Understanding Urban Open Space with a Green Index

HOW URBAN OPEN SPACES MAKE A DESERT CITY A LIVABLE CITY

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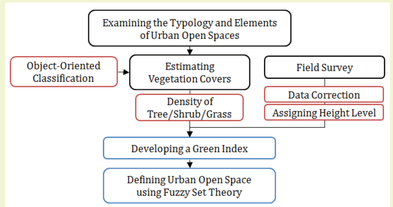
Research Purposes:

The main objective of this research is to establish new definition and approach to understand urban open space in an arid environment. Specifically, this research intends to define urban open space for a desert city using fuzzy set theory and to design a new approach for measuring the greenness of urban open spaces based on a newly developed theoretical concept. A motivation for this research is the desire to provide comparative information for the delineation and benefits of urban open spaces in arid and humid environments. Urban open spaces in arid cities do not have same affect and benefits on cities compared with humid cities because of the different physical qualities of open spaces. In addition to the differences between arid and humid open spaces, there is no standard definition of urban open space, and it is often evaluated with different parameters.

Research Questions:

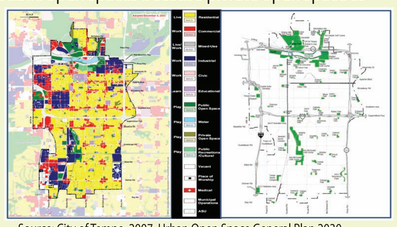
1) What is the typology of open spaces for a desert city?, 2) What is a measure of greenness as a component of a desert city open space typology? , and 3) How can urban open spaces be defined with a green index and fuzzy set thoery?

Figure 1. Research Flow



Data and Study Area:

Data used in this research are 1) Quickbrid image (2005 August 17), 2) 2005 Assessor Parcel Data from Maricopa Assessor Office, 3) Google Earth, and 4) Field Survey Data. The study ares of this research is the City of Tempe. Urban open spaces in Tempe includes civic, open space, recreational/cultural and vacant lands, total 17.4%. This research focuses on urban public open spaces because private open space as private property may not be designated as open space for the purpose of public planning.



Source: City of Tempe. 2007. Urban Open Space General Plan 2030

Figure 2. Existing Land Use Map and Urban Parks in Tempe

Types of Urban Open Spaces:

Various types and subtypes of urban open spaces are found in urban open space research (Figure 3 and Table 1). These diverse types of open spaces bring different functions and characteristics. Understanding the key functions of urban open spaces is an important part of helping to improve their effectiveness, both better management of existing open spaces as well as better desing of new ones. Therefore, it is necessary to consider that different physical quality of open spaces, which bring different degree of influences on cities and their residents.

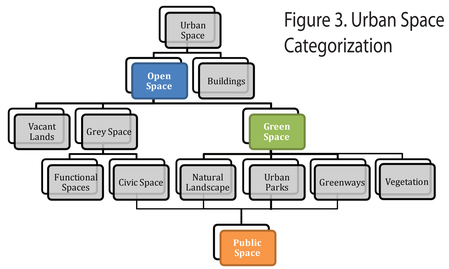


Figure 3. Urban Space Categorization

Table 1. Types of Urban Open Spaces

Types	Elements
Natural Landscapes	Wetland, Woodland (Deciduous, Coniferous, and Mixed woodlands), Habitat
Urban Parks	Public/Central Park, Downtown Park, Neighborhood Park, Mini/Vestpocket Park, Urban Gardens
Functional Open Space	Institutional Grounds (School grounds), Cemeteries, Churchyards, Productive green spaces (City farms), Playgrounds and Sports Complexes
Linear Open Space	Transport Corridors (Buffers), River and Canal Banks, Greenways
Private Green Space	Housing Green Space, Private Community Green Space
Civic Space	Squares and Plazas, Memorials, Shopping Center/Marketplace, Farmers Markets, Atrium
Streets	Pedestrian Sidewalks, Pedestrian Mall, Transit Mall, Traffic Restricted Streets, Town Trails

Source: Adapted and changed from Swanwick et al. 2003

Benefits of Urban Open Spaces:

Urban open space a key component to advance to sustainable development in cities because Urban open space provides environmental, social, and economic benefits on cities and their residents. Urban open space firstly provides a range of tangible environmental benefits, such as mitigating urban heat island as well as air and water pollution (Yu and Hien 2006), and improving biodiversity (Tzoulas and James 2004). It also makes social and economic impacts on cities and their residents, such as providing opportunities for recreation (Sugiyama and Ward Thompson 2008) and fostering cohesive neighborhoods (Austin 2004) as well as stabilizing and increasing housing prices and property values (Geoghegan 2002).

