FONDAZIONE EDMUND MACH

P.S&M 2013

Analisi spaziale in ambiente Open Source

Spatial Analysis in an Open Source environment

Duccio Rocchini

Fondazione Edmund Mach, Research and Innovation Centre

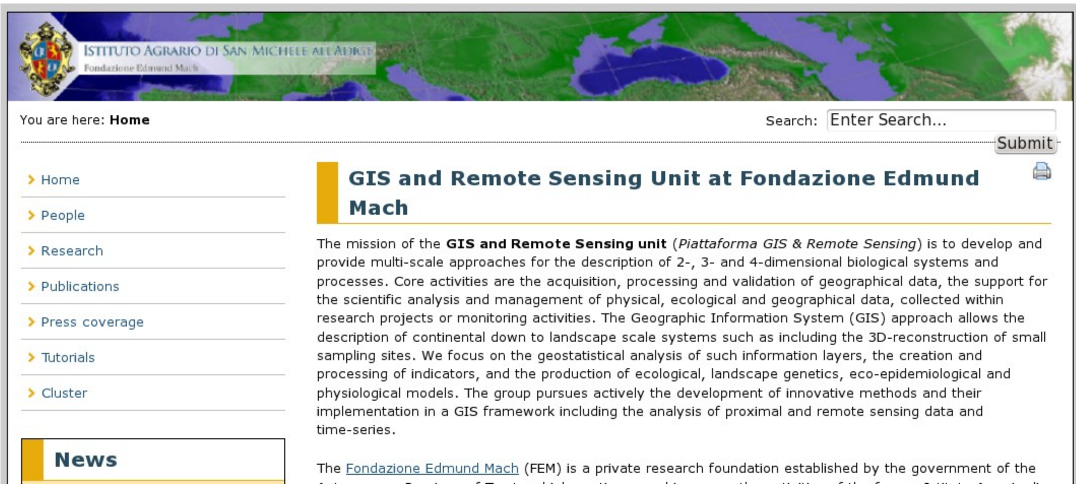
Department of Biodiversity and Molecular Ecology

GIS and Remote Sensing Unit

Via Mach 1, 38010 San Michele all'Adige (TN) - Italy

GIS & RS Platform

P.S&M 2013



GIS and Remote Sensing Unit at Fondazione Edmund Mach

The mission of the **GIS and Remote Sensing unit** (*Piattaforma GIS & Remote Sensing*) is to develop and provide multi-scale approaches for the description of 2-, 3- and 4-dimensional biological systems and processes. Core activities are the acquisition, processing and validation of geographical data, the support for the scientific analysis and management of physical, ecological and geographical data, collected within research projects or monitoring activities. The Geographic Information System (GIS) approach allows the description of continental down to landscape scale systems such as including the 3D-reconstruction of small sampling sites. We focus on the geostatistical analysis of such information layers, the creation and processing of indicators, and the production of ecological, landscape genetics, eco-epidemiological and physiological models. The group pursues actively the development of innovative methods and their implementation in a GIS framework including the analysis of proximal and remote sensing data and time-series.

The Fondazione Edmund Mach (FEM) is a private research foundation established by the government of the

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Contents lists available at SciVerse ScienceDirect
Environmental Modelling & Software
journal homepage: www.elsevier.com/locate/envsoft
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GRASS GIS: A multi-purpose open source GIS

Markus Neteler[a,*], M. Hamish Bowman[b], Martin Landa[c], Markus Metz[a]

[a] Biodiversity and Molecular Ecology Department, IASMA Research and Innovation Centre, Fondazione Edmund Mach, Via E. Mach 1, 38010 S. Michele all'Adige (TN), Italy
[b] Department of Marine Science, University of Otago, P.O. Box 56, Dunedin, New Zealand
[c] Department of Mapping and Cartography, Faculty of Civil Engineering, Czech Technical University in Prague, Thakurova 7, 166 29 Prague, Czech Republic

FEM-GIS cluster

The **FEM GIS cluster** consists of **300 nodes** with **610 Gb RAM** and **35 TB (raw) + 96TB (raw) disk space**.

The Dell Blades are equipped with 16Gb/32Gb/48Gb/64GB RAM; two blades are double-size, all connected via 10 Gb ethernet. The **file server** is a 4-Core Xeon 2.66GHz with 8Gb RAM.

What we do on this cluster

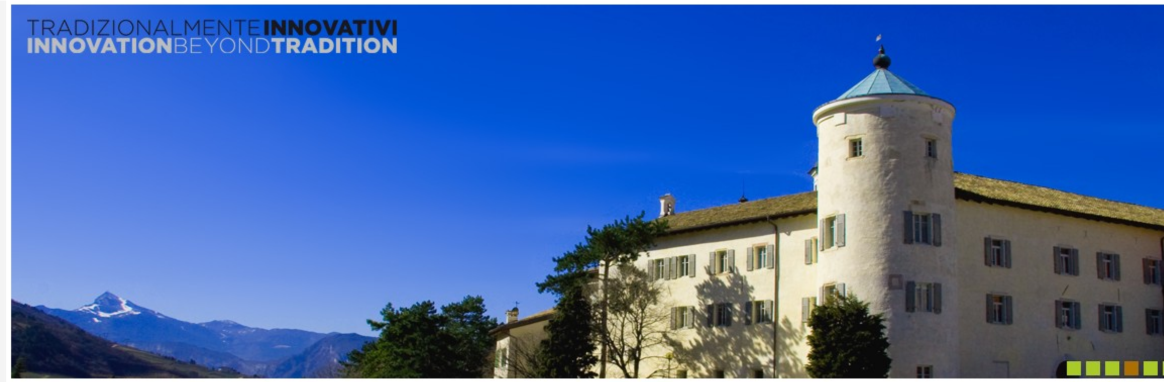
Our GIS and remote sensing projects require the creation of ecological indicators from vast GIS and remote sensing data bases. For example, we postprocess and reconstruct time series of MODIS satellite data and generate photoperiod maps from high resolution elevation maps which are relevant to distribution modelling of parasites. See our project pages (left menu) to learn more about results and publications. Topics are

- *modeling the potential distribution of Aedes albopictus*
- *behavioural gradients in partial migration of roe deer*

http://gis.cri.fmach.it/

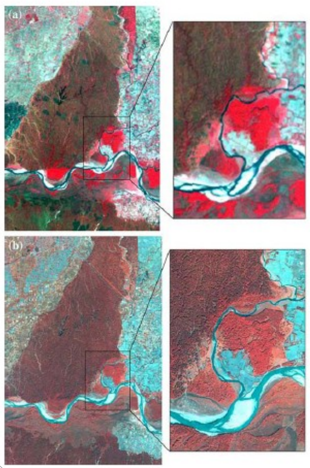
The GIS & Remote Sensing group at FEM

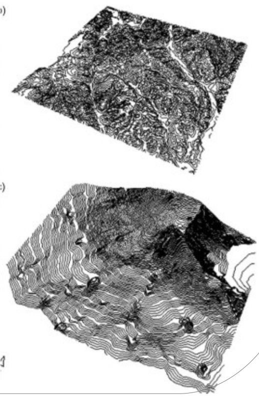
- Chief:
  - Markus Neteler (Germany)
- Technicians
  - Luca Delucchi (IT)
- Researchers:
  - Duccio Rocchini (IT)
  - Roberto Zorer (IT)
- Post-Docs:
  - Markus Metz (Germany)
- PhD students:
  - Sajid Pareeth (India)
  - Matteo Marcantonio (IT)
- Master students:
  - Francesca Bussola (IT)
- Visiting Professors:
  - Gertrud Schaab (Germany)
- Visiting Researchers:
  - Veronica Andreo (Argentina)
  - Pablo Zader (Argentina)
  - Marin Landa (Czech Republic)
  - Vaclav Petras (Czech Republic)
  - Anna Kratochvílová (Czech Republic)
  - Roberta Fagandini (IT)
  - Yann Chemin (France)



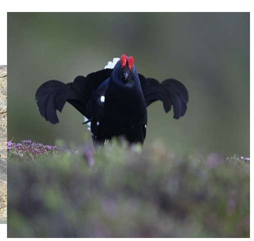
Free and Open Source algorithms

GEOGRAPHICAL DATA





FIELD DATA



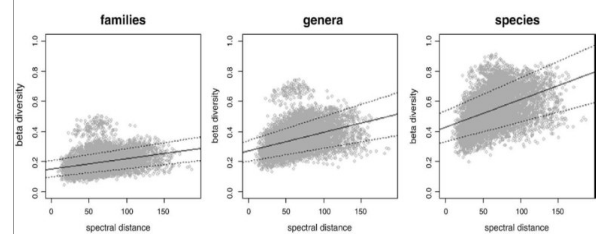
SPATIAL STATISTICS

$$x_c, y_c, \ldots, n_c = \frac{\sum_{i=1}^{m} w_i x_i, w_i y_i, \ldots, w_i n_i}{i}$$

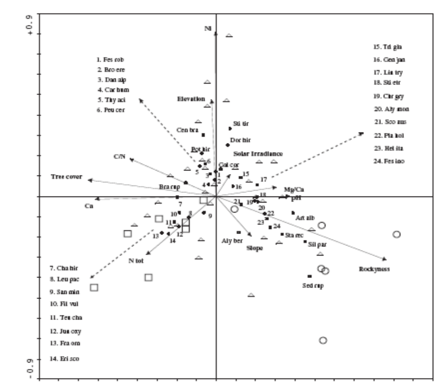
$$V(\hat{T}_2) = M_1(M_1-1)\sum_{l=1}^{L}\sum_{k=1}^{L_1}\sigma^2_{l(k)} + M_1 M_2(M_2-1)\sum_{l=1}^{L}\sum_{h=1}^{N_1}\sum_{k=1}^{L_2}\sigma^2_{lh(k)}$$

