E., Ali, A., Schaepman, M.E., Paganini, M., Kissling, W.D., Vihervaara, P., Darvishzadeh, R., Feilhauer, H., Fernandez, M., Fernández, N., Gorelick, N., Geijzendorffer, I., Heiden, U., Heurich, M., Hobern, D., Holzwarth, S., Muller-Karger, F.E., Van De Kerchove, R., Lausch, A., Leitão, P.J., Lock, M.C., Múcher, C.A., O'Connor, B., Rocchini, D., Turner, W., Vis, J.K., Wang, T., Wegmann, M., Wingate, V., 2021. Priority list of biodiversity metrics to observe from space. *Nat. Ecol. Evol.* <https://doi.org/10.1038/s41559-021-01451-x>
- Skidmore, A.K., Pettorelli, N., Coops, N.C., Geller, G.N., Hansen, M., Lucas, R., Múcher, C.A., O'Connor, B., Paganini, M., Pereira, H.M., Schaepman, M.E., Turner, W., Wang, T., Wegmann, M., 2015. Environmental science: Agree on biodiversity metrics to track from space. *Nat. News* 523, 403. <https://doi.org/10.1038/523403a>
- Slagter, B., Tsendbazar, N.-E., Vollrath, A., Reiche, J., 2020. Mapping wetland characteristics using temporally dense Sentinel-1 and Sentinel-2 data: A case study in the St. Lucia wetlands, South Africa. *Int. J. Appl. Earth Obs. Geoinformation* 86, 102009–102009. <https://doi.org/10.1016/j.jag.2019.102009>
- Soberón, J., 2007. Grinnellian and Eltonian niches and geographic distributions of species. *Ecol. Lett.* 10, 1115–1123. <https://doi.org/10.1111/j.1461-0248.2007.01107.x>
- Soberón, J., Nakamura, M., 2009. Niches and distributional areas: Concepts, methods, and assumptions. *Proc. Natl. Acad. Sci. U. S. A.* 106, 19644–19650.
<https://doi.org/10.1073/pnas.0901637106>
- Srinivasan, S., Popescu, S.C., Eriksson, M., Sheridan, R.D., Ku, N.-W., 2014. Multi-temporal

