

Land Fragmentation under Rapid Urbanization:

A cross-site comparative analysis

Milan Shrestha¹, Abigail York^{1,2}, Christopher Boone^{1,2,3}, Sainan Zhang^{1,3}

Land fragmentation is a critical social and environmental challenge posed by rapid urbanization for many metropolitan cities across the United States. Some of the social and ecological impacts of land fragmentation caused by sprawl, leap-frog development, suburbanization, exurbanization and other forms of urbanization are the loss of the connecting corridors for ecological processes (Grimm et al. 2008, Alberti 2005), reduced efficiency in public services, increased commuting times and fuel consumption, decreased ability to use lands for agricultural or forest production, and loss of culturally relevant open spaces and natural amenities (Schipper 2008). What are the patterns and processes of land fragmentation in the cities of the US Southwest? This question is addressed in a cross-site study involving five Long-Term Ecological Research (LTER) sites: Central Arizona-Phoenix (CAP), Sevilleta (SEV), Jornada Basin (JRN), Konza Prairie (KNZ), and Shortgrass Steppe (SGS) (Figure 1). In this study, we take a cross-site comparative approach to: (1) examine and measure land fragmentation in these five study sites, and (2) analyze the role of urban population dynamics, water provisioning, transportation, amenity-driven growth, and institutional factors on patterns of land fragmentation.