QUANTITATIVE OUTPUT

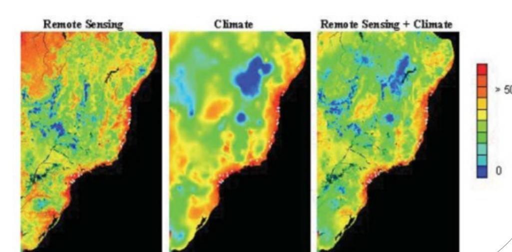
Temporal trends



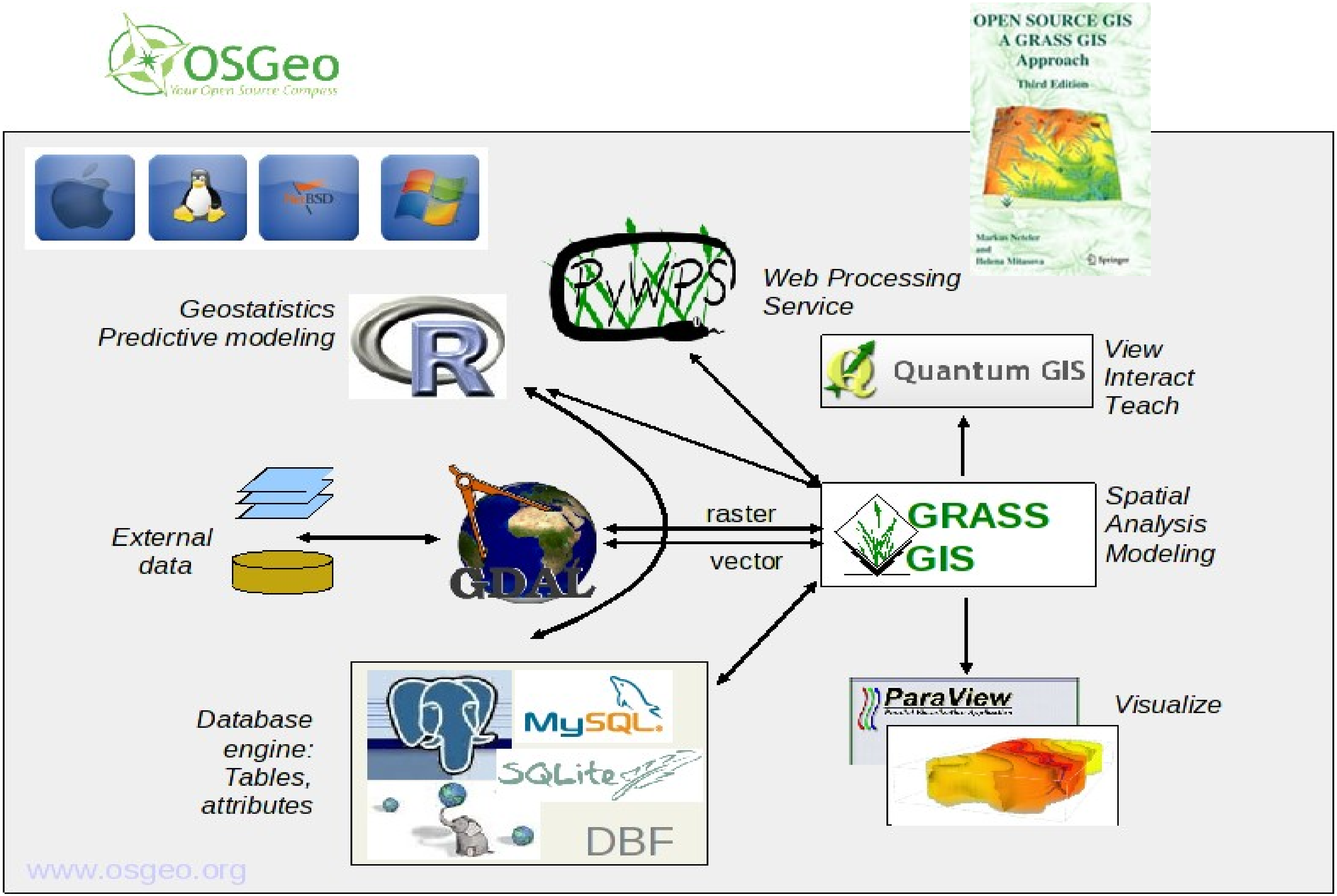
Ecological relations



Species distribution models



GRASS GIS


OSGeo
Your Open Source Compass
OPEN SOURCE GIS
A GRASS GIS
Approach
Third Edition
Web Processing
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PyWPS
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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].

Ecological Informatics

Ecological Informatics 5 (2010) 318–329

Contents lists available at ScienceDirect

Ecological Informatics

journal homepage: www.elsevier.com/locate/ecolinf

Remotely sensed spectral heterogeneity as a proxy of species diversity: Recent advances and open challenges

Duccio Rocchini [a,*], Niko Balkenhol [b], Gregory A. Carter [c,d], Giles M. Foody [e], Thomas W. Gillespie [f], Kate S. He [g], Salit Kark [h], Noam Levin [i], Kelly Lucas [c], Miska Luoto [j], Harini Nagendra [k,l], Jens Oldeland [m,n], Carlo Ricotta [o], Jane Southworth [p], Markus Neteler [a]

Finding ecological proxies of species diversity is important for developing effective management strategies and conservation plans for natural areas at various spatial scales, whether local, regional or global.

Species information has traditionally been collected directly from the field prior to biodiversity assessment.

Standardized field sampling or ground surveys, whether of plant or animal communities, are **time-consuming and costly** despite being the most accurate methods for collecting species diversity data.

Therefore, **a priori knowledge of areas with higher diversity** means that attention can be focused on them, thus helping to minimizing monitoring times and costs.

Higher complexity = higher biodiversity

P.S&M 2013

The Earth and Space Foundation
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INFORMAZIONI UTILI A DEFINIRE STRATEGIE DI PROTEZIONE AMBIENTALE

La biodiversità si controlla dal satellite

Duccio Rocchini, primo italiano premiato da fondazione Usa per il monitoraggio degli habitat dallo spazio

MILANO - Ambiente: cosa proteggere? Ce lo dice il satellite. Dalle enormi matrici numeriche provenienti dallo spazio è possibile ricavare mappe territoriali dettagliate. Queste immagini, opportunamente elaborate, possono essere utilizzate per individuare le zone a più alta biodiversità, ipotizzare l'andamento dei cambiamenti climatici e raccogliere informazioni utili a definire strategie di protezione ambientale. Ne sa qualcosa Duccio Rocchini, ricercatore della Fondazione Edmund Mach appena premiato dalla Earth and Space Foundation per essersi distinto nel campo assai specialistico della «stima della biodiversità da immagini satellitari».

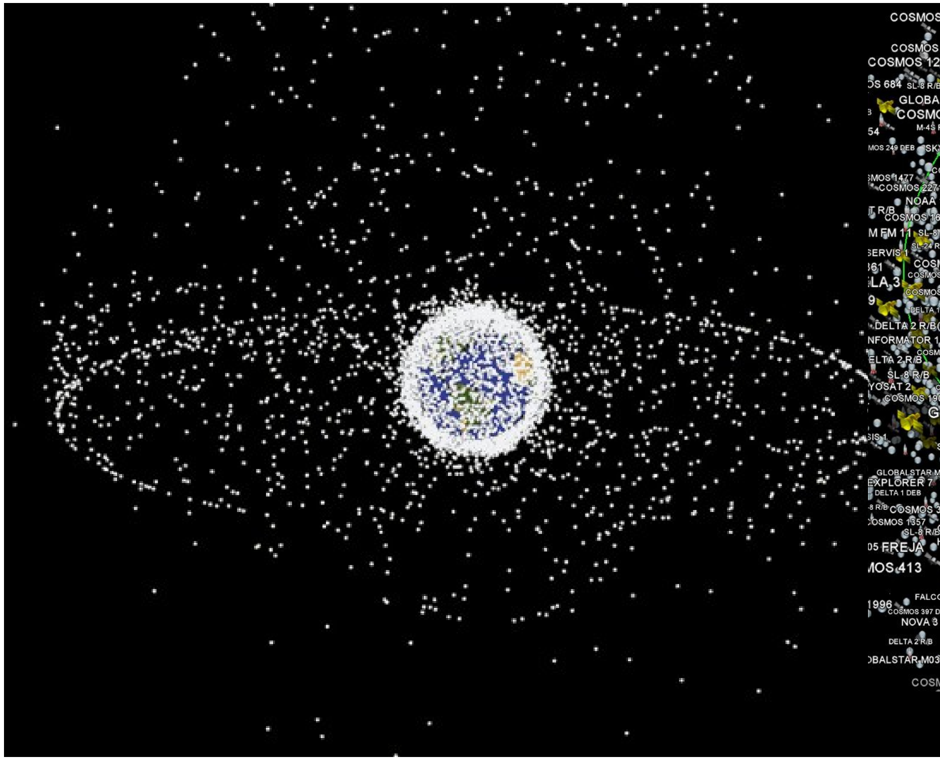
TELERILEVAMENTO - Il ragionamento pare semplice. Rocchini utilizza i meccanismi propri del telerilevamento, che trasformano in pixel i dati numerici prodotti inizialmente dal satellite. Un pixel

Crisis in Earth Observation
Scott Goetz, *et al.*
Science **315**, 1767 (2007);
DOI: 10.1126/science.1142466

"John Marburger, director of the **White House Office of Science** and Technology Policy, apparently **agrees that a strategy for ensuring future Earth observations is badly needed**. In response to a memo he issued in April 2005, a Future of Land Imaging Interagency Working Group was formed. That group's draft recommendations are due out this year. In the meantime, India, China, and Brazil are launching Landsat-class satellites. Others countries, such as Libya and Nigeria, are experimenting with microsatellite systems for Earth observation."

Remote sensing could be the most effective means for predicting species diversity since it can repeatedly allow a synoptic view of an area at regular time intervals

RS & Biodiversity



Low Earth orbit ~ 250-600 km from earth - International space station

Geosynchronous stationary orbit ~ 35,785 km from earth - communications satellites

~ 20,000 km from earth - Global Positioning System (GPS) satellites

Free data

NASA's Global Orthorectified Landsat Data Set

Compton J. Tucker, Denelle M. Grant, and Jon D. Dykstra

Abstract
NASA has sponsored the creation of an orthorectified and geodetically accurate global land data set of Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper data, from the 1970s, circa 1990, and circa 2000, respectively, to support a variety of scientific studies and educational purposes. This is the first time a geodetically accurate

tens of meters spanning the last 30 years. They constitute indispensable history of land-surface state. Data at these tial resolutions can provide a high potential mapping acc of natural vegetation and alterations to it, if and only if h accurate scene-to-scene within- and among-date registrat achieved. Otherwise, misregistration errors between or a dates are confused with land-cover change and resulting

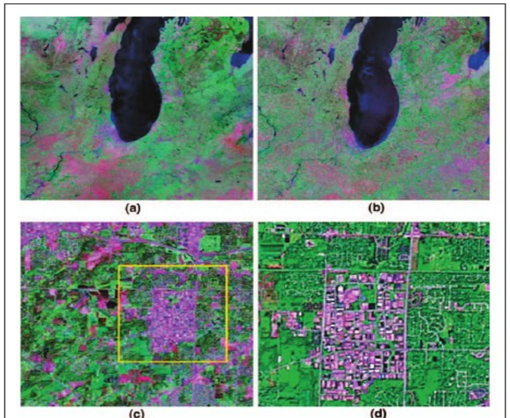
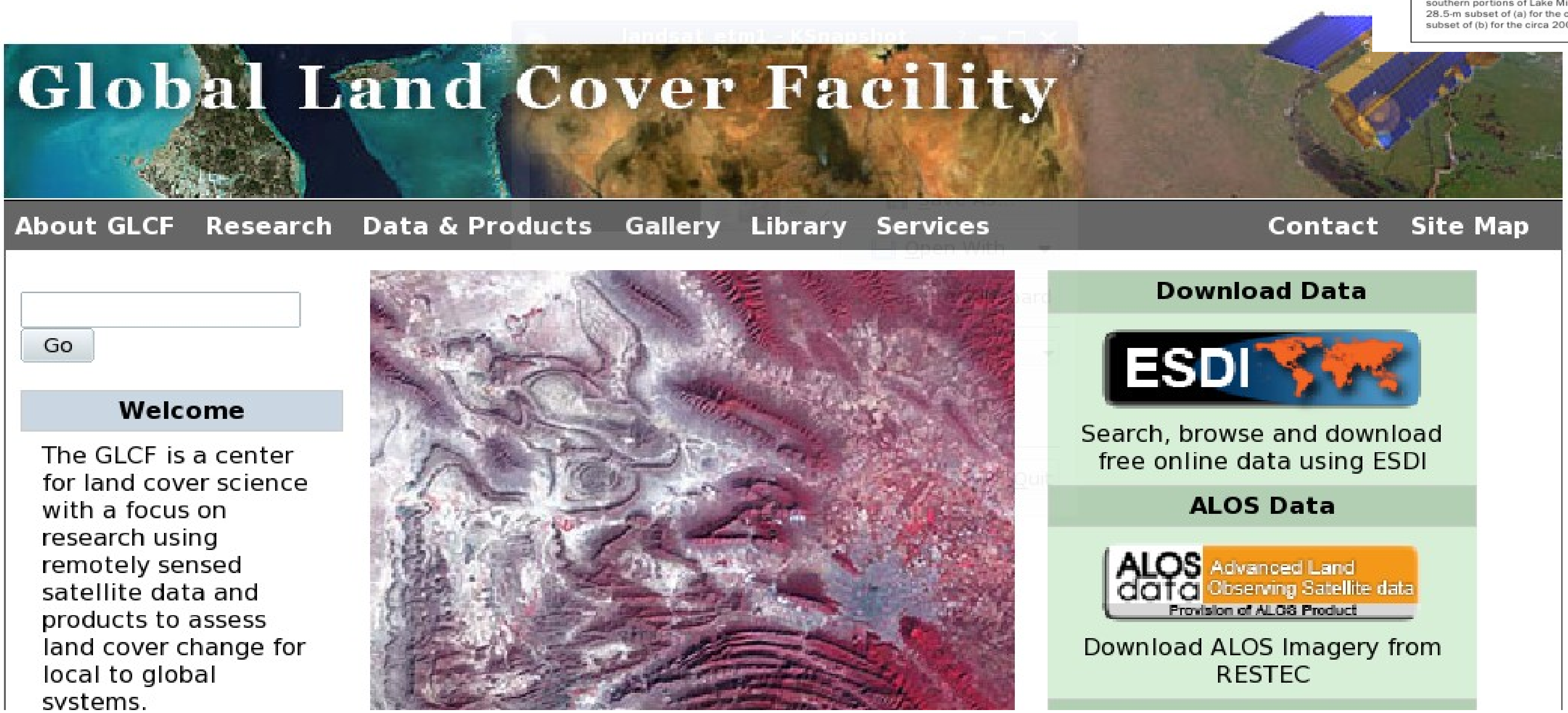
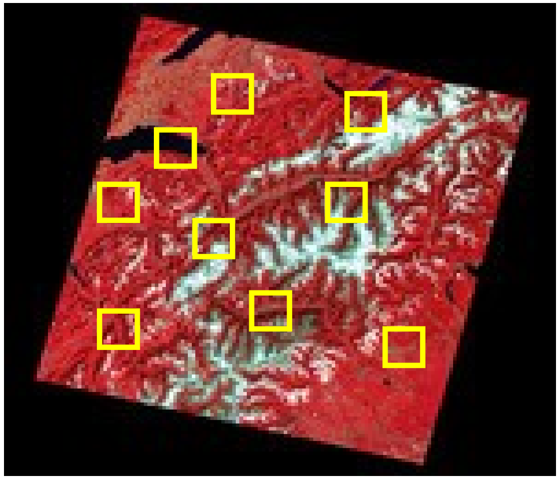


