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bioLEC: A Python package to measure Landscape Elevational Connectivity

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Software

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Summary

Understanding how biodiversity formed and evolved is a key challenge in evolutionary and ecological biology (Newbold et al., 2016).

Despite a theoretical consensus on how best to measure biodiversity from a biological perspective (i.e., number of species, length of all branches on the tree of life of a species, and differences in allele and genotype frequencies within species) standardised and cost-effective methods for assessing it on a broad range of scales are lacking (Chiarucci, Bacaro, & Scheiner, 2011).

In mountainous landscapes long known for playing a significant role in evolution (Elsen & Tingley, 2015; Wallace, 1860), one approach consists of quantifying and measuring abiotic landscape properties. Indeed, complex mountainous landscapes provide species with a rich variety of environmental conditions over restricted surface areas (e.g., range of temperature, solar irradiation, wind exposure, moisture and rainfall, soil thickness and composition) (Hoorn, Mosbrugger, Mulch, & Antonelli, 2013).

Estimates of some of theses landscape abiotic properties are already available through standard software such as *ArcGIS* or *QGIS* (Etherington, 2016) and in more specific mountainous landscape focussed packages such as *LSD Topo Tools* (Clubb et al., 2017) or *pyBadlands* (Salles, Ding, & Brocard, 2018). As an example, these tools include functions to assess slope and slope curvature from which soil thickness can be predicted, slope azimuth (which controls solar radiation); the number of catchments and their size (landscape fragmentation), the hydrological connectivity and drainage density (transfer of water and nutrients); the hypsometry (i.e., elevation vs. surface area), or the direction and rate of divide migration.

`bioLEC`

In 2016, a new metric called the *Landscape Elevational Connectivity* (**LEC**) was proposed to estimate biodiversity in mountainous landscape (Bertuzzo et al., 2016). It efficiently measures the landscape resistance to migration and is able to account for up to 70% of biodiversity predicted by meta-community models (Bertuzzo et al., 2016).

bioLEC is a Python package designed to quickly calculate for any mountainous landscape surface and species niche width its associated **LEC** index. From an elevational fitness perspective, all migratory paths on a flat landscape are equal. This is not the case on a complex landscape where migration can only occur along a network of corridors providing species with their elevational requirements. Hence, predicting how species will disperse across a landscape requires a model of migration that takes into account the physical properties of the landscape, the species fitness range, as well as evolving environmental conditions.

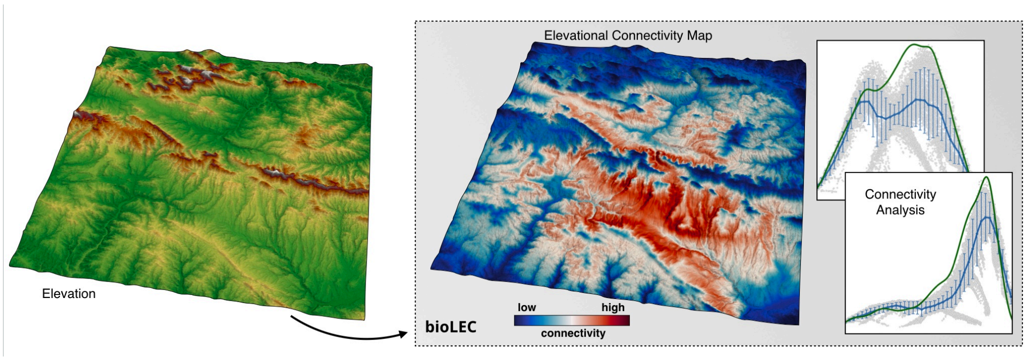

Figure 1: An example of LEC map obtained for a specific elevation surface (left) illustrating the region of high and low connectivity as well as the distribution of resulting LEC values versus elevation range.

bioLEC measures the landscape resistance to migration by calculating the connectivity between points in the landscape based on *scikit-image* Dijkstra's algorithm (van der Walt et al., 2014), the higher the connectivity the lesser the landscape resistance to migration. It quantifies the closeness of any of these points to all others at similar elevation by integrating specific fitness range and represents a robust proxy for the biodiversity a landscape can support (Bertuzzo et al., 2016). It measures how easily a species living in a given patch can spread and colonise other patches. As explained above it is assumed to be elevation-dependent and it depends on how often a species adapted to a given elevation needs to travel outside its optimal elevation range when moving from its patch to any other in the landscape.

bioLEC package can be used in serial or parallel to evaluate biodiversity patterns of a given landscape. It is an efficient and easy-to-use tool to quickly assess the capacity of landscape to support biodiversity and to predict species dispersal across mountainous landscapes.

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References

Bertuzzo, E., Carrara, F., Mari, L., Altermatt, F., Rodriguez-Iturbe, I., & Rinaldo, A. (2016). Geomorphic controls on species richness. *PNAS*, *113*(7), 1737–1742. doi:10.1073/pnas.1518922113

Chiarucci, A., Bacaro, G., & Scheiner, S. M. (2011). Old and new challenges in using species diversity for assessing biodiversity. *Phil. Trans. R. Soc. B Biol Sci.*, *366*(1576), 2426–2437. doi:10.1098/rstb.2011.0065

Clubb, F., Mudd, S. M., Milodowski, D. T., Valters, D. A., Slater, L. J., Hurst, M. D., & Limaye, A. B. (2017). Geomorphometric delineation of floodplains and terraces from objectively defined topographic thresholds. *Earth Surface Dynamics*, *5*, 369–385. doi:10.5194/esurf-5-369-2017

Elsen, P. R., & Tingley, M. W. (2015). Global mountain topography and the fate of montane species under climate change. *Nature Climate Change*, *5*, 772–776. doi:10.1038/nclimate2656

Etherington, T. R. (2016). Least-cost modelling and landscape ecology: Concepts, applications, and opportunities. *Current Landscape Ecology Reports*, *1*, 40–53. doi:10.1007/s40823-016-0006-9

Hoorn, C., Mosbrugger, V., Mulch, A., & Antonelli, A. (2013). Biodiversity from mountain building. *Nature Geoscience*, *6*, 154. doi:10.1038/ngeo1742

Newbold, T., Hudson, L. N., Arnell, A. P., Contu, S., De Palma, A., Ferrier, S., Hill, S. L. L., et al. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. *Science*, *353*(6296), 288–291. doi:10.1126/science.aaf2201

Salles, T., Ding, X., & Brocard, G. (2018). pyBadlands: A framework to simulate sediment transport, landscape dynamics and basin stratigraphic evolution through space and time. *PLOS ONE*, *13*(4), 1–24. doi:10.1371/journal.pone.0195557

van der Walt, S., Schonberger, J. L., Nunez-Iglesias, J., Boulogne, F., Warner, J. D., Yager, N., Gouillart, E., et al. (2014). Scikit-image: Image processing in Python. *PeerJ*, *2:e453*. doi:10.7717/peerj.453

Wallace, A. R. (1860). On the zoological geography of the malay archipelago. *J. Proc. Linnean Soc. Lond. Zool.*, *4*, 172–184. doi:10.1111/j.1096-3642.1860.tb00090.x