Remote Sensing and Landscape Metrics for Global Urban Ecological Monitoring

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ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer (asterweb.jpl.nasa.gov)
MODIS – Moderate Resolution Imaging Spectroradiometer (modis.gsfc.nasa.gov)

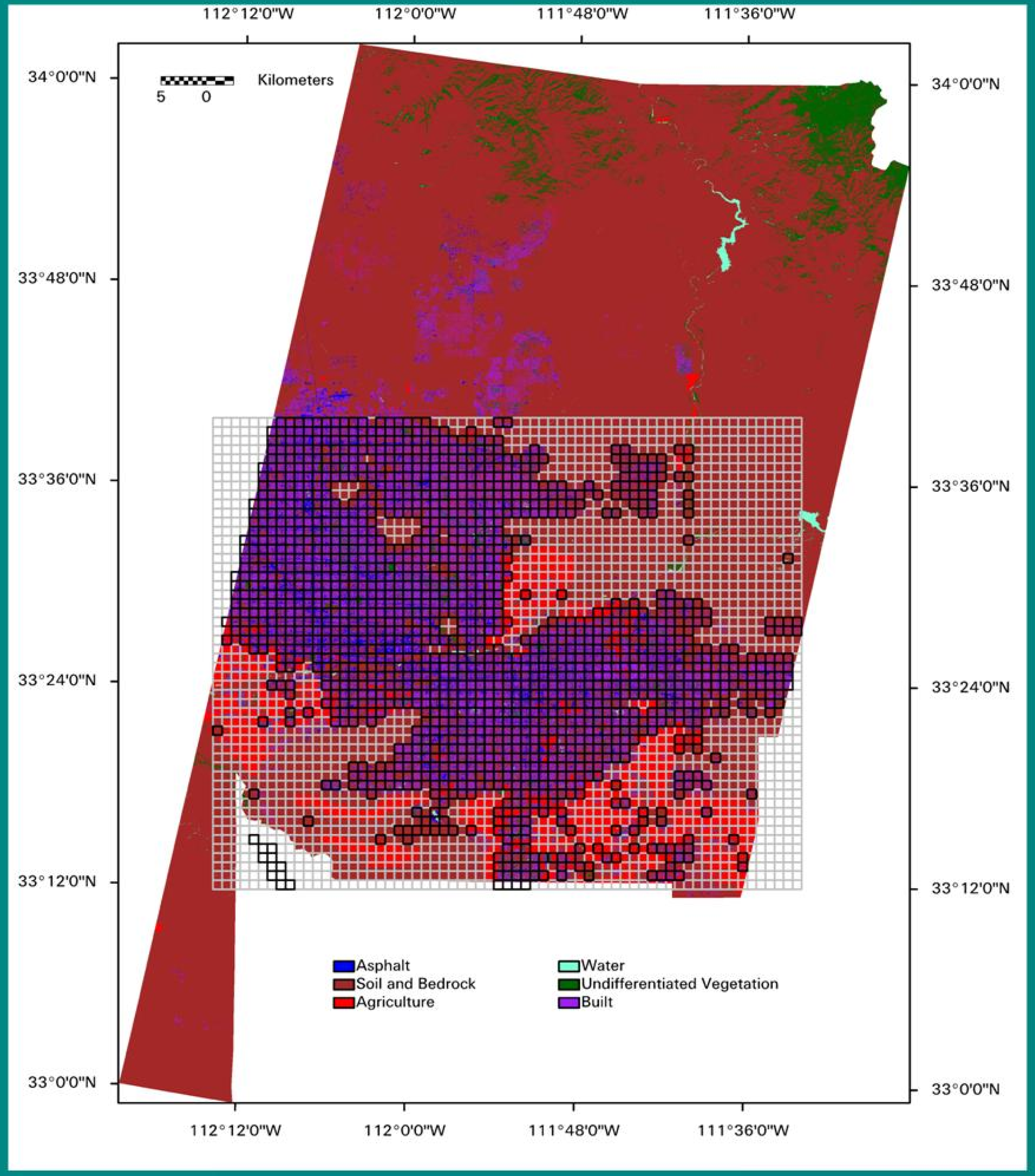

Figure 1. Aggregated land cover classification for the Phoenix study area derived from ASTER data using an expert system similar to that of Stefanov et al. (2001). Black grid cells are "urban", grey grid cells are "nonurban". Grid was constructed from corresponding MODIS 1 km² pixel extents. ASTER data acquired on September 19, 2000.

Data from the NASA Earth Observing System (EOS) sensors (such as ASTER and MODIS) promises to increase our understanding of global urban ecological processes and improve city and land planning capabilities. The ongoing Urban Environmental Monitoring (UEM) project at Arizona State University uses EOS data to characterize past and present urban and peri-urban ecological change. While characterization and monitoring of urban center land cover/land use change is important in establishing baseline information, it is only of limited use in understanding the development pathways of cities and their resilience to potential outside stressors. As an exemplar of the UEM project approach, we present an analysis of ASTER and MODIS data for Phoenix, Arizona, USA to explore the hypothesis that landscape structure directly affects biogeophysical parameters at relatively small spatial scales (1 kilometer). The methodology includes development of a new expert system land cover classification model for ASTER data (Stefanov and Netzband, in review), urban landscape structure analysis of the resulting land cover dataset using spatial metrics (McGarigal and Marks, 1994; Netzband and Kirstein, 2001; Rainis, 2003), and comparison with several measured biogeophysical parameters from MODIS (albedo, day/night surface temperature, fPAR, LAI, and NDVI;). Our results indicate that urban landscape structure is in general poorly correlated with all of the examined MODIS variables. We present potential explanations for this observed lack of correlation.

