Remote sensing of biodiversity: measuring ecological complexity from space

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Outline

Networks

Courtesy: Dr. Martin Wegmann

Networks

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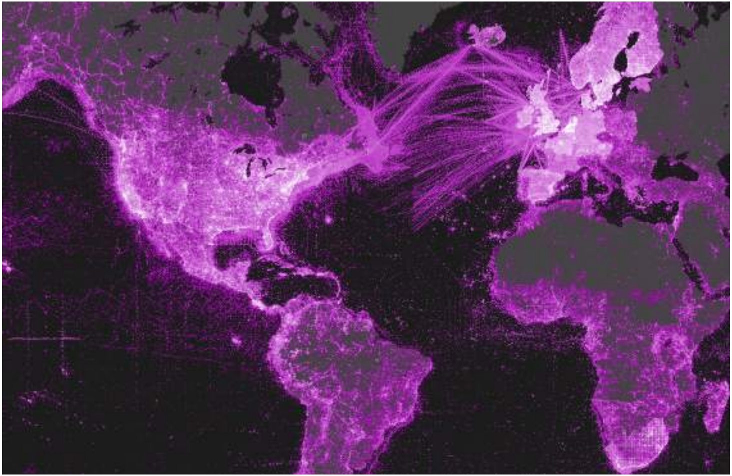


The power of remote sensing

“**Reflectances variability** over an area should result in a positive outcome when dealing with **biodiversity evaluation**, strictly related to **ecosystem entropy**. In particular, when aiming to locate heterogeneous environments one might make use of external information suspected to be correlated with species richness.”
Rocchini (Remote Sens. Environ., 2007)

Aim of this seminar

Remote sensing power to improve:

- Estimation of taxonomic diversity
- Species Distribution Modelling
- Uncertainty

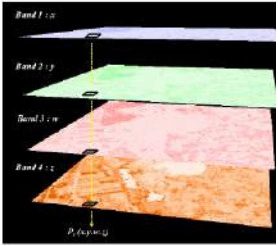
Outline

Local species diversity estimate ($\alpha -$ *diversity*)

ENVIRONMETRICS
Environmetrics 2002; 13: 121–137 (DOI: 10.1002/env.516)

Quantitative tools for perfecting species lists

Michael W. Palmer[1,*,†], Peter G. Earls[1], Bruce W. Hoagland[2],
Peter S. White[3,4], Thomas Wohlgemuth[5]

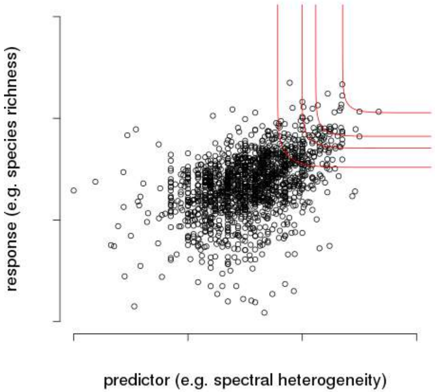


- **SPECTRAL VARIATION HYPOTHESIS**

  "Spatial variation (e.g. expressed as standard deviation of reflectance) is likely to be correlated with spatial variation in the environment [which is] likely to be correlated with species richness"

  (Palmer et al., Environmetrics, 2002)

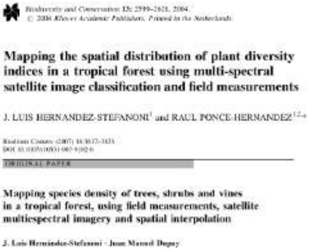
Local species diversity estimate ($\alpha - diversity$)



evd: - Functions for extreme value distributions - R package

Extends simulation, distribution, quantile and density functions to univariate and multivariate parametric extreme value distributions, and provides fitting functions which calculate maximum likelihood estimates for univariate and bivariate maxima models, and for univariate and bivariate threshold models.

Local species diversity estimate ($\alpha - \textit{diversity}$)



Biodiversity and Conservation 13: 2599–2621, 2004.
© 2004 Kluwer Academic Publishers. Printed in the Netherlands.