Plate 5. Circa 1990 epoch (a) and circa 2000 epoch (b) Landsat mosaic products over the southern portions of Lake Michigan and adjacent areas of the United States. A full-resolution 28.5-m subset of (a) for the circa 1990 epoch is shown as (c) and a full-resolution 14.25-m subset of (b) for the circa 2000 epoch is shown as (d).



Ecological Informatics and species diversity



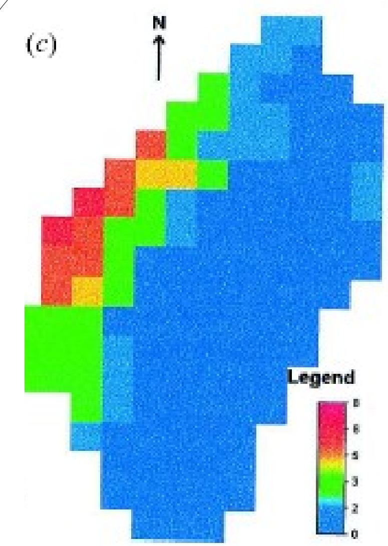
y = species richness
x = spectral variability

$y=a+bx$

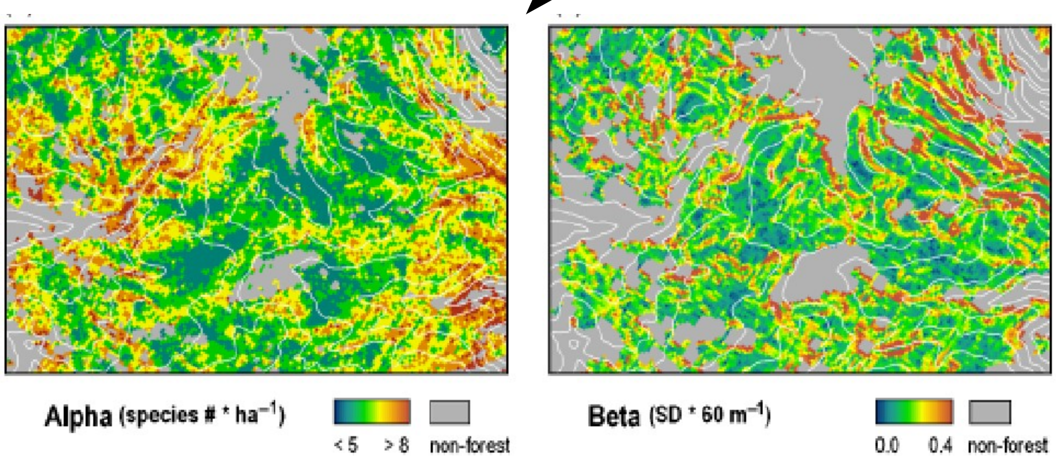
$y=a+b\ln(x)$

$y=a*e^{cx}$

Field sampling → Model selection



Species richness map
(Oindo & Skidmore, Int. J. Remote Sens., 2002)



Feilhauer & Schmidtlein, Applied Veg. Sci., 2009,

RS & invasive species

P.S&M 2013

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Diversity and Distributions A Journal of Conservation Biogeography

Diversity and Distributions

Edited By: David M. Richardson
Impact Factor: 4.248
ISI Journal Citation Reports © Ranking: 2010: 5/33 (Biodiversity Conservation); 5/34 (Biodiversity Conservation); 25/129 (Ecology)
Online ISSN: 1472-4642
Associated Title(s): Global Ecology and Biogeography, Journal of Biogeography

Most Accessed

Most read articles September-December 2011

A statistical explanation of MaxEnt for ecologists
Diversity and Distributions
Volume 17, Issue 1
Jane Elith, Steven J. Phillips, Trevor Hastie, Miroslav Dudík, Yung En Chee, Colin J.
Abstract | References | Full Text: HTML, PDF

Trees and shrubs as invasive alien species – a global review
Diversity and Distributions
Volume 17, Issue 5
David M. Richardson, Marcel Rejmánek
Abstract | References | Full Text: HTML, PDF

Global amphibian declines: sorting the hypotheses
Diversity and Distributions
Volume 9, Issue 2
James P. Collins, Andrew Storfer
Abstract | References | Full Text: HTML, PDF

Spreading messages about invasives
Diversity and Distributions
Early View
Amanda D. Rodewald
Abstract | References | Full Text: HTML, PDF

Benefits of hyperspectral remote sensing for tracking plant invasions
Diversity and Distributions
Volume 17, Issue 3
Kate S. He, Duccio Rocchini, Markus Neteler, Harini Nagendra
Abstract | References | Full Text: HTML, PDF

A Journal of Conservation Biogeography

Diversity and Distributions, (Diversity Distrib.) (2011) **17**, 381–392

BIODIVERSITY REVIEW

Benefits of hyperspectral remote sensing for tracking plant invasions

Kate S. He[1]*, Duccio Rocchini[2], Markus Neteler[2] and Harini Nagendra[3,4]

[1]*Department of Biological Sciences, Murray State University, Murray, KY 42071, USA,* [2]*Fondazione Edmund Mach, Research and Innovation Centre, Department of Biodiversity and Molecular Ecology, GIS and Remote Sensing Unit, Via E. Mach 1, 38010 S. Michele all'Adige, TN, Italy,* [3]*Center for the Study of Institutions, Population, and Environmental Change, Indiana University, 408 N. Indiana Avenue, Bloomington, IN 47408, USA,* [4]*Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Srirampura, Jakkur Post, Bangalore 560064, India*

ABSTRACT

Aim We aim to report what hyperspectral remote sensing can offer for invasion ecologists and review recent progress made in plant invasion research using hyperspectral remote sensing.

Location United States.

Methods We review the utility of hyperspectral remote sensing for detecting, mapping and predicting the spatial spread of invasive species. We cover a range of topics including the trade-off between spatial and spectral resolutions and classification accuracy, the benefits of using time series to incorporate phenology in mapping species distribution, the potential of biochemical and physiological properties in hyperspectral spectral reflectance for tracking ecosystem changes caused by invasions, and the capacity of hyperspectral data as a valuable input for

RS & invasive species

Diversity and Distributions, (Diversity Distrib.) (2011) **17**, 381–392

BIODIVERSITY REVIEW

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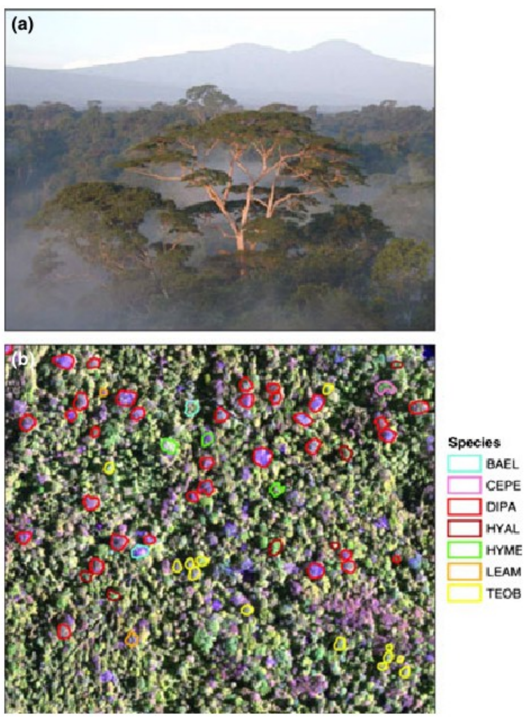
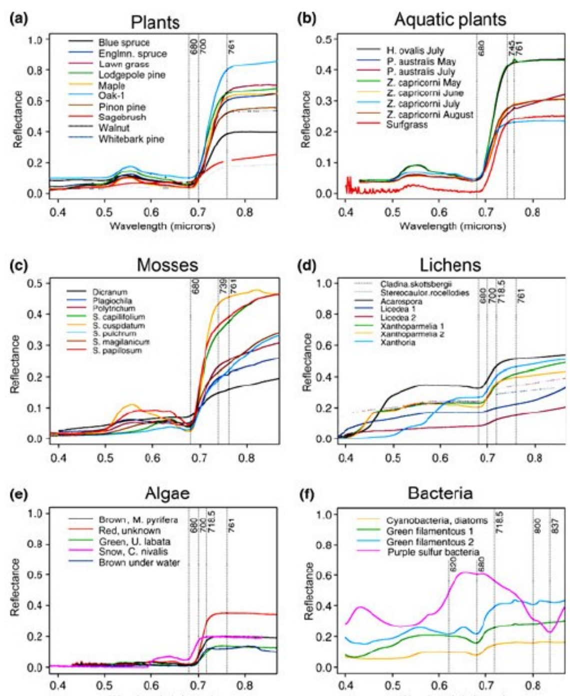
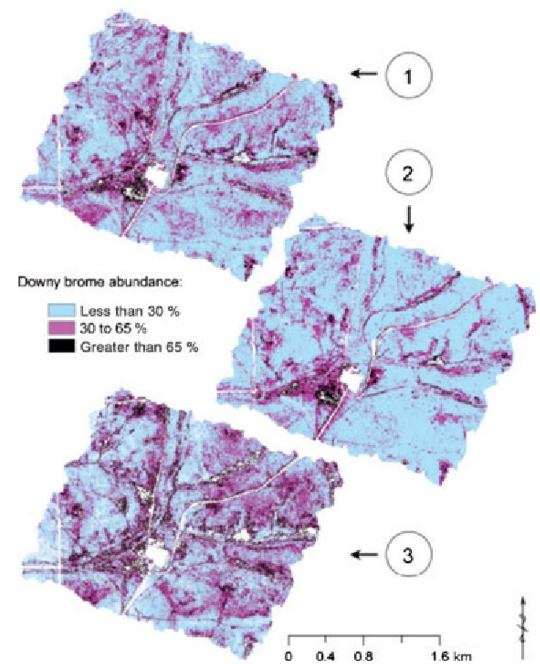


Clark et al., 2005
Example of 1.6-m spatial resolution
HYDICE hyperspectral imagery



Kiang et al., 2007
Major groups of photosynthetic
organisms have distinct spectral signatures
in the visible and near infrared spectrum,



Noujdina & Ustin (2008)
The maps of downy brome (Bromus tectorum) abundance predicted by the analysis of three different data sets

