Remotely Sensed Metrics of Habitat Heterogeneity for Spatial Biodiversity Modeling

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Introduction

The spatial heterogeneity of habitat has been recognized as an important determinant of species distributions and the diversity and structure of communities. Broad-scale biodiversity studies often quantify habitat heterogeneity based on landscape metrics **(LM)** derived from categorical land cover maps, but this data requires human interpretation that is not without error and may not be most pertinent for organisms. It is also limited in spatial and temporal grain and availability. Remote sensing-based texture measures **(TM)** provide spatially continuous and temporally consistent observations of the land surface, and thus may constitute an excellent tool for characterizing habitat heterogeneity and monitoring its dynamics.

Objectives

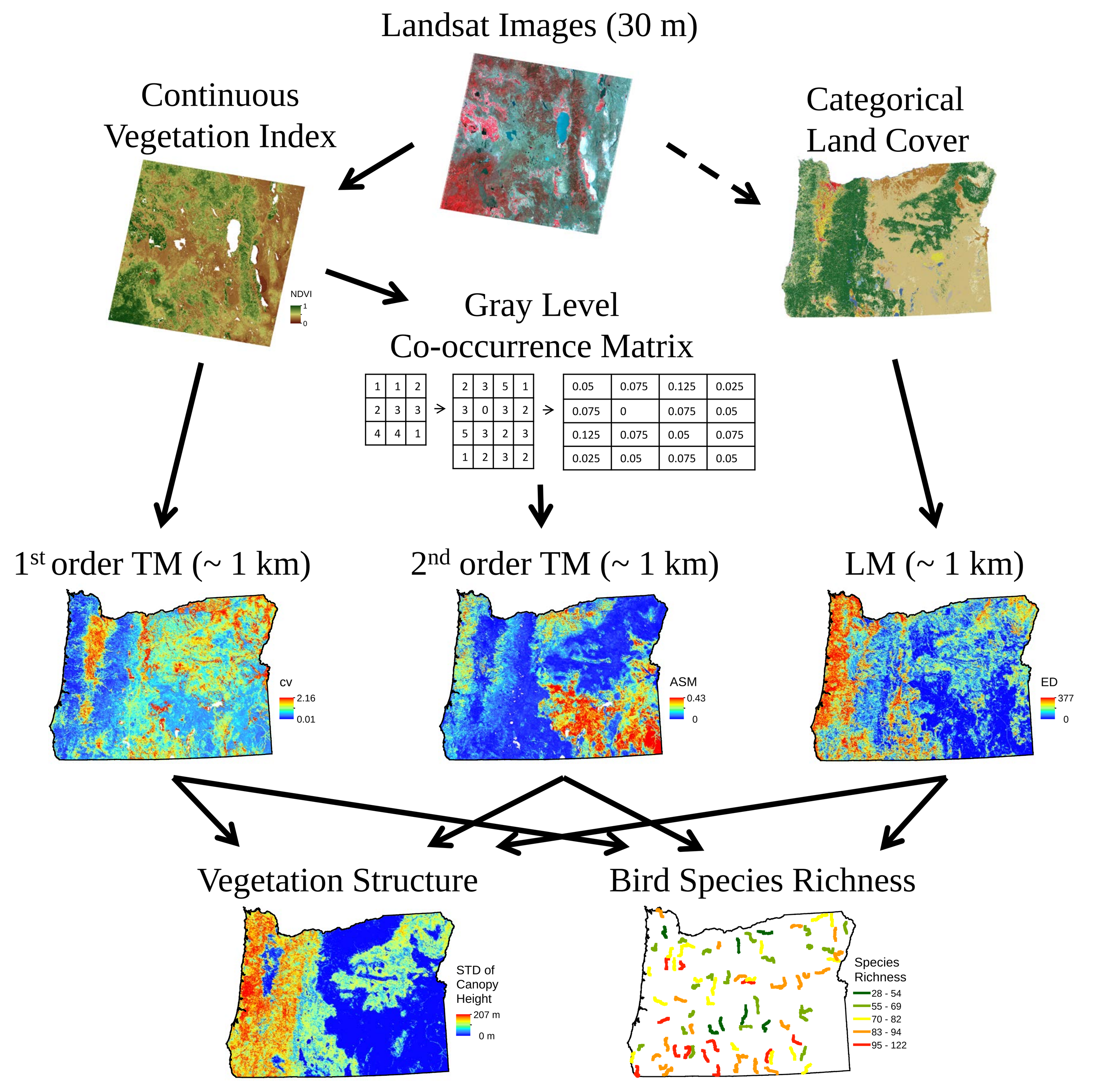
With Oregon as a test region, we assess the potential of various metrics based on non-classified remote sensing images (image texture) to capture habitat heterogeneity and model species richness. Specifically, we:

