B61C - 0739: ASSESSMENT OF LANDSCAPE FRAGMENTATION ASSOCIATED WITH URBAN CENTERS USING ASTER DATA

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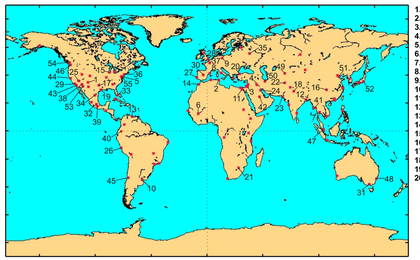
ABSTRACT

The role of humans as an integral part of the environment and ecosystem processes has only recently been accepted into mainstream ecological thought. The realization that virtually all ecosystems on Earth have experienced some degree of human alteration or impact has highlighted the need to incorporate humans (and their environmental effects) into ecosystem models. A logical starting point for investigation of human ecosystem dynamics is examination of the land cover characteristics of large urban centers. Land cover and land use changes associated with urbanization are important drivers of local geological, hydrological, ecological, and climatic change. Quantification and monitoring of urban land cover/land use change is part of the primary mission of the ASTER instrument on board the NASA Terra satellite, and comprises the fundamental research objective of the Urban Environmental Monitoring (UEM) Program at Arizona State University. The UEM program seeks to acquire day/night, visible through thermal infrared data twice per year for 100 global urban centers (with an emphasis on semi-arid cities) over the nominal six-year life of the Terra mission. Data have been acquired for the majority of the target urban centers and are used to compare landscape fragmentation patterns on the basis of land cover classifications. Land cover classifications of urban centers are obtained using visible through mid-infrared reflectance and emittance spectra together with calculated vegetation index and spatial variance texture information (all derived from raw ASTER data). This information is combined within a classification matrix, using an expert system framework, to obtain final pixel classifications. Landscape fragmentation is calculated using a pixel per unit area metric for comparison between 55 urban centers with varying geographic and climatic settings including North America, South America, Europe, central and eastern Asia, and Australia. Temporal variations in land cover and landscape fragmentation are assessed for 9 urban centers (Albuquerque, New Mexico, USA; Baghdad, Iraq; Las Vegas, Nevada, USA; Lisbon, Portugal; Madrid, Spain; Riyadh, Saudi Arabia; San Francisco, California, USA; Tokyo, Japan; and Vancouver, Canada). These data provide a useful baseline for comparison of human-dominated ecosystem land cover and associated regional landscape fragmentation. Continued collection of ASTER data throughout the duration of the Terra mission will enable further investigation of urban

INTRODUCTION AND OBJECTIVES

- **The role of humans as integral components of ecosystems, both driving biogeophysical change and effected by these same changes, has only recently been accepted into mainstream ecological thought. The logical starting point to gain understanding of ecosystem processes in human-dominated systems is investigation of urban centers and their dynamics (Grimm et al. 2000).**
- **The Urban Environmental Monitoring (UEM; elwood.la.asu.edu/grsl/UEM/) project at Arizona State University seeks to investigate urban ecosystem processes by acquiring biseasonal, day/night data collected by NASA EOS sensors (primarily the Advanced Spaceborne Thermal Emission and Reflection Radiometer, or ASTER) for 100 urban centers during the projected six-year mission of the Terra satellite (Stefanov et al. 2001a).**
- **The current research assesses the degree of landscape fragmentation associated with 55 urban centers using land cover classifications as input to calculate Pixel Per Unit Area (PPU) index values. These index values are recast into percent area (for each ASTER scene) to allow comparison between urban centers located on all of the major continents.**

CITY SITE LOCATIONS



1. Albuquerque 17-June-00
2. Algiers 27-July-00
3. Amman 1-May-01
4. Baghdad 18-Oct-00
5. Baltimore 28-Apr-01
6. Bamako 11-March-01
7. Bangkok 29-July-00
8. Barcelona 3-July-01
9. Berlin 2-Apr-01
10. Buenos Aires 18-Nov-00
11. Cairo 10-May-00
12. Calcutta 29-March-00
13. Caracas 3-Sept-00
14. Casablanca 10-Apr-01
15. Chicago 3-May-00
16. Chongqing 31-July-00
17. Dallas 19-Aug-00
18. Delhi 17-March-01
19. Houston 27-Oct-01
20. Istanbul 16-June-00
21. Johannesburg 16-Oct-00
22. Kabul 10-Sept-01
23. Karachi 28-Oct-01
24. Kuwait City 3-July-01
25. Las Vegas 17-Oct-00
26. Lima 4-Apr-01
27. Lisbon 24-Oct-01
28. London 12-Oct-01
29. Los Angeles 23-July-01
30. Madrid 12-Apr-01
31. Melbourne 26-Feb-01
32. Mexico City 9-Apr-01
33. Miami 11-May-00
34. Monterrey 4-Sept-00
35. Moscow 4-May-01
36. New York 8-June-01
37. Paris 23-May-01
38. Phoenix 19-Sept-00
39. Puebla 4-July-00
40. Quito 2-Oct-01
41. Rangoon 16-Apr-01
42. Riyadh 26-July-00
43. San Diego 10-May-00
44. San Francisco 14-June-00
45. Santiago 29-Jan-01
46. Seattle 7-Feb-01
47. Singapore 2-June-01
48. Sydney 26-Nov-01
49. Tashkent 26-Sept-01
50. Tehran 26-June-01
51. Tianjin 20-Aug-00
52. Tokyo 4-June-01
53. Tucson 26-May-01
54. Vancouver 9-Aug-01
55. Washington D.C. 28-Apr-01