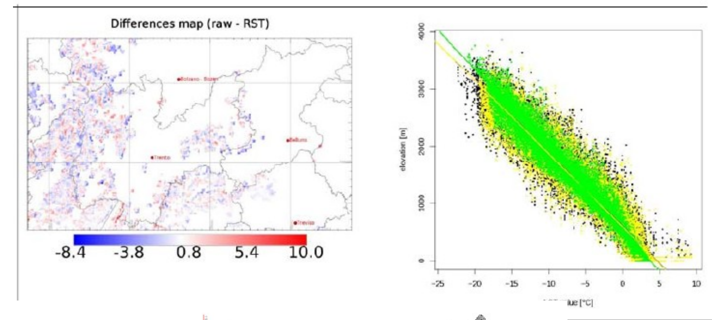
P.S&M 2013

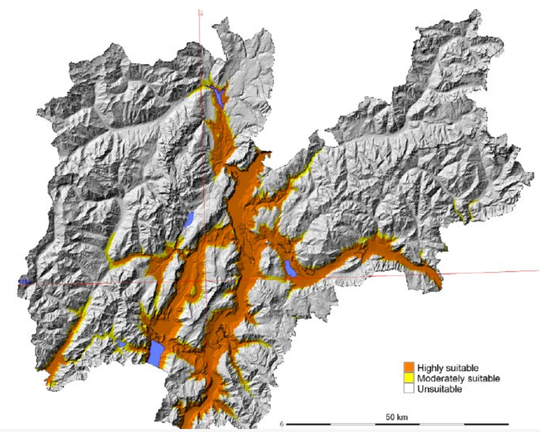
OPEN ACCESS
Remote Sensing
ISSN 2072-4292
www.mdpi.com/journal/remotesensing

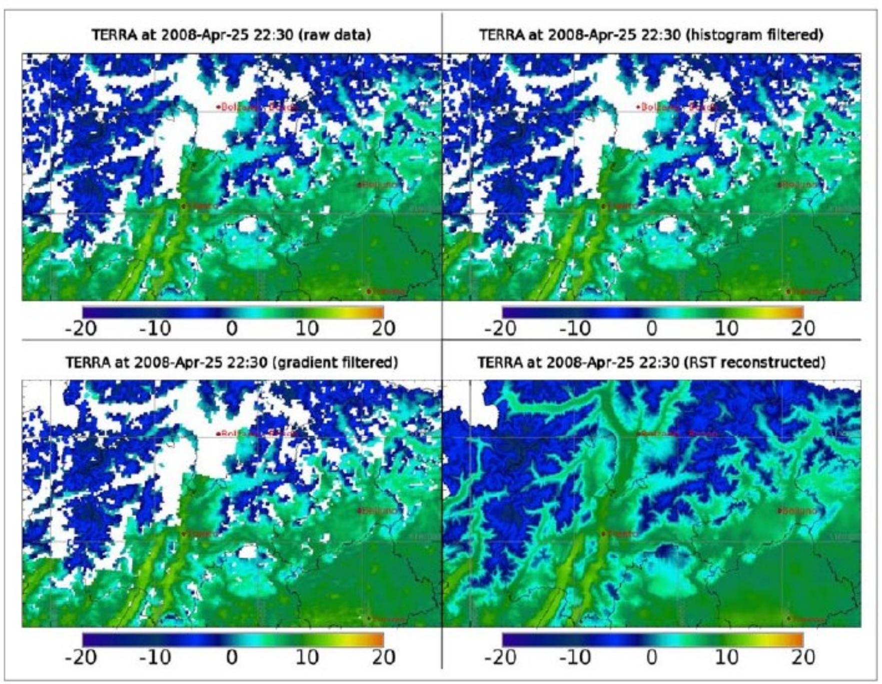
Article

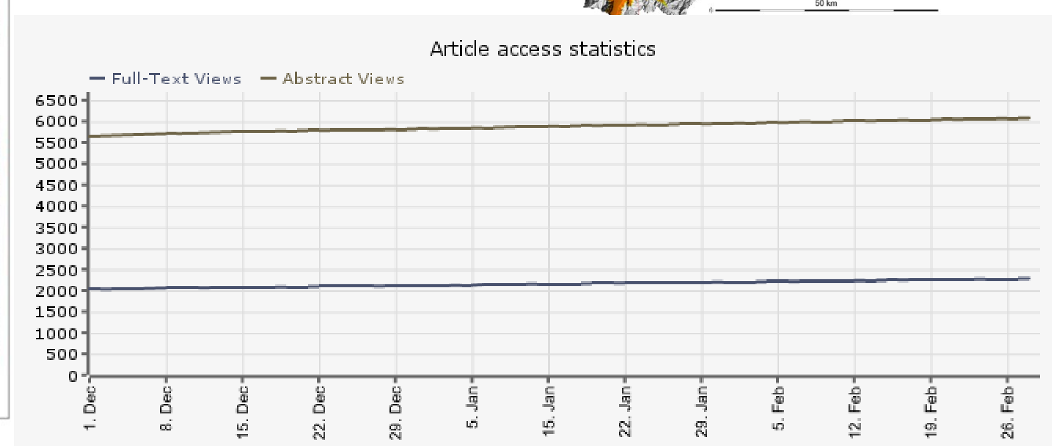
Estimating Daily Land Surface Temperatures in Mountainous Environments by Reconstructed MODIS LST Data

Markus Neteler









BIOLOGICAL CONSERVATION 132 (2006) 76–87

available at www.sciencedirect.com

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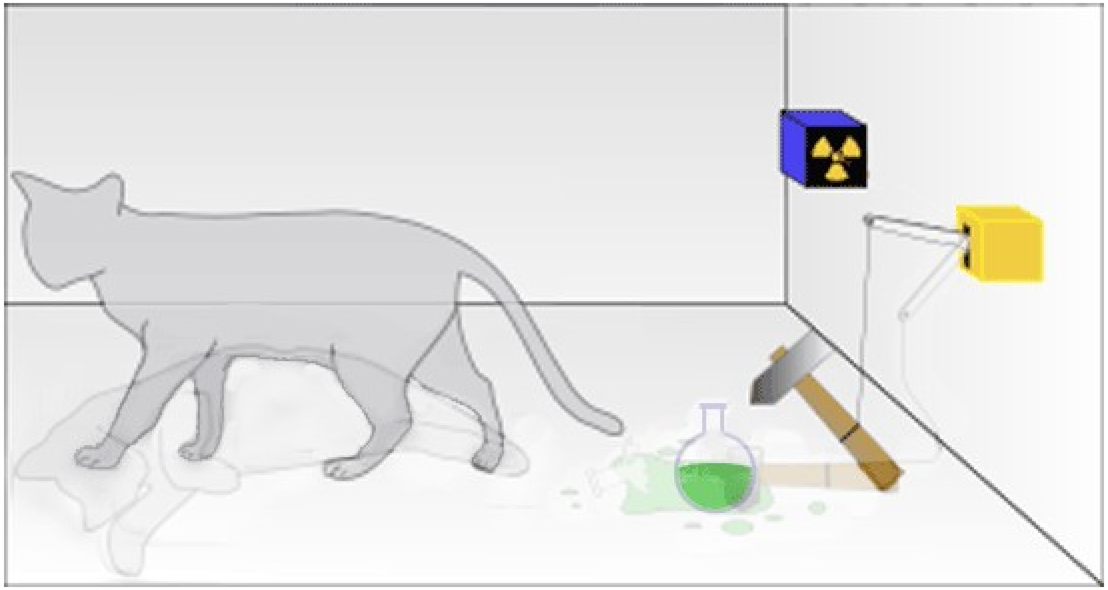
journal homepage: www.elsevier.com/locate/biocon

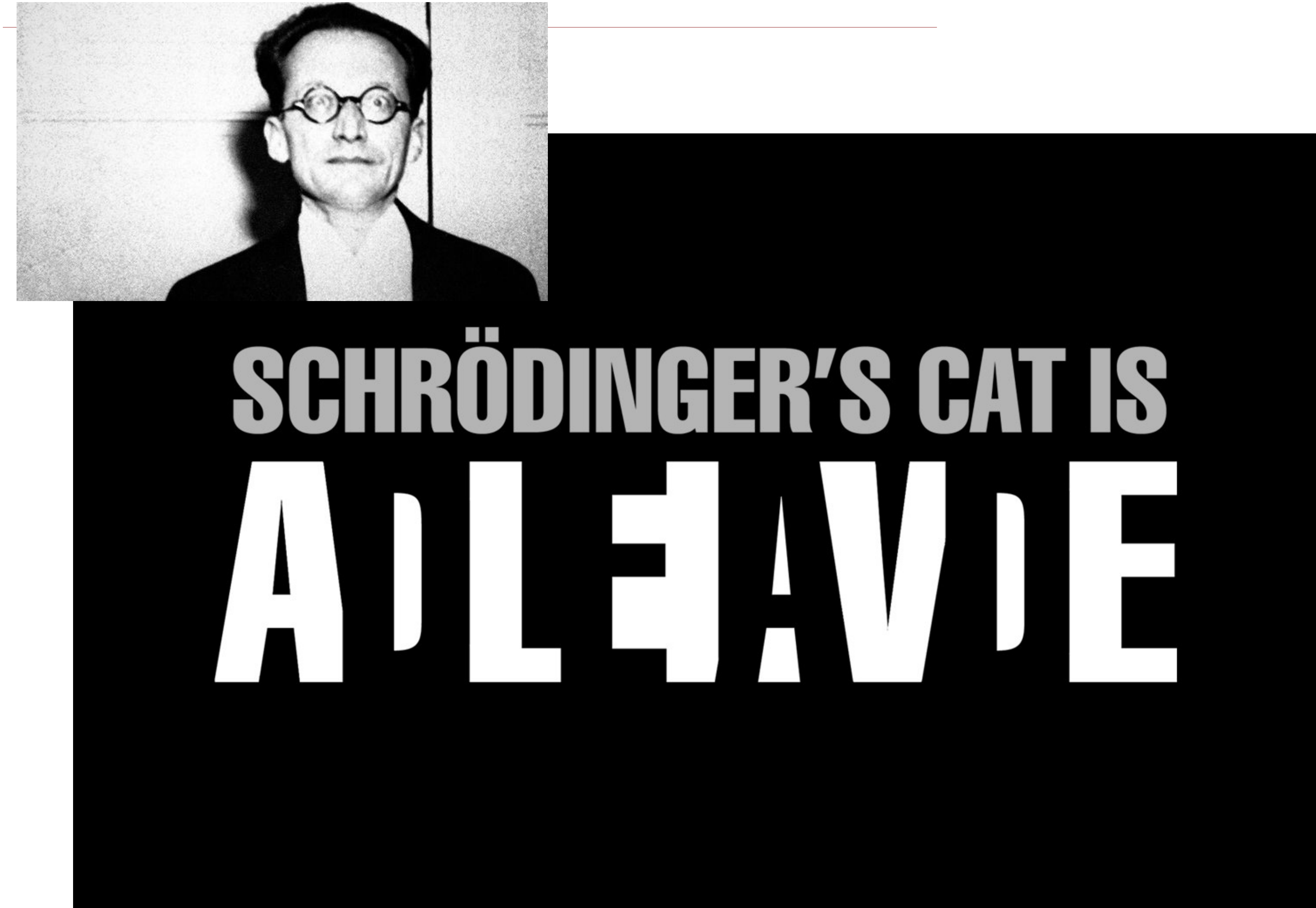
The ecological effectiveness of protected areas: The United Kingdom

Kevin J. Gaston[a,], Kevin Charman[b], Sarah F. Jackson[a], Paul R. Armsworth[a], Aletta Bonn[c], Robert A. Briers[d], Claire S.Q. Callaghan[e], Roger Catchpole[f], John Hopkins[g], William E. Kunin[e], Jim Latham[h], Paul Opdam[i], Rob Stoneman[j], David A. Stroud[k], Ros Tratt[l]*

- **Problem [1]:**
  How to measure the effectiveness of protected areas?
- **Solution [1]:**
  Mapping species or habitats of interest
- **Problem [2]**:
  The cat in the Schrödinger box

- A cat, along with a flask containing a poison and a radioactive source, is placed in a sealed box. If an internal Geiger counter detects radiation, the flask is shattered, releasing the poison that kills the cat. The Copenhagen interpretation of quantum mechanics implies that after a while, the cat is simultaneously alive and dead. Yet, when we look in the box, we see the cat either alive or dead, not both alive and dead.




