Oxford Long-Term Ecology Lab
Long-Term Ecology, Biodiversity Conservation, and Environmental Stewardship Technologies

LEFT

Local Ecological Footprinting Tool

IAIA, Washington DC

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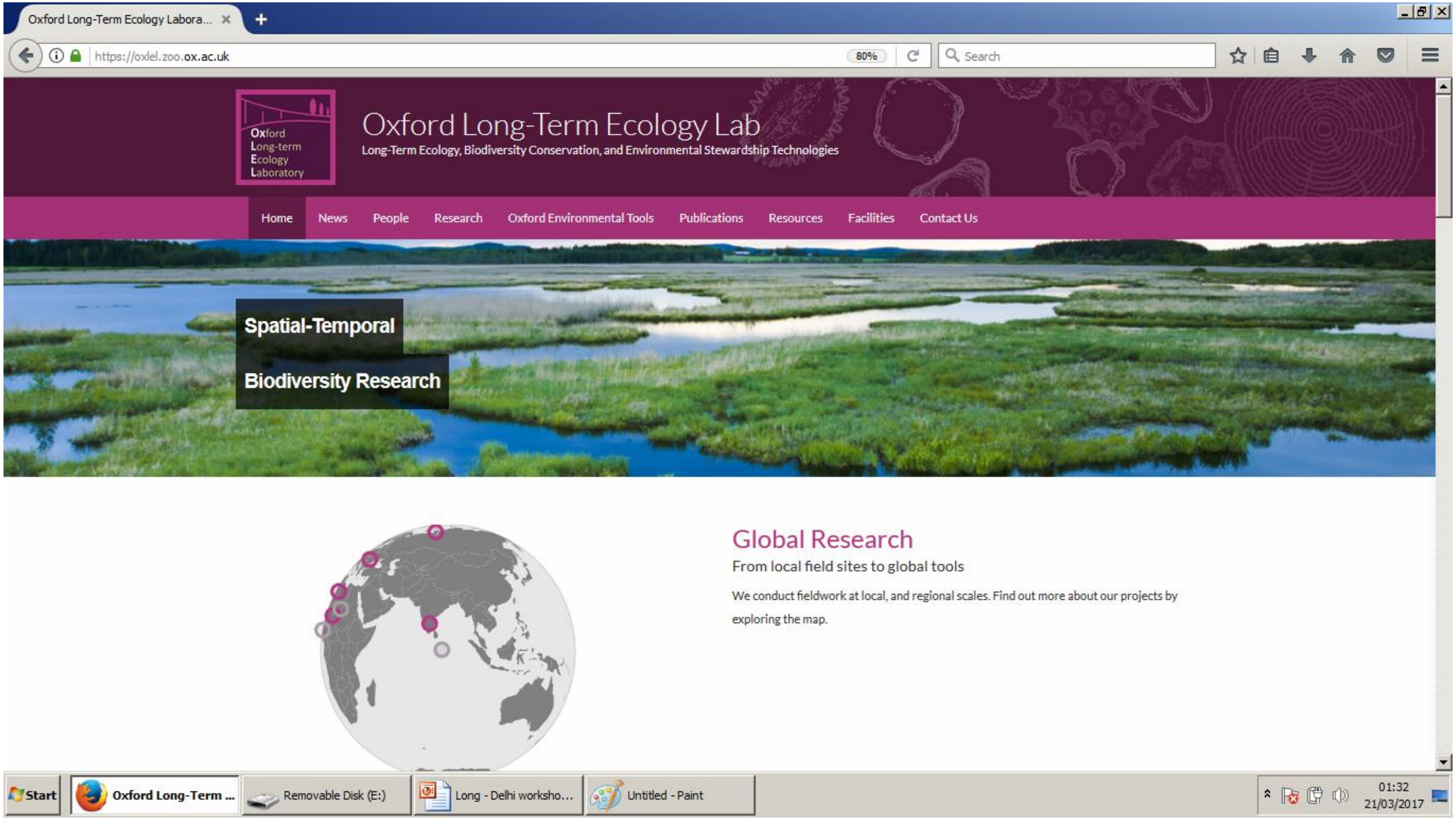
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Competing demands on the natural environment

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.

The problem

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?

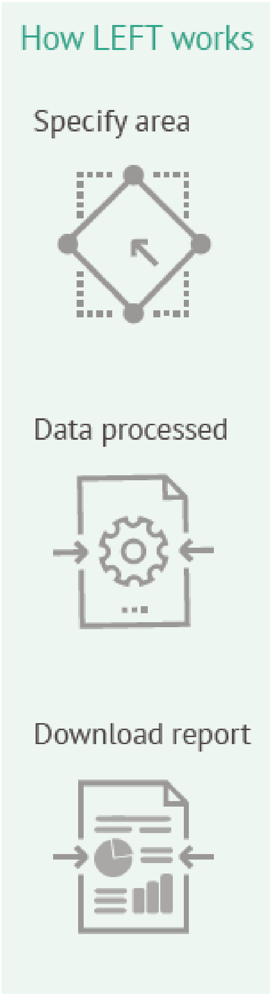
Statoil

Understanding the needs of business…

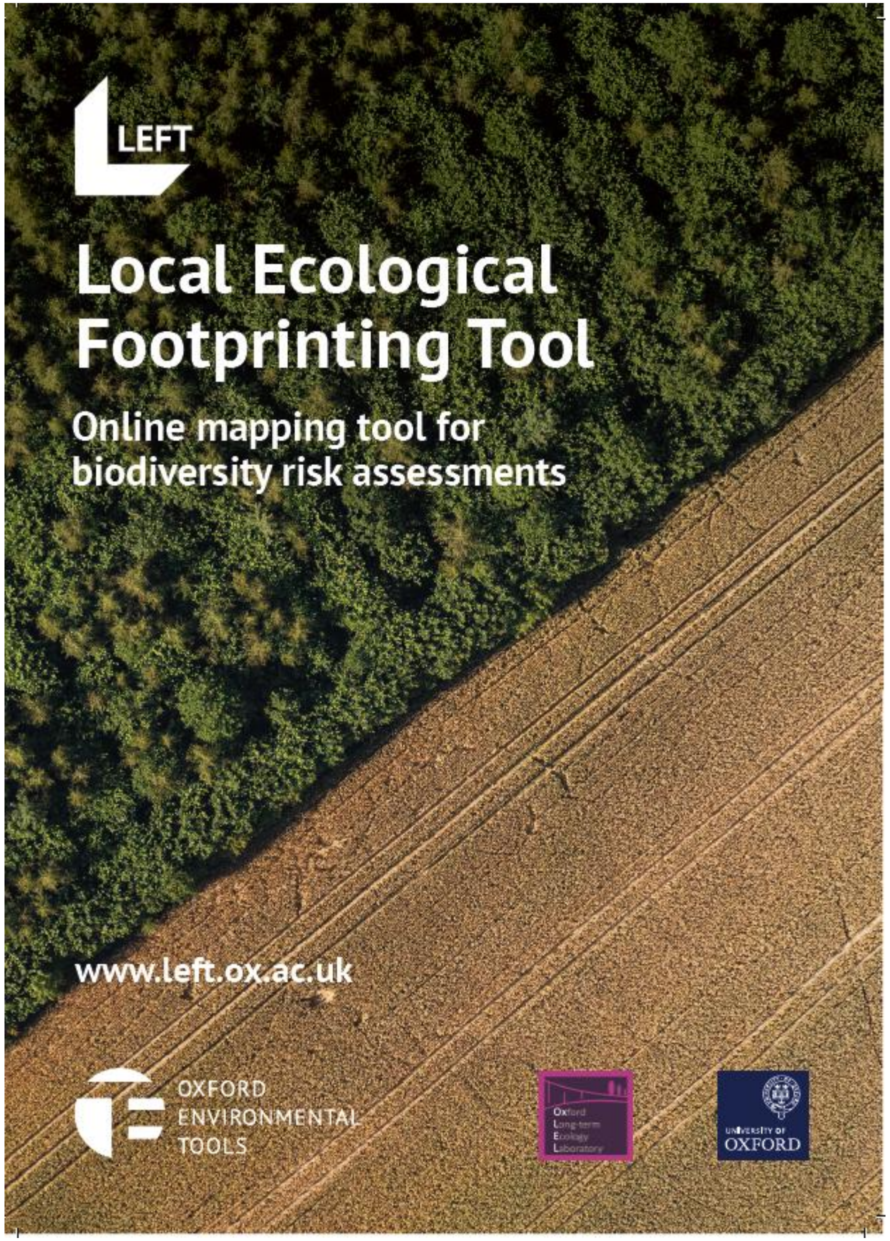
Perceived stakeholder issues with existing tools:

- 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

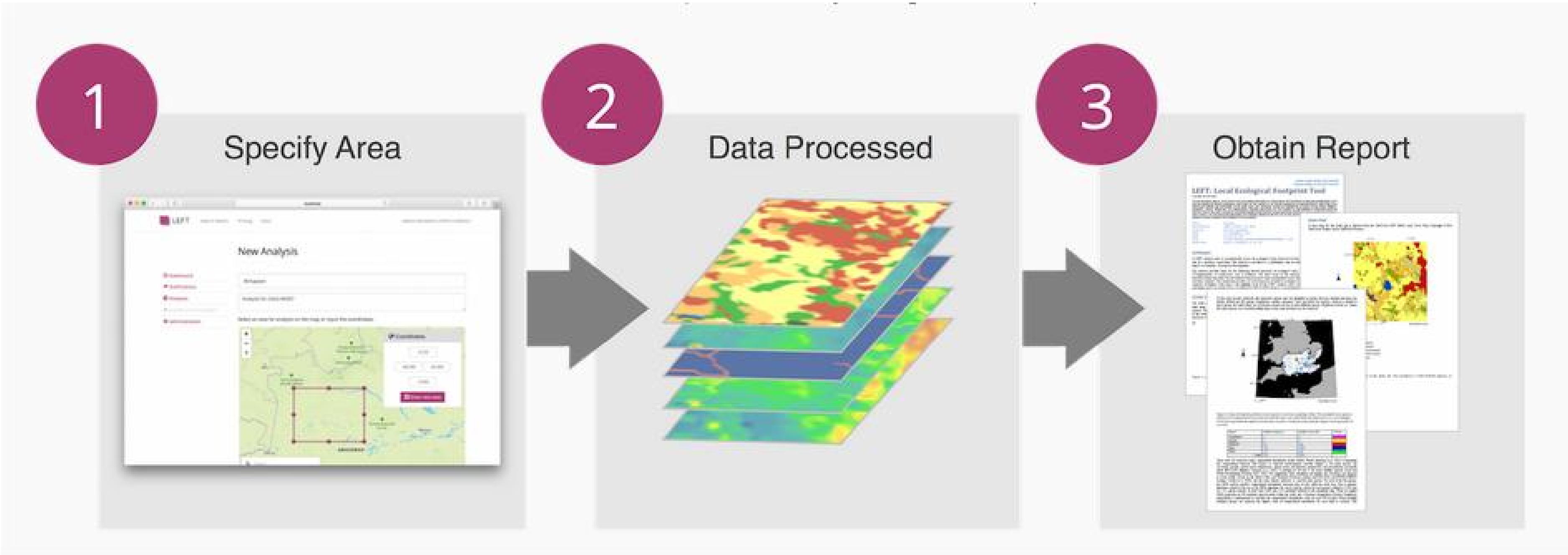
-Threatened species

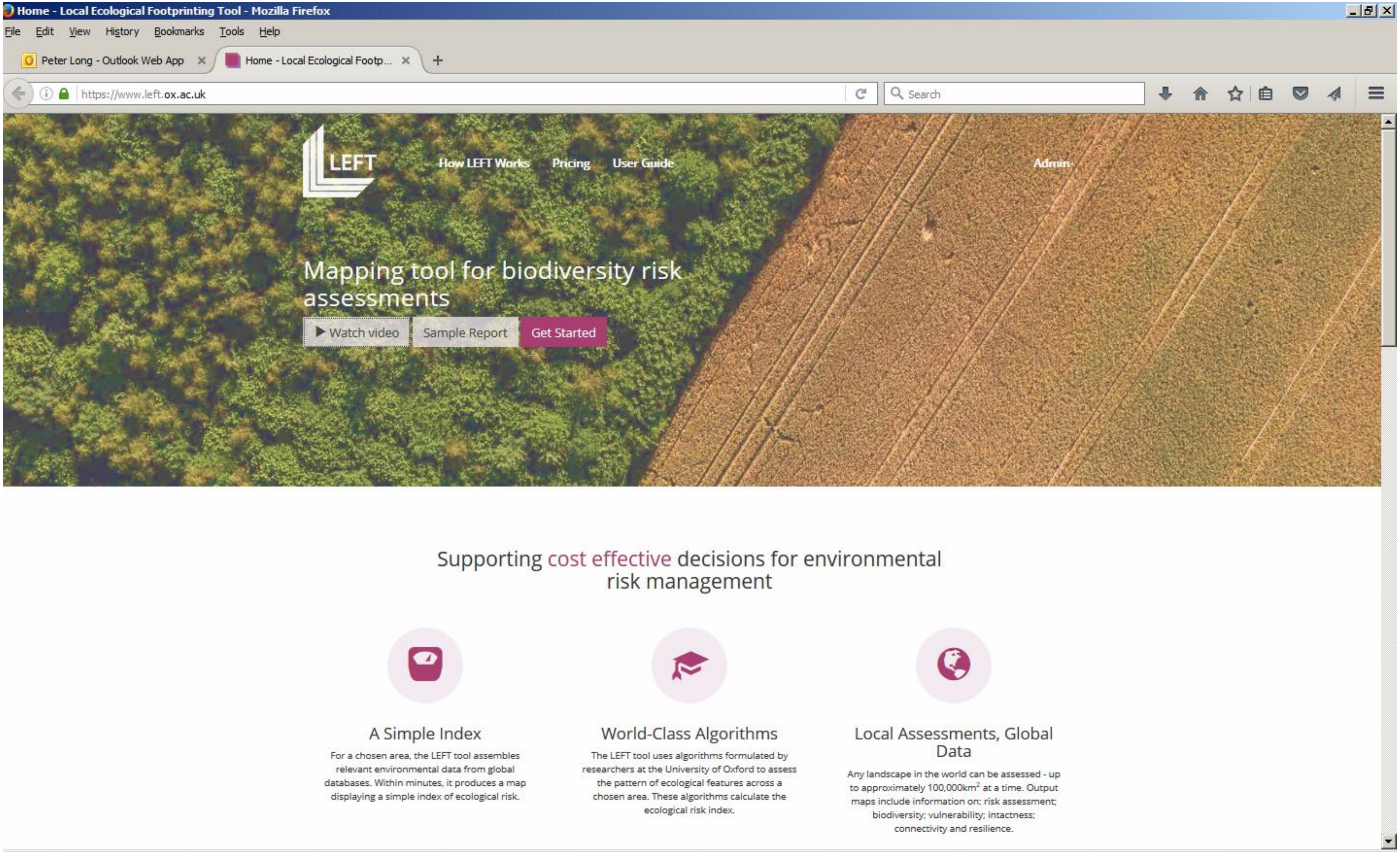
-Intactness

-Connectivity

-Resilience

Long et al (2017) MEE
Willis et al (2012) Biol Cons


1
Specify Area
New Analysis
2
Data Processed
3
Obtain Report
LEFT: Local Ecological Footprint Tool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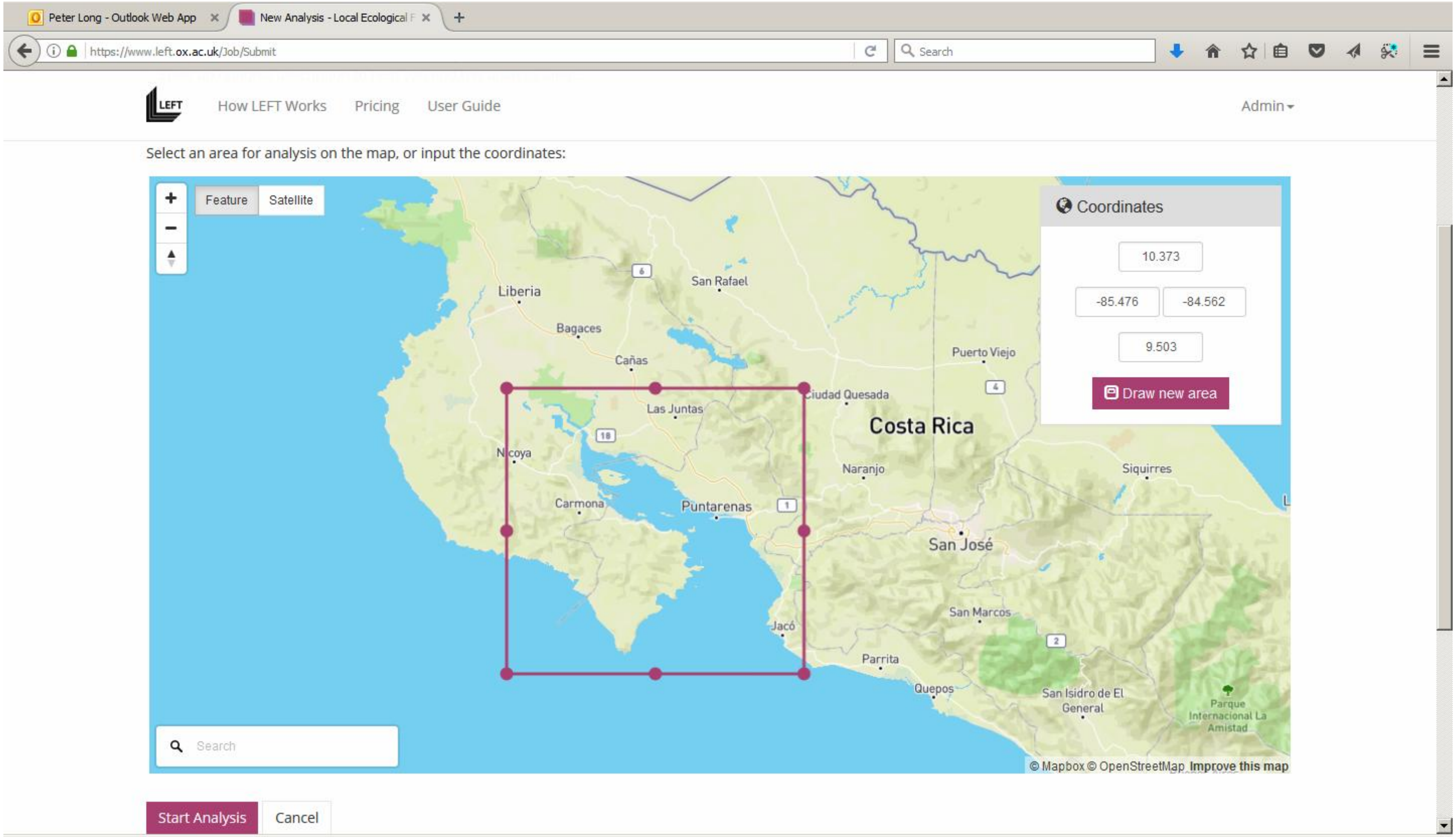
How LEFT Works
Pricing
User Guide
Admin
Mapping tool for biodiversity risk assessments
Watch video
Sample Report
Get Started
Supporting cost effective decisions for environmental risk management
