Natural land pattern and fragmentation

Indicator names

Natural Land Pattern Index (NLPI) and Natural Land Fragmentation Index (NLFI), and their dynamics (NLPD, NLFD).

Indicator unit

Natural (and semi-natural) land fragmentation refers to the reduction of area, the emergence of discontinuities and the isolation of natural land patches within a region of interest. Natural land spatial pattern is a relevant measure to capture changes in size, shape and structural connectivity, in particular the breaking down of large patches of natural land into smaller patches, the presence of linear features and isolated small fragments.

The Natural Land Pattern Index (NLPI) assesses the spatial pattern of the natural and semi-natural lands for a given year (here, at year 2015) by reporting the area (in km^2) covered by six spatial pattern classes (core, edge, linear feature, islet, core-perforation, other non-natural land) within a region of interest.

The Natural Land Pattern Dynamics (NLPD) index reports the trends in the area occupied by these pattern classes in the last 20 years (1995-2015) within a region of interest.

The landscape mosaic is simplified into natural/semi-natural lands, water bodies and non-natural lands. Non-natural lands such as cropland, transport infrastructure and settlements, are considered the fragmenting elements. The six pattern classes are determined based on the spatial arrangement, shape and size of the land cover patches; See below (Use and Interpretation section) for a detailed description of these six classes.

Fragmentation can be further resumed in one single indicator value such as among others, the edge to core ratio. The Natural Land Fragmentation Index (NLFI) and the Natural Land Fragmentation Dynamics (NLFD) will be included in the next update of the DOPA.

Area of interest

NLPI and NLPD are calculated in DOPA for each terrestrial and coastal protected area, as well as for countries and terrestrial ecoregions, and are provided in DOPA Explorer for all terrestrial and coastal protected areas of size ≥ 1 km^2 , for countries and for terrestrial ecoregions.. The spatial distribution of the six pattern classes is mapped and shown in DOPA for all natural/semi-natural land, either inside or outside protected areas.

Related targets

15 LIFE ON LAND

Sustainable Development Goal 15 on life on land

Aichi Biodiversity Target 5 on loss of natural habitats

Aichi Biodiversity Target 11 on protected areas

Policy question

How can we assess the spatial integrity of natural/semi-natural ecosystems? Where and how much are global and local pressures fragmenting natural/semi-natural lands? Pressures on the natural land, particularly human driven pressures, are constantly increasing and it is important to monitor how they translate in changes in the spatial pattern and fragmentation levels of natural/semi-natural ecosystems, in particular inside and around protected areas, to ensure that these ecosystems, and their associated species, their functions and services, are preserved.

Use and interpretation

The NLPI values and their trends (NLPD) allow evaluating the status and dynamics of fragmentation processes in terms of few key relevant spatial pattern changes in protected areas and in their buffer areas. Six landscape pattern classes have been determined, based on the land cover information of the Climate Change Initiative Land Cover (CCI-LC) map, using an edge width of 300 m (corresponding to one pixel in the CCI-LC map at the equator). The six pattern classes, which are exemplified in Figure 1, are the following:

NATURAL LAND

- Core: Area of natural/semi-natural land cover that is not adjacent to non-natural land cover, i.e. that is separated by a distance larger than the considered edge width (300 m in the equator) from non-natural land covers.
- Edge: Area of natural/semi-natural land that surrounds the core areas and that is adjacent to non-natural land cover.
- Islet: A patch of natural/semi-natural land cover that is too small to contain any core area (all the extent of the patch is closer to non-natural land cover than the considered edge width).
- Linear feature: All other areas of non-core natural/semi-natural land that do not fall into any of the two non-core classes above. It typically corresponds to small and elongated extents of natural/semi-natural land that extend from outside the edge of a core patch, either connecting or not to another core patch.

NON NATURAL LAND

- Core-perforation: Non-natural land fully enclosed by core area. It corresponds to the non-natural land found within openings of natural/semi-natural land due to anthropogenic (e.g. settlements, shifting cultivation) processes.
- Other non-natural: other areas not falling in any of the previous categories: it includes non-natural areas (cropland, urban) as well as water bodies.

The focus of the NLPI is the fragmentation caused by the conversion to non-natural land covers; water bodies (either freshwater or marine) are excluded from the analysis, meaning that they do not contribute to fragmentation even if adjacent to natural/semi-natural land.