SCHRÖDINGER'S CAT IS

Acta Appl Math
DOI 10.1007/s10440-012-9786-z

Mathematical Models in Landscape Ecology: Stability Analysis and Numerical Tests

**Federica Gobattoni · Giuliana Lauro ·
Roberto Monaco · Raffaele Pelorosso**

'The European Landscape Convention [1] encourages all European countries to define their landscape quality objectives on the ground of management and planning of territory.

The new proposed model studies equilibrium conditions for landscapes by analyzing spatial data at the level of each LU. It works with two state variables, allowing to point out **possible local fragmentation** or local critical condition in terms of ecological functionality. This new

usually available to land managers. Further effort is needed to accurately test this new dynamical model to real-life applications in order to develop a more helpful tool for “what if” **scenarios analysis** and planning strategy conception.

Acta Appl Math
DOI 10.1007/s10440-012-9786-z

Mathematical Models in Landscape Ecology: Stability Analysis and Numerical Tests

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Roberto Monaco · Raffaele Pelorosso**

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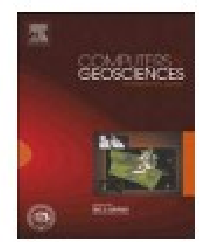

Uncertainty in ecosystem mapping by remote sensing

Duccio Rocchini [a,*], Giles M. Foody [b], Harini Nagendra [c,d], Carlo Ricotta [e], Madhur Anand [f], Kate S. He [g], Valerio Amici [h], Birgit Kleinschmit [i], Michael Förster [i], Sebastian Schmidtlein [j,k], Hannes Feilhauer [l], Anne Ghisla [a], Markus Metz [a], Markus Neteler [a]

Imperfect data

- Observer bias and **species misidentifications**.
- Species records derived from museum or herbarium collections with no planned sampling scheme. **Uncertain coordinates for localities, e.g. toponyms**. positional error associated to presence records.
- **Different resolutions** of input data.
- Bias in the surveyed areas towards **classical localities of particular natural beauty**, localities that were species-rich in the past, or areas near the experts' residences and/or research centres.
- Only presence of a species is recorded. **No 'certain' absences** are recorded. A fundamental source of uncertainty in distributional data comes from assuming the absence of a species from places where it is actually present but remains undetected.

- Examples:
- Foody (Global Ecol. Biogeogr., 20133)
- Hortal (J. Biogeogr., 2008)

European Cooperation
in Science and Technology
- COST -

Brussels, 4 July 2012

COST Action TD1202
MAPPING AND THE CITIZEN SENSOR

The aim of the Action is to enhance the role of citizen sensing in mapping.

'Imperfect' algorithms

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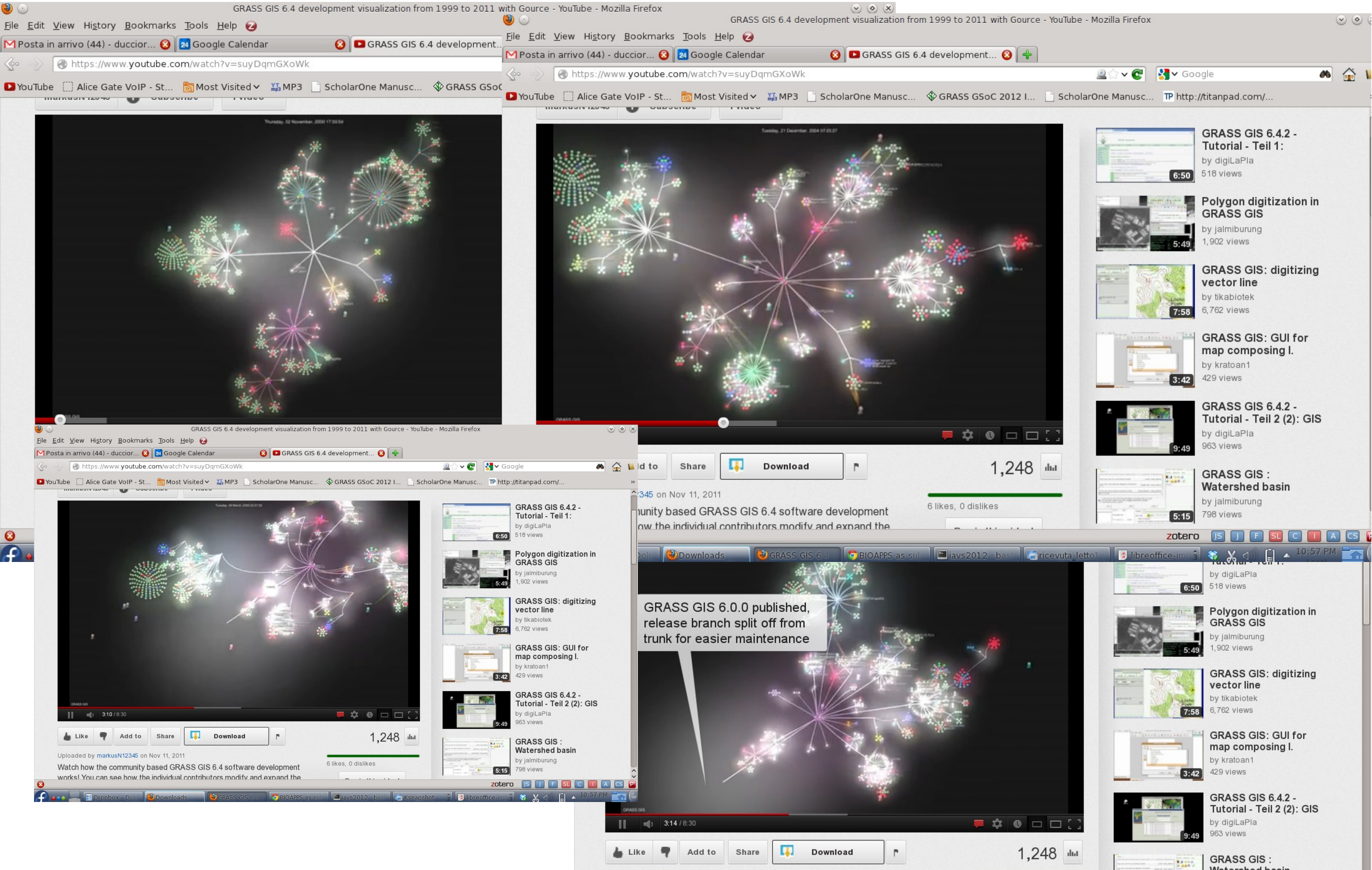
GRASS GIS development



Uncertainty in species diversity mapping

P.S&M 2013

Article

Progress in Physical Geography
35(2) 211–226
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sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0309133311399491
ppg.sagepub.com
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Accounting for uncertainty when mapping species distributions: The need for maps of ignorance

Duccio Rocchini*
IASMA Research and Innovation Centre, Italy
Joaquín Hortal*
Museo Nacional de Ciencias Naturales, Spain, and Imperial College London, UK
Szabolcs Lengyel
University of Debrecen, Hungary
Jorge M. Lobo
Museo Nacional de Ciencias Naturales, Spain
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Giovanni Bacaro
University of Siena, Italy
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'Building on an old idea of **Samuel Whittemore Boggs (1949)**, we thus propose the development of '**maps of ignorance**', which will depict the areas where the reliability of mapped distributions is either known or unknown.

In practice, we argue that **the degree and spatial distribution of uncertainty should be assessed** when creating species distribution maps, and not only their overall accuracy or model errors (in the case of SDMs).'

Uncertainty in species diversity mapping

P.S&M 2013


Article

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Accounting for uncertainty when mapping species distributions: The need for maps of ignorance

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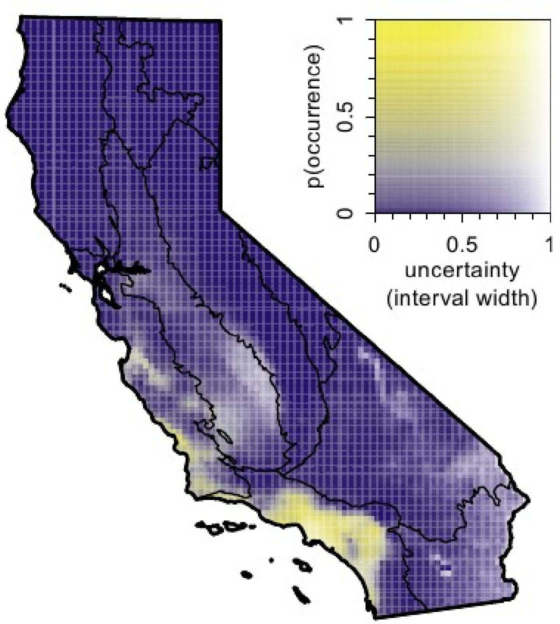


Including such estimates alongside mean projections gives **a 'map of ignorance' as called for by Rocchini et al. (2011)**, highlighting areas where **knowledge is lacking** and could be improved with additional sampling effort or the inclusion of additional covariates.

Swanson et al. (Global Ecol. Biogeogr., 2013)

Land use change (classification)

P.S&M 2013

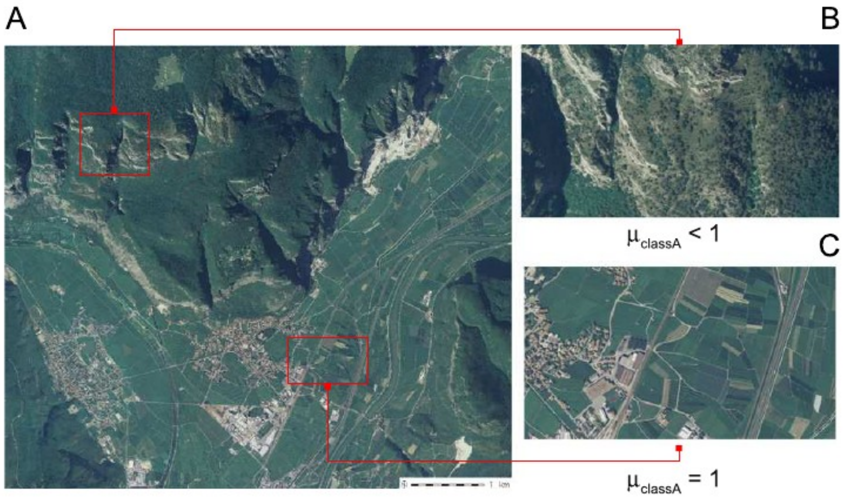
Contents lists available at SciVerse ScienceDirect

Computers & Geosciences

journal homepage: www.elsevier.com/locate/cageo

Uncertainty in ecosystem mapping by remote sensing

Duccio Rocchini [a,*], Giles M. Foody [b], Harini Nagendra [c,d], Carlo Ricotta [e], Madhur Anand [f], Kate S. He [g], Valerio Amici [h], Birgit Kleinschmit [i], Michael Förster [i], Sebastian Schmidtlein [j,k], Hannes Feilhauer [l], Anne Ghisla [a], Markus Metz [a], Markus Neteler [a]



Contents lists available at ScienceDirect

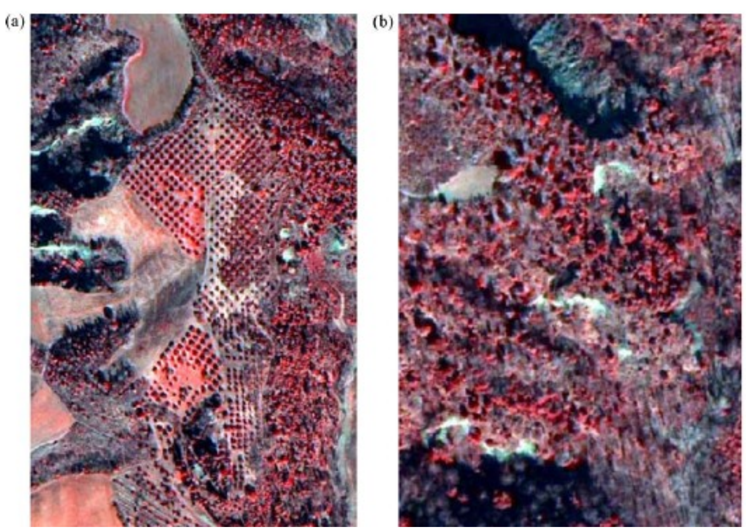
Ecological Complexity

journal homepage: www.elsevier.com/locate/ecocom

Short note

While Boolean sets non-gently rip: A theoretical framework on fuzzy sets for mapping landscape patterns

Duccio Rocchini [a,b,*]



'Imperfect' algorithms

To avoid black box calculations and built-in user interfaces researchers have recourse to several examples of FOSS in areas of ecological research, such as ecological statistics (e.g. **R Language and Environment for Statistical Computing**, http://www.R-project.org)
and spatial ecology [e.g. Geographical Resources Analysis Support System (**GRASS**)] GIS, http://grass.osgeo.org).

