

# Ecological informatics to face biodiversity estimate by remote sensing

Duccio Rocchini

University of Trento, Italy



# Outline

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- 1 Intro
- 2 Virtual communities
- 3 Remote sensing to predict biodiversity
- 4 Open challenges

# Group on Earth Observations



GEO Strategic Plan 2016-2025: Implementing the Global Earth Observation System of Systems (GEOSS), relying on “sound science-based **public policies informed** by Earth observations, **modelling** and **data integration**.”

# Field data on biodiversity

PHILOSOPHICAL  
TRANSACTIONS  
OF  
THE ROYAL  
SOCIETY **B**

*Phil. Trans. R. Soc. B* (2011) **366**, 2426–2437  
doi:10.1098/rsth.2011.0065

*Research*

## **Old and new challenges in using species diversity for assessing biodiversity**

**Alessandro Chiarucci<sup>1,\*</sup>, Giovanni Bacaro<sup>1</sup> and Samuel M. Scheiner<sup>2</sup>**

<sup>1</sup>*Biocomet, Biodiversity and Conservation Network, Department of Environmental Science 'G. Sarfatti',  
University of Siena, 53100 Siena, Italy*

<sup>2</sup>*Division of Environmental Biology, National Science Foundation, Arlington, VA 22230, USA*

# Species sampling issues in protected areas

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Phil. Trans. R. Soc. B (2011) 366, 2426–2437  
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Research

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- number of sampling units

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- number of sampling units
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- statistical population of concern
- operational definition of a species community



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- number of sampling units
- spatial placement of the sampling units
- statistical population of concern
- operational definition of a species community
- **labor intensiveness and costs**

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Phil. Trans. R. Soc. B (2011) 366, 2426–2437  
doi:10.1098/rstb.2011.0069

Research

## Old and new challenges in using species diversity for assessing biodiversity

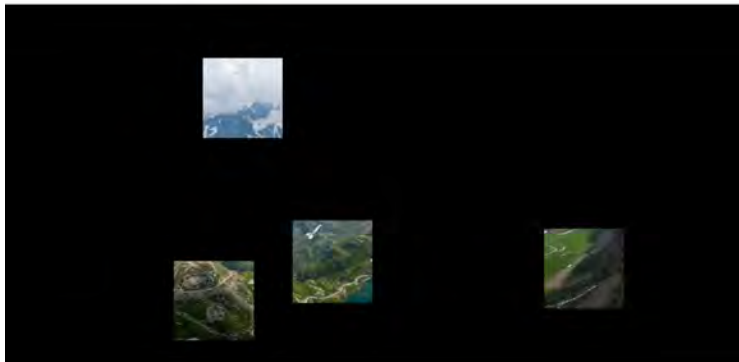
Alessandro Chiarucci<sup>1,\*</sup>, Giovanni Bacaro<sup>1</sup> and Samuel M. Scheiner<sup>2</sup>

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- number of sampling units
- spatial placement of the sampling units
- statistical population of concern
- operational definition of a species community
- **labor intensiveness and costs**
- **a small fraction of a study area may be sampled**

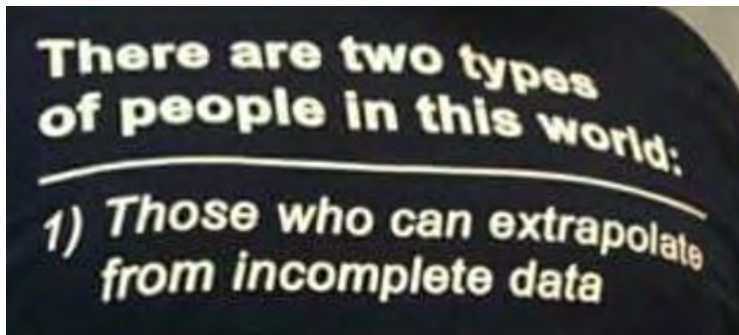
# Species sampling issues in protected areas



# The importance of extrapolation



# The importance of extrapolation



# Aim

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Proposing solutions to evaluate biodiversity change in space and time based on:

- **Virtual communities** as neutral models to test bio- and eco-logical theories before they are applied to empirical case studies
- **Remote sensing proxies** to allow a global coverage in space and time, enabling a more efficient management and planning of protected areas