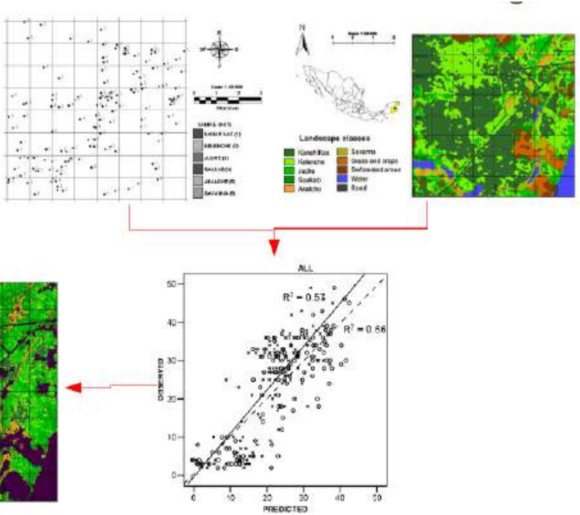
Mapping the spatial distribution of plant diversity indices in a tropical forest using multi-spectral satellite image classification and field measurements

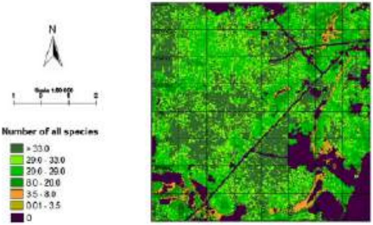
J. LUIS HERNANDEZ-STEFANONI[1] and RAUL PONCE-HERNANDEZ[1,2,*]

ORIGINAL PAPER

Mapping species density of trees, shrubs and vines in a tropical forest, using field measurements, satellite multispectral imagery and spatial interpolation

J. Luis Hernández-Stefanoni · Juan Manuel Dupuy





Local species diversity estimate ($\alpha - diversity$)

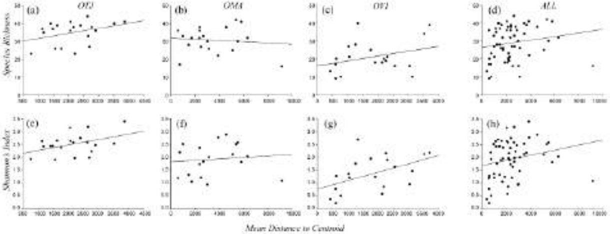
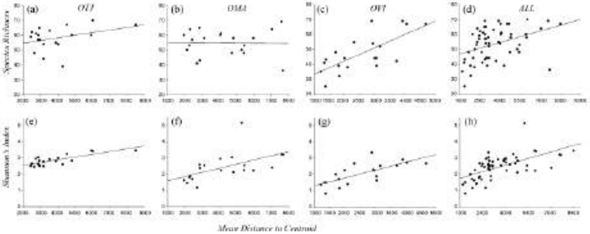


Fig. 3. Species richness and Shannon index versus spectral variability for the three test sites on the scale 10 m × 10 m.



Oldeland et al. (Ecol. indic., 2010)

Local species diversity estimate ($\alpha - diversity$)

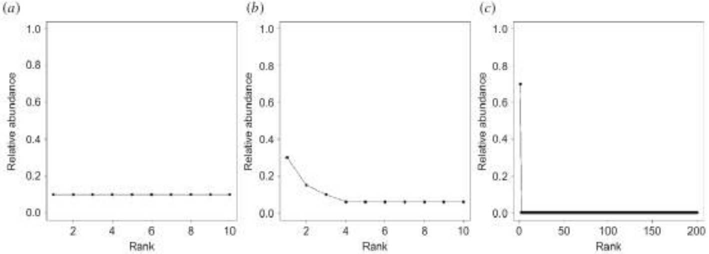


Figure 2. Rank–abundance diagrams derived from three different situations. (*a*) Array A: richness = 10 DN values, complete equitability. (*b*) Array B: richness = 10 DN values, with 3 values being more abundant. (*c*) Array C: richness = 200 DN values, with 1 dominant DN value. Notice that although the images are different in terms of richness or relative abundance, the Shannon entropy index *H* is very similar equalling 2.3, 2.11 and 2.2 for images (*a*), (*b*) and (*c*), respectively. We refer to the main text for major explanations.

