Global Remote Sensing-derived Measures of Habitat Heterogeneity for Biodiversity Modeling

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Introduction

Habitat heterogeneity has long been recognized as an important determinant of biodiversity patterns. However, due to a lack of direct measures across large areas, most broad-scale studies quantify habitat heterogeneity based on topographic variability or categorical land cover data. While the former provides a spatially inconsistent and temporally static surrogate, the latter ignore within-land-cover heterogeneity. In contrast, remote sensing provides spatially and temporal consistent observations on biophysical characteristics of land surface. Textural features of remote sensing imagery have been successfully used in diverse biodiversity research, and thus may have the potential for characterizing habitat heterogeneity and monitoring its dynamics across large spatial extents.

Objectives

To provide a standardized compilation of multiple characteristics of habitat heterogeneity, we:

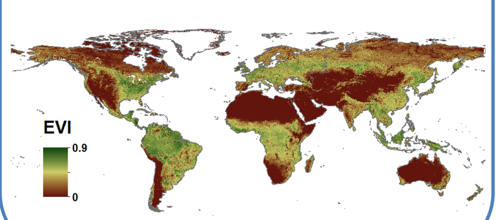
(1) develop 12 global data layers (~1 km resolution) of habitat heterogeneity based on the textural features of EVI imagery from MODIS;

(2) assess the ability of the texture measures to capture among- and within-land-cover heterogeneity;

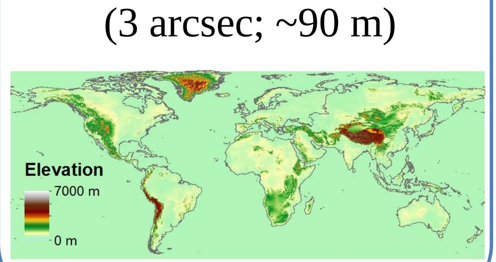
(3) compare their utility with that of conventional metrics for modeling bird species richness (SR) and functional diversity (FD).

Methods

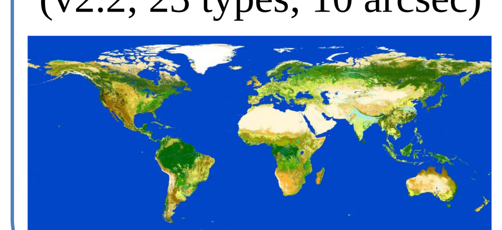
95th percentile of EVI (MOD13Q1; 2001-05; 250m)



EarthEnv-DEM90[1] (3 arcsec; ~90 m)



GlobCover 2005-06 (v2.2; 23 types; 10 arcsec)



Texture Measure [2]

First-order
- Coefficient of Variation (cv)
- Range (range)
- Skewness (skew)
- Standard Deviation (std)

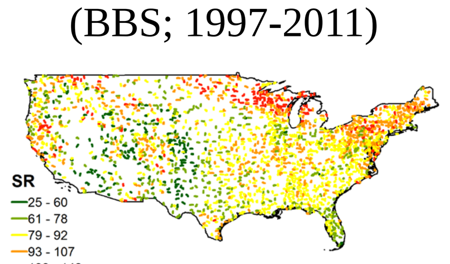
Second-order
- Angular Second Moment (ASM)
- Contrast (CON)
- Correlation (COR)
- Dissimilarity (DIS)
- Entropy (ENT)
- Maximum (MAX)
- Variance (VAR)
- Homogeneity (HOM)

Heterogeneity metrics (30 arcsec; ~1 km)

Topography-based Metrics
- Coefficient of Variation (DEM_cv)
- Range (DEM_range)
- Skewness (DEM_skew)
- Standard Deviation (DEM_std)

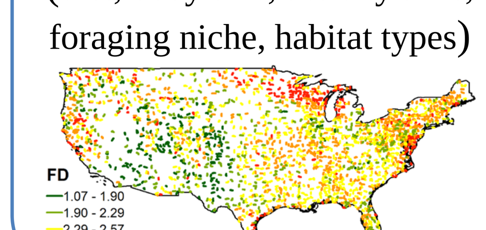
Landcover-based Metrics
- # of landcover types (GBC_rich)
- Pielou evenness (GBC_even)
- Shannon diversity (GBC_shan)
- Simpson diversity (GBC_simp)

