Space oddity: estimating Earth biodiversity from a satellite

Duccio Rocchini

Alma Mater Studiorum University of Bologna, Italy
Czech University of Life Sciences Prague, Czech Republic

Aim

Showing the most powerful approaches to measure the diversity of life from space.

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].

Outline

Information Theory

Reprinted with corrections from *The Bell System Technical Journal,*
Vol. 27, pp. 379–423, 623–656, July, October, 1948.

A Mathematical Theory of Communication

By C. E. SHANNON

INTRODUCTION

THE recent development of various methods of modulation such as PCM and PPM which exchange bandwidth for signal-to-noise ratio has intensified the interest in a general theory of communication. A basis for such a theory is contained in the important papers of Nyquist[1] and Hartley[2] on this subject. In the present paper we will extend the theory to include a number of new factors, in particular the effect of noise

$$H' = -\sum p_i \times ln(p_i) \tag{1}$$

Issues

Main issues related to the use of Shannon's H' in remote sensing:

- **Non-dimensionality**: H' is only based on relative abundance and not on numbers, i.e. pixel values
- **Point description**: H', as many other indices, represents only a part of the whole diversity spectrum

Outline

Distance matrices and relative abundance: the Rao's Q diversity

$$H' = -\sum p_i \times ln(p_i) \tag{2}$$

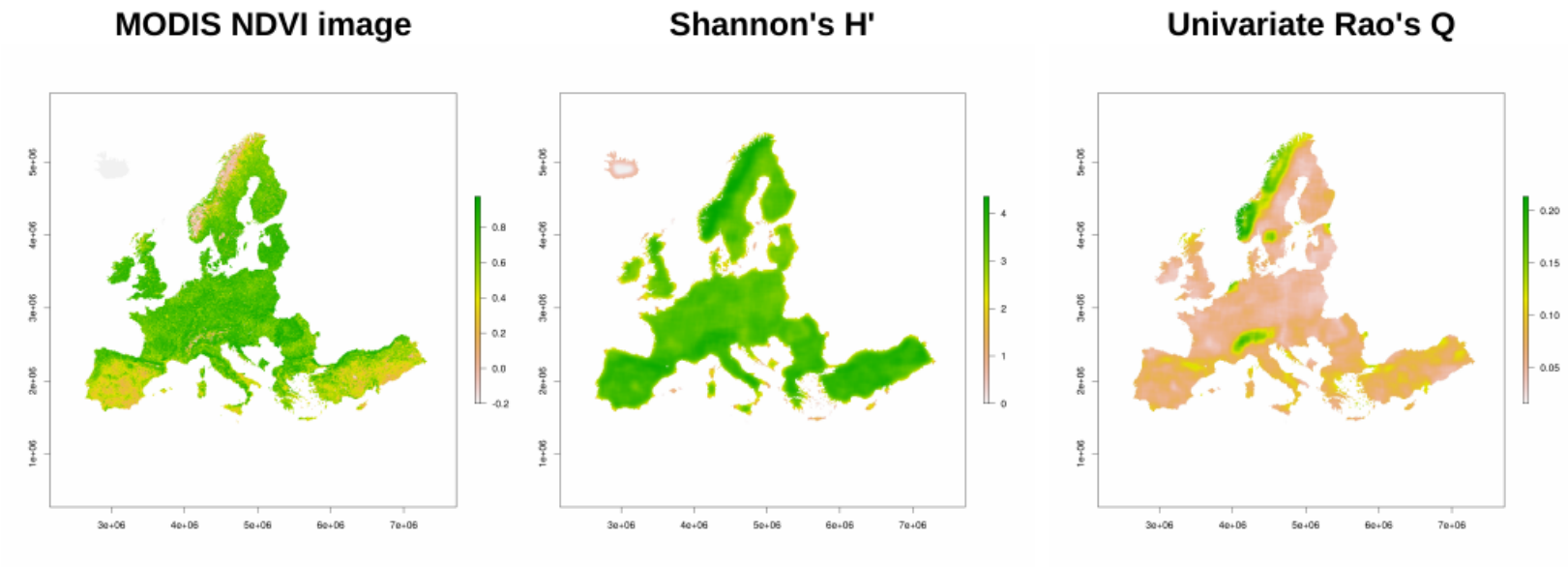
Distance matrices and relative abundance: the Rao's Q diversity

$$H' = -\sum p_i \times ln(p_i) \tag{2}$$

$$Q = \sum\sum d_{ij} \times p_i \times p_j \tag{3}$$

$$\begin{pmatrix} d_{1,1} & d_{1,2} & \cdots & d_{1,n} \\ d_{2,1} & d_{2,2} & \cdots & d_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n,1} & d_{n,2} & \cdots & d_{n,n} \end{pmatrix}$$

Rao's Q diversity



Rocchini et al. (Ecol. Indic, 2017)