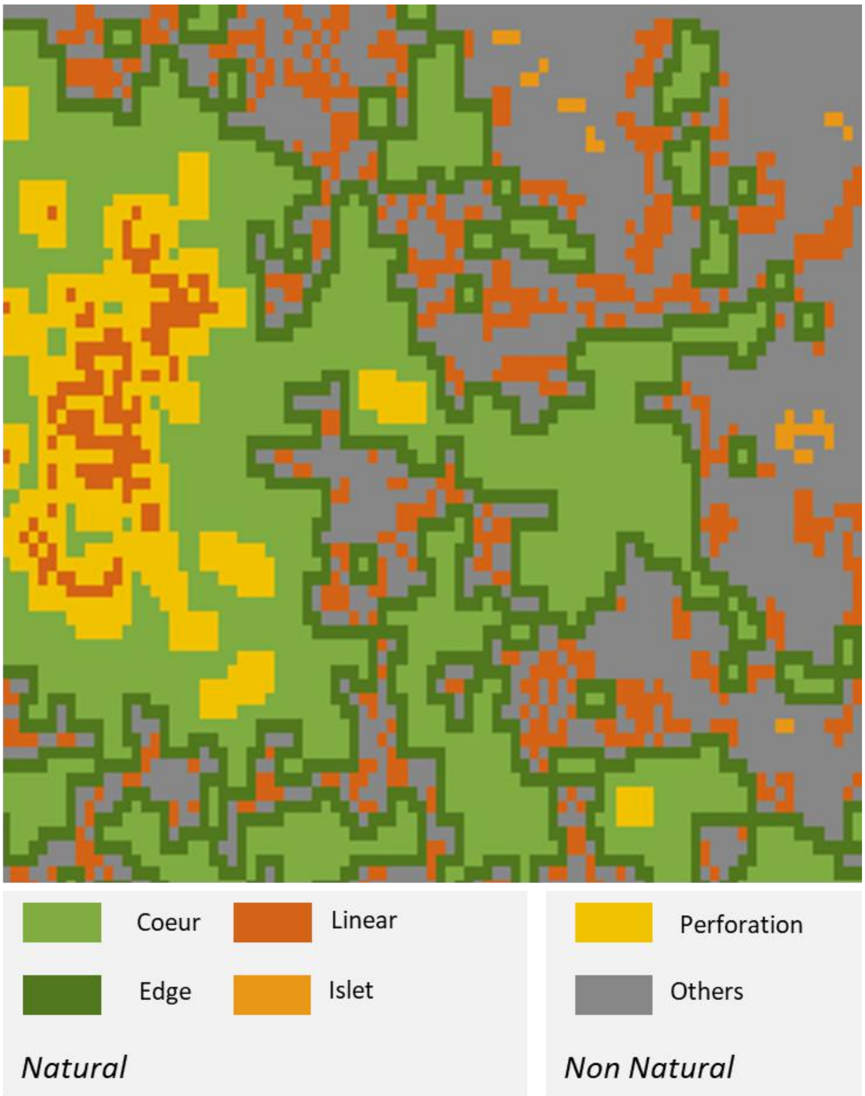

Figure 1. Distribution of the spatial pattern classes on an illustrative area.

The current (2015) amount and distribution of the six spatial pattern classes (NLPI) and their changes (NLPD) over time (1995-2015) can reveal the existence of pressures within the protected areas that would remain undiagnosed if only the amount of natural or semi-natural land cover was considered. In particular, the identification of core areas allows to pinpoint the interior part of the natural land that is not affected by those pressures. Most pressures are typically highest in the edge areas immediately adjacent or close to modified (non-natural) land cover (for the 300 m edge width considered here). This is the case for microclimatic changes near forest edges (increased light and wind penetration), higher hunting pressure and disturbances from human activities, increased occurrence of invasive or generalist (cosmopolitan) species, and related changes in species composition, carbon storage by vegetation, and other ecosystem services. Effects of such pressures can be expected to affect core areas much less compared to edges, islets or linear features. Therefore, and for a given amount of natural land, a lower proportion of core area is indicative for a higher level of fragmentation including its detrimental effects for many species and ecosystem processes. Islets identify patches that, because of their complete lack of core areas, may have already experienced significant changes in species composition through the loss of the interior species that are more sensitive to the edge effects. Core-perforations when due to anthropogenic processes are one of the early stages in the spatial change processes leading to larger-scale habitat loss and fragmentation. They may be considered as an early warning of forthcoming, more prominent changes in the spatial integrity of natural ecosystems that may be detrimental for biodiversity conservation targets. Figure 2 showcases the changes over 20 years (1995-2015) in the land patterns of a protected area in Spain as displayed in DOPA Explorer.