References

- terrestrial laser scanning for modeling tree biomass change. *For. Ecol. Manag.* 318, 304–317. <https://doi.org/10.1016/j.foreco.2014.01.038>
- St-Louis, V., Pidgeon, A.M., Kuemmerle, T., Sonnenschein, R., Radeloff, V.C., Clayton, M.K., Locke, B.A., Bash, D., Hostert, P., 2014. Modelling avian biodiversity using raw, unclassified satellite imagery. *Philos. Trans. R. Soc. B Biol. Sci.* 369, 20130197. <https://doi.org/10.1098/rstb.2013.0197>
- Strayer, D.L., Findlay, S.E.G., 2010. Ecology of freshwater shore zones. *Aquat. Sci.* 72, 127–163. <https://doi.org/10.1007/s00027-010-0128-9>
- Tattoni, C., Rizzolli, F., Pedrini, P., 2012. Can LiDAR data improve bird habitat suitability models? *Ecol. Model.*, 7th European Conference on Ecological Modelling (ECEM) 245, 103–110. <https://doi.org/10.1016/j.ecolmodel.2012.03.020>
- Tews, J., Brose, U., Grimm, V., Tielbörger, K., Wichmann, M.C., Schwager, M., Jeltsch, F., 2004. Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *J. Biogeogr.* 31, 79–92. <https://doi.org/10.1046/j.0305-0270.2003.00994.x>
- Thuiller, W., Araújo, M.B., Lavorel, S., 2004. Do we need land-cover data to model species distributions in Europe?: Do land-cover data improve bioclimatic models? *J. Biogeogr.* 31, 353–361. <https://doi.org/10.1046/j.0305-0270.2003.00991.x>
- Torres, R., Snoeij, P., Geudtner, D., Bibby, D., Davidson, M., Attema, E., Potin, P., Rommen, B., Floury, N., Brown, M., Traver, I.N., Deghaye, P., Duesmann, B., Rosich, B., Miranda, N., Bruno, C., L'Abbate, M., Croci, R., Pietropaolo, A., Huchler, M., Rostan, F., 2012. GMES Sentinel-1 mission. *Remote Sens. Environ.* 120, 9–24. <https://doi.org/10.1016/j.rse.2011.05.028>
- Tóth, V.R., 2016. Reed stands during different water level periods: physico-chemical properties of the sediment and growth of *Phragmites australis* of Lake Balaton. *Hydrobiologia* 778, 193–207. <https://doi.org/10.1007/s10750-016-2684-z>
- Tóth, V.R., Szabó, K., 2012. Morphometric structural analysis of *Phragmites australis* stands in Lake Balaton. *Ann. Limnol. - Int. J. Limnol.* 48, 241–251. <https://doi.org/10.1051/limn/2012015>
- Töyrä, J., Pietroniro, A., Hopkinson, C., Kalbfleisch, W., 2003. Assessment of airborne scanning laser altimetry (lidar) in a deltaic wetland environment. *Can. J. Remote Sens.* 29, 718–728. <https://doi.org/10.5589/m03-040>
- Turner, M.G., Gardner, R.H., 2015. *Landscape Ecology in Theory and Practice: Pattern and Process*, 2nd ed. Springer-Verlag, New York. <https://doi.org/10.1007/978-1-4939-2794-4>
- Vadász, C., Németh, Á., Biró, C., Csörgő, T., 2008. THE EFFECT OF REED CUTTING ON THE ABUNDANCE AND DIVERSITY OF BREEDING PASSERINES, *Acta Zoologica Academiae Scientiarum Hungaricae*.
- Valavi, R., Elith, J., Lahoz-Monfort, J.J., Guillera-Aroita, G., 2019. blockCV: An r package for generating spatially or environmentally separated folds for k-fold cross-validation of species distribution models. *Methods Ecol. Evol.* 10, 225–232. <https://doi.org/10.1111/2041-210X.13107>
- Valbuena, R., O'Connor, B., Zellweger, F., Simonson, W., Vihervaara, P., Maltamo, M., Silva, C.A., Almeida, D.R.A., Danks, F., Morsdorf, F., Chirici, G., Lucas, R., Coomes, D.A., Coops, N.C., 2020. Standardizing Ecosystem Morphological Traits from 3D Information Sources. *Trends Ecol. Evol.* 35, 656–667. <https://doi.org/10.1016/j.tree.2020.03.006>
- van der Hut, R.M.G., 1985. Habitat choice and temporal differentiation in reed passerines of a dutch marsh. *Ardea* 74, 159–176.
- Vergeer, J.-W., van Dijk, A., Boele, A., van Bruggen, J., Hustings, F., 2016. Handleiding Sovon Broedvogelonderzoek: Broedvogel Monitoring Project en Kolonievogels. Sovon Vogelonderzoek Nederland, Nijmegen.
- Vierling, K.T., Vierling, L.A., Gould, W.A., Martinuzzi, S., Clawges, R.M., 2008. Lidar: shedding new light on habitat characterization and modeling. *Front. Ecol. Environ.*

