Terrestrial habitat diversity

Indicator name	**Terrestrial Habitat Diversity Indicator (THDI)**
Indicator unit	The THDI is derived from the square of the number of Terrestrial Habitat Functional Types (THFTs) encountered in a given area divided by the square root of the surface (in km^2) of the protected area. The higher the THDI, the larger the diversity of habitats.
Area of interest	The THDI can be generated for any terrestrial area (e.g. country, ecoregion or protected area). In DOPA Explorer, the THDI has been calculated for each terrestrial protected area of size ≥ 10 km^2 and for the terrestrial parts of each coastal protected areas of size ≥ 10 km^2.
Related targets	 Sustainable Development Goal 15 on life on land  Aichi Biodiversity Target 11 on protected areas  Aichi Biodiversity Target 12 on species
Policy question	How important is a given area in terms of habitat diversity and associated species diversity? By identifying distinct habitats in a given area, one can highlight areas supporting a large variety of structural and functional ecosystem properties and, indirectly, a potentially higher species diversity.
Use and interpretation	The number of distinct habitats in an area can be used to a certain extent as a proxy of biodiversity. The information can also be used to inform ecosystem mapping, protected area zoning and management, and for the planning of wildlife surveys. Applied to protected areas, the identification of the Terrestrial Habitat Functional Types (THFT) can further help to assess the complexity of the management of the area, and to indicate the potential diversity of species present (Rosenzweig 1995; Tews *et al.*, 2004). Everything else being equal, protected areas with many distinct habitats are likely to require more resources for the management than those presenting a more homogenous environment. To compare the relative habitat diversity of protected areas, the Terrestrial Habitat Diversity Indicator (THDI) should be used instead of the number of THFTs as the THDI will not favor large protected areas over smaller ones.
Key caveats	The computation of the number of THFTs, applied to protected areas: • Does not identify the type of habitats but is derived from a set of carefully selected biophysical input variables; • Does not provide any quantitative assessment of the potential links of each habitat type with the associated species;

- Is scaled for each protected area with an upper limit of the number of distinct habitats, and thus makes it difficult to compare habitat diversity across protected areas.

The THDI is also given for each protected area to compensate for the larger number of THFTs expected to be found in larger protected areas. The proposed correction, i.e. using the square of the number of THFTs divided by the square root of the surface (in km^2) of the protected area, is an arbitrary decision which might not be optimal. Future versions of the DOPA will review this indicator more in depth.

Indicator status Published in peer reviewed papers (see Martínez-López *et al.*, 2016; Dubois *et al.*, 2016; Brink *et al.*, 2016).

Available data and resources

Data available The number of THFTs as well as the THDI are available for each protected area of size ≥ 10 km^2. These values can also be compared at country and ecoregion level. Geometries of the THFTs can also be displayed when available but are not downloaded yet. All results are available from DOPA Explorer at http://dopa-explorer.jrc.ec.europa.eu/

Data updates Planned with each update of DOPA.

Codes The THFTs are computed with eHabitat+, a code using GRASS GIS 7, Python 2.7 and R. The eHabitat+ code is contained in four scripts that are run consecutively and that make use of several Python and R libraries for multivariate and spatial analysis. The computation of the THDI is a basic numeral operation applied to the results of the THFTs.

Martínez-López, J. eHabitat+ Version 1.1. Source Code for DOPA, 2016. Available online: http://dx.doi.org/10.5281/zenodo.51879 .

Methodology

Methodology A set of nine biophysical variables, all globally mapped at 1-km^2 resolution, are used in conjunction with the boundaries of all protected areas of size ≥ 10 km^2 to automatically segment each terrestrial part of the protected areas into distinct Terrestrial Habitat Functional Types (THFTs). UNESCO Biosphere Reserves have been discarded as well as protected areas recorded only as points. The nine selected biophysical variables describe: (a) the topographical gradients (b) the climatic context (c) the ecosystem structure and (d) the carbon-water cycling (ecosystem functioning). The approach described in Martínez-López *et al.* (2016) is a two-step methodology based on image segmentation followed by a classification of the resulting segments through hierarchical clustering. The method also uses an upper limit of the number of classes in order to avoid having substantially more classes than input variables while accounting for the size of the protected area.

Two examples of the output of the processing is shown in Figure 1 below. To avoid penalizing smaller protected areas that are more likely to show less

segments than larger areas, with the number of segments (i.e. the THFTs), we also propose a Terrestrial Habitat Diversity Index (THDI) which is defined as the square of the number of distinct segments (THFTs) divided by the square root of the surface of protected area (in km^2). This more intuitive index provides more comparable results and allows smaller areas to be less penalized (Dubois *et al.*, 2016).