(1) compare the signal provided by texture measures (TM) derived from continuous NDVI values with that from landscape metrics (LM) derived from categorical land cover data;

(2) validate and compare the ability of TM and LM to capture the spatial heterogeneity of forest canopy height and aboveground biomass;

(3) evaluate the utility of TM and LM for modeling bird species richness and monitoring its changes.

Methods



Metrics

Texture measures are based on NDVI derived from 30-m LEDAPS Landsat images for two epochs around 1990 and 2000. Landscape metrics are calculated from the NLCD for 1992 and 2001, which were originally derived from 30-m Landsat images.

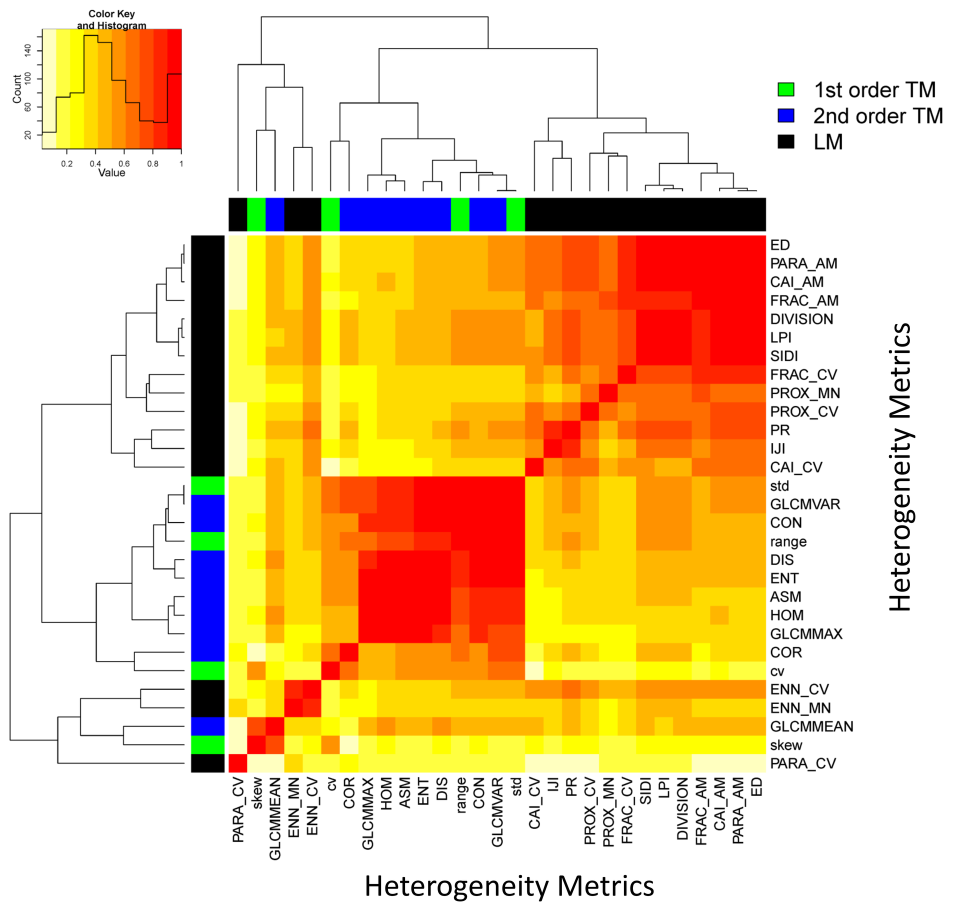
Texture Measure (TM) [1]
First-order
Coefficient of Variation (cv)
Range (range)
Skewness (skew)
Standard Deviation (std)
Second-order
Angular Second Moment (ASM)
Contrast (CON)
Correlation (COR)
Dissimilarity (DIS)
Entropy (ENT)
Homogeneity (HOM)
Maximum (GLCMMAX)
Mean (GLCMMEAN)
Variance (GLCMVAR)

