Characterizing Phoenix urban growth patterns with landscape metrics based on remote sensing data: Effects of thematic resolutions

Alexander Buyantuyev and Jianguo Wu

School of Life Sciences, Arizona State University, Tempe

ABSTRACT

In this study, we investigated (1) land use and land cover change in the Central Arizona – Phoenix (CAPLTER) during the period of 1985-2000, (2) the effects of different levels of land cover classifications (thematic resolutions) on the behavior of commonly used landscape metrics, and (3) the effects of precipitation on land cover classifications. We used 15-year time series data of land use and land cover for the CAPLTER which were derived from Landsat TM imagery. Land cover maps with 12 classes were first created for five different years between 1985 and 2000, and then progressively aggregated into 9, 6, 4, and 2 land cover classes following the same set of criteria. The results showed that during the study period most examined landscape metrics exhibited similar temporal patterns at different levels of classification, although significant differences did occur in some cases. However, the thematic resolution of land cover maps showed consistent and substantial effects on landscape metrics for a given year (or a particular map). These results were in general agreement with our previous findings of the effects of changing spatial resolution and extent on landscape metrics in that they fall into two general groups: metrics showing consistent patterns of variation and metrics showing unpredictable behavior. Also, most metrics were found to be sensitive to inter-annual variations in precipitation as their temporal pattern resembled that of precipitation and Normalized Difference Vegetation Index (NDVI). Finally, our preliminary investigation suggested that the relationships between ecological and socioeconomic variables may vary considerably with the scale of analysis in terms of both grain and extent. Our results have important implications for studying land use and land cover change in urban landscapes using remote sensing data.

DATA AND METHODS

We used historical land use – land cover maps created for CAPLTER from Landsat (Enhanced) Thematic Mapper (TM and ETM+) images (Stefanov et al 2001). All images were originally classified into 12 classes using the expert system approach that allows postclassification sorting through integrating with auxiliary data layers such as land use map, texture, water rights, city boundaries, and Native American reservation lands. We conducted additional reclassification of final maps by analyzing constructed transition matrices between pairs of consecutive maps and checking for unlikely transitions, such as the conversion of asphalt or residential classes back to desert. These unlikely transitions were eliminated where necessary. Overall the time series was made temporally consistent by applying standard reclassification rules (Figure 1). We then reproduced the accuracy assessment for the reclassified 1998 map to estimate the amount of error introduced/eliminated. The results suggest that the overall classification accuracy and Kappa statistic slightly improved (Table 1).

To study scale effects of different classification levels (thematic resolution) on landscape pattern analysis we progressively aggregated the five maps into 9, 6, 4, and 2 classes.

The resulting 25 land use – land cover patterns were quantified by a suite of landscape metrics using FRAGSTATS software (McGarigal & Marks 1995). We computed 16 landscape level indices categorized into two groups. Compositional measures include 9 metrics: Total Area of Patch Type or Class Area (CA), Patch Density (PD), Edge Density (ED), Diversity (SHDI), Evennes (SHEI), Largest Patch (LPI), Mean Patch Size (MPS), Patch Size Standard Deviation (PSSD), and Patch Size Coefficient of Variation (PSCV). Seven configurational measures are Landscape Shape Index (LSI), Mean Patch Shape Index (MSI), Area-Weighted Mean Shape Index (AWMSI), Perimeter-Area Fractal Dimension (PAFRAC), Mean Patch Fractal Dimension (MPFD), Area-Weighted Mean Fractal Dimension (AWMFD), and Contagion (CONTAG).

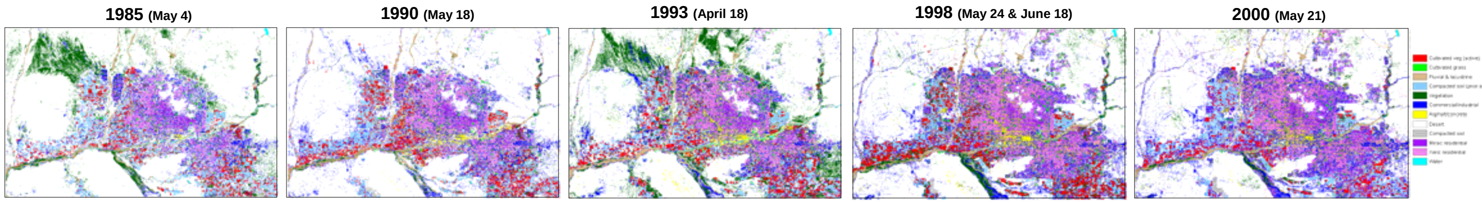

Figure 1. Historical land use – land cover change in Central Arizona – Phoenix LTER from 1985 to 2000 (adapted from Sefanov et al 2001)

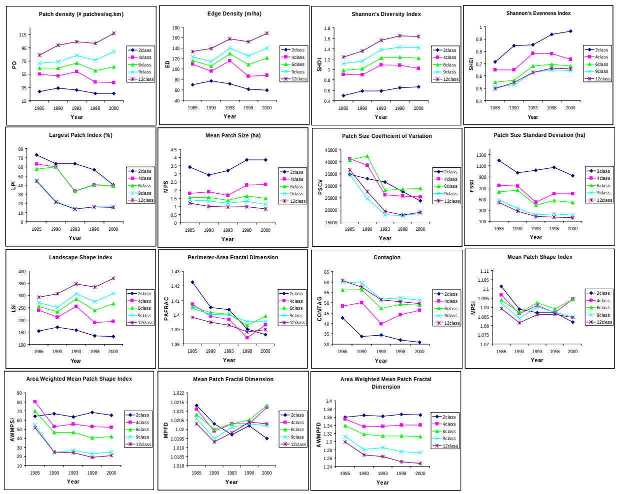

Figure 2. Changes in landscape pattern of the study area during the 15-year period as expressed by compositional and configurational landscape metrics