# Aim

## Trends in Ecology & Evolution

Letter

Cell  
PRESS

### Let the four freedoms paradigm apply to ecology

Duccio Rocchini and Markus Neteler

Fondazione Edmund Mach, Research and Innovation Centre, Department of Biodiversity and Molecular Ecology, Via E. Mach 1,  
38010 S. Michele all'Adige (TN), Italy

In our view, the explicit use of Free and Open Source Software (FOSS) with **availability of the code** is essential for **completely open science**: 'scientific communication relies on evidence that cannot be entirely included in publications'; but '**anything less than the release of source programs is intolerable for results that depend on computation**' [3].

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# Virtual communities

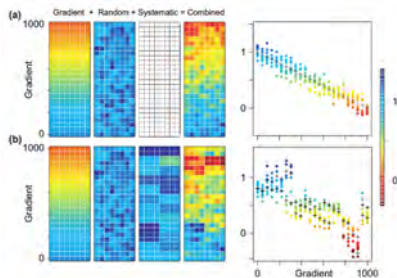


Methods in Ecology and Evolution 2015

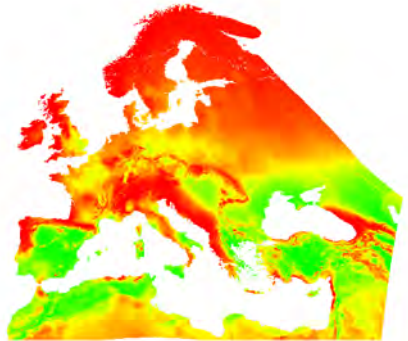
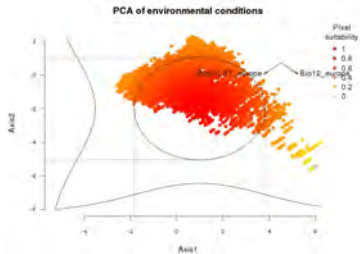
doi: 10.1111/2041-210X.12495

## Optimizing sampling approaches along ecological gradients

Andreas H. Schweiger<sup>1\*</sup>, Severin D. H. Irl<sup>1</sup>, Manuel J. Steinbauer<sup>1,2</sup>, Jürgen Dengler<sup>3,4</sup> and Carl Beierkuhnlein<sup>1</sup>



# Virtual communities



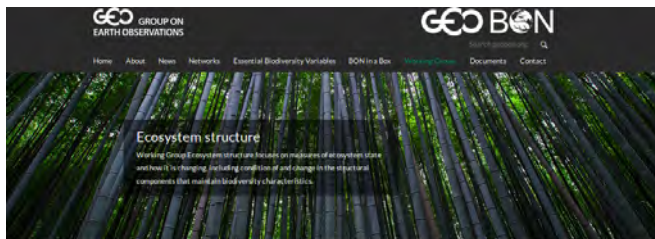
Garzon-Lopez, C.X., Bastin, L., Foody, G.M., Rocchini, D. (2016). A virtual species set for robust and reproducible Species Distribution Modelling tests. *Data in Brief*, 7: 476-479.

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# Spectral variation hypothesis



The screenshot shows the top section of the GEO BON website. On the left is the GEO logo and the text 'GROUP ON EARTH OBSERVATIONS'. On the right is the GEO BON logo with a search bar below it. A navigation menu includes 'Home', 'About', 'News', 'Networks', 'Essential Biodiversity Variables', 'BON In a Box', 'Working Groups', 'Documents', and 'Contact'. The 'Working Groups' link is highlighted in red. Below the navigation is a large banner image of a forest canopy with a semi-transparent text box. The text box contains the title 'Ecosystem structure' and a paragraph: 'Working Group Ecosystem structure focuses on measures of ecosystem state and how it is changing, including condition of and change in the structural components that maintain biodiversity characteristics.'

## Ecosystem structure



The activities of this new working group are closely related to those of the former WGSJ but with a specific focus on characterizing Ecosystem Structure. In general, the WG focuses on measures of ecosystem state and how it is changing, including condition of and change in the structure of components that maintain biodiversity characteristics. The WG develops new techniques and algorithms for earth observation from space to characterize ecosystem structure and its change over time. Activities on Ecosystem function as well as species population and abundance related to EO will be coordinated with the Ecosystem Structure working group, particularly in regard to RS-EVA.