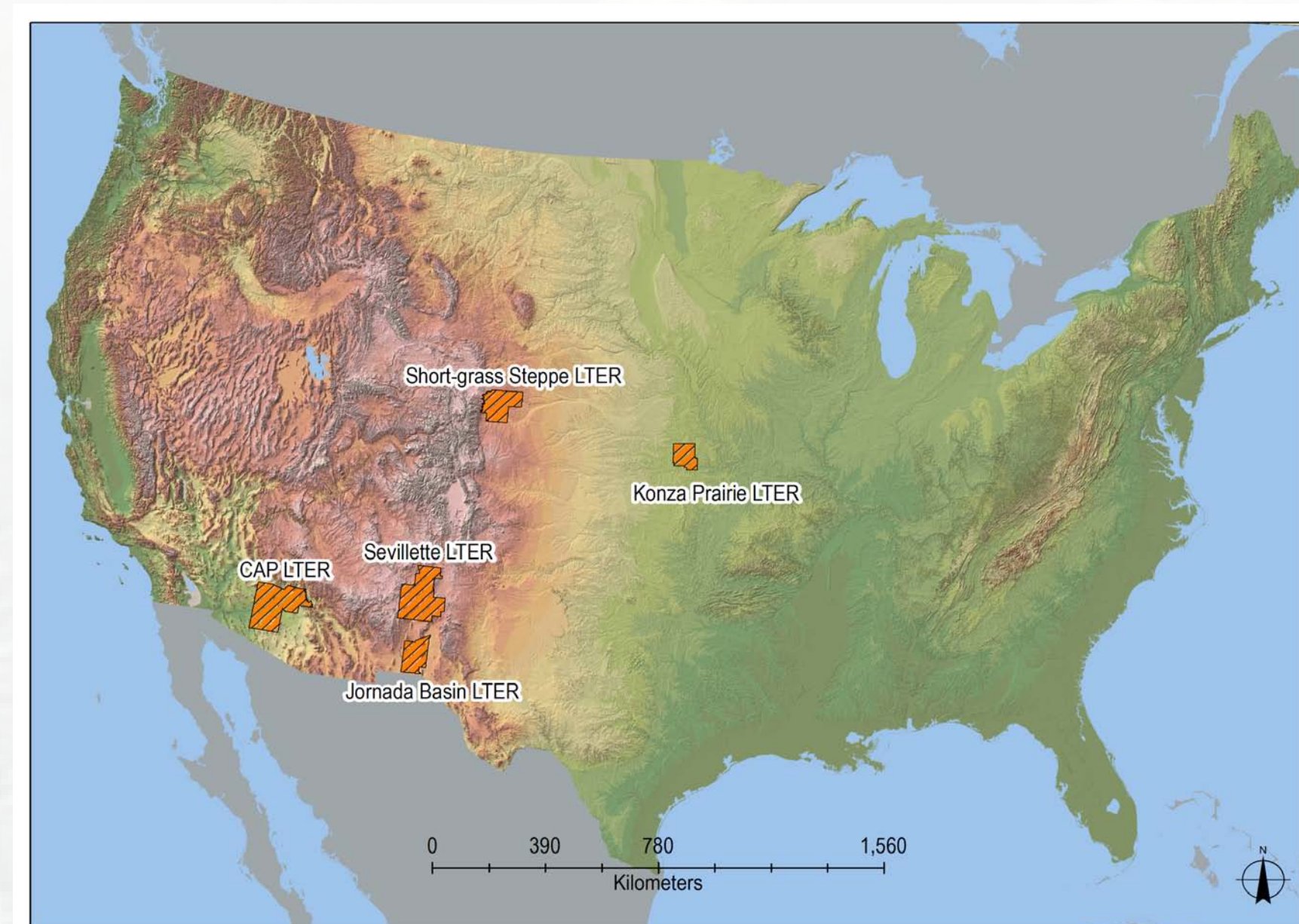


Figure 1. Study Sites

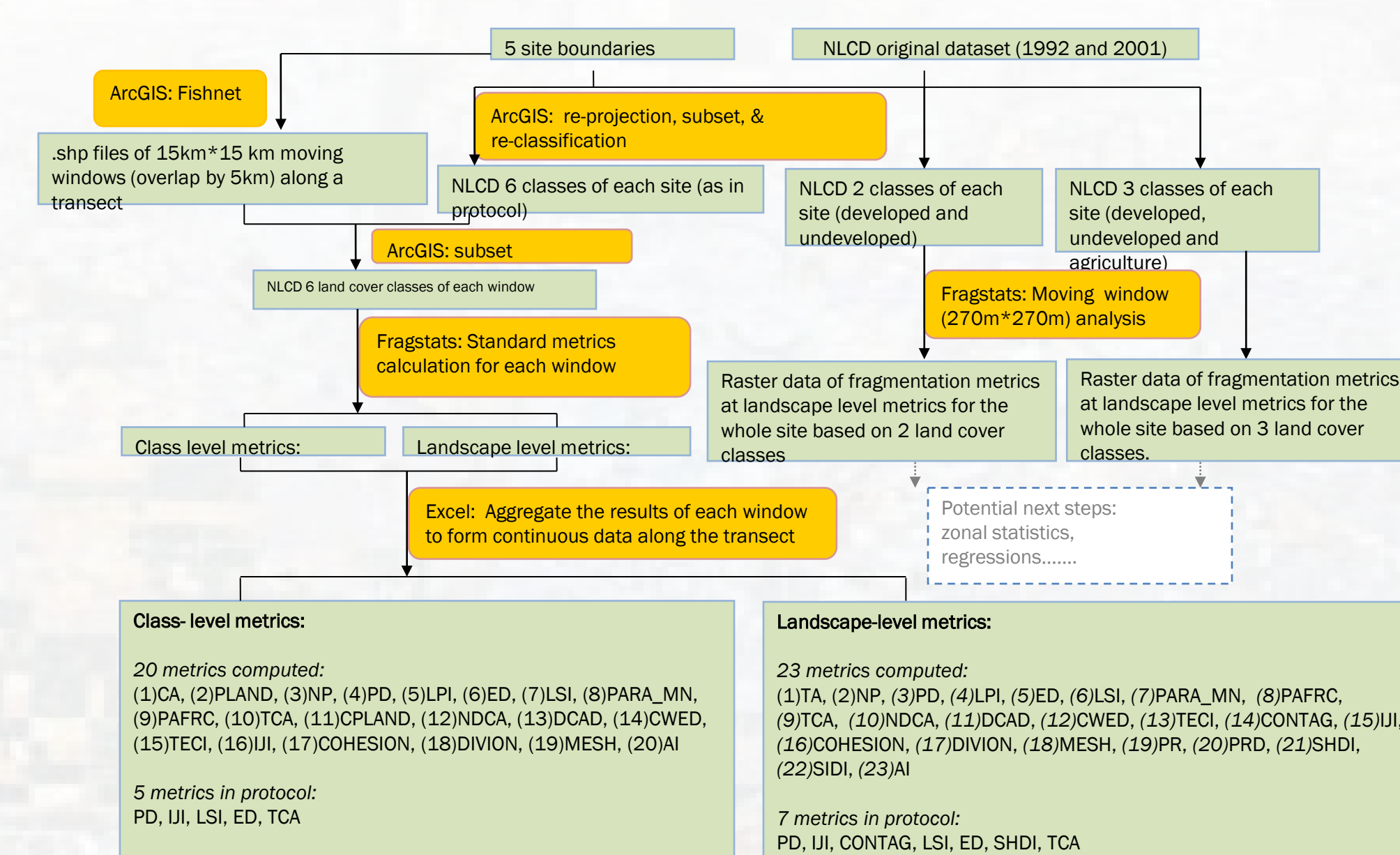


Figure 2. Study methodology

Dataset and methodology

Data used in this study are from the National Land Cover Dataset (NLCD) of 1992 and 2001, compiled from Landsat TM series. NLCD is the first nationwide initiative to provide consistent and seamless land-cover inventory for the US (Vogelmann et al. 1998; Homer et al. 2004) and it also has been widely used in fragmentation studies (Heilman et al. 2009; Riitters et al. 2002), despite a few of its limitations (Irwin and Bockstael 2007). As shown in in Figure 2, We reclassified the original land cover classes into seven categories: developed-higher intensity, developed-lower intensity, agriculture, forest, undeveloped, grass/shrubland, and water. We also quantified the fragmentation patterns using landscape metrics: Patch Density (PD), Interspersion and Juxtaposition Index (IJI), Contagion (CONTAG), Landscape Shape Index (LSI), Edge Density (ED), and Shannon's Diversity Index (SDI). Using the transect analysis (Luck and Wu 2002), we calculated these landscape metrics for each site at both the landscape level (Figure 3) and the class-level (Figure 4), and compared fragmentation patterns across the sites. The final step is to analyze the drivers of land fragmentation across the sites and the relationship of land fragmentation with ecosystem services.