Figure 3. Changes in total area of Patch types (Class area) of 6 classes

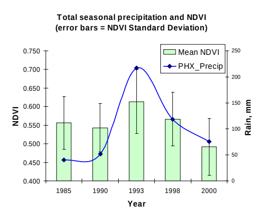

Figure 4. Relationship between mean Normalized Difference Vegetation Index (NDVI) and total precipitation accumulated from January to the corresponding image acquisition date

Table 1. Accuracy assessment of 1998 land use - land cover map (original statistics from the accuracy report by (Stefanov et al 2001) are in parentheses)

Class	Reference totals	Classified totals	No. correct	Producer's accuracy (%)	User's accuracy (%)	Kappa (%)
Cultivate vegetation (active)	95 (99)	99 (99)	92 (93)	96.84 (93.94)	92.93 (93.94)	92.17 (93.26)
Cultivated grass	77 (77)	78 (78)	76 (76)	98.70 (98.70)	97.44 (97.44)	97.22 (97.22)
Fluvial & Lacustrine	80 (77)	88 (88)	78 (72)	97.50 (93.51)	88.64 (81.82)	87.63 (80.27)
Compacted soil (prior ag use)	96 (81)	84 (84)	79 (71)	82.29 (87.65)	94.05 (84.52)	93.40 (83.13)
Vegetation	97 (80)	84 (84)	78 (61)	80.41 (76.25)	92.86 (72.62)	92.07 (70.19)
Disturbed (commercial/industrial)	43 (54)	71 (71)	35 (35)	81.40 (64.81)	49.30 (49.30)	46.97 (46.34)
Disturbed (asphalt/concrete)	75 (67)	71 (71)	67 (61)	89.33 (91.04)	94.37 (85.92)	93.90 (84.88)
Undisturbed (Desert)	95 (101)	95 (95)	86 (86)	90.53 (85.15)	90.53 (90.53)	89.51 (89.44)
Compacted soil	107 (110)	87 (87)	83 (83)	77.57 (75.45)	95.40 (95.40)	94.84 (95.82)
Disturbed (mesic residential)	70 (70)	72 (72)	62 (59)	88.57 (84.29)	86.11 (81.94)	85.04 (80.56)
Disturbed (xeric residential)	77 (86)	74 (74)	65 (62)	84.42 (72.09)	87.84 (83.78)	86.80 (82.23)
Water	69 (79)	78 (78)	68 (77)	98.55 (97.47)	87.18 (98.72)	86.21 (98.61)
Total	981 (981)	981 (981)	869 (836)			
Overall Classification Accuracy =	88.58% (85.22%)					
Overall Kappa Statistics =	.8753 (.8385)					

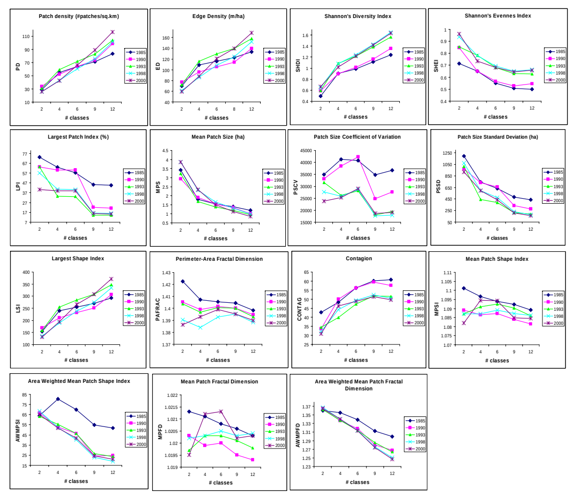

Figure 5. Responses of landscape metrics to changing thematic resolutions

RESULTS

•The plots in Figures 2 and 3 demonstrate consistent increases in patch density, edge density, landscape diversity and complexity. Urbanization has resulted in decreases of most configurational measures of landscape pattern.

•About 10% of the desert had been taken up by various urban land uses, mainly impervious surfaces and new residential developments (Figure 3).

•Normalized Difference Vegetation Index (NDVI) and the amount of precipitation are highly correlated (Figure 4) while most landscape metrics are sensitive to inter-annual variations in precipitation as their temporal pattern resembled that of precipitation and NDVI. The highest correlation is observed with PD, ED, MPS, LSI, and PAFRAC (graphs not shown here).

•Most examined landscape metrics show similar temporal patterns at different levels of classification (Figures 2 and 5). However in some cases the direction of change reverses at coarse thematic resolutions (2-4 class land use – land cover maps).

•Landscape metrics show different patterns in response to changes in the number of classes (or thematic resolutions).

CONCLUSIONS

•Processes of intensive urbanization of Sonoran desert can be effectively described by temporal trends of landscape patterns derived from remote sensing imagery and quantified by a suite of landscape metrics. Observed temporal patterns suggest increasing fragmentation and heterogeneity of the urbanizing landscape.

•Timing and amount of atmospheric precipitation play an important role in landscape pattern formation and physiognomy of Sonoran desert. They are capable of producing dramatic changes of spatial patterns and should be carefully considered when comparing multi-date images. Urban vegetation, however, is less affected by these factors.

•Effects of thematic aggregation are considerable, and to some extent, these effects are similar to those with changing grain size and extent we reported previously.