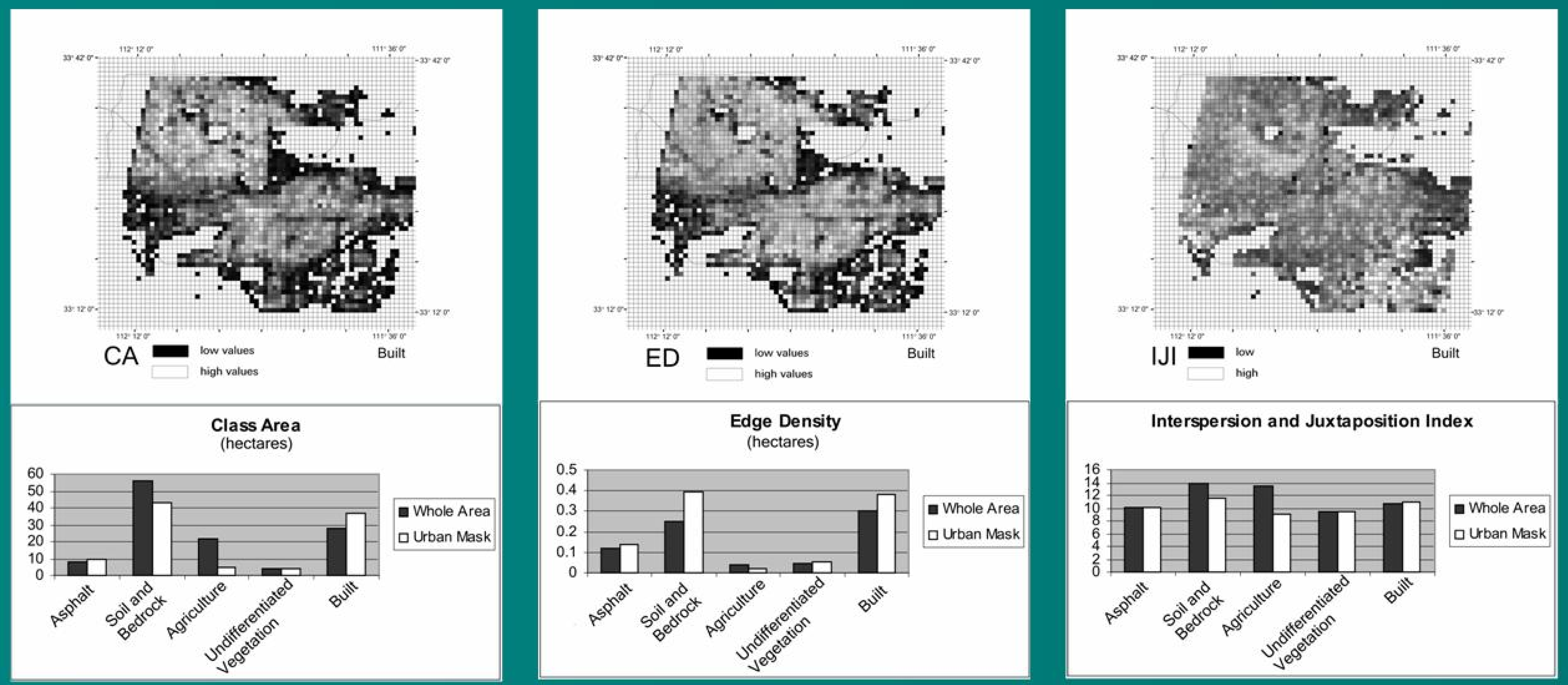

Figure 2. Representative graphic metric results for the Built class for Class Area (CA), Edge Density (ED), and the Interspersion and Juxtaposition Index (IJI). Mean Patch Size not shown due to relative lack of variance in data values.

Bar graphs illustrate metric results for all six aggregate land cover classes for both the urban grid cells and the entire gridded area. Note that the urban area accounts for most of the observed variance in the metric results.

Explanation of metrics

- ***Class Area*** equals the sum of the areas (m²) of all patches of the corresponding patch type, divided by 10,000 to convert to hectares.
- ***Edge Density*** equals the sum of the lengths of all edge segments involving the corresponding patch type, divided by the total landscape area, converted to hectares.
- The ***Interspersion and Juxtaposition Index*** describes the observed interspersion over the maximum possible interspersion for a given number of patch types within the landscape. IJI approaches 0 when the corresponding patch/land