Figure 7. Urban centers were selected for analysis based on their geographic location and availability of high-quality ASTER data (low cloud cover and the majority of the urban center captured). Numbers correspond to individual cities on the map (scene acquisition dates are also given). Red squares without an associated number are other city targets of the UEM project not included in the current work.

METHODOLOGY

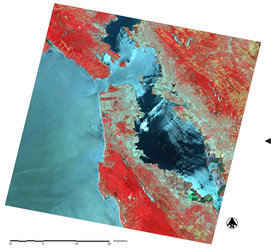


Figure 1. ASTER visible-near infrared (321 RGB) scene of the San Francisco metropolitan area acquired 14-June-00.Vegetation is red, urban areas are blue-green, and water is blue-black.

Table 1. ASTER Specifications (Abrams, 2000)

Wavelength region	Band	Bandwidth (m)	Resolution (m/pixel)
Visible to near infrared	1	0.52 – 0.60	15
	2	0.63 – 0.69	15
	3	0.76 – 0.86	15
Shortwave infrared	4	1.60 – 1.70	30
	5	2.145 – 2.185	30
	6	2.185 – 2.225	30
	7	2.235 – 2.285	30
	8	2.295 – 2.365	30
	9	2.360 – 2.430	30
Mid- (thermal) infrared	10	8.125 – 8.475	90
	11	8.475 – 8.825	90
	12	8.925 – 9.275	90
	13	10.25 – 10.95	90
	14	10.95 – 11.65	90

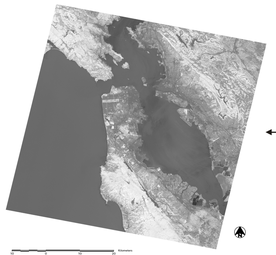


Figure 2. NDVI (Normalized Difference Vegetation Index) data derived from the visible-near infrared ASTER data in Fig. 1. Brightness corresponds to vegetation abundance (bright = high, dark = low).

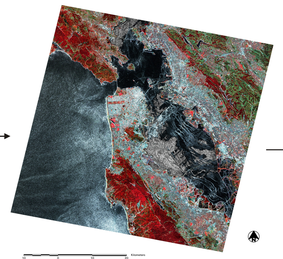


Figure 3. Variance texture image for ASTER bands 321 (as RGB) calculated from Fig. 1. Pixel brightness corresponds to edge density (bright = high, dark = low). Urban areas appear bright due to high edge density resulting from buildings, streets, etc.

	Low Vegetation	Moderate Vegetation	High Vegetation
Low Texture	Bare Soil/Low Vegetation, Roadways	Moderate Vegetation	High Vegetation
Moderate Texture	Low Density Urban, Roadways and Dry Washes	Moderate Density Urban	High Vegetation
High Texture	High Density Urban	Moderate Density Urban	Moderate Density Urban

Figure 4. Matrix used with classified NDVI, texture, and spectral information (for water) to produce land cover classifications for urban centers using a modification of the expert classification system of Stefanov et al. (2001b).

Unsupervised classification of NDVI and texture data into low, moderate, and high classes

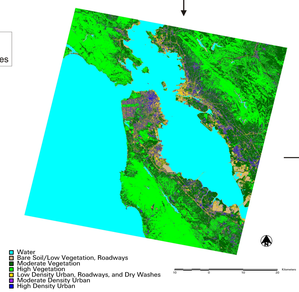


Figure 5. Land cover classification of the metropolitan San Francisco region.

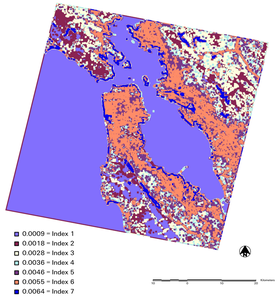


Figure 6. Landscape fragmentation is calculated using the Pixel Per Unit area (PPU) index of Frohn (1998). The index is (number of pixel classes per unit area)/1089, which corresponds to a unit area of 250 m x 250 m (equal to 1089 ASTER pixels). This unit area was selected as it is intermediate between the typical scale of landscape modeling (1 km^2) and the full resolution of ASTER visible to near infrared data (15 m/pixel). Full resolution data was not used in order to more clearly distinguish fragmentation associated with urban centers from small-scale surficial variations in undisturbed landscapes.

