Local Ecological Footprinting Tool

IAIA, Washington DC
Dr Peter Long
peter.long@zoo.ox.ac.uk
Spatial-Temporal Biodiversity Research

Global Research
From local field sites to global tools
We conduct fieldwork at local, and regional scales. Find out more about our projects by exploring the map.
Competing demands on the natural environment

- Land required to ensure resource security and supply of e.g. food, biofuels, timber, clean water, pollination services etc.

- Land required for urban growth, industry (including extractives) and infrastructure etc.

- Land required for recreation, wildlife conservation and other cultural services etc.
Land use decisions by businesses create risks and opportunities related to biodiversity and ecosystem function.

It is necessary for business users to have a quick but robust way to screen investments and benchmark current activities to identify potential operational and reputational risks.
What tools are available to determine pattern of relative ecological value across landscapes?
Understanding the needs of business…

Perceived stakeholder issues with existing tools:

• Too complicated, time-consuming and expensive

• Too coarse spatial resolution to be relevant

• Limited to only some regions of the world

• Unknown accuracy
Key objectives in the design of LEFT

– Must use existing global databases & algorithms
– Work at a spatial scale relevant to landowners (30m pixel resolution)
– Provide assessments for almost anywhere in the world
– Have a simple user input
– Deliver output as maps and GIS layers that can be easily interpreted/ embedded into other analyses
– Output that is quick to obtain and secure
Worked to develop a fully automated system capable of delivering information on:

- Landcover
- Biodiversity
- Threatened species
- Intactness
- Connectivity
- Resilience

Long et al (2017) MEE
Willis et al (2012) Biol Cons
Mapping tool for biodiversity risk assessments

Supporting cost effective decisions for environmental risk management

A Simple Index
For a chosen area, the LEFT tool assembles real-time environmental data from global databases. Within minutes, it produces a map displaying a simple index of ecological risk.

World-Class Algorithms
The LEFT tool uses algorithms formulated by researchers at the University of Oxford to assess the pattern of ecological features across a chosen area. These algorithms calculate the ecological risk index.

Local Assessments, Global Data
Any landscape in the world can be assessed – up to approximately 100,000km² at a time. Output maps include information on risk assessment biodiversity, numerical IP, biomass, connectivity and resilience.
Select an area for analysis on the map, or input the coordinates:
Zip file of geospatial data for use in Desktop GIS software.
Puntarenas

Local Ecological Footprint Tool

A concise report indicating spatial patterns of ecological value within a landscape. Your report includes a summary ecological value. This report contains a series of maps and tables identifying parts of the landscape which are relatively more important because of the ecological features found there.

This report was generated automatically by Oxford Environmental Tools on 09/08/2017 14:57:33.
Introduction

The Local Ecological Footprinting Tool (LEFT) was developed to provide a simple-to-use tool for industries and landowners who have to make quick preliminary decisions about land-use change, and to assist in minimising the environmental impact of their operations.

The tool processes a series of high-quality open-access environmental datasets using standardised algorithms to produce maps at 30m resolution of land cover class, number of globally threatened terrestrial vertebrate and plant species, biodiversity of terrestrial vertebrates and plants, habitat intactness, wetland habitat connectivity, number of migratory species, and vegetation resilience. These results are aggregated in a single summary map showing the pattern of relative ecological value.

This report briefly describes the methods and datasets used to generate the maps for the specified area of interest. Further details on the modelling approach, datasets, and choice of ecological variables can be found in Willis et al. (2012; 2014; 2015), Seddon et al. (2016), and Long et al. (2016 - in press).

Please note that this report was generated automatically. If you have any questions about LEFT or this output, please email support@left.zoo.ox.ac.uk.

Location

Specified Area of Interest

Latitude: 9.6 to 10.39 Decimal Degrees.
Longitude: -85.4 to -84.36 Decimal Degrees.
Ecoregions

The WWF Terrestrial Ecoregion Classification (Olson et al. 2001) identifies zones of similar ecological characteristics.