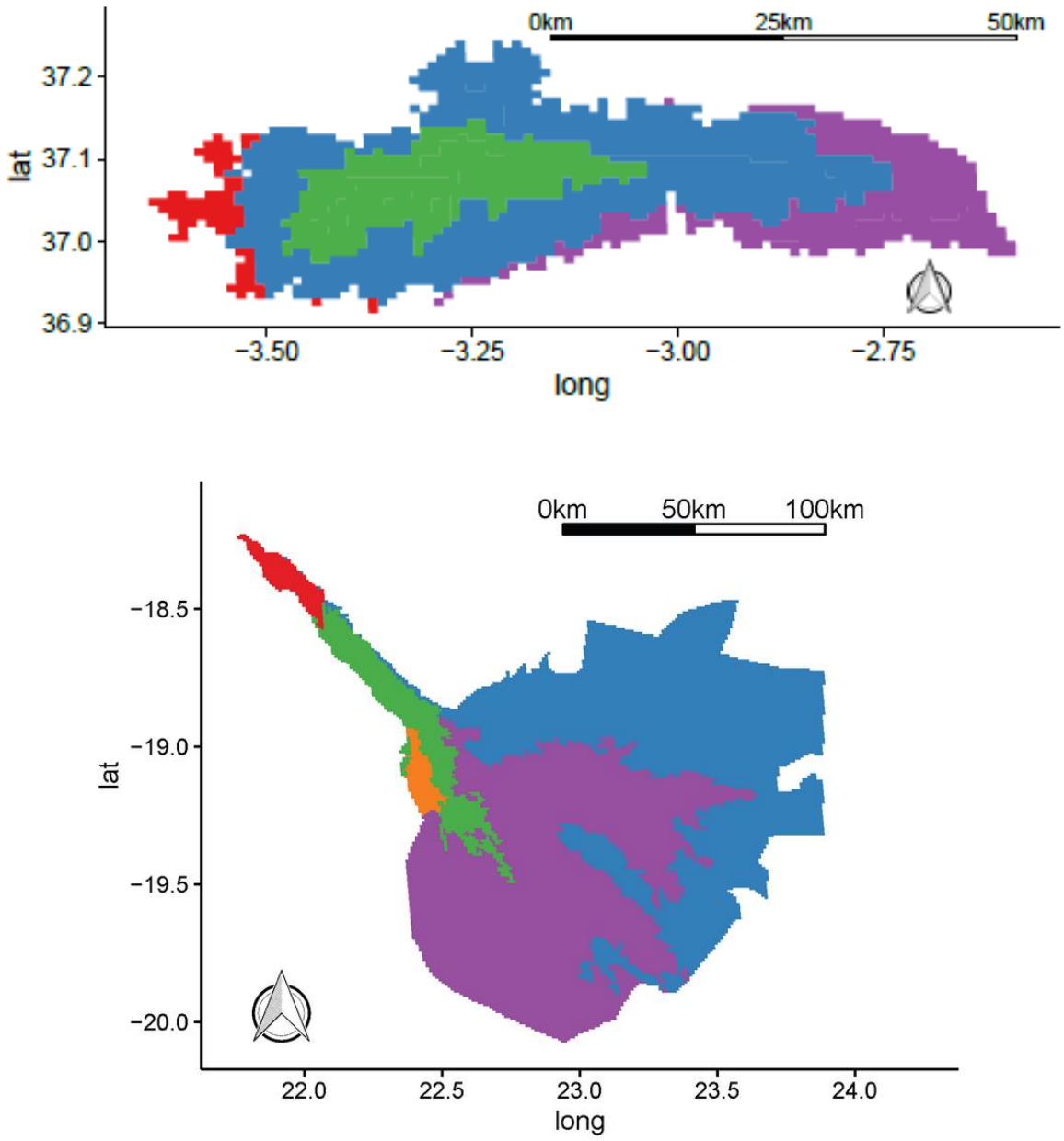

Figure 1. Map of the distinct terrestrial habitat functional types (THFT) identified in the Sierra Nevada National Park, Spain (top) and for the Okavango delta World Heritage Site, Botswana (bottom)

Input datasets

The indicator uses the following input datasets:

Protected Areas

- WDPA of May 2019 (UNEP-WCMC & IUCN, 2019)
  - Latest version available from: www.protectedplanet.net

Biophysical variables

- A set of nine biophysical variables, all globally mapped at 1 km^2 resolution used for the segmentation, namely
  - the slope derived from a digital elevation model;
  - mean annual bio-temperature (temperature excluding below zero values);
  - mean annual precipitation;
  - percentage of woody vegetation cover;
  - percentage of grassland cover;
  - mean annual evapotranspiration divided by the precipitation (square root transformed in order to account for small differences in the most arid areas);
  - means of the maximum and minimum annual Normalized Difference Vegetation Index (NDVI) for the period 2001 to 2010, representing average maximum and minimum vegetation activity;
  - the mean Normalized Difference Water Index (NDWI) for the period 2001 to 2010 as an indicator of the average vegetation and soil water content.

Detailed information about the sources of the input variables can be found in the Supplementary Online Material of Martínez-López *et al.* (2016) available online at http://www.mdpi.com/2072-4292/8/9/780/s1

References

Dubois, G., *et al.* (2016). Integrating multiple spatial datasets to assess protected areas: Lessons learnt from the Digital Observatory for Protected Area (DOPA). *International Journal of Geo-Information* 5(12), 242. http://dx.doi.org/10.3390/ijgi5120242

Brink, A., *et al.* (2016). Indicators for assessing habitat values and pressures for protected areas - An integrated habitat and land cover change approach for the Udzungwa Mountains National Park in Tanzania. *Remote Sensing* 8(10), 862. http://dx.doi.org/10.3390/rs8100862

Martínez-López, J., *et al.* (2016). Biophysical characterization of protected areas globally through optimized image segmentation and classification. *Remote Sensing* 8(9), 780. http://dx.doi.org/10.3390/rs8090780

Rosenzweig, M. L. (1995). Species diversity in time and space. –Cambridge Univ. Press.

Tews, J., *et al.* (2004). Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *Journal of Biogeography* 31, 79–92. https://dx.doi.org/10.1046/j.0305-0270.2003.00994.x

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