A crab canon: ordering remotely-sensed diversity metrics in the `rasterdiv` R package

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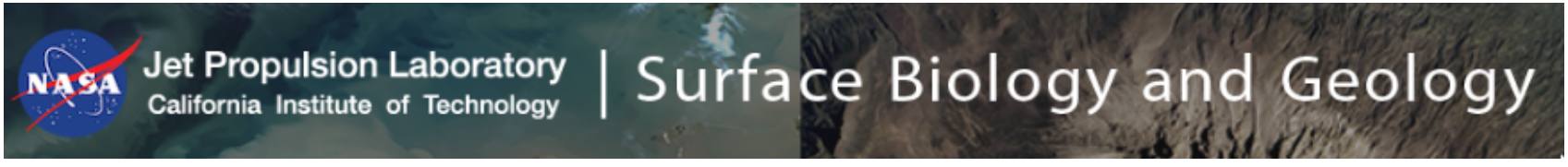
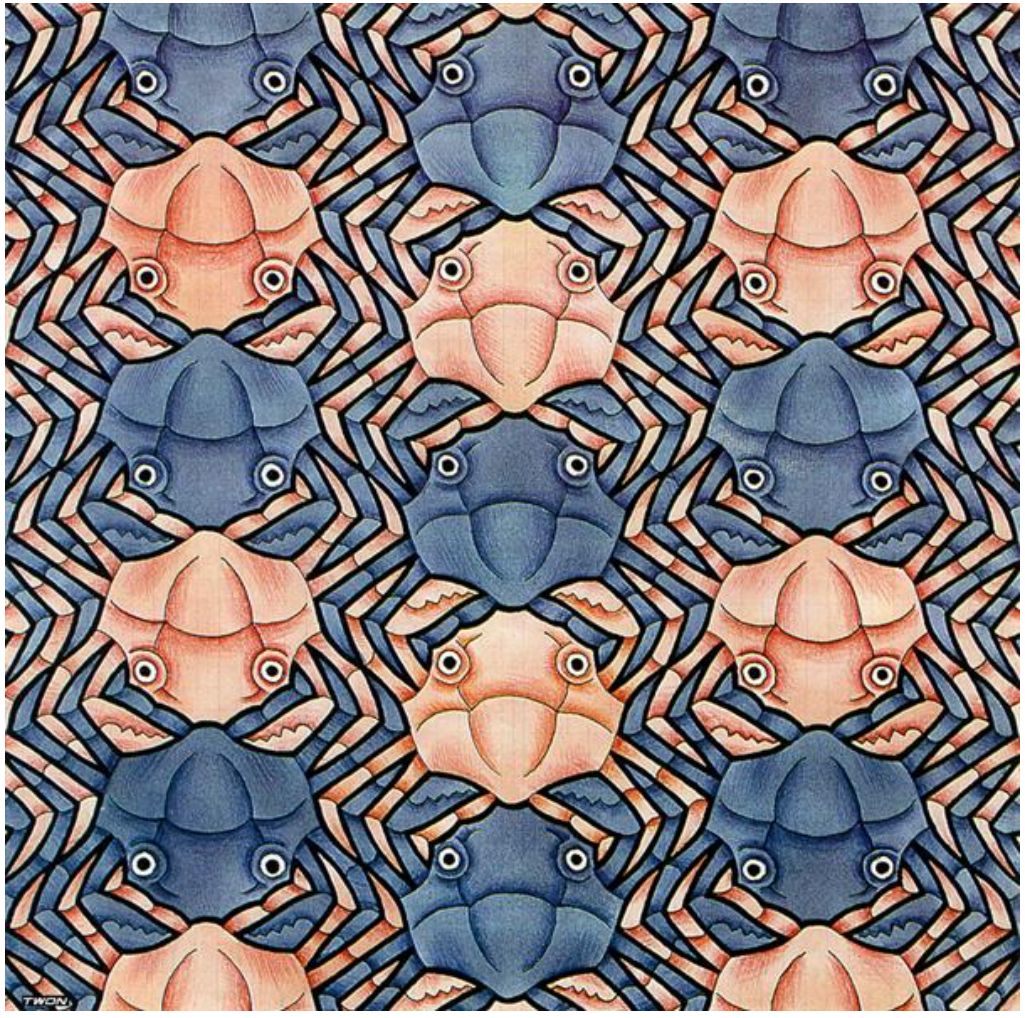