Terrestrial Ecoregions in the specified area of interest and in a surrounding 3-degree buffer. Spatial resolution is 1 arcsec, or approximately 30 metres.
Land Cover

A map showing land cover in the year 2010 was derived from the Globelands30 data set (Copyright National Geomatics Center of China, Doc:10.11769/GlobeLand30.2010.db). Pixels were classified to land cover categories from multispectral Landsat and HJ-1 images, plus ancillary data. In isolated areas without Globelands30 coverage, GlobCover 2009 land cover was used instead (Copyright ESA GlobCover Project, led by MEDIAS-France). OpenStreetMap land polygons were used to mask sea pixels.

Land cover map of the specified area of interest. Spatial resolution is 1 arcsec, or approximately 30 metres.
Species Occurrence

Georeferenced species occurrence records were retrieved from the Global Biodiversity Information Facility (GBIF, www.gbif.org, see page three). The adjacent map indicates the distribution of the georeferenced GBIF species occurrence records of amphibians, reptiles, birds, mammals, and plants for the specified area of interest plus a 3-degree buffer zone. Any duplicate records (of the same species recorded more than once in the same location) were removed. Text files containing these records are available in a premium analysis.

<table>
<thead>
<tr>
<th>Class</th>
<th>No. of Species</th>
<th>No. of Occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphibians</td>
<td>192</td>
<td>5713</td>
</tr>
<tr>
<td>Birds</td>
<td>1110</td>
<td>242883</td>
</tr>
<tr>
<td>Mammals</td>
<td>226</td>
<td>5479</td>
</tr>
<tr>
<td>Reptiles</td>
<td>261</td>
<td>4775</td>
</tr>
<tr>
<td>Plants</td>
<td>14056</td>
<td>600327</td>
</tr>
</tbody>
</table>

Data Assurance Information: Data Assurance Metric (DAM)

The robustness of results will be influenced by the availability of occurrence data, the density of sites available in the specific region. The most reliable data to determine are the species occurrence records contained in GBIF, but for many areas, GBIF coverage for some regions of the world is limited (Hawkes et al., 2010). To ensure that a sufficient data set was available for each taxonomic group (amphibians, birds, mammals, reptiles, plants) the number of occurrence points was checked to ensure that the number of occurrence points was sufficient. This was done by dividing the number of different species in an area by the area of the region in question. The number of occurrence points was then calculated by dividing the number of different species in an area by the area of the region. The results for each taxonomic group are shown in the table below.

Page 3 of 18
Vulnerability

The IUCN Red List of Threatened Species (IUCN 2014) was queried to find the names of threatened species in the specified area of interest. All terrestrial amphibians, reptiles, birds, mammals, and plants determined by the IUCN to be either Critically endangered (CR), Endangered (EN), Vulnerable (VU), or Near Threatened (NT) were extracted. The Red List also identified the countries and sub-national administrative regions where each species is native (excluding areas where the species is vagrant or introduced).

The Global Administrative Areas database version 2.0 (www.gadm.org) was then used to create polygons comprising all the administrative regions in each species range defined by the IUCN. Each polygon represented the potential maximum extent of occurrence, within which a species distribution should be modelled. The same extent was used to sample background environmental variables for species distribution modelling.

For each threatened species, all unique geo-referenced records within the potential maximum extent were obtained from the Global Biodiversity Information Facility (GBIF, gbk.org). A set of environmental covariates was then created for each location with a GBIF record. The covariates used were land cover from GlobCover 2009, mean annual temperature, temperature seasonality, total annual precipitation, and precipitation seasonality from Hijmans (2005), and elevation and slope from Farr (2007).

The potential distribution of each threatened species with more than 10 unique occurrence records was modelled using MaxEnt (Maximum Entropy Algorithm; Phillips et al., 2006). MaxEnt creates a climate suitability model for each species, predicting where a species could potentially occur based on habitat conditions.

A list of the threatened vertebrate species included in modelling can be found in Appendix 1.

<table>
<thead>
<tr>
<th>Number of Globally Threatened Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Vulnerability map showing the number of globally threatened (CR, EN, VU) and near-threatened (NT) terrestrial vertebrates and plant species estimated to occur in the specified area of interest. Yellow indicates where the landscape probably contains the highest number of threatened species. See Appendix 1 for a list of species names. Spatial resolution is 1 arcsec, or approximately 30 metres.
Spatial Pattern of Biodiversity

Georeferenced occurrence records for plants and terrestrial vertebrates were retrieved from GBIF (see page three). Species records were combined with environmental covariates to express the pattern of biodiversity (beta-diversity, i.e. spatial turnover in species) across the area of interest. To do this, a Generalised Dissimilarity Model (GDM; Ferrier et al. 2002) was run. The environmental covariates used in the model were annual mean temperature, annual mean precipitation, temperature seasonality, precipitation seasonality (Hijmans et al. 2005), soil nitrogen, soil water holding capacity (Land and Water Development Division, FAO 2003), and land cover class (GlobCover 2009). To ensure the maximum number of records for modelling, occurrence data were obtained for the area of interest and a surrounding 3-degree buffer.