Extracting Vegetation Cover Information:

Object-oriented classificatnion method is used to extract vegetation cover. First, segmentation is conducted to extract groups of pixels that have similar spectral value. Second, decision rules are investigated with spectral values of 7 bands (Original 4 bands and Principle component 3 bands). Based on these decision rules, the classification is implemented with segmented objects (Figure 4).

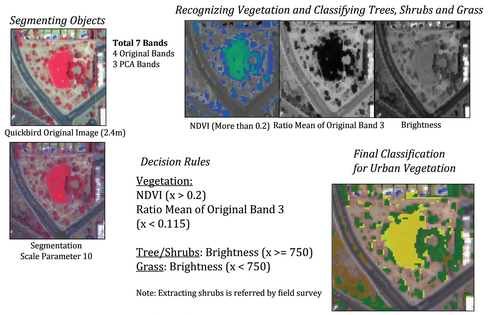
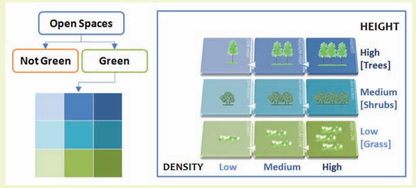


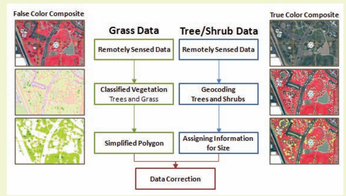
Figure 4. Object-oriented Classification Procedures

Developing a Green Index:

This research focuses on the different degree of greenness and openness for urban open spaces in evaluating their quality. This research designs a new conceptual framework of "Green Index" and uses a mixed methodology to investigate urban open spaces in an arid environment. A "Green Index" can assist to understand the greenness of urban open spaces with the information of density and height for urban vegetation and forests through the analysis of high-resolution image and ground survey (Figure 5). Green index will be a useful tool to quantify urban open spaces with a little greenness and to focus on different characteristics of urban green in open spaces.

Figure 5. Basic Concept of a Green Index





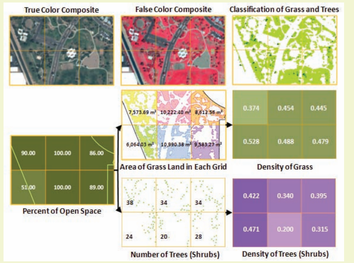


Figure 6. Constructing Input Data and Producing a Green Index

The green index was calculated for selected 20 urban open spaces in the city of Tempe. Final output is a "Green Index" calculated with three density values of grass, shrub, and tree. I produced one simple green index and three weighted green index to find more appropriate weighted index with various considerations. First, simple green index (SGI) is calculated from sum of the areas of three trees, shrubs and grass divided by open space area. Three kinds of weighted green index are calculated with NDVI (normalized difference vegetation index) and Tree weight. For first weighted green index (WGI 1), the area of trees is increased by 50% of existing value to give the weight to trees. I assume that a tree provide us green landscape as well as shaded area, and it is more helpful to reduce urban heat island effect. Second weighted green index (WGI 2) is SGI multiplied by mean NDVI, and third weighted green index (WGI3) is calculated after standardizing of NDVI.

Table 2. The Results of Green Index for Urban Open Spaces in Tempe

Open Spaces	Density of Trees	Density of Shrubs	Density of Grass	SGI	WGI1	WGI2	WGI3
Celaya Park	0.237	0.000	0.871	0.7223	0.9853	0.3709	1.0836
Indian Bend	0.207	0.002	0.402	0.5182	0.7562	0.1504	0.4188
Arredondo	0.189	0.000	0.508	0.7304	1.0518	0.2944	0.8039
Scudder Park	0.331	0.000	0.769	0.6961	0.9499	0.3625	1.0668
Waggoner	0.169	0.000	0.945	1.1004	1.4850	0.6108	1.8694
Moeur Park	0.036	0.017	0.131	0.6899	0.9524	0.2530	0.6877
Benedict	0.040	0.002	0.550	0.9362	1.2274	0.2541	0.7179
Daley Park	0.193	0.004	0.526	1.1135	1.5858	0.4953	1.3745
Tempe Beach	0.041	0.001	0.476	1.1311	1.5718	0.6556	2.0739
Redden Park	0.160	0.005	0.525	1.1077	1.5432	0.5206	1.4671
Hudson	0.285	0.003	0.551	0.9301	1.3470	0.3488	0.9482
Goodwin	0.251	0.000	0.979	0.9424	1.3521	0.4675	1.3445
Tempe Diablo	0.015	0.001	0.547	0.1831	0.2484	0.0467	0.1341
Twin Butte	0.016	0.105	0.091	0.7241	1.0448	0.2151	0.5965
Double Butte Cemetery	0.213	0.001	0.289	1.2302	1.7198	0.6576	1.9644
Stroud Park	0.096	0.000	0.834	0.8390	1.1145	0.3902	1.0960
Corbell	0.123	0.000	0.819	0.5626	0.8359	0.2544	0.7088
Cole Park	0.354	0.000	0.582	0.5915	0.8665	0.1696	0.4736
Clark Park	0.087	0.000	0.643	0.1081	0.1537	0.0474	0.1310