Rocchini and Neteler (Int. J. Remote Sens., 2012)

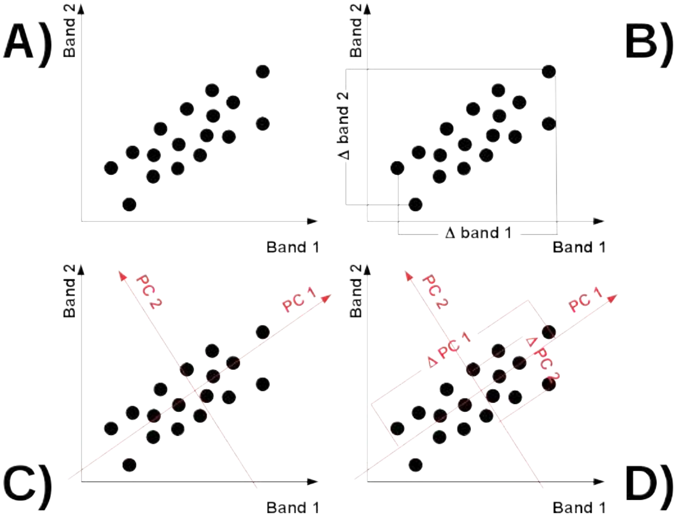
Local species diversity estimate ($\alpha - \textit{diversity}$)

Rényi (1970) generalised entropy:

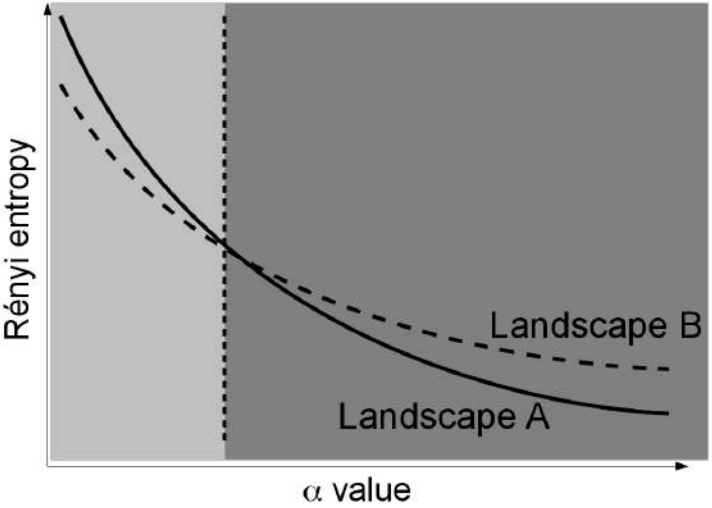
$$H_\alpha = \frac{1}{1-\alpha} \ln \sum p^\alpha \tag{1}$$

where p=relative abundance of each spectral reflectance value (DN). Such measure is extremely flexible and powerful since many popular diversity indices are simply special cases of H_α.

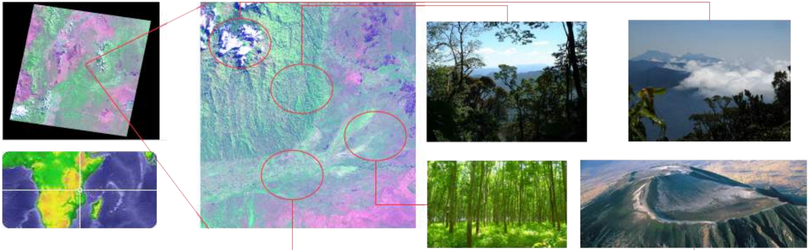
Local species diversity estimate ($\alpha - diversity$)