Map displaying beta-diversity in the specified area of interest. High values of beta-diversity (in yellow) represent greater spatial heterogeneity in the set of species present compared to other parts of the area of interest. Low beta-diversity values (in blue) indicate a relatively homogeneous set of species. Spatial resolution is 1 arcsec, or approximately 30 metres.
**Intactness**

To identify patches of intact habitat in the specified area of interest, the land cover map (see page four) was reclassified. Pixels in the urban/artificial, bare ground, and snow/ice categories were omitted from consideration. Every remaining pixel was assigned to a group of neighbouring pixels with the same land cover class, and the area of each group in hectares was calculated. In the resulting map those areas with a greater intact patch size are less fragmented, and carry a higher ecological value.

![Intactness Map](image-url)  
**Intactness map.** Values express the size of the land cover patch to which each pixel belongs. Urban, bare, and snow pixels were assigned an intactness value of 0. Resolution of the data is 1 arcsec, or about 30m.
Connectivity: Migratory Species

To remotely characterise important migratory routes, the Global Register of Migratory Species (GROMS; www.groms.de; Riede 2004) was queried. This database provides a list of migratory vertebrate species (terrestrial birds and mammals) and digital maps describing migratory routes. Grids for all species shown to have a migratory route across the area of interest were added together to yield an estimate of migratory species density.

<table>
<thead>
<tr>
<th>Number of Migratory Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
</tr>
</tbody>
</table>

Number of migration routes where those areas with the greatest number of migratory species potentially passing through an area are marked in yellow. A list of the migratory species potentially crossing this area can be found in Appendix 2. Resolution of the data is 1 arcsec, or about 30m.
Connectivity: Wetlands

Wetlands and drainage channels are also important for supporting migration of species across landscapes. The land cover classification (page four) and the Hydrosheds drainage channels database (Lehner et al 2008) were used to identify all areas of open water, permanent wetlands and a buffer zone within 100m of drainage channels within the specified area of interest. These areas were assigned a value of 1 and all other areas were given a value of 0 for this measure of connectivity.

![Map of wetland connectivity showing areas of open water, permanent wetland, or within 100m of water. Areas of potential wetland connectivity i.e. areas of open water, within 100m of water, permanent wetland and/or drainage channels are marked in yellow. The resolution of the data is 1 arcsec, approximately 30m.](image)

<table>
<thead>
<tr>
<th></th>
<th>Wetland</th>
<th>Non-wetland</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Purple</td>
<td>Yellow</td>
<td>Grey</td>
</tr>
</tbody>
</table>


Resilience

The resilience of vegetation to climate perturbations was estimated using monthly time series of Enhanced Vegetation Index (EVI) and three climate variables over the period 2000-2012. A PCA regression was performed between EVI and air temperature, the ratio of actual to potential evapotranspiration, and cloud cover for the period 2000-2013. This identified the months when EVI is related to climate drivers and measured the strength of that relationship over 14 years. For those months with a strong climate response, variability in vegetation productivity was divided by climate variability as a metric of vegetation sensitivity.

In the resultant resilience map, high values indicate areas where vegetation greenness showed relatively little change despite fluctuations in climate. Low resilience values reveal areas where photosynthetic activity changed even in the face of small fluctuations in climate. For full details of the methodology used to calculate the resilience metric please see Seddon et al (2016).