Key caveats

The diversity of approaches and metrics in the fragmentation literature arises mainly from differences in how quantify the multiple key aspects of habitat fragmentation processes, which are mainly the reduction of patch size, the increase in edge effects and the increase in patch isolation. A single indicator cannot fully capture all the spatial features and change processes associated to these several aspects of fragmentation. In particular, the NLPI and NLPD indicators in DOPA Explorer report a set of six different pattern classes, each to be analyzed separately and in combination with the total amount of natural land in order to capture both area loss and change in spatial pattern that are associated with fragmentation processes. The NLPI and NLPD indicators capture the reduction in core areas and the related increase in edge effect through increased amount of edges as well as the presence of vulnerable tiny pattern features (islet and linear pattern classes). The area increase of core-perforation is also captured.

The next update of the DOPA will include the NLFI and NLFD indicators, which specifically focus on capturing, through a single summary value (rather than through multiple pattern classes), the level of fragmentation of the natural/seminatural land and its changes through time. A description of these NLFI and NLFD indicators, and some examples of their application, can be found at http://ies-ows.jrc.ec.europa.eu/gtb/GTB/psheets/GTB-Fragmentation-FADFOS.pdf.

NLPI and NLPD are derived from the CCI-LC land cover maps, which are obtained from Earth Observation (classification of remotely sensed images). The observation of the fragmentation process and spatial pattern depends on, and is thus limited to, the spatial resolution of the land cover maps (here 300 m). In addition, the uncertainties and accuracy in the land cover classification, which vary in space and time, are transmitted to the values of the NLPI and NLPD. Additional uncertainties are caused by clouds, which are often obstructing observations in tropical regions and coastal areas. Because land cover and spatial changes affecting areas smaller than 1 km^2 will remain unnoticed, changes in the fragmentation and pattern classes affecting only small areas will have to be interpreted with more caution. Finally, different sensors have also been used over time and the older yearly land cover maps are less reliable than the most recent ones. Still, because we use a time interval of 20 years, the main trends in fragmentation and spatial patterns (NLPD) are expected to be captured. We refer to the documentation of the land cover CCI-LC product (Land Cover CCI, 2017) for a detailed discussion about the main limitations of this product underlying the NLPI and NLPD.

Figure 2. Results of the Natural Land Pattern indicators (NLPI and NLPD) from 1995 (top) to 2015 (middle) in a protected area (Sierra de Gredos) in Spain, which was designated in 1990. The processes of rural land abandonment by humans during the last decades have resulted in decreased fragmentation of the natural/semi-natural land in this protected area. The temporal changes are also shown (bottom)

The NLPI and NLPD have been obtained using the smallest edge width possible, that is an edge width equal to one pixel of the CCI-LC map, which has a nominal resolution of 300 m at the equator, and is distributed in a geographic coordinate system. The spatial pattern analyses used to obtain the NLPI and NLPD have been applied directly in the non-projected CCI-LC map in geographic coordinates, with an edge width equal to one pixel of this map. While a CCI-LC pixel at the equator has a width of 300 m, the width of a pixel located at higher latitudes will be smaller. Therefore, the results of the NLPI and NLPD are not meant to be compared across different countries or ecoregions located at very different latitudes. The comparison of the NLPI values through time (NLPD) in a given protected area, as well as the comparison of the NLPI values for different protected areas within a given country or ecoregion (or for countries or ecoregions located at similar latitudes) is not affected by this issue and can be made much more confidently.

Fragmentation levels, and the impacts of fragmentation on species and ecosystem processes are strongly dependent on the selected species, habitats or ecosystems. The NLPI does not differentiate specific types of natural or semi-natural land; for instance, forests or grasslands, or some types of forests (open or closed canopy), are not separately considered by the NLPI. Similarly, the intensity of the fragmentation impacts on ecosystems may differ depending on the specific non-natural land cover type (urban areas, intensive agriculture, extensive agriculture, etc.) that is causing the changes in the landscape spatial patterns. The immediate surroundings of natural lands as well as the landscape mosaic in between natural land patches have a crucial effect to measure isolation processes and they are not accounted in the NLPI. They could be accounted in the future using a different and supplementary landscape pattern model as reported in Estreguil et al, 2012, 2016 and in Forest Europe 2015 (Indicator 4.7).
More detailed or case-specific fragmentation assessments for specific species, habitats or land cover change pressures would also need to be conducted in each particular situation by the interested persons or organizations, and are out of the scope of the DOPA global NLPI and NLPD indicators. The aim of the NLPI and NLPD indicators is to provide a general assessment of the broader trends and levels of fragmentation of natural land cover.