cover type is adjacent to only 1 other land cover type. IJI equals 100 when the corresponding land cover type is equally adjacent to all other land cover types within the landscape.
- ***Mean Patch Size*** (not shown) indicates the mean patch/land cover pixel size in hectares and is a function of the total area of the landscape and the number of patch types.

MODIS Data (acquired 13-28 September 2000)

Table 1. Descriptive Statistics for MODIS Datasets for Urban (U) and Nonurban (NU) Cells

Dataset (units)	Minimum U	Minimum NU	Maximum U	Maximum NU	Mean U	Mean NU	± 1 σ U	± 1 σ NU
Albedo (unitless)	0.10	0.05	0.30	0.31	0.19	0.20	0.03	0.04
fPAR (%)	0.10	0.08	0.81	0.82	0.28	0.26	0.10	0.11
LAI (m²/m²)	0.10	0.10	3.30	4.30	0.38	0.37	0.22	0.29
Day Surface Temperature (Kelvin)	24.50	24.50	51.00	52.00	47.26	47.74	1.66	2.96
Night Surface Temperature (Kelvin)	0.00	0.00	30.00	30.00	27.55	26.82	2.08	4.48
NDVI (unitless)	0.04	0.07	0.72	0.74	0.24	0.23	0.08	0.11

Table 2. Selected Results for Landscape Metric/MODIS Variable Correlation for Urban (U) and Nonurban (NU) Cells