Species richness (BBS; 1997-2011)



GLMs & SLMs
Stop & route levels

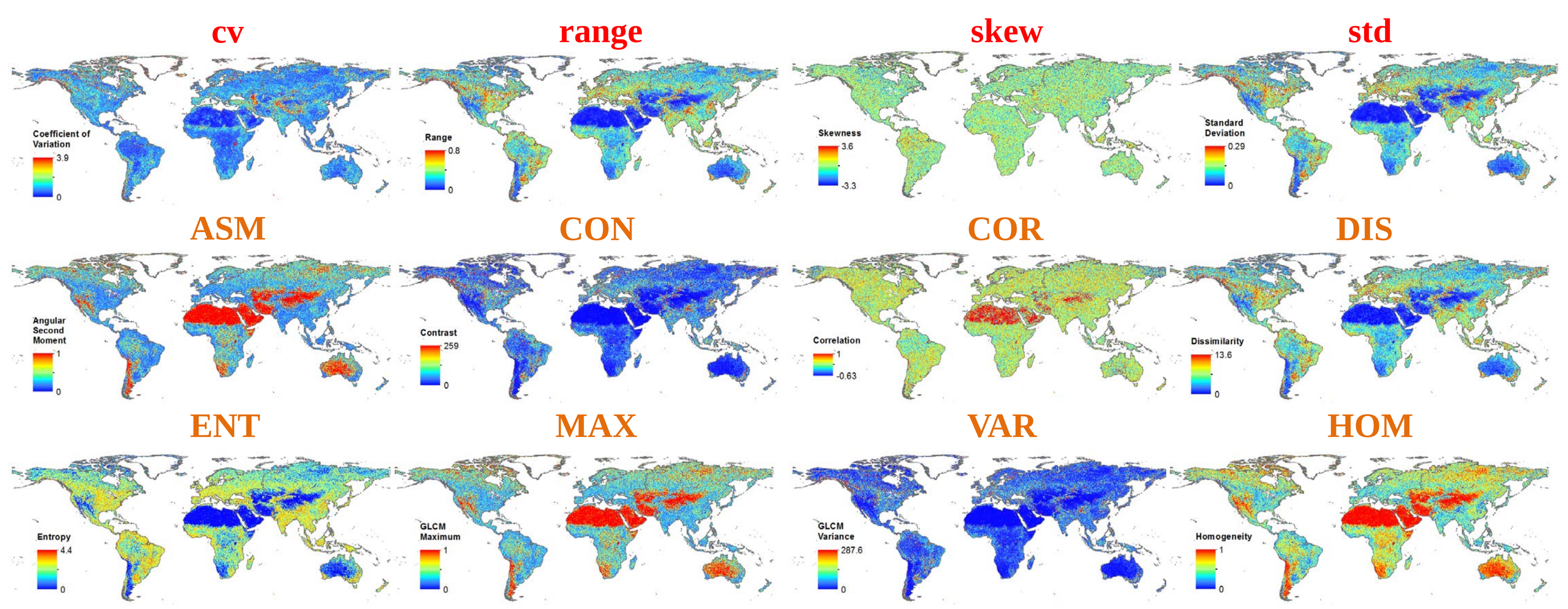
Functional diversity (diet, body size, activity time, foraging niche, habitat types)