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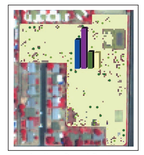
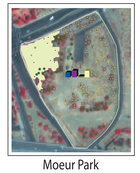
The Outputs of Green Index:

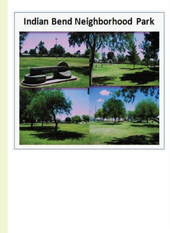
The green index was helpful to measure the greenness of urban open spaces, and it provides the solution to understand the quality of open spaces' vegetation covers. Indian Bend Park, one of urban open spaces with higher green index, has good quality of grass and many large trees throughout the park. Moeur Park has the lowest green index becasue of large shrub area and low density of grass land.

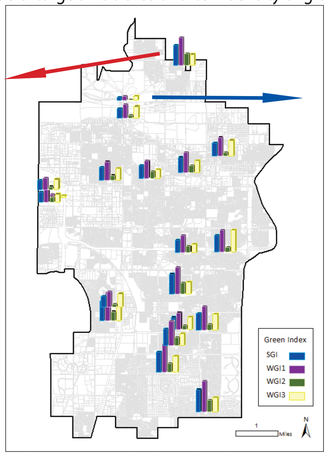


Indian Bend Park



Moeur Park





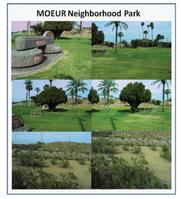


Figure 7. The Green Index Outputs of Selected Urban Open Spaces in Tempe

Defining Urban Open Spaces using Fuzzy Set Theory:

Fuzzy set theory generalizes ordinary or classical sets in an attempt to model and simulate human linguistic reasoning in a domain characterized by incomplete, imprecise, uncertain and vague data (Musee et al. 2008). The fuzzy set theory provides methods for allotting objects into categories in which the transition from membership to non-membership is gradual rather than abrupt (Sui 1992). A crisp set can be described by its characteristic function: μ(x)=1, if x is element of M, and μ(x)=0, if x is not element of M. In contrast, a fuzzy set can be described by a characteristic function with the generalization that 0≤ μ(x) ≤1, if x is element of M.

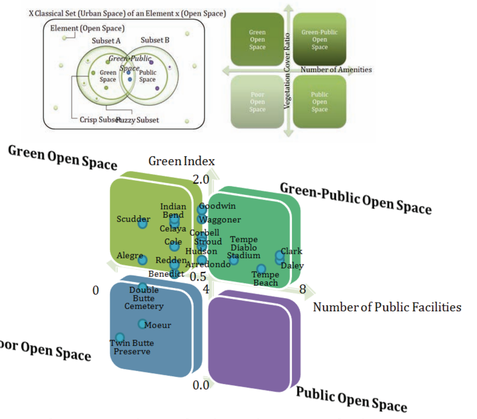


Figure 8. The Application of Fuzzy Set Theory for the Delineation of Urban Open Spaces

Research Findings:

Generally, Regional Open Space and Community Park may include park area as well as recreation center and parking lot, but Neighborhood Park is almost composed with green area. Most Neighborhood Parks are usually classified to Green Open Space, and Community Parks including Clark and Tempe Beach parks can be referred to Green-Public Open Space. However, Natural Resources have limited greenness and publicness in the city of Tempe. This research provides an overview to understand urban open spaces using a green index and fuzzy set theory, and new delineation and measurement of urban open spaces can be a way to improve urban open space management considering water consumption and urban heat island mitigation.