	Asphalt U	Asphalt NU	Soil and Bedrock U	Soil and Bedrock NU	Agriculture U	Agriculture NU	Undifferentiated Vegetation U	Undifferentiated Vegetation NU	Built U	Built NU
Class Area										
Albedo	**-0.231**	-0.076	0.155	-0.074	0.189	**0.221**	-0.008	-0.018	-0.188	0.061
fPAR	-0.002	0.156	**-0.334**	-0.107	0.085	0.024	**0.210**	-0.027	**0.231**	0.038
Day Surface Temperature	0.149	0.060	**0.258**	0.109	-0.083	-0.011	**-0.271**	-0.028	-0.190	0.007
Night Surface Temperature	0.034	0.196	0.097	**0.293**	**-0.232**	**-0.289**	-0.112	0.047	0.113	-0.004
NDVI	-0.048	-0.100	**-0.289**	**-0.367**	0.076	**0.390**	0.182	0.039	**0.218**	0.024
Mean Patch Size										
Night Surface Temperature	0.015	0.073	0.094	**0.222**	-0.199	-0.102	-0.074	0.005	0.155	-0.046
NDVI	-0.091	-0.048	-0.129	**-0.298**	0.047	0.194	-0.038	-0.029	0.177	0.168
Edge Density										
Albedo	**-0.298**	-0.114	-0.174	0.109	0.146	0.183	-0.033	-0.019	-0.165	0.052
fPAR	0.031	0.122	0.049	0.090	0.078	-0.009	**0.275**	-0.022	0.159	0.007
Day Surface Temperature	0.157	0.070	-0.039	0.030	-0.167	-0.025	**-0.341**	-0.029	-0.160	0.023
Night Surface Temperature	0.019	**0.216**	0.023	-0.005	-0.124	**-0.257**	-0.134	0.041	0.055	0.022
NDVI	-0.014	-0.107	0.052	-0.010	0.068	**0.245**	**0.248**	0.066	0.167	-0.018
Interspersion/Juxtaposition										
Albedo	-0.144	-0.027	0.056	-0.066	0.099	0.094	-0.049	0.099	**-0.213**	-0.044
fPAR	**0.246**	0.120	-0.059	-0.022	0.193	0.066	0.191	-0.011	**0.353**	0.147
LAI	0.048	0.096	0.004	0.017	0.047	-0.043	0.058	0.061	0.102	0.073
Day Surface Temperature	**-0.279**	-0.070	0.104	0.042	-0.164	-0.040	-0.191	0.026	**-0.281**	-0.070
Night Surface Temperature	-0.062	0.009	-0.091	0.177	**-0.225**	**-0.293**	-0.137	-0.054	-0.067	-0.156
NDVI	**0.230**	0.105	-0.055	-0.187	0.186	**0.378**	0.167	0.184	**0.307**	**0.335**

Results and Discussion

Table 2 indicates that correlations between ASTER-derived landscape structure and MODIS biogeophysical variables are weak to non-existent, suggesting that our original hypothesis is incorrect. However, the weak correlations that are observed suggest that some connection between certain biogeophysical variables (surface temperature, vegetation density, albedo) and urban landscape structure are present and captured by the MODIS data.

Comparative studies using multiple datasets are crucial to assessment of the usefulness of high temporal resolution MODIS biogeophysical data for urban ecological studies and monitoring – our results suggest that the 1km² datasets we used are of limited utility, at least for the Phoenix metro area.

Some potential causes for the observed lack of correlation:

- the 1km² pixel size of the MODIS data may average subpixel variation over the Phoenix metro area, leading to relatively low variance in the data (Table 1). **We will investigate this by repeating this analysis using MODIS 250 m/pixel data and a 250 m grid spacing.**

- overall spatial heterogeneity of Phoenix land cover distribution may produce relatively little variation in landscape structure at the scale of grid analysis (Figure 2) for the metrics used. **We will address this by performing similar analysis on a structurally different city such as Berlin.**

References

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