- **Modular design**
- **Decentralized contributions** can be made to the source code and allows
- **Different institutions and individuals around the world to improve the code base**

The EU BON project

P.S&M 2013

Building the European Biodiversity Observation Network

Duccio Rocchini
Fondazione Edmund Mach, Research and Innovation Centre
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GIS and Remote Sensing Unit
Via Mach 1, 38010 San Michele all'Adige (TN) - Italy

FONDAZIONE EDMUND MACH

General info

- **EC FP7** - Cooperation Theme 6: Environment (incl. climate change)
- **Project Leader**: Museum für Naturkunde – Berlin
- **Mission**: strategies for a global implementation of the **Group on Earth Observation's Biodiversity Observation Network**
- **Duration**: 54 months (48 + 6), ending May 31st 2017
- **Partners**: 30 partners, 18 countries (including e.g. The Natural History Museum, London; University of Cambridge)
- **Total budget**: ~ 11M EUROS, EU contribution ~ 9M EUROS

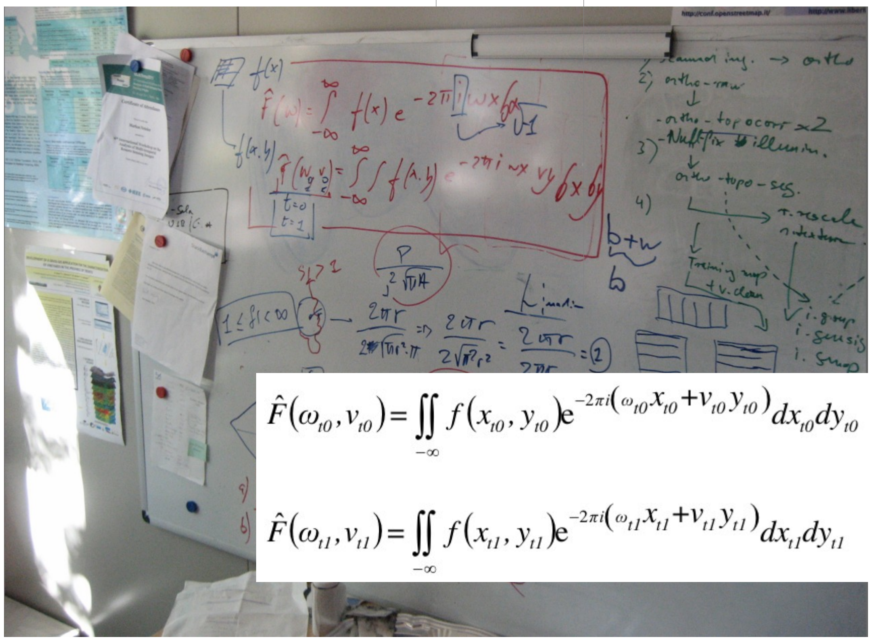
FEM scientific involvement

- Principal Investigator (PI): Duccio Rocchini
  - Task Leader: Task 4.1 Integrative analyses of distribution status and trends
- Scientific Deputy: Markus Neteler
- Post-Doc: TBA

Higher complexity = higher biodiversity

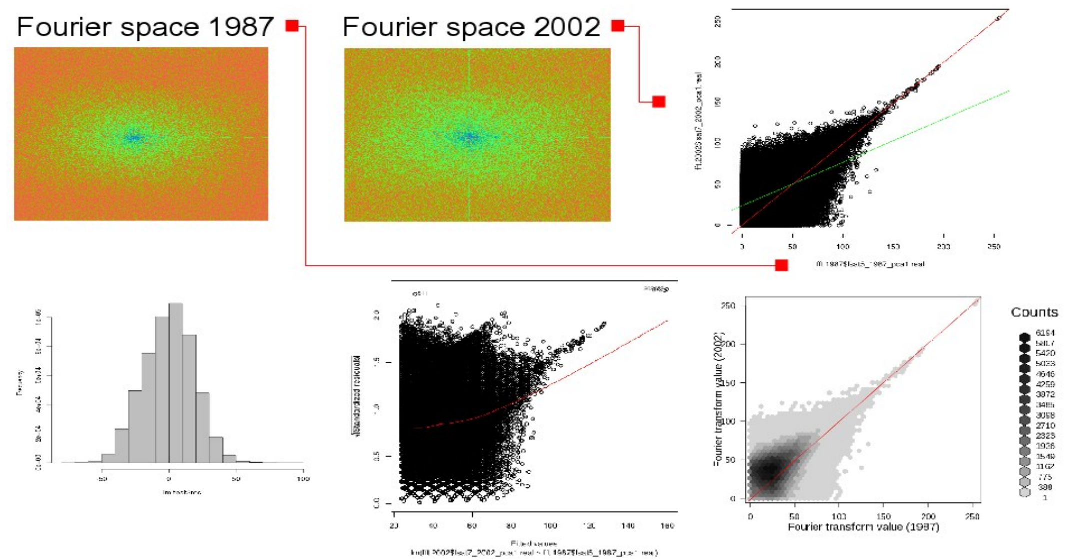
Free and Open Source Algorithms

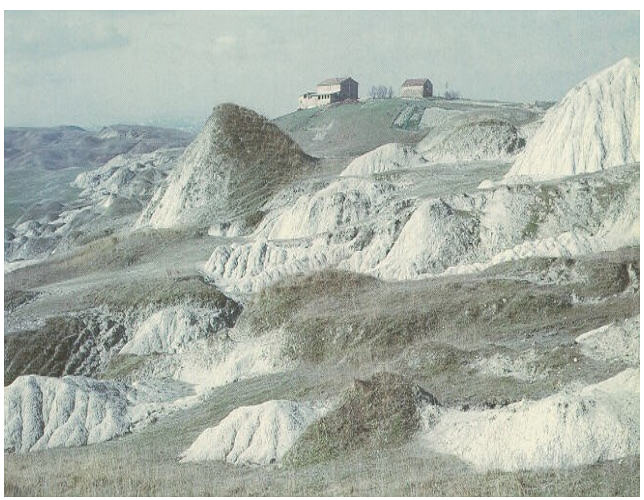
P.S&M 2013

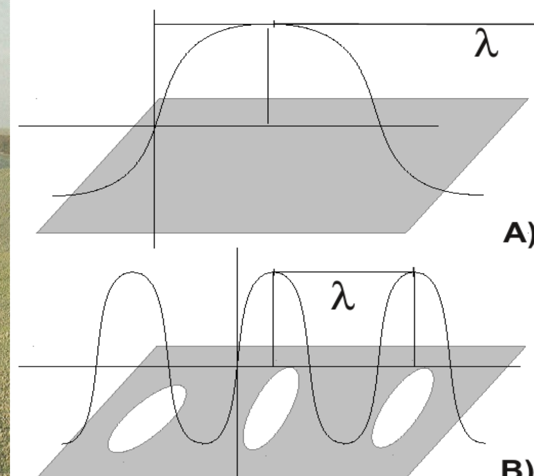


$$\hat{F}(\omega_{t0}, v_{t0}) = \iint_{-\infty} f(x_{t0}, y_{t0}) e^{-2\pi i(\omega_{t0} x_{t0} + v_{t0} y_{t0})} dx_{t0} dy_{t0}$$

$$\hat{F}(\omega_{t1}, v_{t1}) = \iint_{-\infty} f(x_{t1}, y_{t1}) e^{-2\pi i(\omega_{t1} x_{t1} + v_{t1} y_{t1})} dx_{t1} dy_{t1}$$