### About

→ Learn

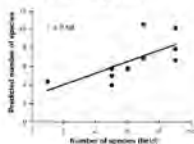


Andrew K. Skidmore  
University of Twente, Enschede

# Spectral variation hypothesis

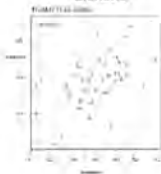
**Foody & Cutler**  
(Ecol. Model., 2006)

Vascular plants



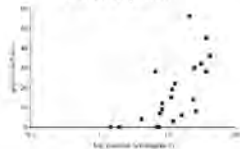
**Waser et al.**  
(Comm. Ecol., 2007)

Lichens



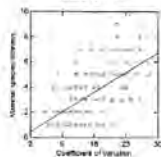
**Rocchini**  
(Remote Sens. Environ., 2007)

Vascular plants

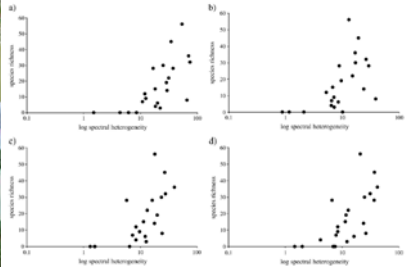
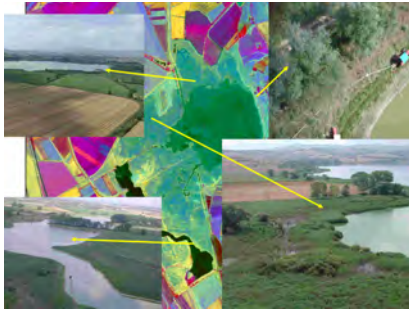


**Oindo & Skidmore**  
(Int. J. Remote Sens., 2002)

Mammals

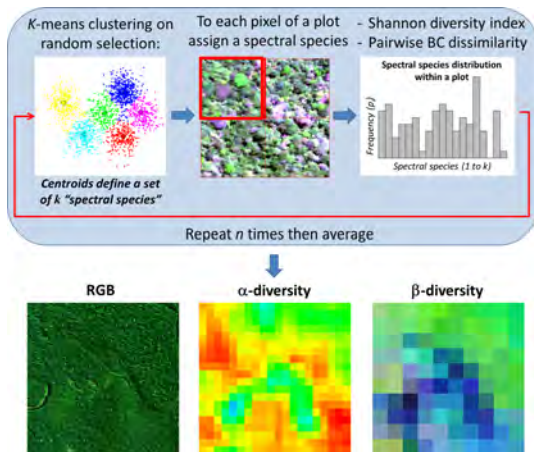


# Spectral variation hypothesis in protected areas



Rocchini, D. (2007). Effects of spatial and spectral resolution in estimating ecosystem alpha-diversity by satellite imagery. *Remote Sensing of Environment*, 111: 423-434.

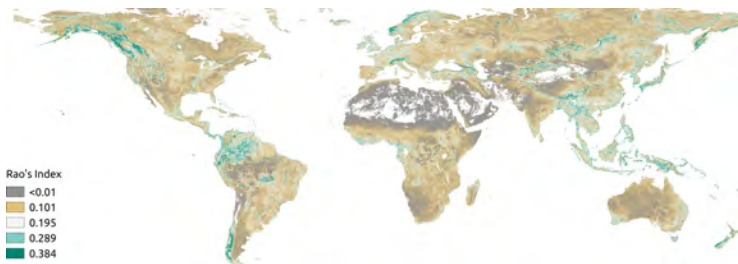
# Spectral species concept



Féret and Asner (Ecol. Appl., 2014)

## Rao's Q: first map at worldwide scale

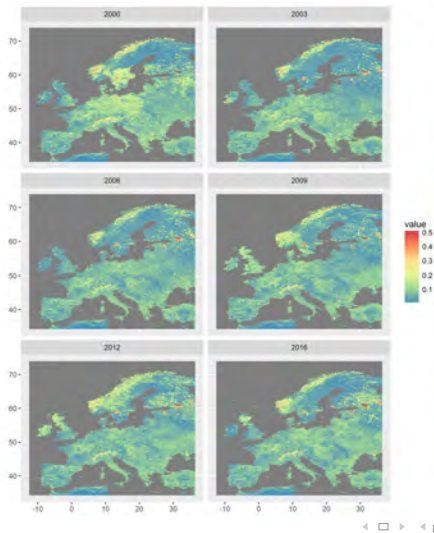
$$Q = \sum \sum d_{ij} \times p_i \times p_j \quad (1)$$