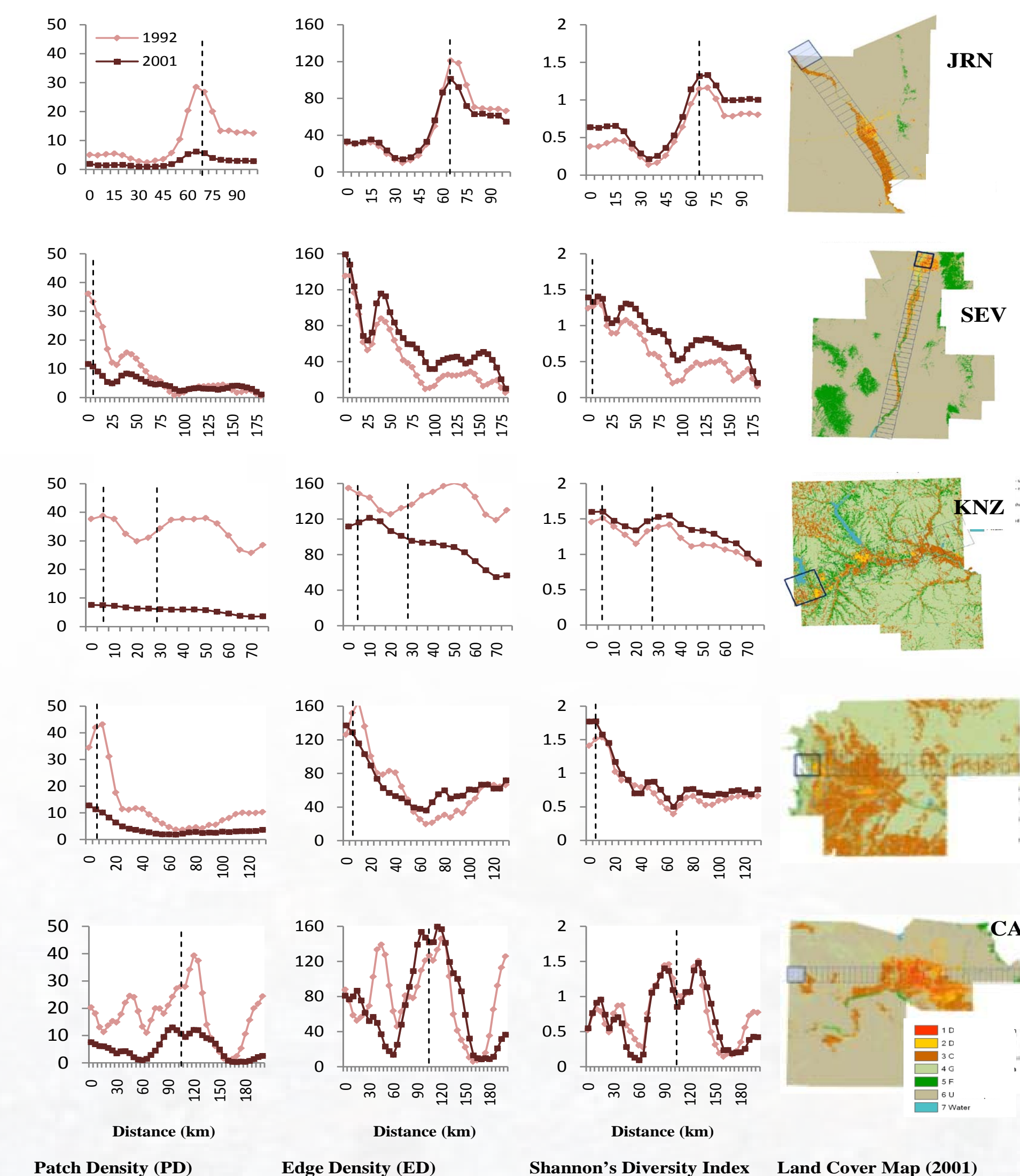


Figure 3. Spatial distribution of different landscape metrics at landscape-level along transect for the 5 sites in 1992 and 2001