References

- 6, 90–98. <https://doi.org/10.1890/070001>
- Vries, J.P.R., Koma, Z., WallisDeVries, M.F., Kissling, W.D., 2021. Identifying fine-scale habitat preferences of threatened butterflies using airborne laser scanning. *Divers. Distrib.* ddi.13272. <https://doi.org/10.1111/ddi.13272>
- Warren, D.L., Glor, R.E., Turelli, M., 2008. Environmental niche equivalency versus conservatism: Quantitative approaches to niche evolution. *Evolution* 62, 2868–2883. <https://doi.org/10.1111/j.1558-5646.2008.00482.x>
- Wasser, L., Day, R., Chasmer, L., Taylor, A., 2013. Influence of Vegetation Structure on Lidar-derived Canopy Height and Fractional Cover in Forested Riparian Buffers During Leaf-Off and Leaf-On Conditions. *PLoS ONE* 8, e54776. <https://doi.org/10.1371/journal.pone.0054776>
- Weinmann, Martin, Weinmann, Michael, Mallet, C., Brédif, M., 2017. A Classification-Segmentation Framework for the Detection of Individual Trees in Dense MMS Point Cloud Data Acquired in Urban Areas. *Remote Sens.* 9, 277. <https://doi.org/10.3390/rs9030277>
- Weller, M.W., 1999. *Wetland Birds: Habitat Resources and Conservation Implications*. Cambridge University Press.
- Wilson, M.F.J., O'Connell, B., Brown, C., Guinan, J.C., Grehan, A.J., 2007. Multiscale Terrain Analysis of Multibeam Bathymetry Data for Habitat Mapping on the Continental Slope. *Mar. Geod.* 30, 3–35. <https://doi.org/10.1080/01490410701295962>
- Winiwarter, L., Pena, A.M.E., Weiser, H., Anders, K., Sanchez, J.M., Searle, M., Höfle, B., 2021. Virtual laser scanning with HELIOS++: A novel take on ray tracing-based simulation of topographic 3D laser scanning. *ArXiv210109154 Cs Eess*.
- Zellweger, F., Baltensweiler, A., Ginzler, C., Roth, T., Braunisch, V., Bugmann, H., Bollmann, K., 2016. Environmental predictors of species richness in forest landscapes: Abiotic factors versus vegetation structure. *J. Biogeogr.* 43, 1080–1090. <https://doi.org/10.1111/jbi.12696>
- Zellweger, F., Braunisch, V., Baltensweiler, A., Bollmann, K., 2013. Remotely sensed forest structural complexity predicts multi species occurrence at the landscape scale. *For. Ecol. Manag.* 307, 303–312. <https://doi.org/10.1016/j.foreco.2013.07.023>
- Zellweger, F., Frenne, P.D., Lenoir, J., Rocchini, D., Coomes, D., 2019. Advances in Microclimate Ecology Arising from Remote Sensing. *Trends Ecol. Evol.* 34, 327–341. <https://doi.org/10.1016/j.tree.2018.12.012>
- Zellweger, F., Morsdorf, F., Purves, R.S., Braunisch, V., Bollmann, K., 2014. Improved methods for measuring forest landscape structure: LiDAR complements field-based habitat assessment. *Biodivers. Conserv.* 23, 289–307. <https://doi.org/10.1007/s10531-013-0600-7>
- Zellweger, F., Roth, T., Bugmann, H., Bollmann, K., 2017. Beta diversity of plants, birds and butterflies is closely associated with climate and habitat structure. *Glob. Ecol. Biogeogr.* 26, 898–906. <https://doi.org/10.1111/geb.12598>
- Zhang, J., 2010. Multi-source remote sensing data fusion: status and trends. *Int. J. Image Data Fusion* 1, 5–24. <https://doi.org/10.1080/19479830903561035>
- Zhang, Shu-Ching Chen, Whitman, D., Mei-Ling Shyu, Jianhua Yan, Chengcui Zhang, 2003. A progressive morphological filter for removing nonground measurements from airborne LIDAR data. *IEEE Trans. Geosci. Remote Sens.* 41, 872–882. <https://doi.org/10.1109/TGRS.2003.810682>
- Zlinszky, A., 2013. Mapping and conservation of the reed wetlands on Lake Balaton. *Dept Plant Syst. Ecol. Theor. Biol.* Bp. Eötvös Loránd Univ. PhD 1–217.
- Zlinszky, A., Kania, A., 2016. Will it blend? visualization and accuracy evaluation of high-resolution fuzzy vegetation maps. *ISPRS - Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* XLI-B2, 335–342. <https://doi.org/10.5194/isprsarchives-XLI-B2-335-2016>
- Zlinszky, A., Mücke, W., Lehner, H., Briese, C., Pfeifer, N., 2012. Categorizing Wetland

References

Vegetation by Airborne Laser Scanning on Lake Balaton and Kis-Balaton, Hungary. *Remote Sens.* 4, 1617–1650. <https://doi.org/10.3390/rs4061617>