Outline

Solving point description: the Rényi Generalised Entropy

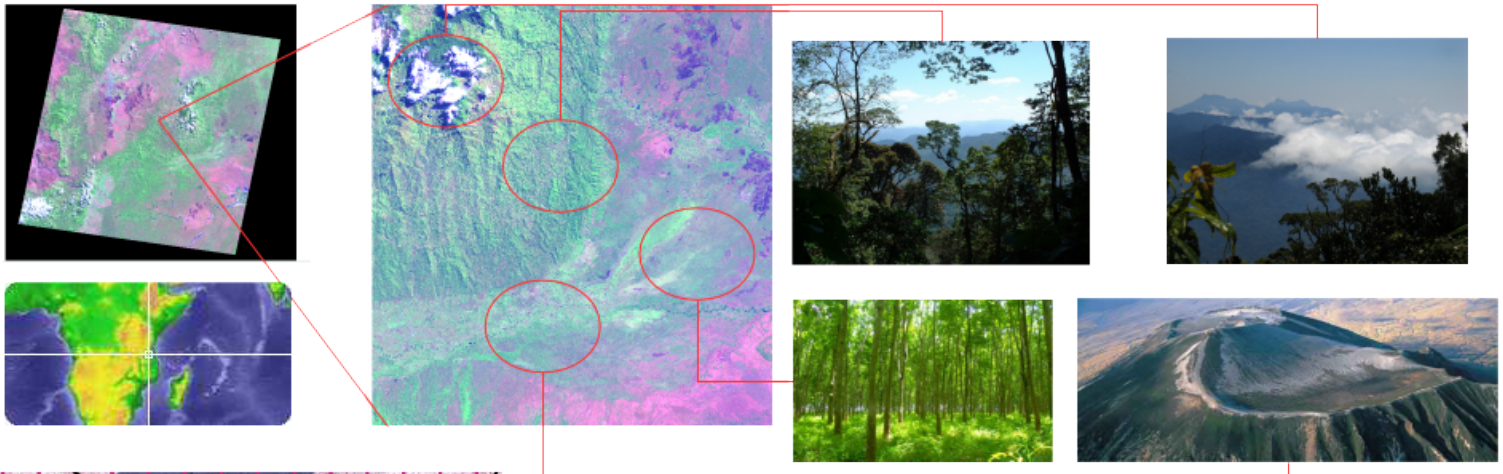
Rényi (1970) generalised entropy:

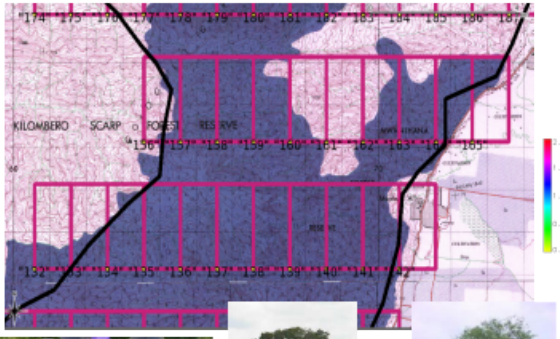
$$H_\alpha = \frac{1}{1-\alpha} \ln \sum p^\alpha \tag{4}$$

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.

$$H\alpha = \begin{cases} \alpha = 0, H_0 = ln(N) \\ \alpha \to 1, H_1 = -\sum p \times ln(p) \\ \alpha = 2, H_2 = ln(1/D) \end{cases} \tag{5}$$

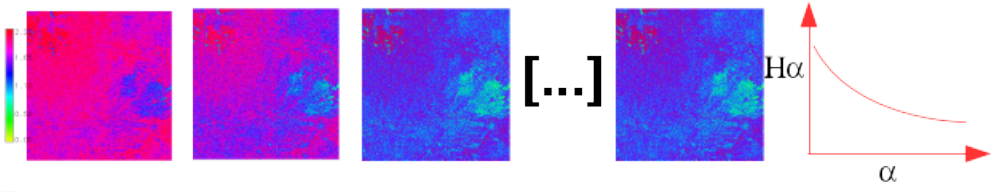
Solving point description: the Rényi Generalised Entropy





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

R package: `rasterdiv`

Package 'rasterdiv'

February 25, 2020

Title rasterdiv Package Version 0.0

Authors Duccio Rocchini, Martina Iannacito, Elisa Thouverai, Giovanni Bacaro, Manuele Bazzichetto, Alessandra Bernardi, Daniele Da Re, Giles M. Foody, Jonathan Lenoir, Marco Malavasi, Matteo Marcantonio, Alessandro Montaghi, Vítězslav Moudrý, Carlo Ricotta, Petra Šímová, Clara Tattoni, Enrico Tordoni, Michele Torresani, Saverio Vicario, Martin Wegmann

...

Maintainer Duccio Rocchini<duccio.rocchini@unitn.it>

Many thanks!

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Contact:
Duccio Rocchini, PhD - Full Professor @:
Alma Mater Studiorum University of Bologna, Italy
duccio.rocchini@unibo.it

This presentation has been made by only relying on Free and Open Source philosophy: Linux, LaTeX, R, GRASS GIS.