Intro



Intro

nature ecology & evolution

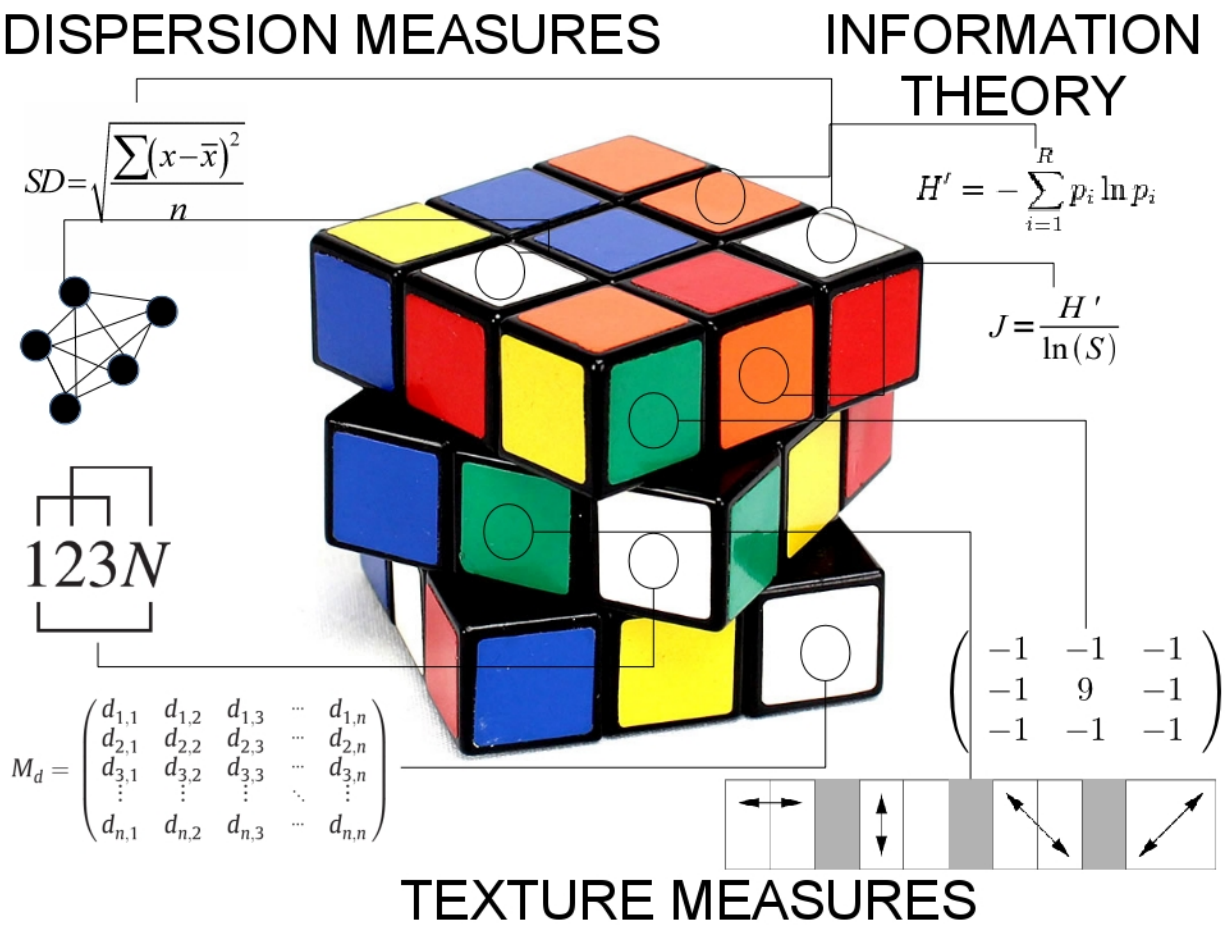
Article | Published: 02 November 2020

Remote spectral detection of biodiversity effects on forest biomass

Laura J. Williams, Jeannine Cavender-Bares, Philip A. Townsend, John J. Couture, Zhihui Wang, Artur Stefanski, Christian Messier & Peter B. Reich

Nature Ecology & Evolution **5**, 46–54(2021) | Cite this article

Point descriptors



Aim

Aim

rasterdiv: Diversity Indices for Numerical Matrices

Providing functions to calculate indices of diversity on numerical matrices based on information theory. The rationale behind the package is described in Rocchini, Marcantonio and Ricotta (2017) <doi:10.1016/j.ecolind.2016.07.039>.