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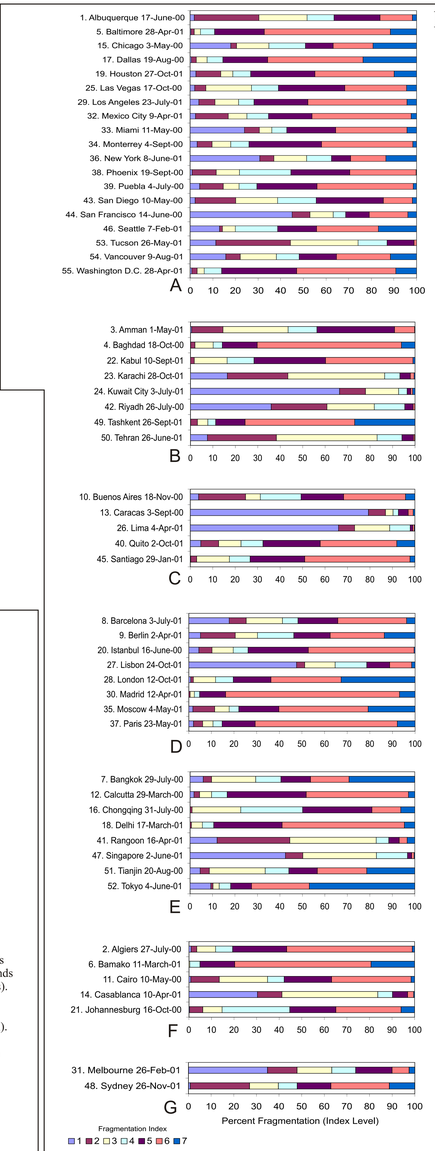

Figure 8. Percent landscape fragmentation level by ASTER scene for urban centers. Fragmentation index values correspond to calculated values presented in Fig. 6; higher index values represent higher levels of landscape fragmentation per unit area. Urban centers are grouped according to location: A - North America; B - Middle East; C - South America; D - Europe; E - Asia/India; F - Africa; G - Australia.

RESULTS AND DISCUSSION

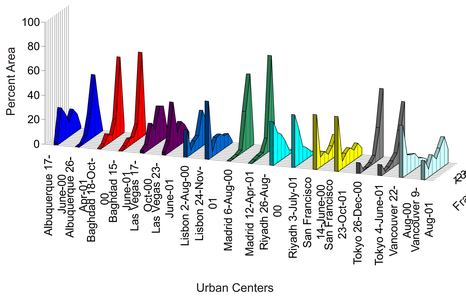

Figure 9. Comparison of fragmentation levels for urban centers over approximately one year. In general, fragmentation levels are comparable for each individual city. Major differences in fragmentation levels are due to variation in ASTER scene coverage over the urban center (i.e. Vancouver).

Table 2. Urban Centers with over 50% Area Fragmentation Indices 5 and Higher

Region	total n	# of Cities	%
All Regions	55	37	67
North America	19	13	68
South American	5	3	60
Africa	5	4	80
Asia/India	8	6	75
Europe	8	7	87.5
Australia	2	1	50
Middle East	8	3	37.5

- Results of the fragmentation analyses of 55 urban centers suggest that relatively intense landscape fragmentation (defined as fragmentation indices of 5 or higher per unit area) of the urban/exurban region is present in over half of the metropolitan areas examined (Fig. 8 and Table 2).
- European, African, and Asian/Indian urban centers exhibit the highest degrees of landscape fragmentation relative to other continental areas. This result reflects the high population densities in the selected cities, as the majority of cities in this grouping are "megacities". The impact of large human populations, and associated landscape alteration, on ecosystem connectiveness is well illustrated and quantified by the current work.
- The results presented here are based solely on ASTER data. The high spectral and spatial resolution allows for increased classification accuracy (estimated at 75-80% overall) of both built and natural materials, however spatial and temporal coverage of the data is not uniform. This difficulty is illustrated for several cities in Fig. 9. Future work will involve the incorporation of other datasets (such as Landsat Thematic Mapper, Enhanced Thematic Mapper Plus, and Advanced Land Imager data, and astronaut photography) to create a more uniform temporal and spatial dataset for each city.
- Incorporation of additional ancillary geospatial data (i.e. land use, geologic, and vegetation maps; agricultural or water use data; and zoning information) for each city could be used to further refine the classification algorithm.

ACKNOWLEDGEMENTS

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