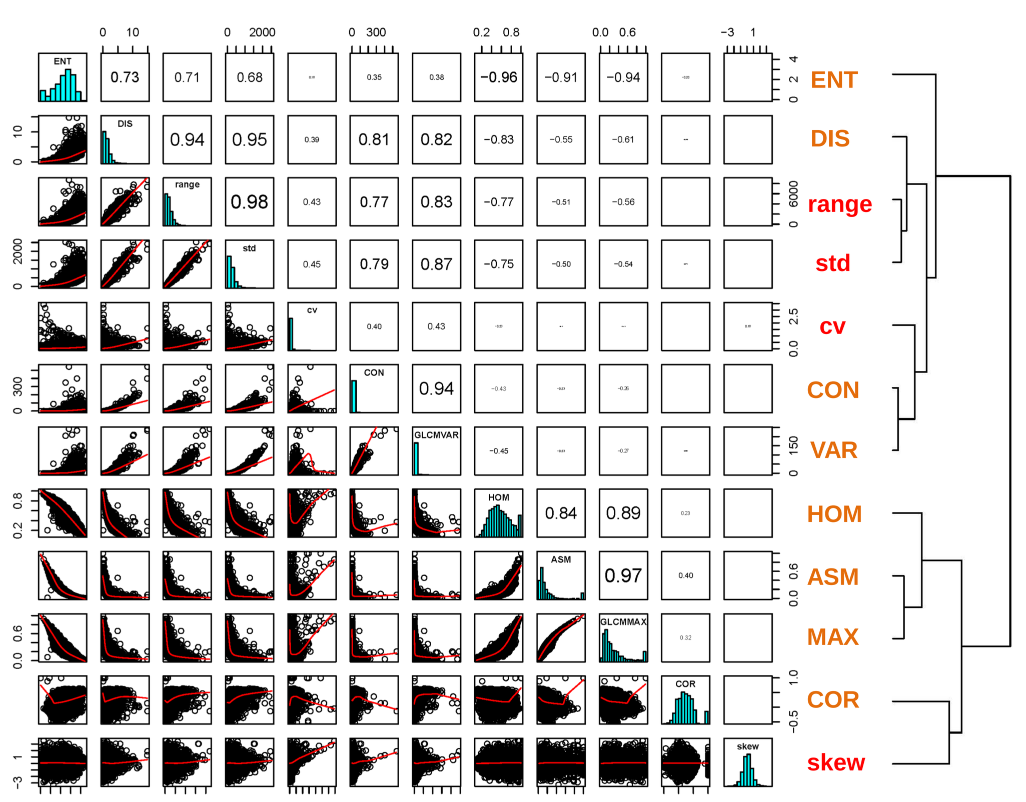
Results

Distinctness and complementarity of texture measures

Although they are correlated, texture measures capture some different aspects of habitat heterogeneity.



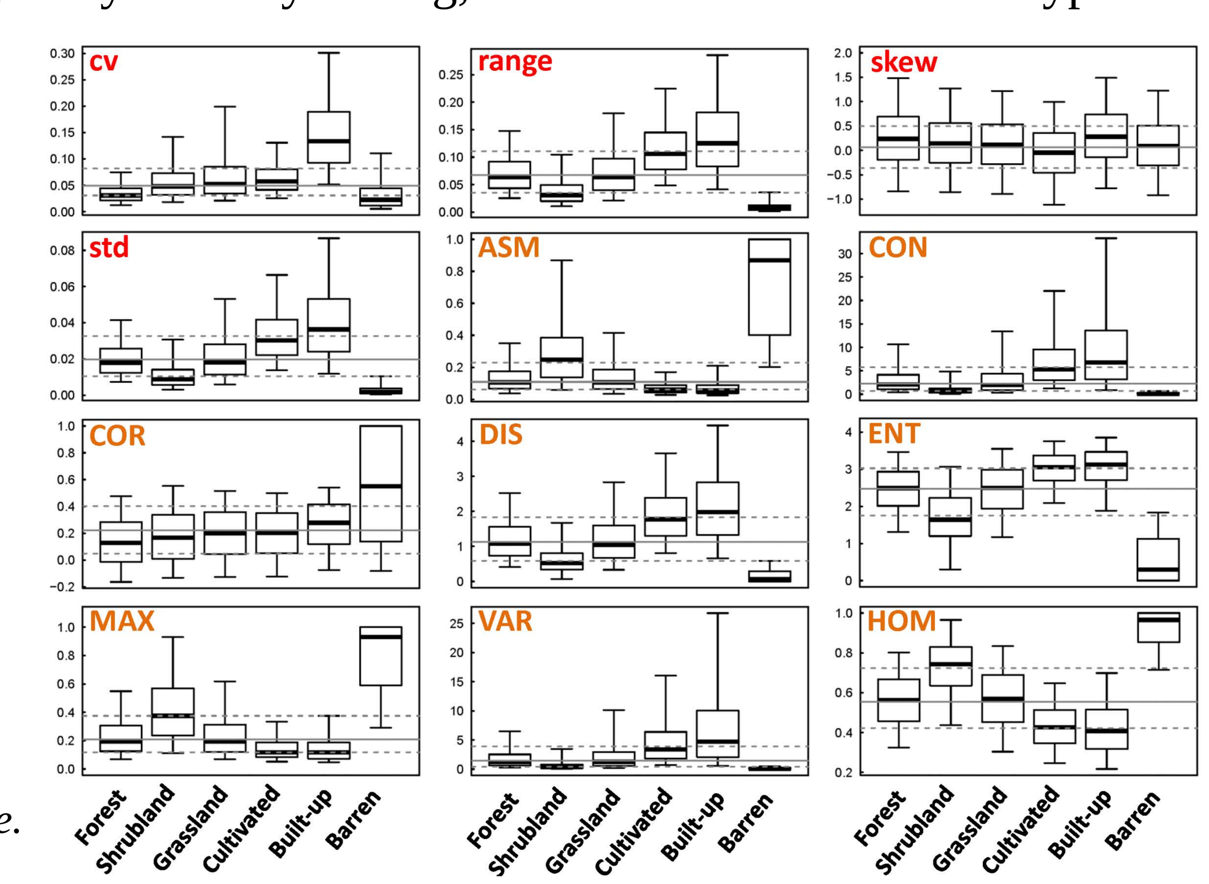
First- and second-order texture measures calculated at ~1-km resolution based on the 95th percentile of MODIS EVI between 2001 and 2005.