Version:	0.2-2
Depends:	R (≥ 3.6.0), raster
Imports:	methods, proxy, foreach, progress, svMisc
Suggests:	parallel, doParallel, knitr, rmarkdown, rasterVis, RColorBrewer, gridExtra, gstat
Published:	2020-11-17
Author:	Matteo Marcantonio [aut, cre], Martina Iannacito [aut, ctb], Elisa Marchetto [ctb], Elisa Thouverai [aut, ctb], Daniele Da Re [aut], Clara Tattoni [aut], Giovanni Bacaro [aut], Saverio Vicario [aut, ctb], Carlo Ricotta [aut], Duccio Rocchini [aut, ctb]
Maintainer:	Matteo Marcantonio <marcantoniomatteo at gmail.com>
BugReports:	https://github.com/mattmar/rasterdiv

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

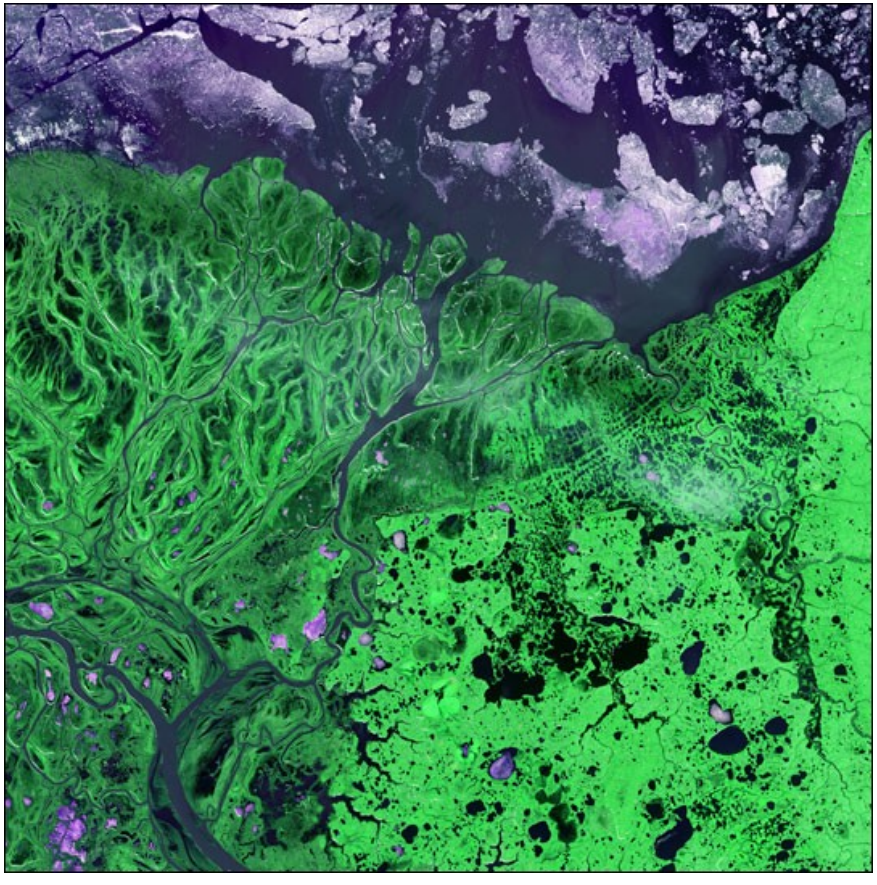
By C. E. SHANNON

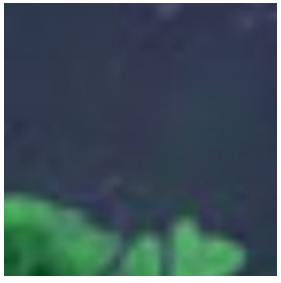
INTRODUCTION

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 in the channel, and the savings possible due to the statistical structure of the original message and due to the nature of the final destination of the information.