Rocchini et al. (Ecol. Indic., 2018)



# Multitemporal diversity sets



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# Multitemporal ancillary sets



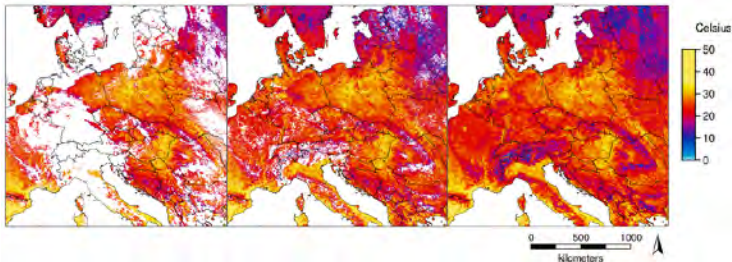
*remote sensing*



Article

## A New Fully Gap-Free Time Series of Land Surface Temperature from MODIS LST Data

Markus Metz <sup>1</sup>, Verónica Andreo <sup>2</sup> and Markus Neteler <sup>1,\*</sup>



# Promoting computational ecology in a FOSS environment

Received: 1 May 2017 | Accepted: 23 May 2017

DOI: 10.1111/2041-210X.12827

## APPLICATION

Methods in Ecology and Evolution 

## *r.pi*: A GRASS GIS package for semi-automatic spatial pattern analysis of remotely sensed land cover data

Martin Wegmann<sup>1</sup> | Benjamin F. Leutner<sup>1</sup> | Markus Metz<sup>2</sup> | Markus Neteler<sup>3</sup> | Stefan Dech<sup>1,4</sup> | Duccio Rocchini<sup>2,5,6</sup>

<sup>1</sup>Department of Remote Sensing, University of Wuerzburg, Wuerzburg, Germany

<sup>2</sup>Departments of Biodiversity and Molecular Ecology, Fondazione Edmund Mach, Research and Innovation Centre, S. Michele all'Adige, Italy

<sup>3</sup>Mundialis GmbH & Co. KG, Bonn, Germany

<sup>4</sup>German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Weßling, Germany

<sup>5</sup>Center Agriculture Food Environment, University of Trento, S. Michele all'Adige, Italy

<sup>6</sup>Centre for Integrative Biology, University of Trento, Povo, Italy

### Correspondence

Duccio Rocchini  
Email: [duccio.rocchini@unitn.it](mailto:duccio.rocchini@unitn.it)

### Funding Information

### Abstract

1. Analysing the changing spatial patterns of landscapes due to climate change or anthropogenic impact is important for various disciplines. Land cover change and its resulting modification of spatial patterns in the landscape influence various geographical or ecological parameters. Changing formerly continuous into discontinuous ecosystems due to land cover conversion causes isolated fragments in the landscape. Maintaining the connectivity of a fragmented landscape is relevant for, e.g. in nutrient cycle, water-runoff or species population persistence.
2. Satellite imagery derived land cover can be used to analyse continuously the changing spatial arrangement of land cover types. However, analyses are computer intensive and require robust and efficient processing routines.
3. We developed a patch-based spatial analysis system (*r.pi*) integrated natively into a Free and Open Source GIS (GRASS GIS) to be able to analyse large amounts of satellite derived land cover data in a semi-automatic manner, and to ensure high reproduc-

# Promoting computational ecology in a FOSS environment

The screenshot shows the ESA Sentinel-2 website. At the top, there is a green header with the text "sentinel-2" on the left and the ESA logo on the right. Below the header is a dark navigation bar with the following items: "ESA", "OBSERVING THE EARTH", "COPERNICUS", and "SENTINEL-2".

Below the navigation bar, there is a "Colour vision" section with a link to "Introducing Sentinel-2". To the right of this is a breadcrumb trail: "ESA > Our Activities > Observing the Earth > Copernicus > Sentinel-2". A search bar is located in the top right corner.