Map displaying vegetation persistence across the selected region over the past 13 years despite climatic perturbations. Yellow indicates regions where vegetation appears to demonstrate greater resilience to climatic perturbations occurring between 2000-2013.
mask dormant periods

EVI

temp
water
clouds

EVI \leq 0.1

temp \leq 0^\circ C

PCA regression

Identify important variables

Get climate weights

growing season

Monthly Z-score calc.
De-trend data for sig. months

Monthly Z

Monthly Anom

Variance

Sensitivity

Detrended mean/var

veg variance ÷ Clim var

Clim sens

Global VSI


\begin{align*}
\text{Global VSI} &= \beta_{\text{temp}} \times \text{temp sens.} + \beta_{\text{Water}} \times \text{Water sens} + \beta_{\text{cloud}} \times \text{cloud sens} \\
\end{align*}
Summary Ecological Value

In addition to the preceding maps, a summary ecological valuation (SEV) was calculated for the specified area of interest. In this, each of the above layers was standardised into a map of Z-scores. Z-scores were then added together to show the landscape pattern of each layer on a scale comparable to all the other layers. Pixels with a high Z-score are areas which appear to be relatively important in a number of the preceding analyses (e.g. more resilient, higher number of threatened species, higher levels of beta-diversity etc) and therefore are of high ecological risk if damaged. In contrast, those with a low score are less ecologically important.

Summary Ecological Value Z-Score

| Low | High |

Summary ecological value of all LEFT layers in the area of interest. The resolution of the data is 1 arcsec, approximately 30m.
**Data Assurance Information:** Comparison to Other Regions (COAM)

To appreciate the importance of the ecological values obtained for the specified area of interest relative to other regions, a 'compared to other areas metric' (COAM) was calculated. This metric used the polygons of the WWF Terrestrial Ecoregion Classification (Olson et al. 2001) to identify zones ecologically similar to the area of interest. Zonal statistics were then used to assess the importance of each LEFF layer relative to the same measure over the entire ecoregion. For each layer, the difference in standard scores between the area of interest and the broader ecoregion is presented in the following chart. This shows whether a study area is relatively more or less ecologically valuable than other regions with similar biogeographic characteristics.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Ref. Mean</th>
<th>Ref. SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerability</td>
<td>0</td>
<td>94</td>
<td>48.78</td>
<td>14.956</td>
<td>46.446</td>
<td>4.02</td>
</tr>
<tr>
<td>Spatial Pattern of Biodiversity</td>
<td>6053</td>
<td>7533</td>
<td>6368.762</td>
<td>292.192</td>
<td>7437.831</td>
<td>657.155</td>
</tr>
<tr>
<td>Intactness</td>
<td>0</td>
<td>168</td>
<td>122.575</td>
<td>49.064</td>
<td>41.625</td>
<td>51.311</td>
</tr>
<tr>
<td>Connectivity: Migratory Species</td>
<td>9</td>
<td>93</td>
<td>81.117</td>
<td>9.093</td>
<td>81.658</td>
<td>9.805</td>
</tr>
<tr>
<td>Connectivity: Wetlands</td>
<td>0</td>
<td>1</td>
<td>0.036</td>
<td>0.186</td>
<td>0.059</td>
<td>0.221</td>
</tr>
<tr>
<td>Resilience</td>
<td>8256</td>
<td>9283</td>
<td>8208.513</td>
<td>378.091</td>
<td>8077.851</td>
<td>474.794</td>
</tr>
</tbody>
</table>

Table and chart indicating the importance of the area of interest relative to the reference region for each layer (standard scores +/- uncertainty in standard scores). If a layer has a positive standard score then the area of interest is more important than the reference region; a layer with a negative standard score is less important in the study area than in the reference region.
References


Credits

LEFT was funded by Statoil ASA. The project was conceived by Kathy Willis and Elizabeth Jeffers of the Zoology Department, University of Oxford and Randi Hagemann. Tone Karin Frost, Mathis Smit, Christian Collin-Hansen, and Jorgen Weiselenberger from Statoil. The algorithms in LEFT were elaborated by Peter Long, David Benz, Marc Macias Fauria, and Alistair Seddon of the Zoology Department, University of Oxford. LEFT’s software architecture was developed by Andrew Martin and Philip Holland of the Zoology Department, University of Oxford.