A Simple Index
For a chosen area, the LEFT tool assembles relevant environmental data from global databases. 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; vulnerability; intactness; connectivity and resilience.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Ciudad Quesada
Las Juntas
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Nicoya
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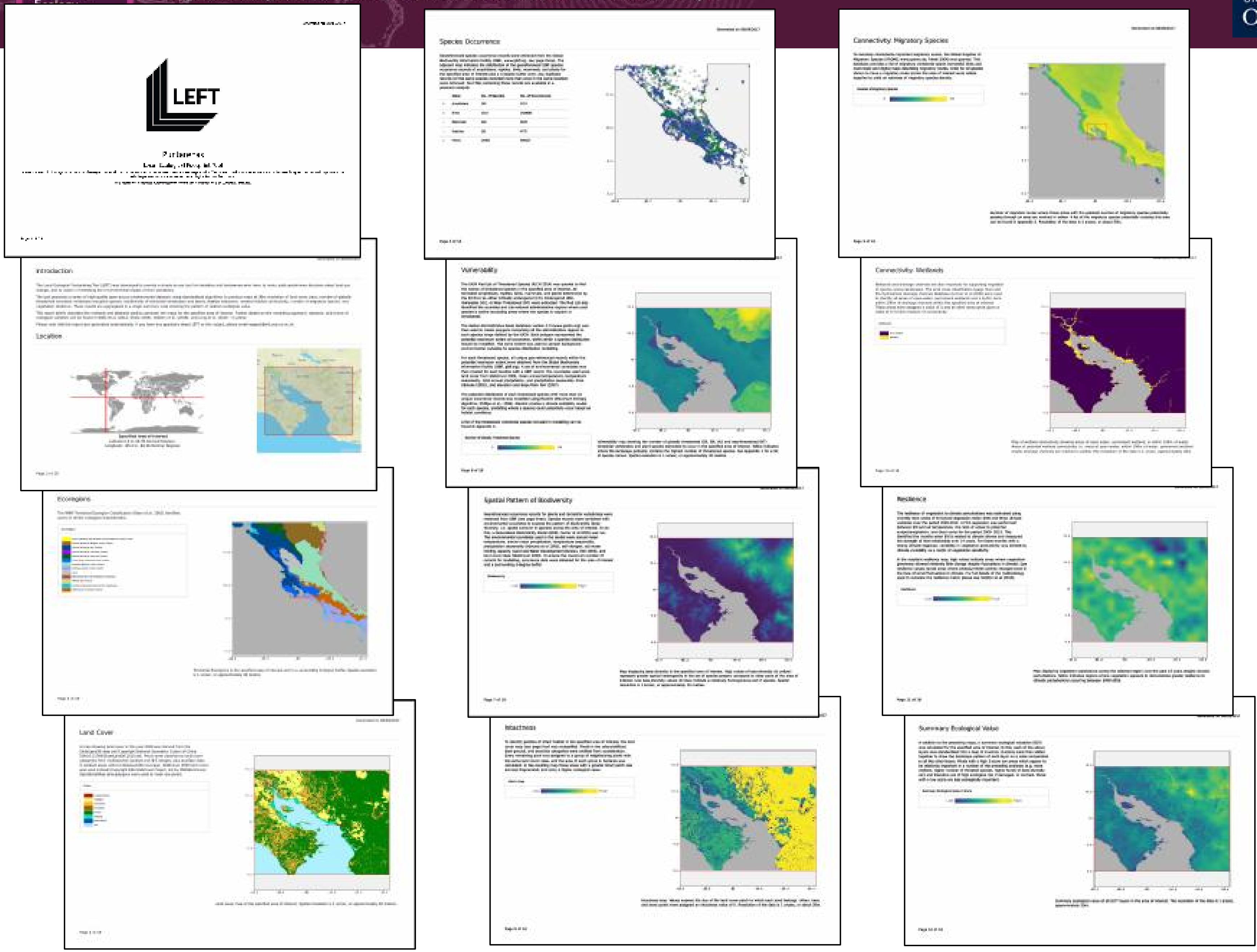

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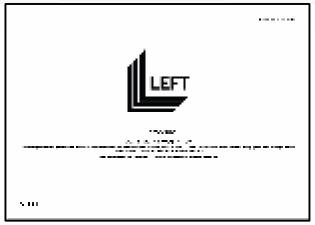
Free

Analyse a landscape up to 3x3 decimal degrees.