Local species diversity estimate ($\alpha - \textit{diversity}$)

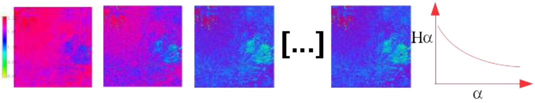


Local species diversity estimate ($\alpha - diversity$)



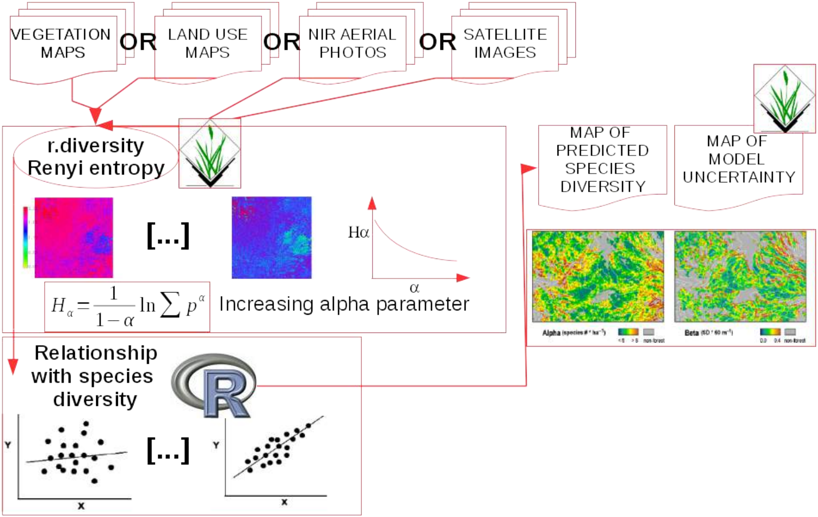
Saintpaulia Sterculia appendiculata Antiaris toxicaria

```
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

Local species diversity estimate ($\alpha - diversity$)



Species turnover estimate ($\beta - diversity$)

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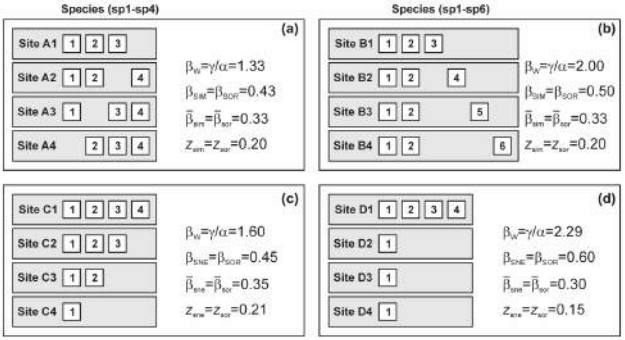
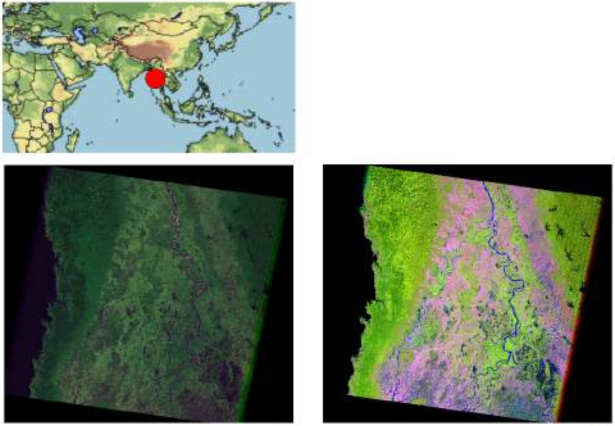


Baselga, A., 2013. Multiple site dissimilarity quantifies compositional heterogeneity among several sites, while average pairwise dissimilarity may be misleading. Ecography 36, 124-128.

Species turnover estimate ($\beta - diversity$)

i.colors.enhance - Performs auto-balancing of colors for RGB images.



(a) (b)

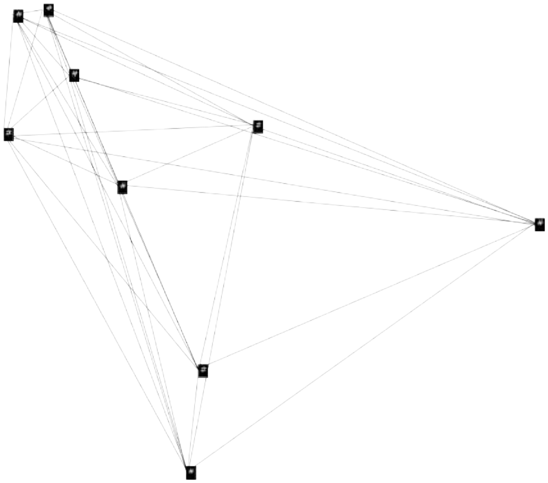
i.colors.enhance red=L71133048_04820051230_B50 green=L71133048_04820051230_B40 blue=L71133048_04820051230_B30

Species turnover estimate ($\beta - diversity$)

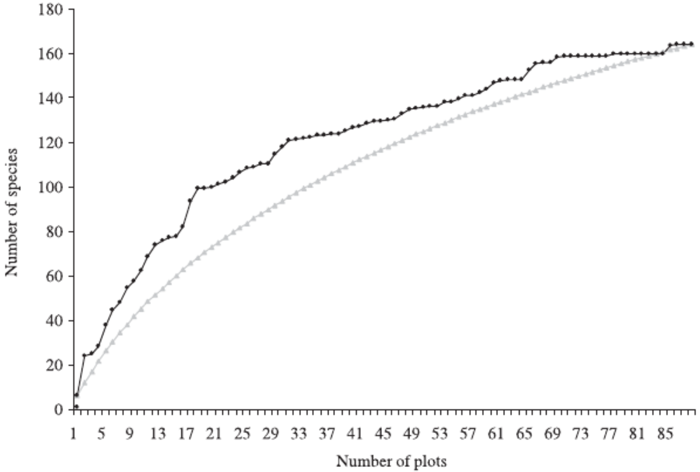
$$M_d = \begin{pmatrix} d_{1,1} & d_{1,2} & d_{1,3} & \cdots & d_{1,n} \\ d_{2,1} & d_{2,2} & d_{2,3} & \cdots & d_{2,n} \\ d_{3,1} & d_{3,2} & d_{3,3} & \cdots & d_{3,n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ d_{n,1} & d_{n,2} & d_{n,3} & \cdots & d_{n,n} \end{pmatrix} \quad (2)$$

or more simply $123[2ex]123n123n123n$, once n plots are considered, based on an *a-priori* defined statistical sampling design.

Species turnover estimate ($\beta - diversity$)