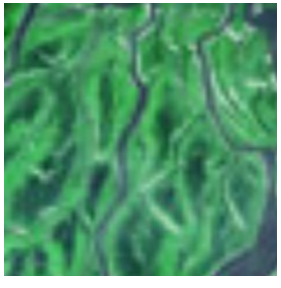
$$H' = -\sum p_i \times ln(p_i) \tag{1}$$

Information Theory





H'=0.32



H'=0.69

Issues

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

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

Outline

Solving point description: the Rényi generalised entropy

Rényi (1970) generalised entropy:

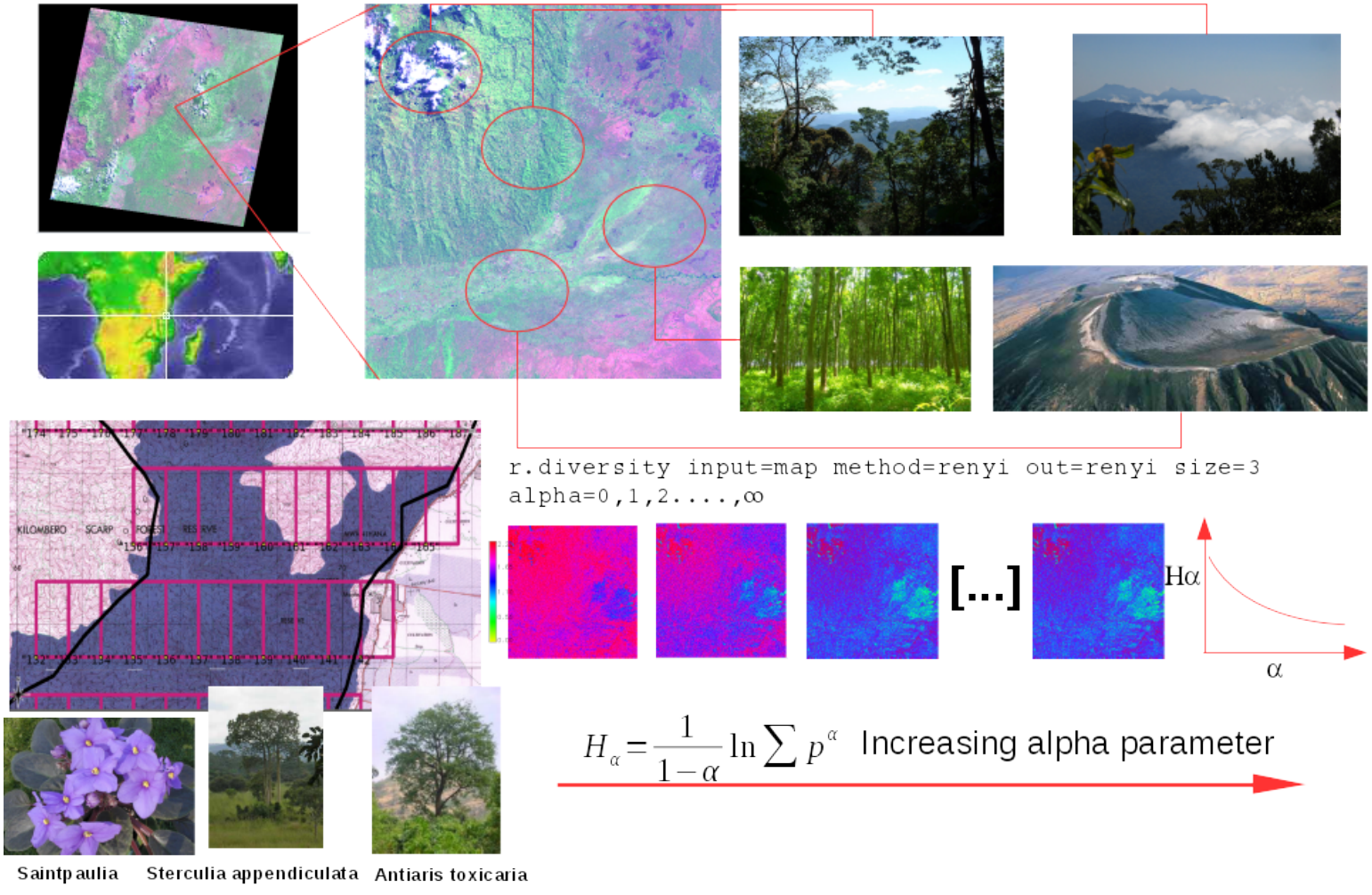
$$H_\alpha = \frac{1}{1-\alpha} \ln \sum p^\alpha \tag{2}$$

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.