Your analysis includes:

One LEFT Report

Get Started



Premium

£250 (VAT included)

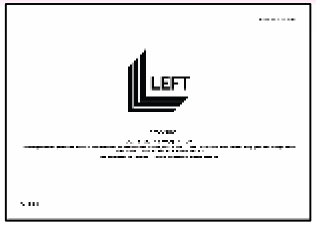
Analyse a landscape up to 3x3 decimal degrees.

Your analysis includes:

One LEFT Report

GeoSpatial Data

Get Started



+

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

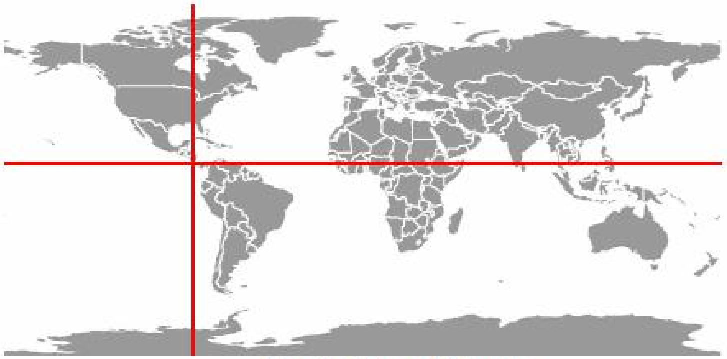
The Local Ecological Footprinting Tool (LEFT) was developed to provide a simple-to-use tool for industries and landowners who have to make quick preliminary decisions about land-use change, and to assist in minimising the environmental impact of their operations.

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.

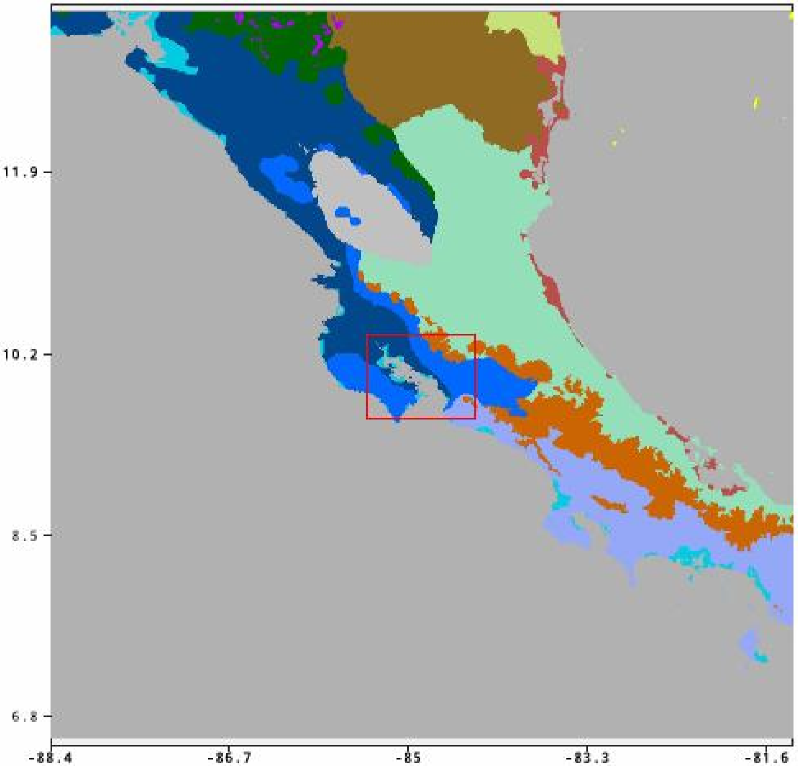
Generated on 08/09/2017

Ecoregions

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

Ecoregion

- Cayos Miskitos-San Andreas and Providencia moist forests
- Central American Atlantic moist forests
- Central American dry forests
- Central American montane forests
- Central American pine-oak forests
- Costa Rican seasonal moist forests
- Isthmian-Atlantic moist forests
- Isthmian-Pacific moist forests
- Lake
- Mesoamerican Gulf-Caribbean mangroves
- Miskito pine forests
- Southern Mesoamerican Pacific mangroves
- Talamancan montane forests



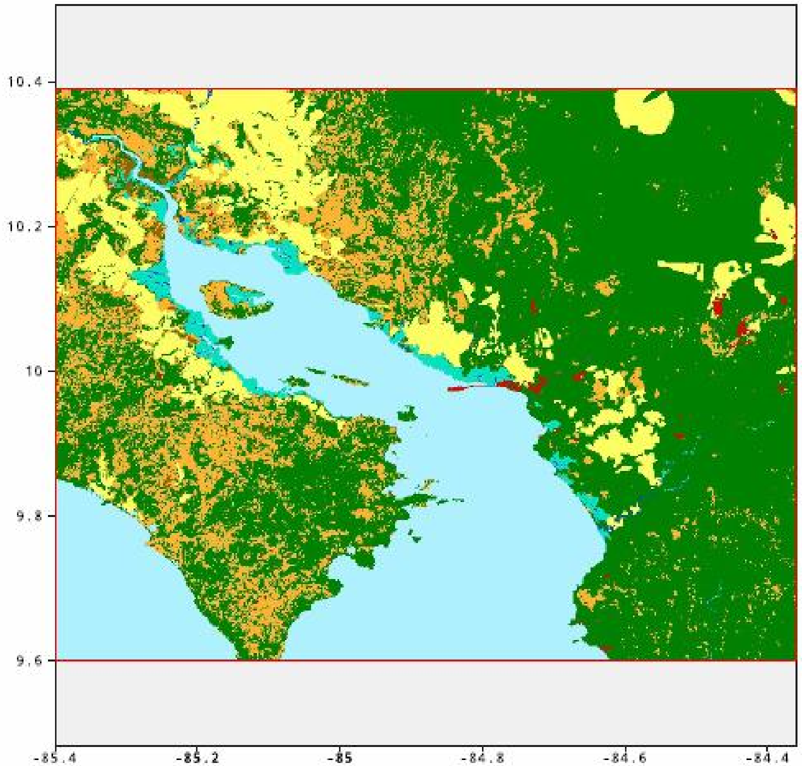
Terrestrial Ecoregions in the specified area of interest and in a surrounding 3-degree buffer. Spatial resolution is 1 arcsec, or approximately 30 metres

Land Cover

A map showing land cover in the year 2010 was derived from the GlobeLand30 data set (Copyright National Geomatics Center of China, DOI:10.11769/GlobeLand30.2010.db). Pixels were classified to land cover categories from multispectral Landsat and HJ-1 images, plus auxiliary data. In isolated areas without GlobeLand30 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.

