Measuring ecosystem complexity from remotely sensed imagery in an Open Source space

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RS & Biodiversity

Measuring and modelling biodiversity from space

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“There can be no question that spaceborne imagery has made significant contributions to the science of biogeography and biodiversity over the last seven years.”

Progress report

GIS: biodiversity applications

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“GIS has played a major role in recent biogeographical research. In relation to biodiversity, GIS has provided, especially through remote sensing, a range of data on environmental properties as well as techniques to explore and use data to further understanding of biodiversity and aid its conservation.”

“Recent research has based biodiversity assessment on measures of spectral diversity [...]”
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To Sample or Not to Sample? That is the Question... For the Vegetation Scientist

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• Issues to be solved before a sampling design may be prepared
  – (i) number of sampling units
  – (ii) spatial placement of the sampling units
  – (iii) statistical population of concern
  – (iv) operational definition of a species community
  – (v) labor intensiveness and costs
  – (vii) a small fraction of a study area may be sampled
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.
Aim

• THE ISSUES

1 - Scale

2 - Metrics

\[ H = - \sum p \times \ln(p) \]
\[ 1 - D = 1 - \sum p^2 \]
\[ J = \frac{- \sum p \times \ln(p)}{\ln(N)} \]
\[ H_\alpha = \frac{1}{1 - \alpha} \ln \sum p^\alpha \]

• THE FOSS SOLUTION

- r.diversity
Issue 1: Scale

Oldeland et al. (Ecol. Indic., 2010)
Issue 1: Scale

**Detail Scale**
With a smaller window of analysis, no relationship is found.

**Regional Scale**
Increasing the window of analysis, a positive relationship is found.
Issue 2: Metrics

- Problems with richness measure

- Richness = 3
- \( p = [0.7, 0.2, 0.1] \)

- Richness = 3
- \( p = [0.3, 0.3, 0.3] \)
**Issue 2: Metrics**

- **Single diversity metrics**
  - Shannon Diversity Index
    \[ H = - \sum p \times \ln(p) \]
  - Simpson Diversity Index
    \[ 1 - D = 1 - \sum p^2 \]
  - Pielou Diversity Index
    \[ J = \frac{-\sum p \times \ln(p)}{\ln(N)} \]

- **Continuum of diversity measures**
  - Rényi Generalized Entropy
    \[ H_\alpha = \frac{1}{1 - \alpha} \ln \sum p^\alpha \]
Issue 2: Metrics

- Continuum of diversity measures
  - Rényi Generalized Entropy

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

\[ \alpha=0 \quad \text{Rényi } H_0 = \ln(N) \]

\[ \lim_{\alpha \to 1} \quad \text{Rényi } H_1 = \text{Shannon } H \]

\[ \alpha=2 \quad \text{Rényi } H_2 = \log(1/\text{Simpson Dominance}) \]
Issue 2: Metrics


The graph shows the relationship between $H_\alpha$ and $\alpha$ for different landscapes: Landscape A, Landscape B, and Landscape C. The graph indicates how the metric $H_\alpha$ changes with different values of $\alpha$ for each landscape type.
Issue 2: Metrics

Lisa Simpson (Fox, 1990)

Issue 1: Scale | Issue 2: Metrics | The Solution
The solution

• GRASS add-on $r.diversity$

Issue 1: Scale | Issue 2: Metrics | The Solution
The solution

- GRASS add-on \textit{r.diversity}

\texttt{r.diversity input=raster\_grass}
\texttt{out=diversity size=3-7 alpha=2}

Issue 1: Scale | Issue 2: Metrics | The Solution
The solution

• Advantages of *r.diversity*

  – Complex diversity calculus available by a *straightforward command* into GRASS GIS

  – *Multiscale* calculation

  – Multiple metrics available, including a *Continuum of diversity measures* (e.g. Rényi Generalized Entropy)

  – *Code* available for further improvement
Concluding remarks: where from here?

- Emphasis should NOW be put in finding new ways for robust:
  - **data gathering**: “Future research should focus on incorporating recent and new spaceborne sensors, more extensive integration of available data from passive and active imagery that can be used across spatial scales, and the collection and dissemination of high-quality field data.” (Gillespie et al., Progr. Phys. Geogr., 2008)
  - **data analysis**: Free and robust tools for statistical analysis of ecological and remotely sensed data are now available in an Open Source space to allow applying the celebrated “four freedoms” paradigm (Stallman 1997) to remote sensing
Concluding remarks: where from here?
Thanks!

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

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