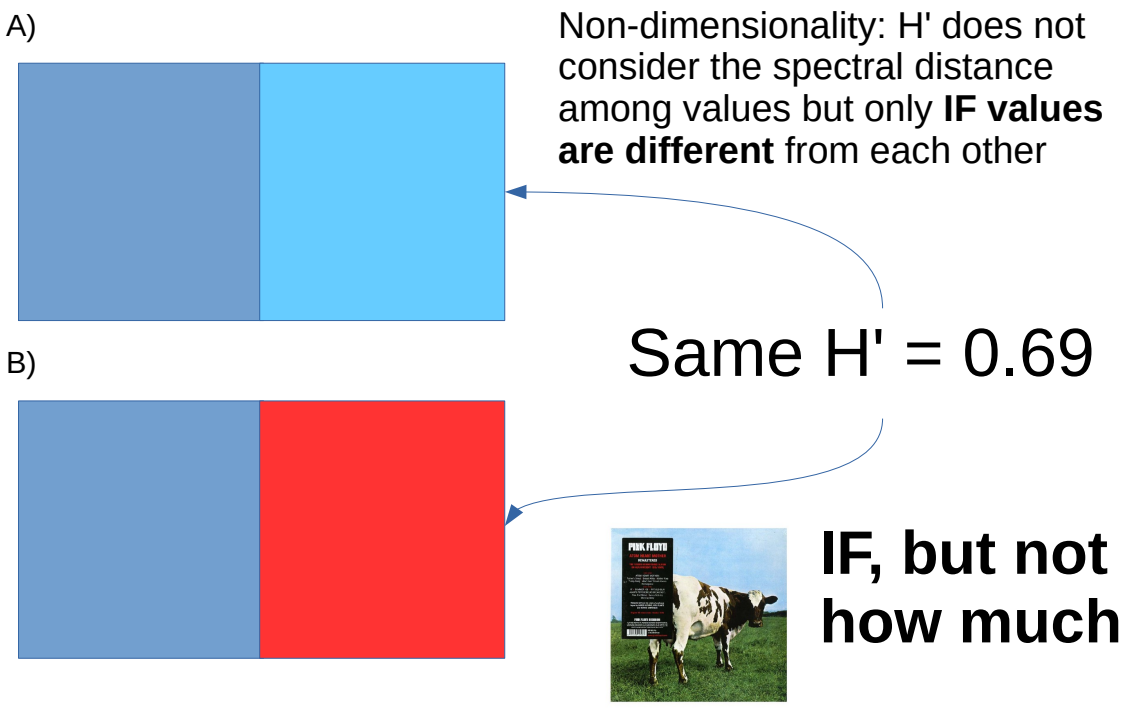
$$H\alpha = \begin{cases} \alpha = 0, H_0 = ln(N) \\ \alpha \to 1, H_1 = -\sum p \times ln(p) \\ \alpha = 2, H_2 = ln(1/D) \end{cases} \tag{3}$$

Solving point description: the Rényi generalised entropy



Outline

Solving non-dimensionality: the Rao's quadratic entropy (Rao's Q)