Class

- Urban/artificial
- Cropland
- Grassland
- Shrubland
- Forest
- Wetland
- Inland water
- Sea

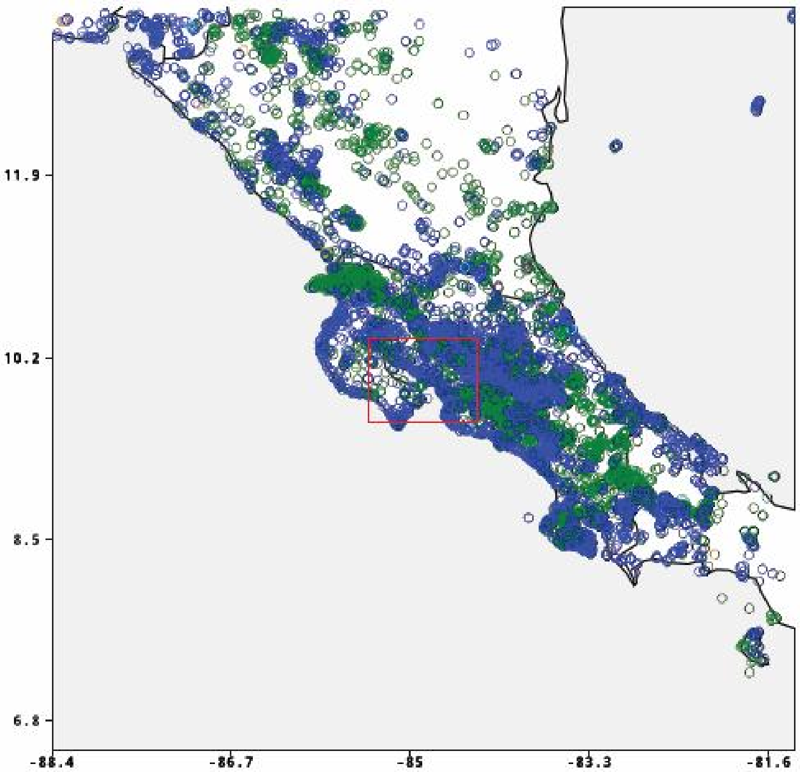


Land cover map of the specified area of interest. Spatial resolution is 1 arcsec, or approximately 30 metres.

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.

	Class	No. of Species	No. of Occurrences
o	Amphibians	192	5713
o	Birds	1110	2428083
o	Mammals	226	5479
o	Reptiles	261	4775
o	Plants	14056	690327



Data Assurance Information: Data Assurance Metric (DAM)

The output and validity of results will be significantly influenced by the availability or, conversely, the paucity, of data available in the databases for the selected region. The most critical data in this respect are the species occurrence records contained in GBIF. Due to sampling bias, GBIF coverage for some regions of the world is better than others (Gaiji et al., 2012). In order to provide a first estimate of the confidence that can be placed in the output from a region, a metric to assess the density of species occurrence records was devised. In this, the number of species records was obtained from GBIF for each taxonomic group (amphibians, reptiles, birds, mammals, plants) in the user-specified area of interest, as well as in a much larger reference area comprising the WWF ecoregions that intersect the area of interest. Species density was then calculated by dividing the number of different species in an area by the size of the area raised to an exponent of 0.2. Exponentiation is necessary in order to consistently control for the logarithmic form of species-area relationships and allow species densities from areas of different sizes to be directly comparable (Rosenzweig 2011). The density of local species occurrence records for a taxonomic group can be compared to the density of records for the same group in the much larger reference area. This gives a first approximation of the degree to which the GBIF records available for a specified area of interest provide a good representation of the species expected in that area, based on wider biogeographical patterns and species-area relationships.

The table below shows species densities for the area of interest and the broader reference area, and the ratio of those densities. A representation score above 1.0 means that the number of species records retrieved was higher than expected, so the data are more reliable. Representation below 1.0 indicates poorer GBIF coverage and less reliable species data.

Taxon	Species density (area of interest)	Species density (reference area)	Representation
Amphibians	19.22	22.03	0.87
Reptiles	25.05	26.44	0.95
Birds	102.82	107.65	0.96
Mammals	79.47	79.34	1
Plants	1226.61	1256.23	0.98

Vulnerability

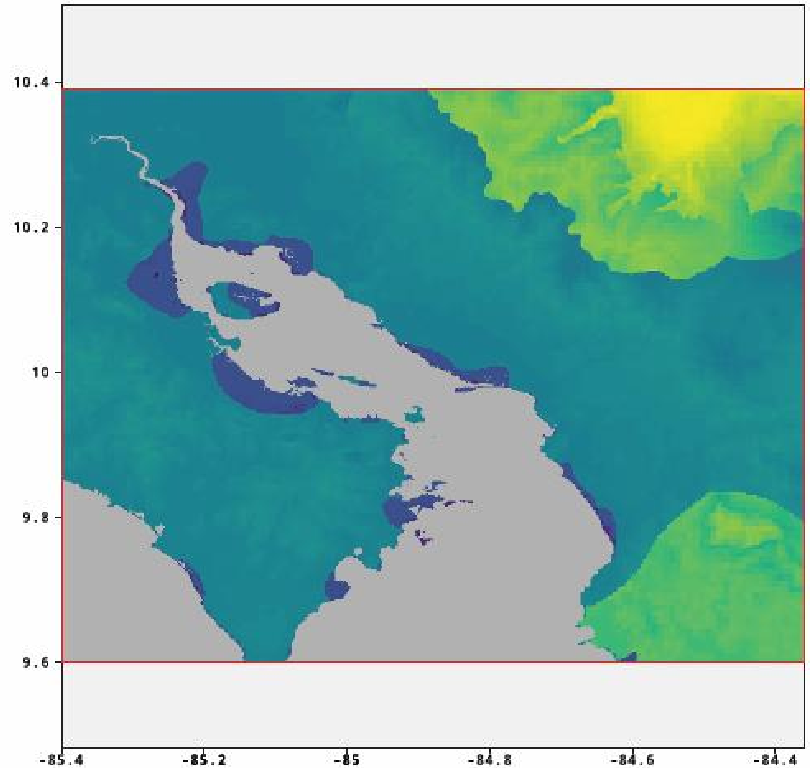
The IUCN Red List of Threatened Species (IUCN 2014) was queried to find the names of threatened species in the specified area of interest. All terrestrial amphibians, reptiles, birds, mammals, and plants determined by the IUCN to be either Critically endangered (CR), Endangered (EN), Vulnerable (VU), 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, gbif.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.



Number of Globally Threatened Species

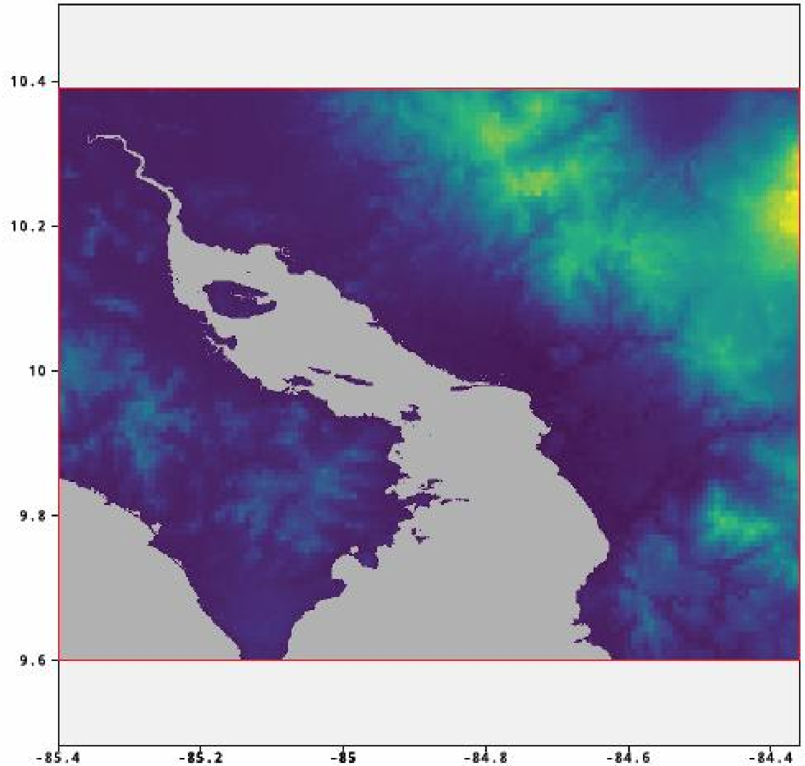
0 94

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.