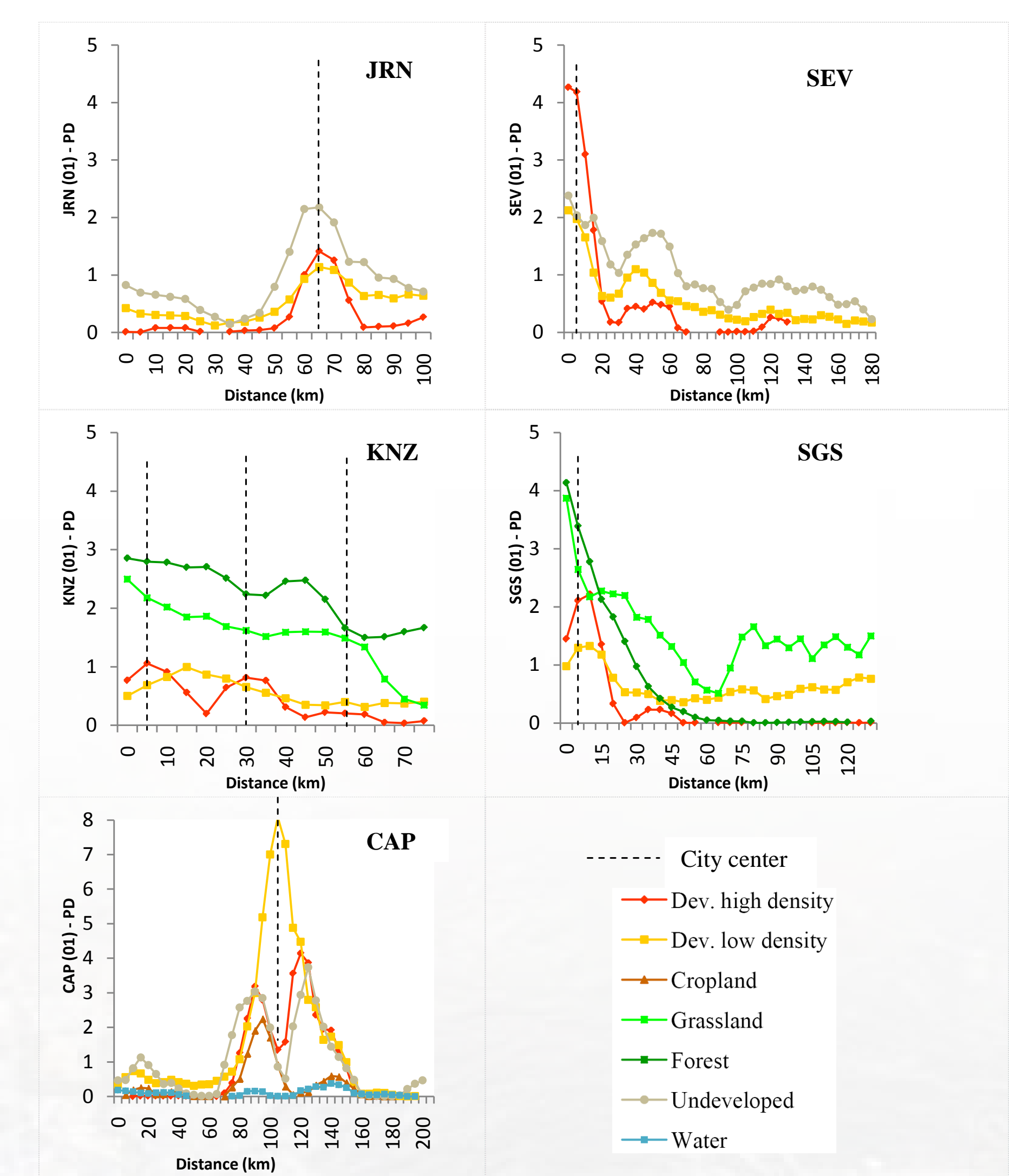


Figure 4. Spatial distribution of Patch Density (PD) at class-level along transect for the 5 sites in 2001

Results

Our preliminary research results (Figure 3 and 4) suggest that rapid urbanization in these study sites has increased land fragmentation, generally in the fringes or peri-urban areas of the study sites. However, three distinct patterns of fragmentation were observed: (1) within SEV and JRN sites, fragmentation occurred the fastest in the very low-density and agricultural areas far away from the core city areas (indicated with a dash line in the transect), mostly along the river; (2) KNZ and SGS sites have seen a steady increase in suburbanization and exurbanization in the cities included in the study, resulting in the higher level of fragmentation in "grassland"; and (3) CAP experienced the most rapid urban growth among all the study sites in this period with significant fragmentation occurring at the urban fringes, around 35-40km from the urban center. The study team is currently analyzing the proximate causes of land fragmentation, primarily focusing on urban population dynamics, water provisioning, transportation, amenity-driven growth, institutional factors, and topographic barriers.

References

- Alberti, M. 2005. The effects of urban patterns on ecosystem function. *International Regional Science Review* 28 (2):168-192.
- Dietzel, C., M. Herold, J. Hemphill, and K. Clarke. 2005. Spatio-temporal dynamics in California's Central Valley: Empirical links to urban theory. *International Journal of Geographical Information Science* 19:175-195.
- Grimm, N. B., D. Foster, P. Groffman, J. M. Grove, C. S. Hopkins, K. J. Nadelhoffer, D. E. Pataki, and D. P. Peters. 2008. The changing landscape: ecosystem responses to urbanization and pollution across climatic and societal gradients. *Frontiers in Ecology and the Environment* 6 (5):264-272.
- Heilman, G. E., J. R. Stritholt, N. C. Slosser, and D. A. Dellasala. 2009. Forest Fragmentation of the Conterminous United States: Assessing Forest Intactness through Road Density and Spatial Characteristics. *BioScience* 52 (5):411-422.
- Homer, C., C. Q. Huang, L. M. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Land-Cover Database for the United States. *Photogrammetric Engineering and Remote Sensing* 70 (7):829-840.
- Irwin, E. G., and N. E. Bockstael. 2007. The evolution of urban sprawl: Evidence of spatial heterogeneity and increasing land fragmentation. *Proceedings of the National Academy of Sciences* 104 (52):20672-20677.
- Luck, M., and J. Wu. 2002. A gradient analysis of urban landscape pattern: a case study from the Phoenix metropolitan region, Arizona, USA. *Landscape Ecology* 17 (4):327-339.
- Riitters, K. H., J. D. Wickham, R. V. O'Neill, K. B. Jones, E. R. Smith, J. W. Coulston, T. G. Wade, and J. H. Smith. 2002. Fragmentation of Continental United States Forests. *Ecosystems* 5 (8):0815-0822.
- Schipper, J. 2008. *Disappearing desert: the growth of Phoenix and the culture of sprawl*. Norman: University of Oklahoma Press.
- Vogelmann, J. E., T. L. Sohl, P. V. Campbell, and D. M. Shaw. 1998. Regional Land Cover Characterization Using Landsat Thematic Mapper Data and Ancillary Data Sources. *Environmental Monitoring and Assessment* 51 (1):415-428.



This material is based upon work supported by the National Science Foundation under Grant No. DEB-0423704, Central Arizona - Phoenix Long-Term Ecological Research (CAP LTER).



CAP LTER

Central Arizona-Phoenix
Long-Term Ecological Research

¹ Central Arizona - Phoenix LTER, GIOS, Arizona State University

² School of Human Evolution and Social Change, Arizona State University

³ School of Sustainability, Arizona State University