Because the area of the NLPI classes and the NLPD are computed within the boundaries for each protected area, results will be affected by the accuracy of the available protected area boundaries.

Extinction debts, consisting in a delay or time lag between the fragmentation of a natural habitat and the changes it ultimately produces in the species composition, have been reported for many ecosystems. Therefore, the NLPD trends reported here may not be necessarily correlated to species composition changes in the affected areas but to those that may be expected to happen in the future.

Indicator status NLPI and NLPD are based on well-established methods for landscape pattern and fragmentation analysis (Riitters *et al.* 2000, Soille and Vogt 2008, Estreguil et al, 2012, 2014 and 2016). The NLPI and NLPD results for protected areas, globally or in specific regions, have not been published yet but are planned to be covered in a forthcoming article.

Available data and resources

Data available NLPI values and their changes through time (NLPD) are available for each protected area of size ≥ 1 km^2, country and terrestrial ecoregion on the DOPA Explorer website:

http://dopa-explorer.jrc.ec.europa.eu/dopa_explorer/.

Data updates NLPI and NLPD are planned to be included with each update of DOPA.

Codes Spatial pattern analysis has been applied to the CCI-LC raster map using the free software Guidos Toolbox, available at:

https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/

Statistics for land pattern classes have been computed using standard GIS operations applied to vector and raster data.

Methodology

Methodology First, the land cover types in the Climate Change Initiative Land Cover (CCI-LC) raster maps for the years 1995 and 2015 were reclassified in three broader types: natural/semi-natural land cover, non-natural land cover, and water. The natural/semi-natural land aggregated the CCI-LC types corresponding to forests, shrublands, grasslands, wetlands, sparse vegetation areas, permanent snow and ice, and bare areas (codes 50, 60, 70, 80, 90, 100,110, 120, 130, 140, 150, 160, 170, 180, 200 and 220 in the CCI-LC map legend). The non-natural land cover aggregated agricultural and urban areas (codes 10, 20, 30, 40 and 190 in the CCI-LC map legend).

Second, the SPA6 spatial pattern analysis scheme in Guidos Toolbox was applied to each of these maps using an edge width of one CCI-LC pixel (300 m at the equator) to obtain the NLPI and NLPD indicators. Here, natural/semi-natural land was assigned to foreground (areas subject to fragmentation), non-natural land as background (areas that can fragment foreground), and water was set to no data (excluded from the analysis, meaning that it did not contribute to fragment the foreground even if they occurred next to natural or semi-natural land). The application of this analysis segmented all land cover in six spatial pattern classes (four land cover natural classes: core, edge, islet, linear; two land cover non-natural classes: core perforation and other non-natural) as described above (Figure 1).

Third, the mapped pattern classes were overlaid with the boundaries of each terrestrial or coastal protected area, with country boundaries and with terrestrial ecoregions boundaries, to calculate the area (in km^2) of each of these classes as given by the NLPI. Finally, the changes over time in the area of the six spatial pattern classes were computed to give the NLPD results for each protected area, each country and each terrestrial ecoregion. UNESCO Biosphere Reserves were discarded as well as protected areas with known areas but undefined boundaries. To ease interpretation and understand fragmentation processes, areal changes in pattern should be analysed in combination with the total area change of natural land cover (loss, gain, stable) within the area of interest.

Input datasets

The indicator uses the following input datasets:

Protected Areas

- WDPA of February 2023 (UNEP-WCMC & IUCN, 2023).
    - Latest version available from: www.protectedplanet.net

Land Cover

- Global Climate Change Initiative Land Cover (CCI-LC) maps for years 1995, 2000, 2005, 2010 and 2015 (Land Cover CCI, 2017).
    - Latest version available from: http://maps.elie.ucl.ac.be/CCI/viewer/index.html

Terrestrial Ecoregions of the World

- TEOW (2001). Terrestrial ecoregions of the world (Olson *et al.*, 2001)
    - Latest version available from: https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

Country boundaries

- Global Administrative Unit Layers (GAUL), revision 2015 (2017-02-02).
    - Latest version available from: http://www.fao.org/geonetwork/srv/en/metadata.show?id=12691

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