Biodiversity
Low ▬▬▬ High



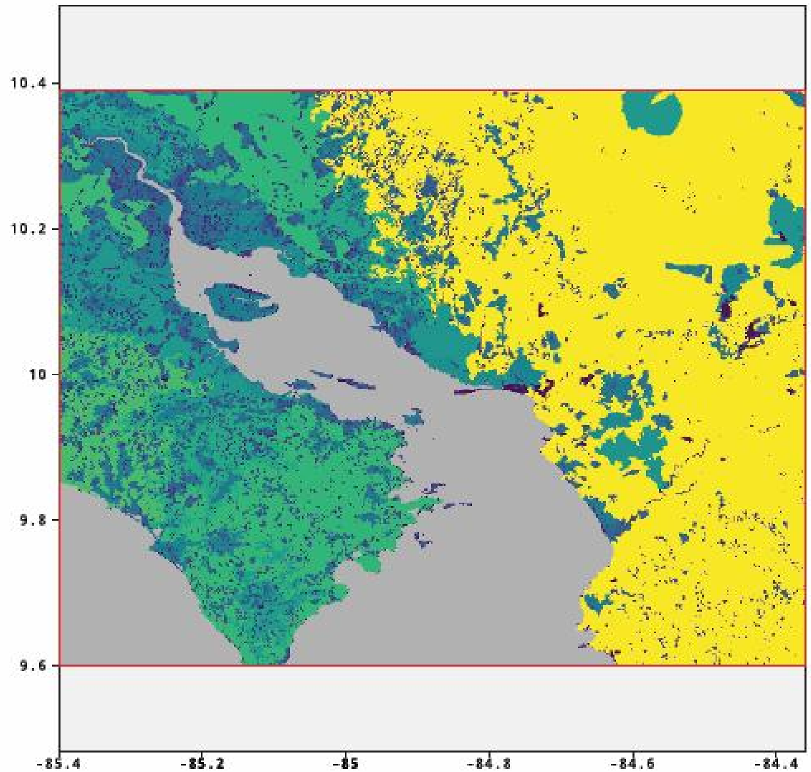
Map displaying beta-diversity in the specified area of interest. High values of beta-diversity (in yellow) represent greater spatial heterogenity in the set of species present compared to other parts of the area of interest. Low beta-diversity values (in blue) indicate a relatively homogeneous set of 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.

Patch Area

Low — High



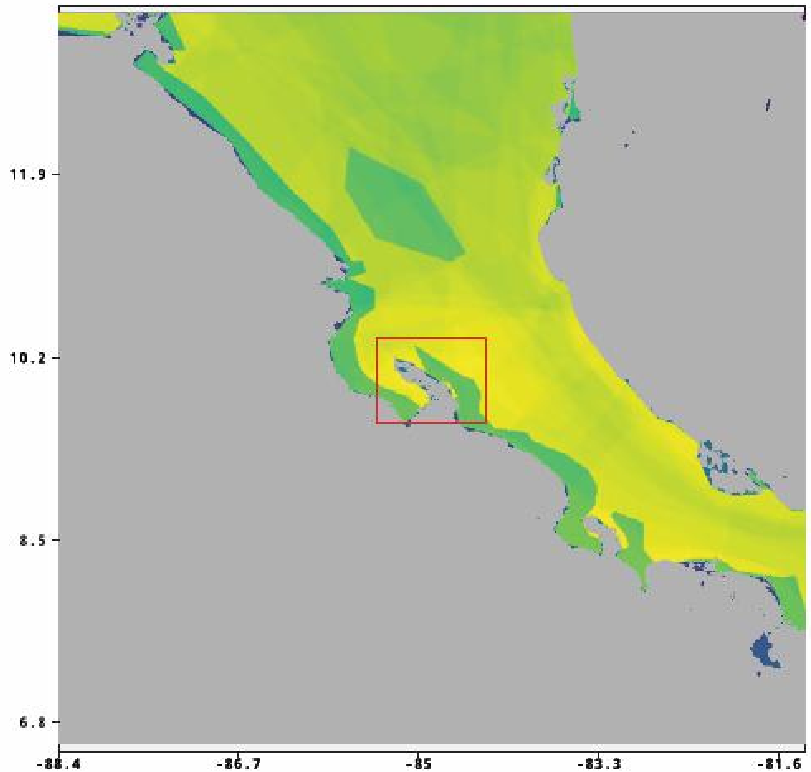
Intactness map. Values express the size of the land cover patch to which each pixel belongs. Urban, bare, and snow pixels were assigned an intactness value of 0. Resolution of the data is 1 arcsec, or about 30m.

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 specie (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.

Number of Migratory Species

9 — 93

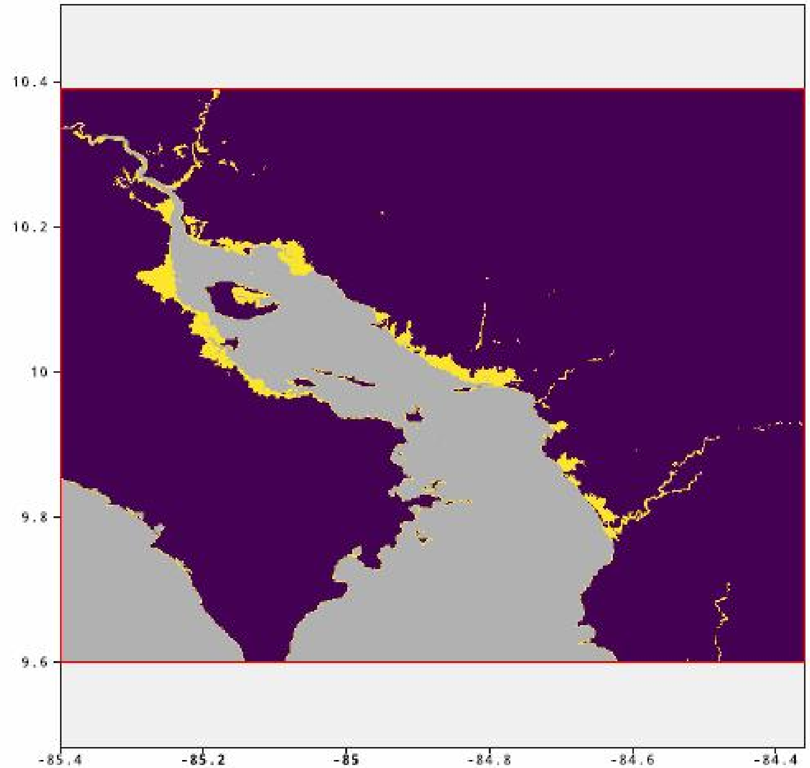


Number of migration routes where those areas with the greatest number of migratory species potentially passing through an area are marked in yellow. A list of the migratory species potentially crossing this area can be found in Appendix 2. Resolution of the data is 1 arcsec, or about 30m.

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.

Wetland
Non-wetland
Wetland



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.