Free and Open Source Algorithms

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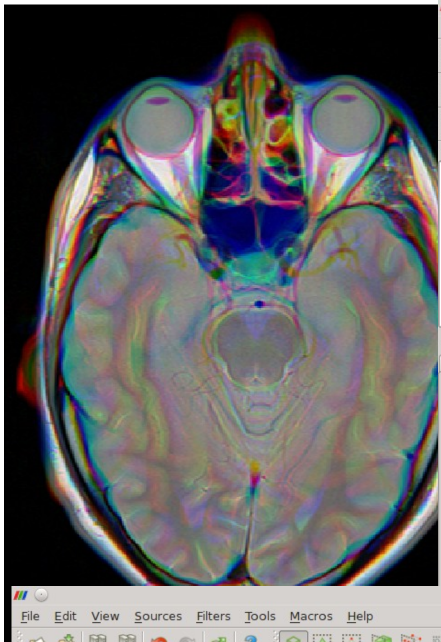
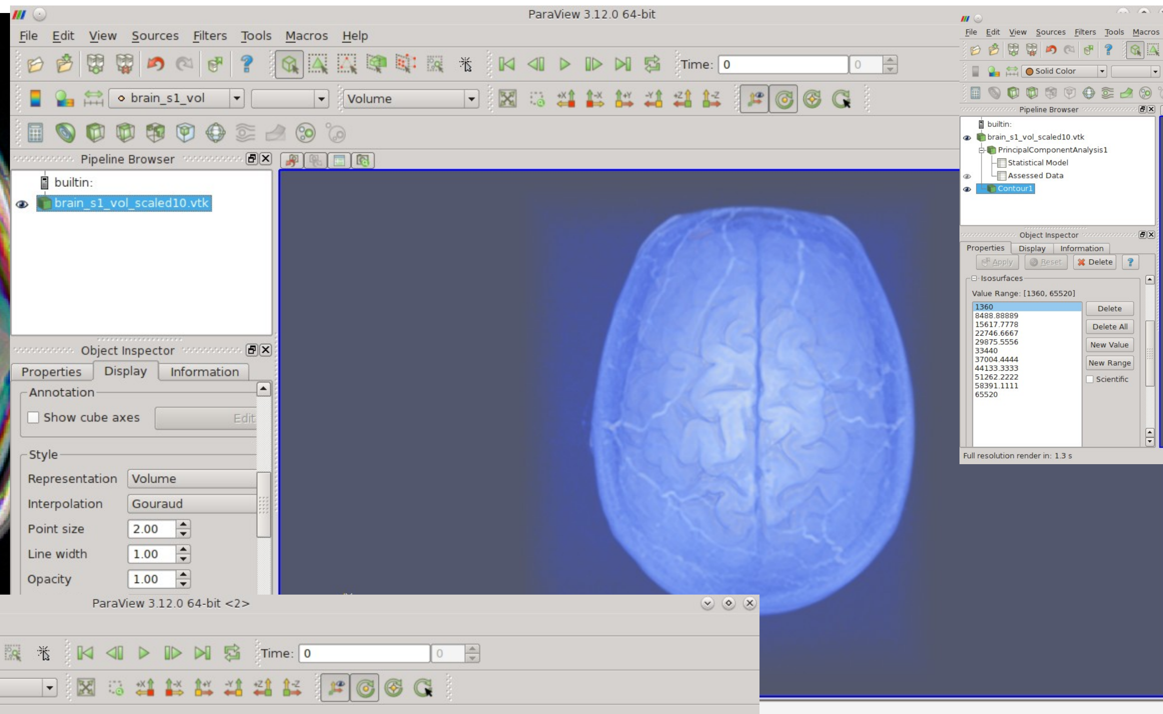
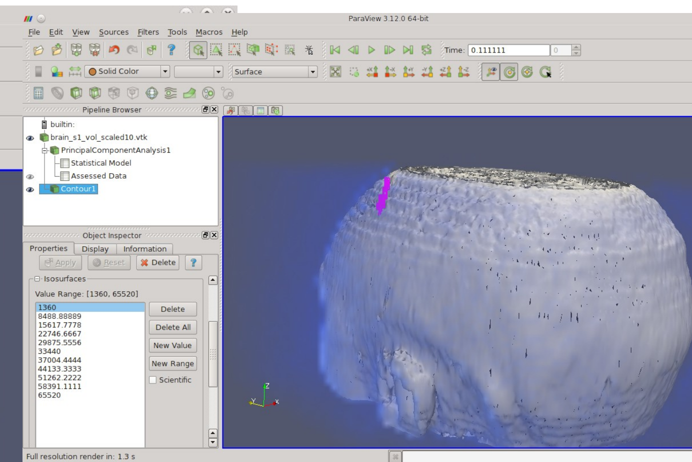
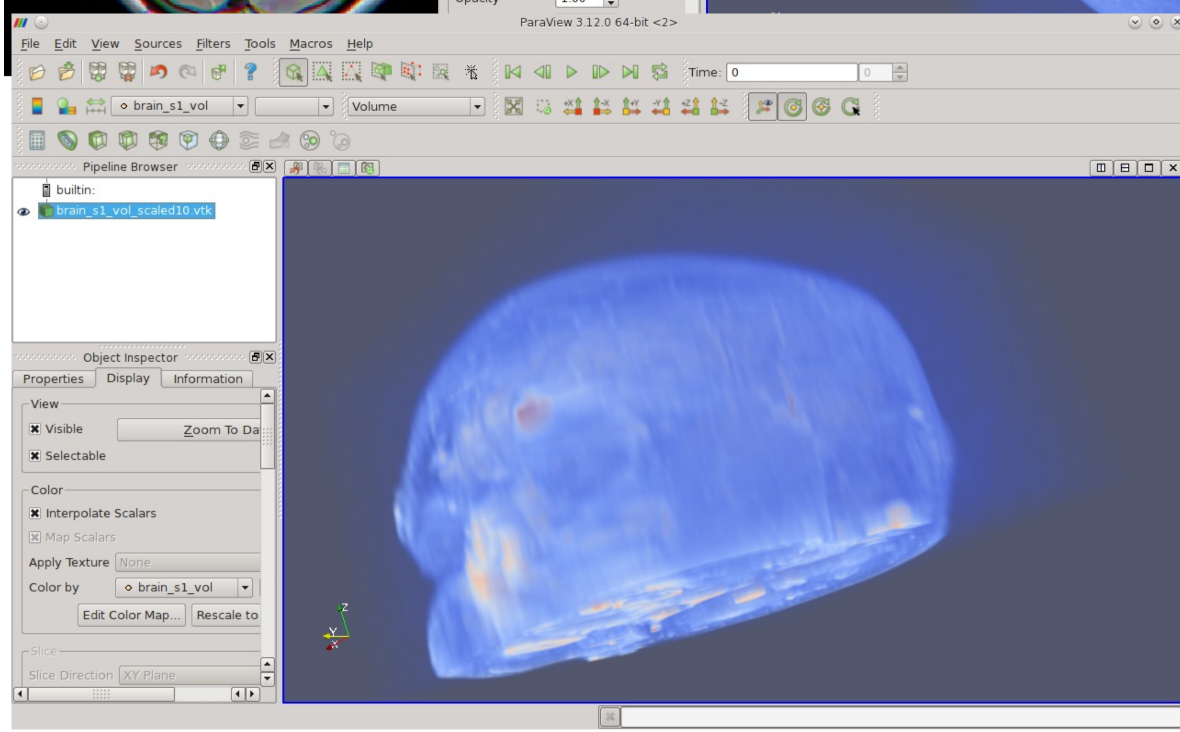
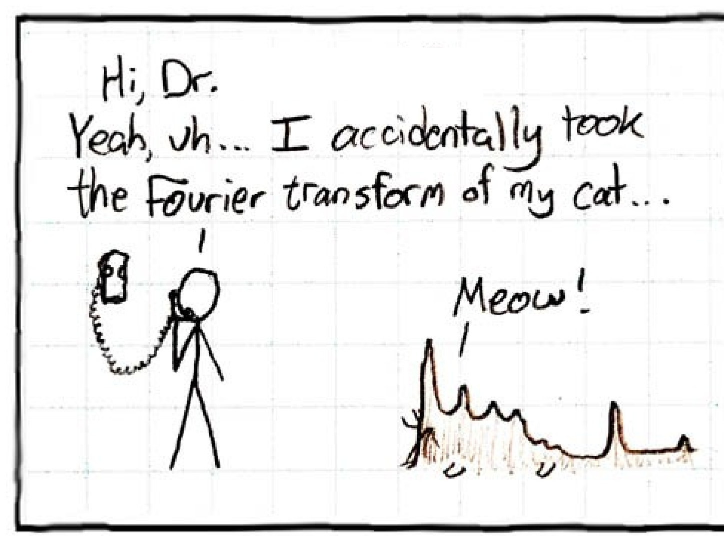






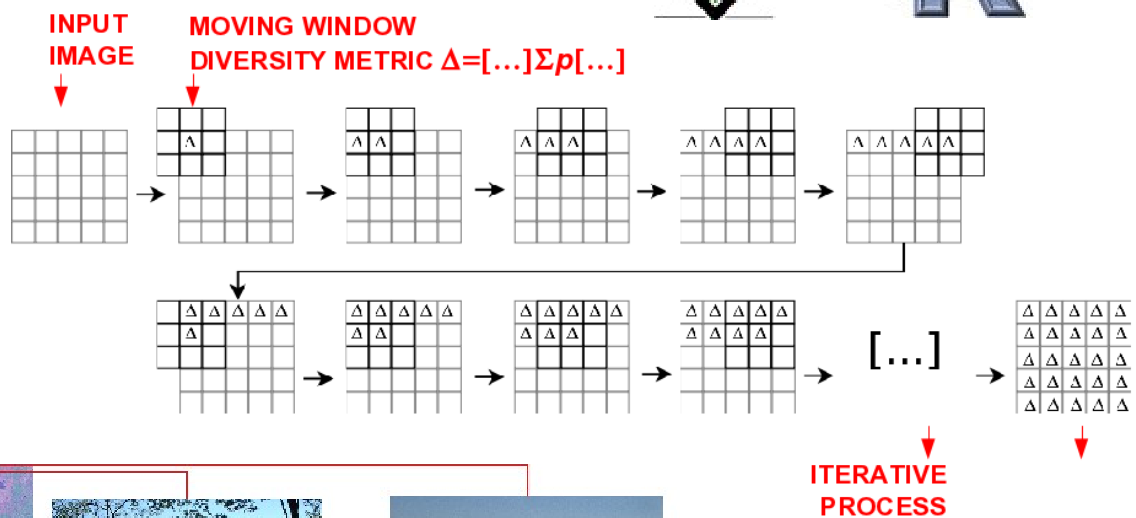


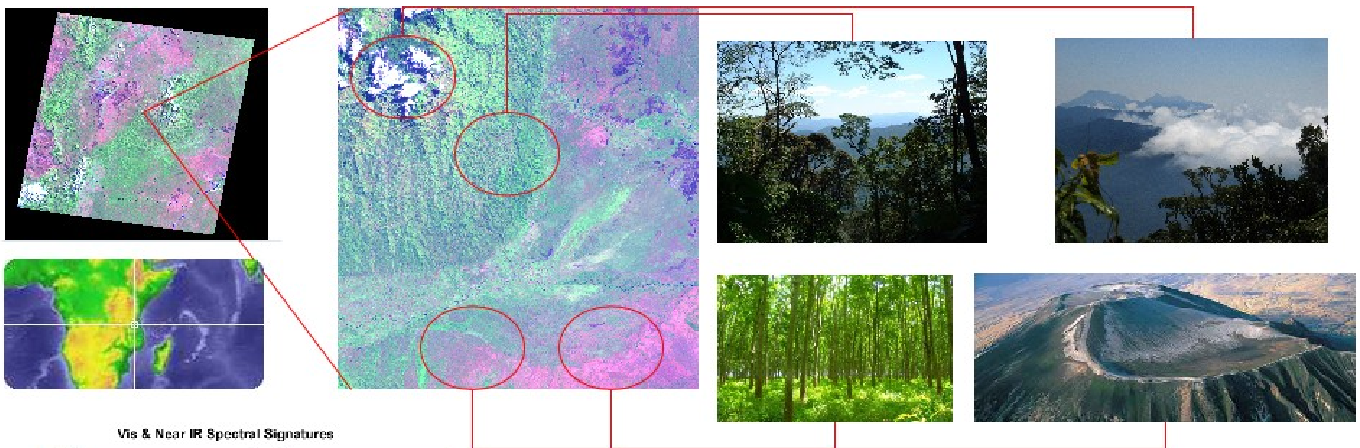


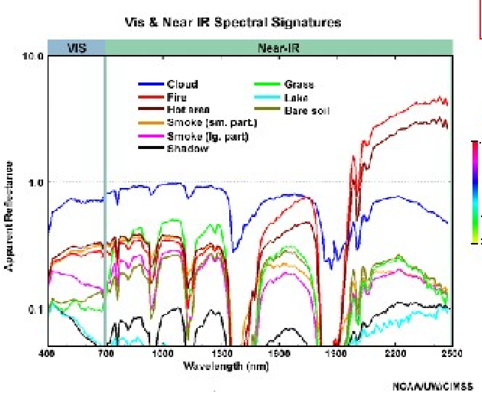
Entropy algorithms example

Rényi Generalized Entropy

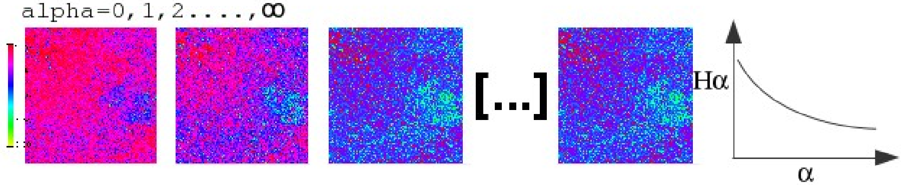
$$H_\alpha = \frac{1}{1-\alpha} \ln \sum p^\alpha$$





