Land Use Patterns, Water Quality, and Social Vulnerability: A Spatial Analysis of Phoenix's Drainage Systems

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Introduction

Background

- Population growth and urbanization converted natural landscape into impervious areas. Increased impervious surfaces resulted in stormwater quantity and quality issues.
- Previous studies showed that the relationships between land use and water quality in watersheds. However, Little studies considered land use configuration of spatial patterns reflected upon the urban hydrological characteristics ,which would have impacts on rainfall-runoff processes.
- Nearly half of the Phoenix metropolitan area is dominated by urban land uses. Impervious land cover associated with urban land uses have contributed to increased stormwater runoff and degradation of water quality.
- About 12.6% of the population in the City of Phoenix is considered under high vulnerable status in socioeconomic aspects (i.e., poverty, employment, Income, education). The degradation of environmental quality and high social vulnerability pose threats to Phoenix's sustainability.

Objectives

- This study aims to investigate the relationships between land cover patterns, water quality, and social vulnerability within seven urban drainage-sheds along the Salt River in Phoenix.

Study Design

Framework

Literature Review

Data Collection

- Arizona State university (Central Arizona–Phoenix Long-Term Ecological Research) Land Cover (2.5 square meter resolution)
- The City of Phoenix 2016 stormwater report
  Municipal Separate Storm Sewer Systems (MS4) Boundary, Drainage Systems Information, and Stormwater quality data
- US Census Bureau
  Socio-economic data

Analysis

GIS	FRAGSTATS	SPSS
• Delineate Urban drainage Watersheds	• Analyze land cover patterns	• Analyze relationships between land cover patterns, stormwater runoff quality, and social vulnerability

Results Interpretation

Conclusion and Discussion

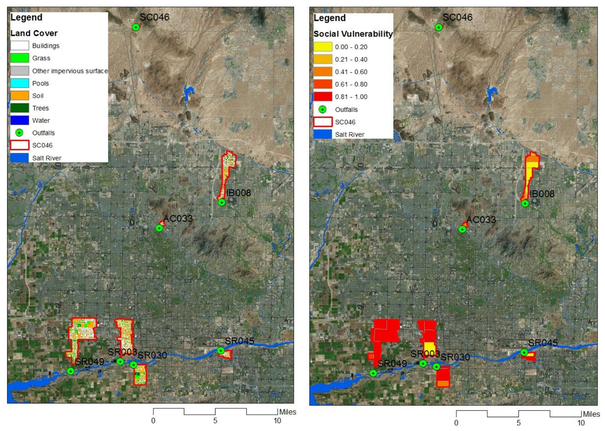
Green Infrastructure Design Strategies to the land use planners and water resource managers

Study Sites

- Seven urban drainage sheds adjacent to the Salt river were selected based on the 2016 stormwater annual report from the City of Phoenix.

Data and Methods

- Urban drainage-sheds are delineated by referring to MS4 boundary.
- Among land cover composed of 6 class—Buildings, Grass, Other impervious surfaces, Pools, Soil, Trees, and Water.
- Social Vulnerability was defined by the rank of percentile of education, employment, poverty, and income data from U.S. Census Bureau.



- Stormwater runoff quality: Summer and winter 1) Nutrients : TN (S/Fa,mgL−1) and TP (S/Fa,mgL−1) 2) Organic matters: BOD (S/Fa,mgL−1) and COD (S/Fa,mgL−1)
- FRAGSTATS was used to analyze land cover patterns with nine landscape indices associated with water quality characteristics.

A. Landscape
Contagion (CONTAG) : Tendency of land cover types to be aggregated (unit: %)
Shannon's diversity index (SHDI) : Based on information theory; indicates the patch diversity in a landscape (unit less)

B. Class
Patch density (PD) : Number of patches per unit area **(number per 100 ha)**
Largest patch index (LPI) : Percentage of the landscape in the largest patch (unit: %)
Edge density (ED) : Total length of all edge segments per hectare for the considered landscape (unit: m/ha)
Mean shape index (SHMN) : Mean patch perimeter divided by the minimum perimeter of the corresponding land cover area (unitless)
Mean Euclidian nearest-neighbor distance : Distance to the nearest neighboring patch of the same land cover type based on the edge-to-edge distance (unit: m)
Aggregation index (AI) : Number of like adjacencies involving the corresponding land cover type, divided by the maximum possible number of like adjacencies involving the corresponding land cover type (unit: %)
Cohesion index (COHE) : Indicates the physical connectedness of the corresponding land cover type (unit less)

- Pearson's correlation analysis was conducted in SPSS to investigate the associations between land use spatial patterns, stormwater quality characteristics, and social vulnerability.

Results and Conclusions

- **Relationships between land cover and stormwater quality**: Regardless of land cover types, BOD, COD, and TN in winter are positively associated with the degree of aggregation of land cover patches. This means that water quality is more likely to be degraded when there is high interspersion of various land use types and when a large number of different land use types exist within a watershed.

	Water Quality Data							
Landscape Index	BOD_S	COD_S	TN_S	TP_S	BOD_W	COD_W	TN_W	TP_W
CONTAG	0.63	.052	-.691	.027	.847*	.858*	.845*	.530
SHDI	0.731	.591	.368	-.233	-.541	-.555	-.280	-.104
N = 7								
* p<0.05. ** p<0.01								

- **Relationships between land cover patterns (Trees and grass) and stormwater quality**: Summer organic matters (BOD_S and COD_S) in water tend to increase when tree areas increase in a watershed. Winter organic matters (BOC_W, COD_W)are likely to increase when tree patches are closer to each other. ENN_MN of Grass is negatively related to three water quality characteristics in winter (COD_W, COD_W, TN_W), which means the closer the distance between grass patches is, the better the water quality is.

		Water Quality Data							
Land cover	Landscape Index	BOD_S	COD_S	TN_S	TP_S	BOD_W	COD_W	TN_W	TP_W
Trees	CA	.986**	.868*	.182	-.072	-.298	-.326	-.011	-.066
	PD	.028	.134	.870*	.168	-.738	-.729	-.730	-.677
	ENN_MN	-.493	-.575	-.761*	-.260	.842*	.868*	.702	.722
Grass	ENN_MN	-.195	-.342	-.486	-.287	.966**	.899**	.893**	.754
N = 7									
* p<0.05. ** p<0.01									

- **Relationships between land cover patterns and social vulnerability:** while Tree PD and ED are negatively associated with social vulnerability, Tree ENN_MN and SHAPE_MN of Grass are positively associated with social vulnerability. This means drainageshed with lower social vulnerability tends to have higher density of trees, smaller tree patches, closer distance between the tree patches, and grass patches have less irregular shape.

		Social Vulnerability
Land cover	Landscape Index	SOVI_MN
Trees	PD	-.858*
	ED	-.856*
	ENN_MN	.763*
Grass	SHAPE_MN	.851*
N = 7		
* p<0.05. ** p<0.01		

Next Steps

Our study demonstrates that the diverse land use patterns and dense trees in fact have negative impacts on water quality. It implies one land cover type may be more effective in addressing water quality than the other. Our next steps will include identify influential land cover types at a city scale. Additionally, green infrastructure LID tools at a neighborhood scale, particularly in high social vulnerability areas, will be evaluated for their impacts on improving water quality under climate change scenarios.

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