Scatter plots and Pearson's correlation coefficients for pairs of the 12 metrics. The diagonal shows the histogram for each metric. The dendrogram shows the dissimilarity among the metrics based on Mahalanobis distances in metric values.

Ability to capture among- and within-land-cover heterogeneity

Variation in metric values indicates the ability of texture measures to capture heterogeneity not only among, but also within land-cover types.

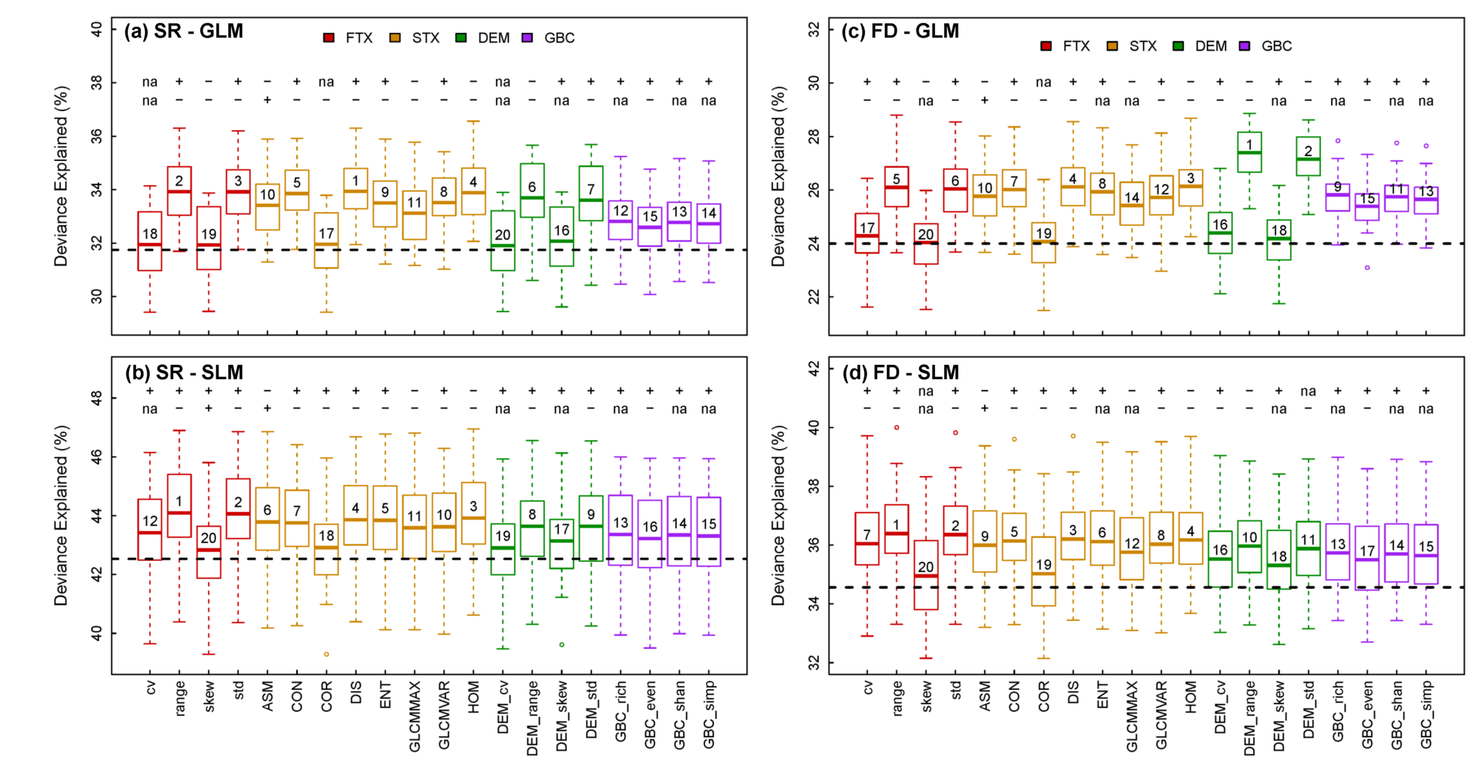


Values of texture measures for the pixels with homogeneous land cover based on the global consensus land-cover data[3]. Horizontal solid (dashed) lines indicate the medians (25th and 75th percentiles) for the terrestrial areas of the globe.

Results

Utility for biodiversity modeling

Models built with texture measures, compared to those built with conventional metrics, generally explain more deviance in both stop- and route-level bird species richness (SR) and functional diversity (FD) across the conterminous US.



Percentage of deviance in the stop-level SR (a, b) and FD (c, d) explained by GLMs (a, c) and SLMs (b, d) built with a single heterogeneity metric plus NPP. Boxplots show the values over 20 model replicates for randomly selected one BBS stop from each route. The labels above boxes indicate the sign and significance of coefficients for the linear and quadratic forms of the heterogeneity metric. The numbers indicate ranks of the models in terms of their explained deviance.