Distance matrices and relative abundance: the Rao's Q

$$H' = -\sum p_i \times ln(p_i) \tag{4}$$

Distance matrices and relative abundance: the Rao's Q

$$H' = -\sum p_i \times ln(p_i) \tag{4}$$

$$Q = \sum\sum d_{ij} \times p_i \times p_j \tag{5}$$

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

Solving non-dimensionality: the Rao's Q

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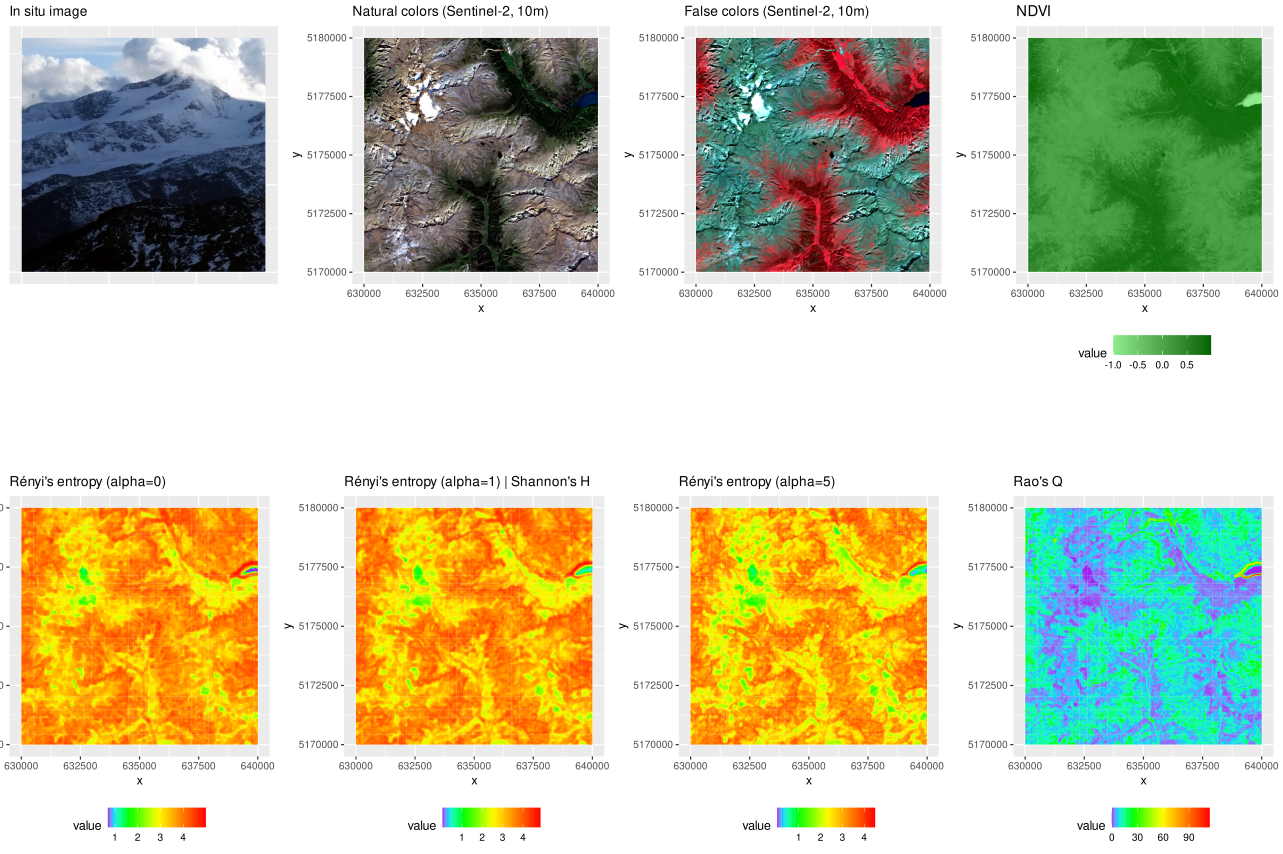
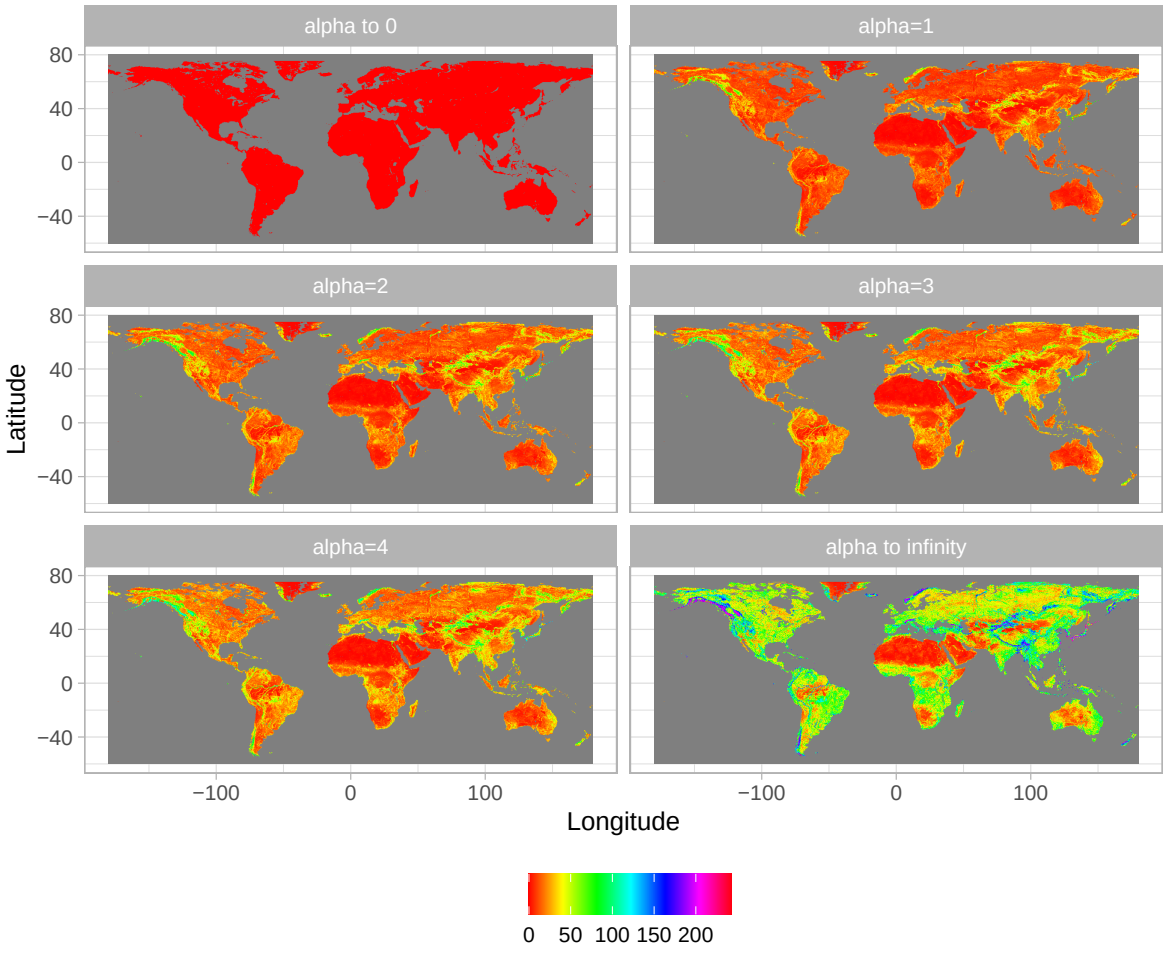