On the left side, there are two main menu sections:

- Applications**
  - Plant health
  - Changing lands
  - Water bodies
  - Disaster mapping
- About the mission**
  - Facts and figures
  - Satellite constellation
  - Instrument
  - About the launch

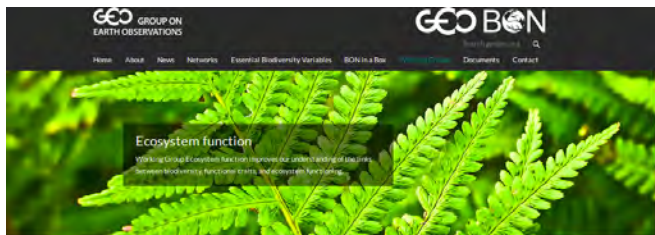
The central content area features a large satellite image of a forest with a circular inset showing a zoomed-in view. Below the inset is a blue box with the text "→ EARTH FROM SPACE" and a paragraph: "In the 25th edition, discover Canada's Reindeer Island - where we believe Santa Claus stops for a rest during his busy night before Christmas".

On the right side, there are two featured articles:

- "Sentinel-2 launch campaign blog" with a blue arrow icon.
- "The launch campaign in pictures" with a photo of a launch event.

At the bottom left, there is a partially visible section titled "Operations and data".

# Functional diversity



## Ecosystem function



Biodiversity is defined by the Convention on Biological Diversity as "the variability among living organisms", the ecological complexes in which they naturally occur, and the ways in which they interact with each other and with the physical environment. It is a fundamentally multidimensional concept that can be measured in terms of different components (genetic, population/species, and community/ecosystems); each of these components has compositional, structural and functional attributes which can be considered the three-dimensions of biodiversity. Organism-based metrics that count the number of distinct species in a defined area (species richness) are the most common groups used in biodiversity assessments.

### About

→ Lead

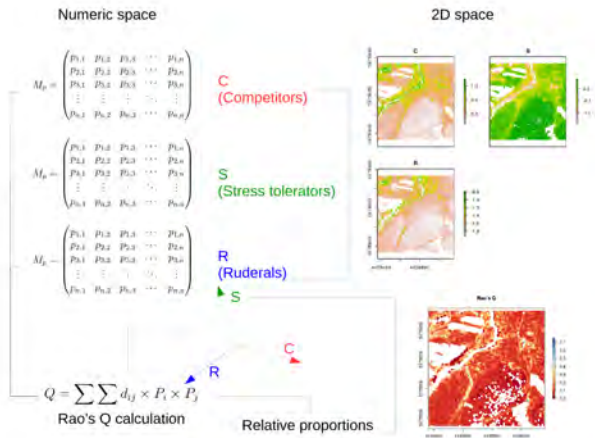


Nerina Petrone  
Zoological Society of London (ZSL)



Emily Nicholson  
Duke University

# Functional diversity



# Outlook

DOI: 10.1111/2041-210X.12941

**SPECIAL ISSUE ARTICLE**

Methods in Ecology and Evolution



## Measuring $\beta$ -diversity by remote sensing: A challenge for biodiversity monitoring

Duccio Rocchini<sup>1,2,3</sup> | Sandra Luque<sup>4</sup> | Nathalie Pettorelli<sup>5</sup> | Lucy Bastin<sup>6</sup> |  
Daniel Doktor<sup>7</sup> | Nicoló Faedi<sup>3,8</sup> | Hannes Fellhauer<sup>9</sup> | Jean-Baptiste Féret<sup>4</sup> |  
Giles M. Foody<sup>10</sup> | Yoni Gavish<sup>11</sup> | Sergio Godinho<sup>12</sup> | William E. Kunin<sup>13</sup> |  
Angela Lausch<sup>7</sup> | Pedro J. Leitão<sup>14,15</sup> | Matteo Marcantonio<sup>16</sup> | Markus Neteler<sup>17</sup> |  
Carlo Ricotta<sup>18</sup> | Sebastian Schmidtlein<sup>19</sup> | Petteri Vihervaara<sup>20</sup> |  
Martin Wegmann<sup>21</sup> | Harini Nagendra<sup>22</sup>



# Thanks!

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