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Appendix 1. Vulnerable Species

The IUCN Red List of Threatened Species (IUCN 2014) includes the following species of terrestrial mammals, birds, reptiles, and amphibians that have been modelled to be potentially present in the specified area of interest (NT = Near Threatened, VU = Vulnerable, EN = Endangered):

- Anoura guttata (mammal NT)
- Cryptosia gracilis (mammal VU)
- Myrmecophaga tridactyla (mammal VU)
- Sturnira mordax (mammal NT)
- Bolitoglossa alvaradoi (amphibian EN)
- Notostomus araneus (amphibian VU)
- Oedalea uniformis (amphibian NT)
- Craugastor andis (amphibian CR)
- Craugastor podicipenos (amphibian NT)
- Ecomystax limbrimembranaceus (amphibian VU)
- Isthminia angustistriata (amphibian CR)
- Isthminia tricolor (amphibian CR)
- Pristimantis ater (amphibian NT)
- Ctenotus rubra (bird VU)
- Eleutherodactylus vallenatus (bird VU)
- Amazilia bocachica (bird EN)
- Hylidae solitaire (bird NT)
- Camelus dromedarius (bird VU)
- Cephalopterus glabrirostris (bird VU)
- Desmodus rotundus (bird VU)
- Ateles geoffroyi (mammal EN)
- Leptodactylus lepidus (mammal VU)
- Panthera onca (mammal NT)
- Tapirus bairdii (mammal EN)
- Boidionta lineolata (amphibian VU)
- Oedalea pustulata (amphibian EN)
- Apalanchis ansae (amphibian EN)
- Craugastor angelicus (amphibian CR)
- Craugastor rufoxen (amphibian CR)
- Ecomystax miliaris (amphibian VU)
- Isthminia acuticauda (amphibian NT)
- Isthminia zeteki (amphibian CR)
- Pristimantis carposcyphoides (amphibian NT)
- Phaneropterus macklini (bird NT)
- Teleostigma castanescens (bird VU)
- Loricariichthys jamaicensis (bird NT)
- Erythrura rufigaster (bird NT)
- Cotinga ridgwayi (bird VU)
- Procras tricolor (bird VU)
- Bubalus arnee (bird NT)
- Bovocorixa denticorax (mammal NT)
- Oryx leucoryx (mammal NT)
- Sambar cervus (mammal VU)
- Ventioryx spectabilis (mammal NT)
- Bolitoglossa subpalmata (amphibian EN)
- Oedalea pseudocarinata (amphibian EN)
- Atelopus varius (amphibian CR)
- Craugastor persimilis (amphibian VU)
- Desmianthodinae araneoides (amphibian CR)
- Hylidae latens (amphibian CR)
- Isthminia rivulata (amphibian CR)
- Lithobates vibiscus (amphibian CR)
- Chamaeleo unicolor (bird NT)
- Trogan bairdi (bird NT)
- Chaetura pelagica (bird NT)
- Sterna elegans (bird NT)
- Aetaninae capitalis (bird VU)
- Carpodectes antonini (bird EN)
- Vermivora chrysoptera (bird NT)
- Paroaria ciris (bird NT)

Appendix 2. Migratory Species

The following migratory species identified in the Global register of Migratory Species (GROMS; Riede et al 2004) have migration routes which intersect the specified area of interest:

- Accipiter striatus
- Anas acuta
- Anas cyanoptera
- Anas discors
- Anhinga anhinga
- Aphriza virgata
- Archilochus colubris
- Ardea herodias
- Arenaria interpres
- Aythya affinis
- Buteo albonotatus
- Buteo berigora
How accurate in comparison to field data?

Cusuco, Honduras

• Montane tropical moist forest
• Surveyed 2004-2010
• Extensive datasets e.g. >50,000 records of terrestrial vertebrates in database
Mahamavo, Madagascar

- Tropical dry forest & wetlands
- Surveyed 2009-2010
- Again extensive datasets e.g. >30,000 records of terrestrial vertebrates in database
β-diversity maps for Cusuco (Honduras) computed using LEFT on the left and field data on the right

Ecological Applications (2015)
Time taken for one person to manually extract, process, and produce a LEFT report

- Land cover: 1/2 day
- GBIF species retrieval: 1/2 day
- Beta diversity analysis: 4 days
- Vulnerability: 3 days
- Intactness: 1 day
- Migratory: 2 days
- Wetlands: 1/2 day
- Resilience: 2 days
- SEV: 1/2 day
- GBIF data assurance: 2 days
- Comparison to other regions: 2 days
- Styling maps and writing report: 1 day

Total skills: 14-18 days – depending on level of GIS skills

Time taken to obtain LEFT report: 5 minutes with output usually delivered ~1 hour
Thank you