	cv	range	skew	std	ASM	CON	COR	DIS	ENT	MAX	VAR	HOM	DEM_cv	DEM_range	DEM_skew	DEM_std	GBC_rich	GBC_even	GBC_shan	GBC_simp
SR_GLM	23	28	23	28	28	30	22	30	29	28	29	30	21	23	25	24	24	24	25	24
SR_SLM	52	52	48	53	52	53	49	53	53	52	53	53	48	49	50	50	52	51	52	52
FD_GLM	30	35	26	35	33	35	26	35	34	33	35	35	25	26	28	26	29	28	29	29
FD_SLM	50	50	44	50	48	50	45	50	49	48	50	49	45	45	46	46	48	47	48	48

Percentage of deviance in the route-level SR and FD explained by GLMs and SLMs built with a single heterogeneity metric plus NPP.

Conclusions

(1) This study provides ready-to-use data layers of EVI-based texture measures capturing fine-grain (~1 km) habitat heterogeneity across most of the globe's land surface areas (85N-70S).

(2) The texture measures capture both among- and within-land-cover heterogeneity and generally outperform conventional metrics in terms of the utility for modeling large-scale community attributes.

(3) Due to the direct and temporally consistent measure of vegetation characteristics at a continuous scale by EVI, the texture measures may provide a vital tool for capturing ecologically relevant habitat attributes and monitoring their changes through time.

References

[1] Robinson et al., 2013, *ISPRS J PHOTOGRAMM*. [2] Haralick et al., 1973, *IEEE T SYST MAN CYB*; [3] Tuanmu & Jetz, 2014, *GLOBAL ECOL BIOGEOGR*.

Acknowledgements

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