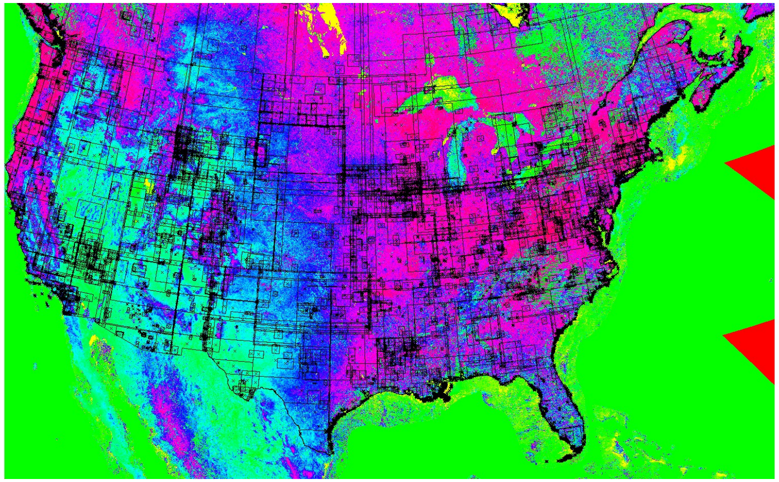


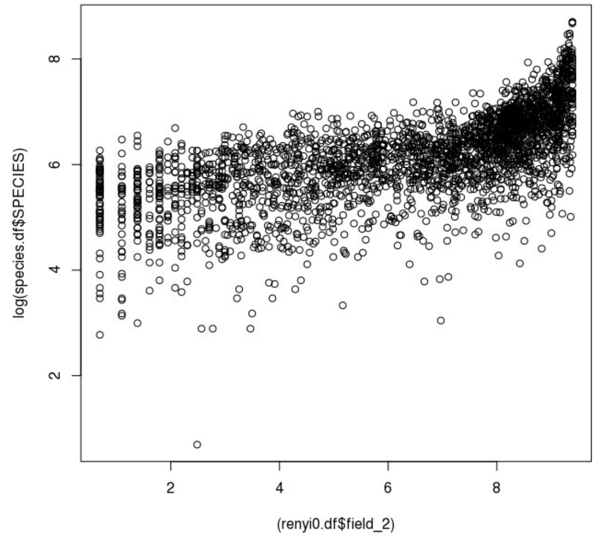

```
r.diversity input=map method=renyi out=renyi size=3
alpha=0,1,2....,∞
```

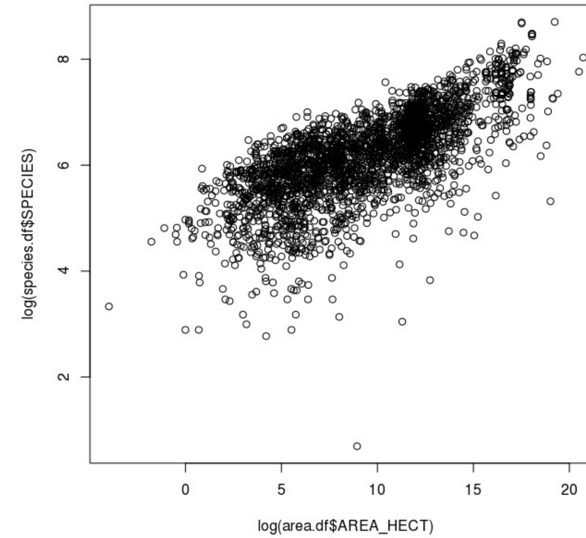


$H_\alpha = \frac{1}{1-\alpha} \ln \sum p^\alpha$ Increasing alpha parameter

Higher complexity = higher biodiversity

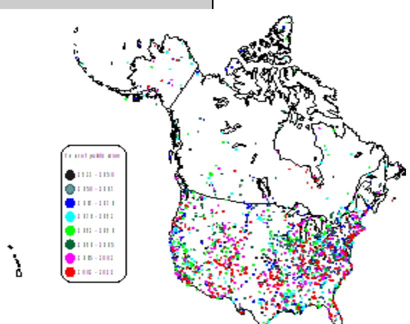




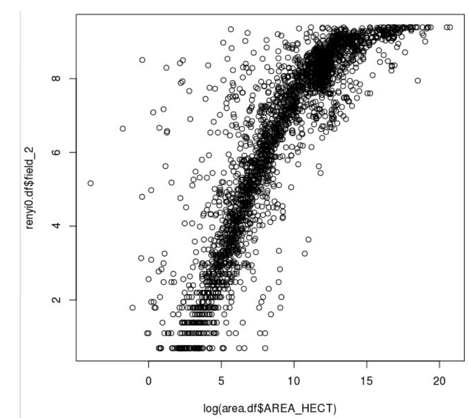


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Borcard, D., Legeendre, P., Drapeau, P., 1992. PARTIALLING OUT THE SPATIAL COMPONENT OF ECOLOGICAL VARIATION. Ecology, 73: 1045-1055



X2	0.07993
X1	0.00483
X1 ∩ X2	0.42763
Residual	0.48761



North American FloraS project

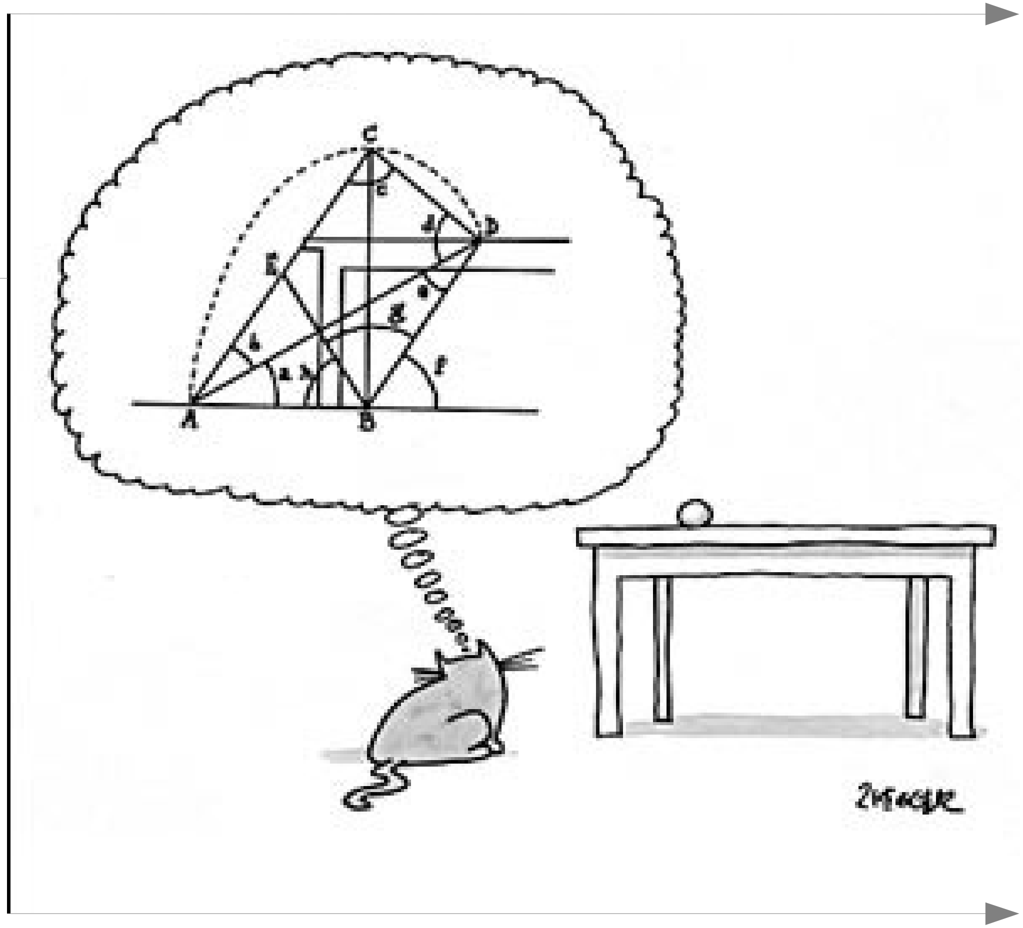
Ref:

Leticia Dadalt

Michael W. Palmer

Conclusion [1]

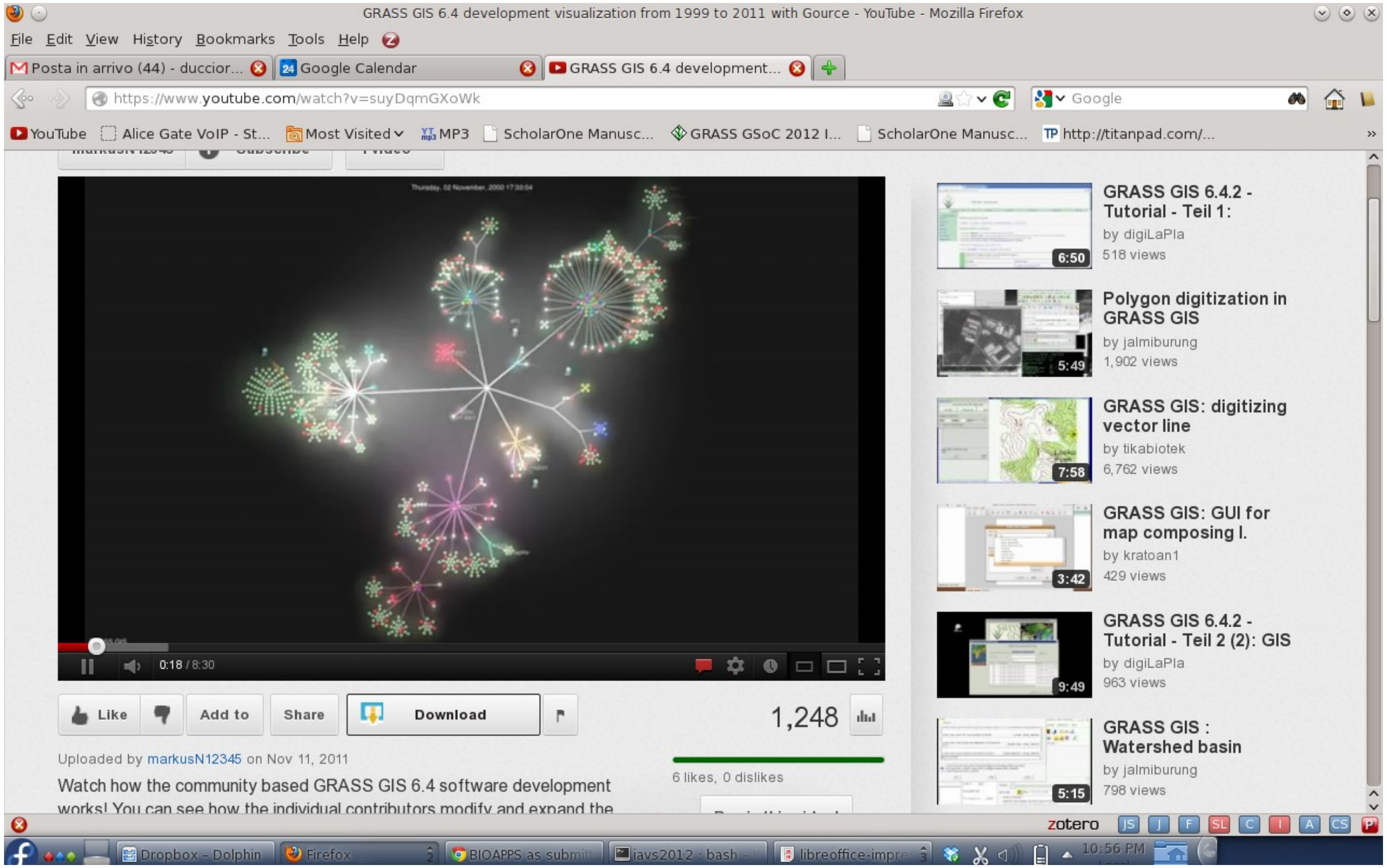
- **Once a map is drawn, people tend to accept it** (Chilès & Delfiner, 1999)
- … BUT THE NATURE WE ARE SEEKING TO REPRESENT IS OFTEN MORE **COMPLEX** THAN WE MIGHT THINK...
- A map must always reflect the quality of the information on which it is based. (Stott, 1981: 31)
- **WHAT IS REALLY NEEDED NOW!**
- 1. Standardized procedures for species diversity mapping
- 2. Open source code available
- 3. Uncertainty based maps should be considered as an essential component when relating environmental variability to genetic diversity



Conclusion [2]

- The increasing availability of open ecological data through networks such as the Global Biodiversity Information Facility (**GBIF**, http://www.gbif.org) or the Data Observation Network for Earth (**DataONE**) federated data archive (http://www.dataone.org) makes it increasingly possible to test cutting-edge ecological theories, such as dark diversity, evolutionary paths and climate change scenarios.
- In using a **shared open-source code** for testing these ecological theories, researchers can be sure that their results are **reliable** and also that **the code they have used is robust**. This is particularly true when complex algorithms (or statistical approaches) are involved.

Thanks



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