Landscape Metric (LM) [2]
Area-Edge
Edge Density (ED)
Large Patch Index (LPI)
Core Area
Core Area Index (CAI_AM, CAI_CV)
Diversity
Patch Richness (PR)
Simpson's Diversity Index (SIDI)
Shape
Fractal Dimension Index (FRAC_AM, FRAC_CV)
Perimeter-Area Ratio (PARA_AM, PARA_CV)
Aggregation
Euclidean Nearest Neighbor Distance (ENN_MN, ENN_CV)
Interspersion Juxtaposition Index (IJI)
Landscape Division Index (DIVISION)
Proximity Index (PROX_MN, PROX_CV

Results

Distinctness and complementarity of TM and LM

Some TMs show medium correlations (0.7 > r > 0.4) with LMs, while others contain complementary information on landscape patterns.

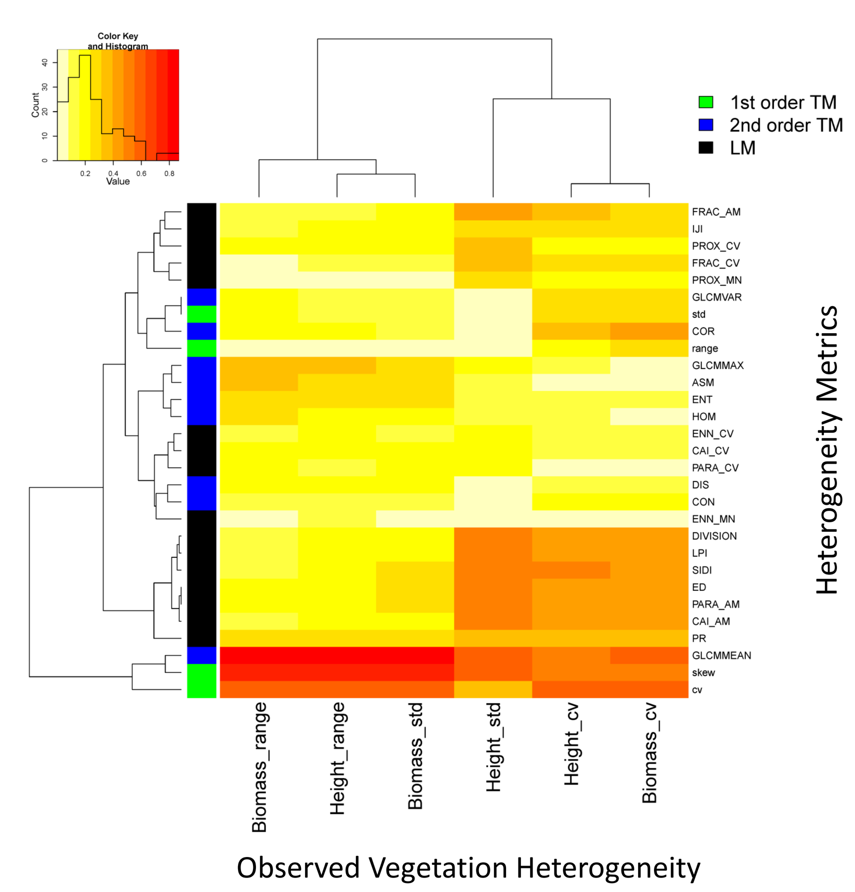


Absolute Spearman's correlation coefficients between every pair of the remotely sensed heterogeneity metrics based on 20,000 pixels (ca. 1 × 1 km) randomly selected within Oregon.

Validating the ability to quantify vegetation structure

Some TMs (cv, skew & GLCMMEAN) are highly correlated with observed spatial heterogeneity of vegetation structure, whereas LMs show only low to medium correlations.