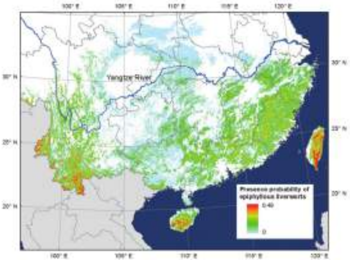
Species turnover estimate ($\beta - diversity$)



Rocchini, D., Andreini Butini, S., Chiarucci, A. (2005). Maximizing plant species inventory efficiency by means of remotely sensed spectral distances. **Global Ecology and Biogeography**, 14: 431-437.

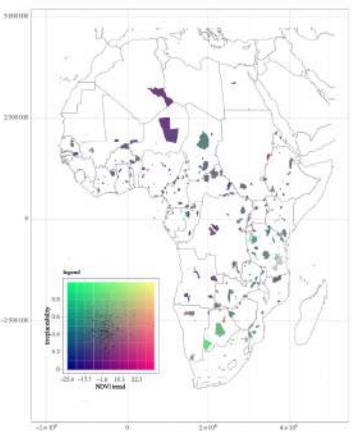
Outline

Species Distribution Modelling



Yanbin Jiang, C.A.J.M. de Bie, Tiejun Wang, A.K. Skidmore, Xuehua Liu, Shanshan Song and Xiaoming Shao Hyper-temporal remote sensing helps in relating epiphyllous liverworts and evergreen forests (pages 214–226) journal of vegetation Scinece.

Species Distribution Modelling



Wegmann, M., Santini, L., Leutner, B., Safi, K., Rocchini, D., Bevanda, M., Latifi, H., Dech, S., Rondinini, C. (2014). Role of African protected areas in maintaining connectivity for large mammals. **Philosophical Transactions of the Royal Society B-Biological Sciences**, 369: 20130193.

Species Distribution Modelling

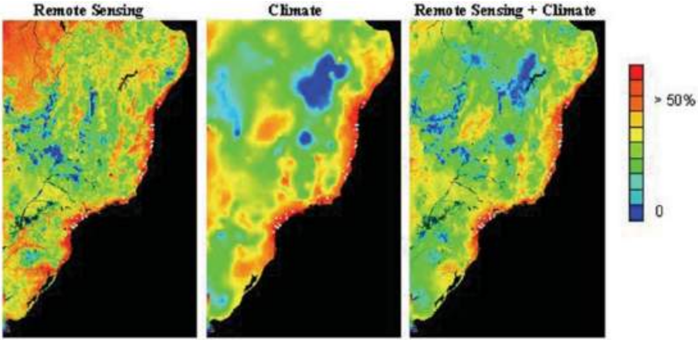


Figure 3 Maxent model of *Carpornis melanocephala* (Black-Headed Berryeater) in Brazil using remote sensing data, climate data, and a combination of both remote sensing and climate data

Gillespie, T.W., Foody, G.M., Rocchini, D., Giorgi, A.P., Saatchi, S. (2008). Measuring and modeling biodiversity from space. **Progress in Physical Geography**, 32: 203-221.

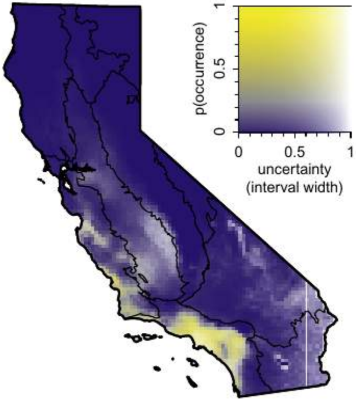
Outline

Uncertainty

$$Decision = \begin{pmatrix} < E_m| > I & < E_m| < I \\ > E_m| > I & > E_m| < I \end{pmatrix} \quad (3)$$

where $\mathrm{E}_m = modelerror(oruncertainty), I = potentialinvasion$