Generalised parametric Rao's Q

$$Q_\alpha = \left(\sum_{i,j=1}^{N} \omega_{ij} d_{ij}^\alpha \right)^{\frac{1}{\alpha}} = \left(\sum_{i,j=1}^{N} \frac{1}{N^2} d_{ij}^\alpha \right)^{\frac{1}{\alpha}}$$

$$Q_\alpha = \begin{cases} \alpha \to 0, Q_0 = \sqrt[N^2]{\prod_{i,j=1}^{N} d_{ij}} & \textit{geometric} \\ \alpha = 1, Q_1 = Q = \sum_{i,j=1}^{N} \frac{1}{N^2} d_{ij} & \textit{arithmetic} \\ \alpha = 2, Q_2 = \sqrt{\sum_{i,j=1}^{N} \frac{1}{N^2} d_{ij}^2} & \textit{quadratic} \\ \alpha = 3, Q_3 = \sqrt[3]{\sum_{i,j=1}^{N} \frac{1}{N^2} d_{ij}^3} & \textit{cubic} \\ \alpha \to \infty, Q_{\alpha \to \infty} = \max d_{ij} & \textit{max}_d \end{cases}$$

Generalised parametric Rao's Q



Coda

There is actually **no single measure** that could be adopted to represent all the different aspects of diversity, **with an intrinsic fallacy** in considering a **'true' diversity** (Gorelick, Oecologia, 2011).

Coda

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].

Coda

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Maintainer:	Matteo Marcantonio <marcantoniomatteo at gmail.com>
BugReports:	https://github.com/mattmar/rasterdiv

Coda

Abundance based metrics

Shannon's H'

Rao's Q

Distance based metrics

Rényi's H

Parametric Rao's Q

Many thanks!

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

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

Generalised parametric Rao's Q vs in-situ data