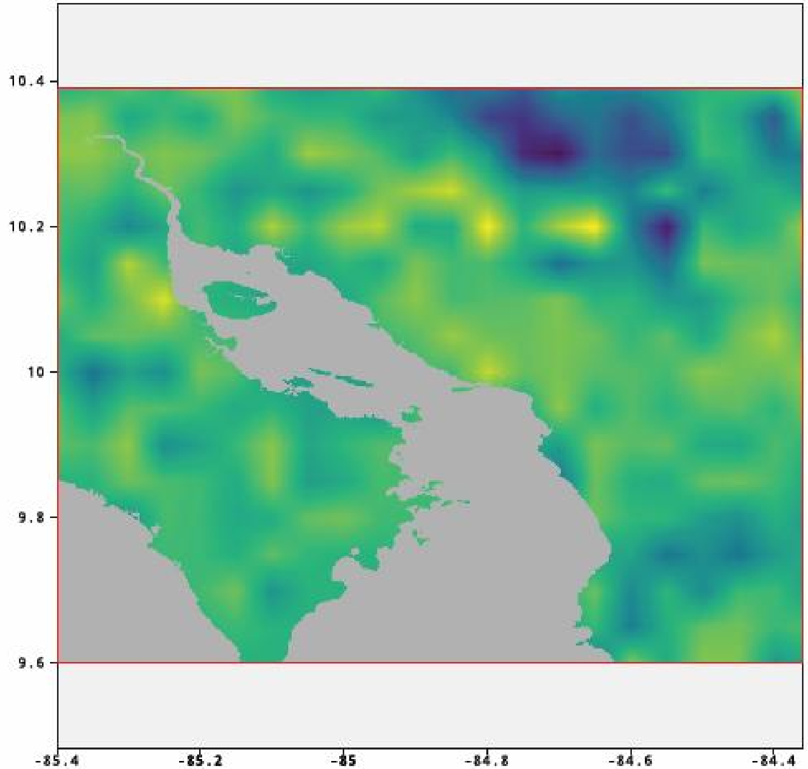
Resilience

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.

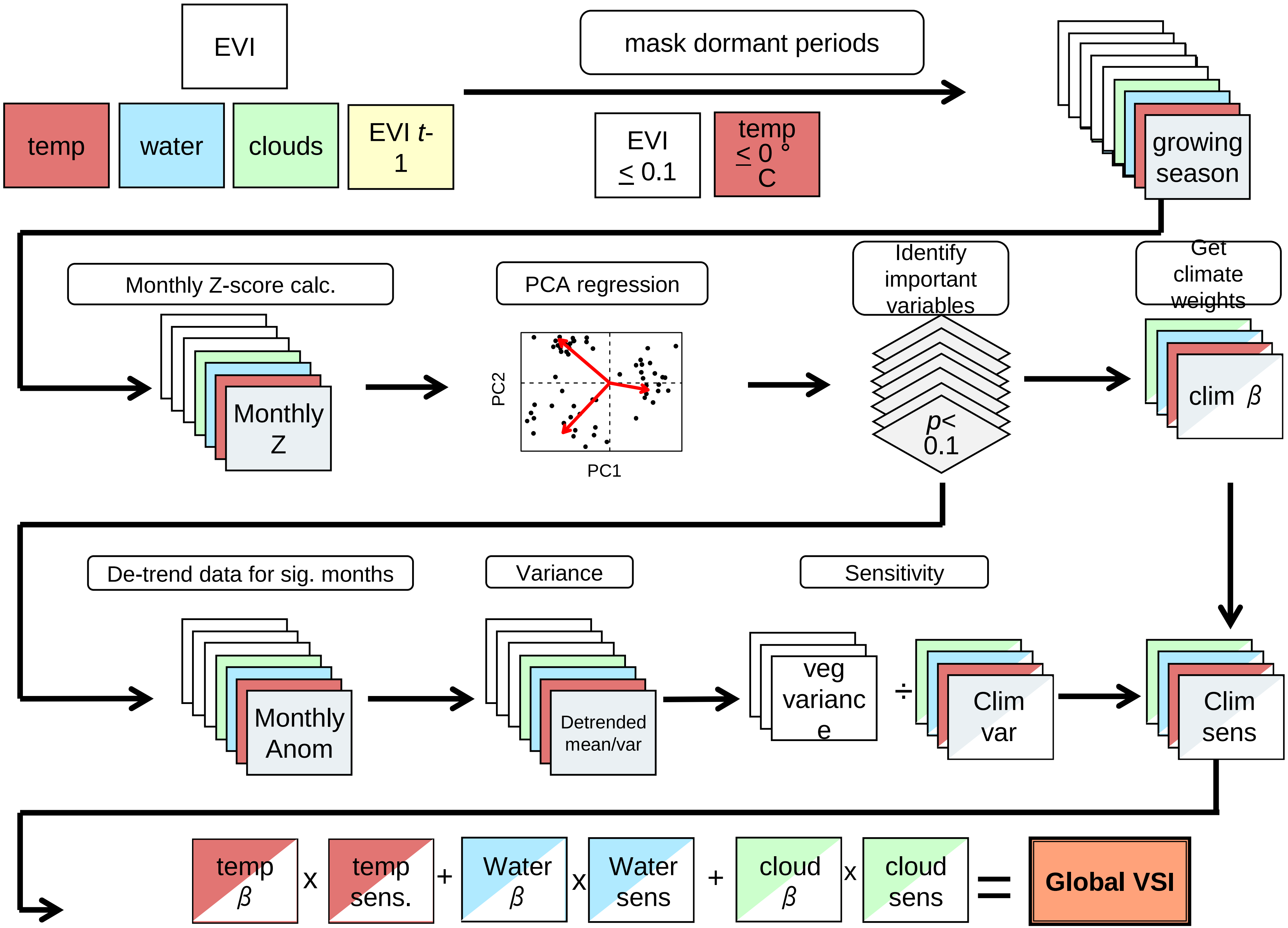
In the resultant resilience map, high values indicate areas where vegetation greenness showed relatively little change despite fluctuations in climate. Low resilience values reveal areas where photosynthetic activity changed even in the face of small fluctuations in climate. For full details of the methodology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

Resilience

Low — High



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.



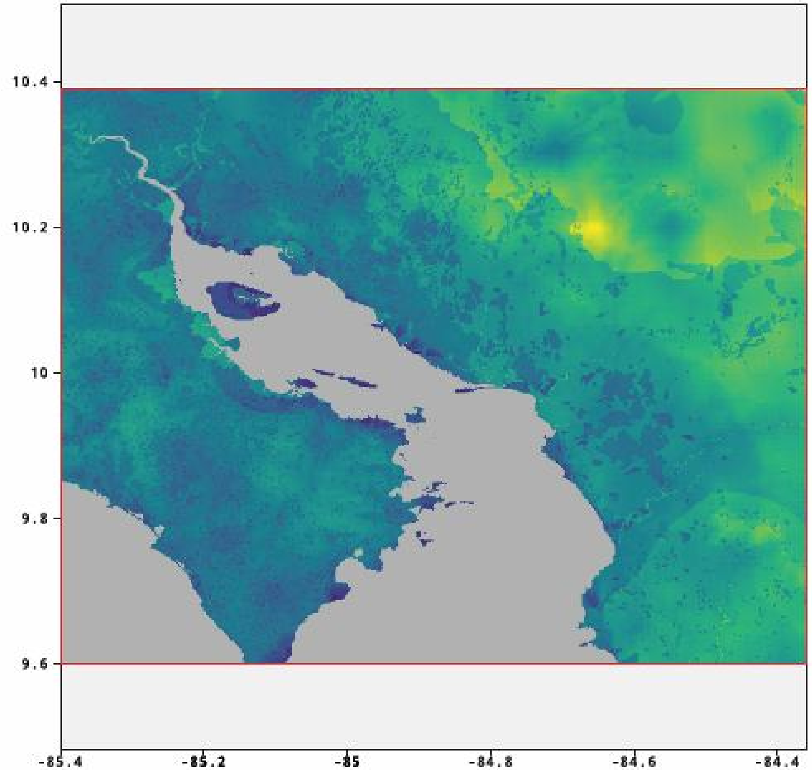
Seddon et al (2016) Nature

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 threated 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 LEFT 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 ecoregions 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 characterisitics.