Uncertainty



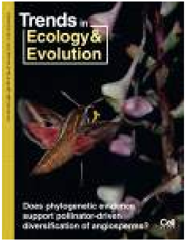
"Including such estimates alongside mean projections gives a "map of ignorance" as called for by Rocchini et al. (2011), highlighting areas where knowledge is lacking and could be improved with additional sampling effort or the inclu- sion of additional covariates." [Swanson et al., Global Ecol. Biogeogr., 2013]

Outline

Concluding remarks

- Assessment of biodiversity at local and regional scales often relies on fieldwork-based data collection .
- Species assessment in relatively large areas has always been a challenging task for ecologists.
- Large spatial scales
- Remote sensing data sources and techniques are being rapidly developed, but quantitative tests need to be carried out to assess diversity using these data and techniques.
- Improving theoretical and empirical measurements of diversity by remote sensing should help to find the ecological gradients shaping diversity on a large spatial scale.
- Studying genetic structure at the landscape scale is a promising field of research which could provide us with a better understanding of species dispersal and gene flow across habitats.

Ecological informatics



- "The increasing availability of **open ecological data** [...] 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** [...] researchers can be sure that their results are **reliable** and also that the code they have used is **robust**"

Rocchini, D., Neteler, M. (2012). Let the four freedoms paradigm apply to ecology. **Trends in Ecology & Evolution**, 27: 310–311.

Thank you!

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