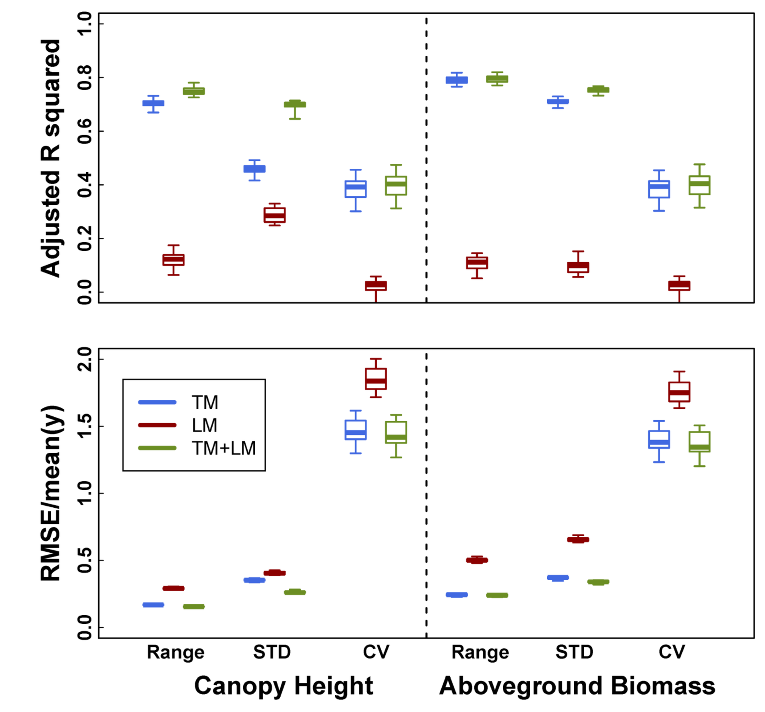
Absolute Spearman's correlation coefficients between the heterogeneity metrics and the observed spatial heterogeneity of forest canopy height & aboveground biomass (obtained from NBCD) based on 20,000 forested pixels (ca. 1 × 1 km) randomly selected within Oregon.



Results

Models built with TM explain more variation (higher adjusted R^2) in the spatial heterogeneity of vegetation structure and have more accurate predictions (lower RMSE normalized to the mean of observed values) than models built with LM. Including both TM and LM improves model performance only for predicting STD of canopy height.

Fit of the models predicting observed spatial heterogeneity of forest structure using principal components of TM , LM or TM+LM as predictors (selected by AIC with the stepwise approach). The models were built and evaluated with 20 sets of randomly selected 1,000 training and 1,000 test pixels.



Utility for modeling species richness

Models built with TM and those with LM have similar performance for predicting bird species richness within a time period, but the TM models succeed better in monitoring temporal changes in species richness.

Fit of the models predicting bird species richness along the BBS routes in Oregon during two time periods (1986-1995 & 1996-2005). The models were built with principal components (accounting for > 90% variation) of TM, LM or TM+LM for each time period as predictors.

Prediction		Model					
		TM (1990)	*LM (1992)*	*TM +LM (1990)*	*TM (2000)*	*LM (2001)*	*TM +LM (2000)*
BBS (1986-1995)	*Adjusted R^2*	0.60	0.60	0.51	0.48	**0.08**	0.54
	RMSE/mean(y)	0.15	0.15	0.14	0.18	**0.23**	0.16
BBS (1996-2005)	*Adjusted R^2*	0.28	**0.02**	0.38	0.39	0.35	0.50
	RMSE/mean(y)	0.18	**0.22**	0.16	0.17	0.17	0.14

Conclusions

(1) Texture measures successfully capture information about landscape patterns and land cover heterogeneity.

(2) Texture measures are better than landscape metrics in quantifying spatial heterogeneity of vegetation structure.

(3) Both texture measures and landscape metrics are useful for modeling community species richness, but texture measures are more sensitive to its temporal changes.

(4) As highly-resolved and fine-grain land cover data are not available for many places, texture measures may provide a vital tool for capturing ecologically relevant habitat attributes.

References

[1] Haralick et al., 1973, *IEEE Transactions on Systems, Man and Cybernetics*; [2] McGarigal et al., 2012, *FRAGSTATS v4: Spatial Pattern Analysis Program for Categorical and Continuous Maps*.

Acknowledgements

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