Layer	Min	Max	Mean	SD	Ref. Mean	Ref. SD
Vulnerability	0	94	48.78	14.956	46.446	4.02
Spatial Pattern of Biodiversity	6053	7513	6365.762	292.192	7437.831	657.155
Intactness	0	168	122.575	49.064	41.605	51.311
Connectivity: Migratory Species	9	93	81.117	9.093	81.658	9.865
Connectivity: Wetlands	0	1	0.036	0.186	0.059	0.221
Resilience	6256	9283	8208.513	378.091	8077.851	474.794

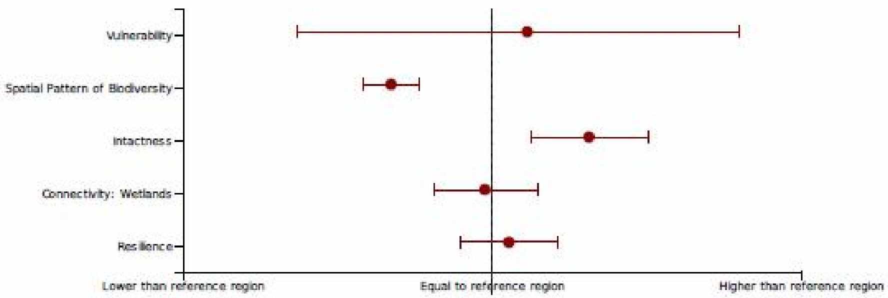


Table and chart indicating the importance of the area of interest relative to the reference region for each layer (standard scores +/- uncertainty in standard scores). If a layer has a positive standard score then the area of interest is more important than the reference region; a layer with a negative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

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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, Mathijs Smit, Christian Collin-Hansen, and Jurgen Weissenberger 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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Appendices

Appendix 1. Vulnerable Species

The IUCN Redlist of Threatened Species (IUCN 2014) includes the following species of terrestrial mam- mals, 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, CR = Critically Endangered):

Anoura cultrata (mammal NT)
Ateles geoffroyi (mammal EN)
Bauerus dubiaquercus (mammal NT)
Cryptotis gracilis (mammal VU)
Leopardus tigrinus (mammal VU)
Leopardus wiedii (mammal NT)
Myrmecophaga tridactyla (mammal VU)
Panthera onca (mammal NT)
Saimiri oerstedii (mammal VU)
Sturnira mordax (mammal NT)
Tapirus bairdii (mammal EN)
Vampyrum spectrum (mammal NT)
Bolitoglossa alvaradoi (amphibian EN)
Bolitoglossa lignicolor (amphibian VU)
Bolitoglossa subpalmata (amphibian EN)
Nototriton gamezi (amphibian VU)
Oedipina poelzi (amphibian EN)
Oedipina pseudouniformis (amphibian EN)
Oedipina uniformis (amphibian NT)
Agalychnis annae (amphibian EN)
Atelopus varius (amphibian CR)
Craugastor andi (amphibian CR)
Craugastor angelicus (amphibian CR)
Craugastor persimilis (amphibian VU)
Craugastor podiciferus (amphibian NT)
Craugastor ranoides (amphibian CR)
Duellmanohyla uranochroa (amphibian CR)
Ecnomiohyla fimbrimembra (amphibian EN)
Ecnomiohyla miliaria (amphibian VU)
Hylomantis lemur (amphibian CR)
Isthmohyla angustilineata (amphibian CR)
Isthmohyla picadoi (amphibian NT)
Isthmohyla rivularis (amphibian CR)
Isthmohyla tica (amphibian CR)
Isthmohyla zeteki (amphibian NT)
Lithobates vibicarius (amphibian CR)
Pristimantis altae (amphibian NT)
Pristimantis caryophyllaceus (amphibian NT)
Chamaepetes unicolor (bird NT)
Crax rubra (bird VU)
Pharomachrus mocinno (bird NT)
Trogon bairdii (bird NT)
Electron carinatum (bird VU)
Touit costaricensis (bird VU)
Chaetura pelagica (bird NT)
Amazilia boucardi (bird EN)
Laterallus jamaicensis (bird NT)
Sterna elegans (bird NT)
Harpyhaliaetus solitarius (bird NT)
Egretta rufescens (bird NT)
Aphanotriccus capitalis (bird VU)
Contopus cooperi (bird NT)
Cotinga ridgwayi (bird VU)
Carpodectes antoniae (bird EN)
Cephalopterus glabricollis (bird VU)
Procnias tricarunculatus (bird VU)
Vermivora chrysoptera (bird NT)
Dendroica cerulea (bird VU)
Bangsia arcaei (bird NT)
Passerina 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 brachyurus

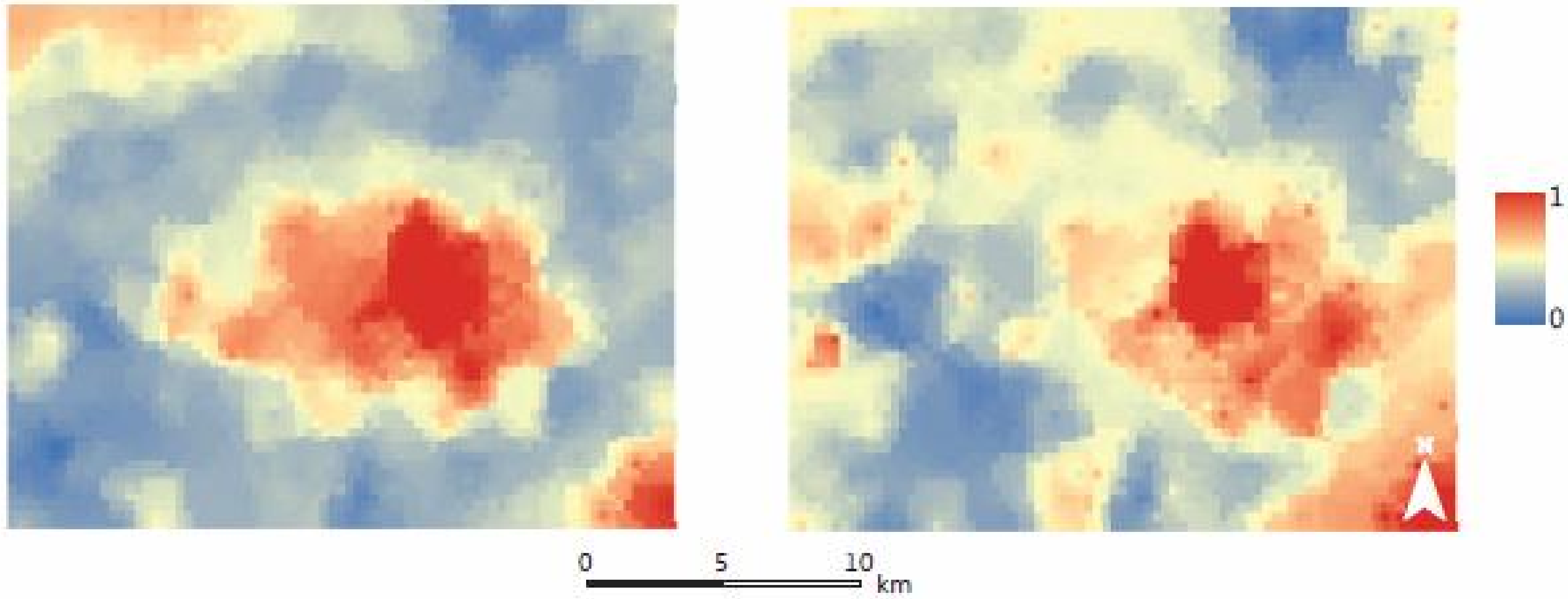
How accurate in comparison to field data?

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 — **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