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Re-examining the Definition of Urban Open Space using Fuzzy Set Theory

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Introduction:

Urban open space is a key infrastructure to the quality of the urban environment and sustainable living in cities. Extensive research on urban open space shows that there are environmental, social, and economic benefits. Nevertheless, there is no standard definition for urban open space. Various factors, such as size, shape, diversity, greenness, facilities, and distribution, as well as the design and management of urban open spaces play a decisive role in defining urban open space and its function.

Benefits of Urban Open Spaces:

Urban open space is 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).

The Demand for New Definition of Urban Open Spaces:

Various types and subtypes of urban open spaces are found in urban open space research. These different types of open spaces bring different functions and characteristics. Understanding diverse types and roles of urban open spaces helps urban planners and designers to recognize how to develop and manage urban open spaces and to improve their effectiveness. Therefore, it is necessary to have reliable definition and approaches to the valuation of open spaces in order to have better understanding open spaces in desert cities.

Research Questions:

1) What is the typology of open spaces for a desert city?, and
2) How can urban open spaces be defined with fuzzy set thoery?

Research Objective:

This research suggests the new approach to define urban open space to satisfy the demand for better understanding urban open space with different characteristics. Fuzzy set theory can be a solution to delineate many phenomena, which are difficult to delineate because of vague definition and meaning.
We develop a theoretical perspective of urban open space typology based on how their attributes and elements of a configuration are connected to open space benefits. Urban open space mapping is implemented to compare the approaches of binary and fuzzy sets. Examining for a solution to mitigate urban heat island is complex because many variables of urban environment interact.

Data and Study Area:

Data used in this research are 1) Quickbird image (2005 August 17), and 2) 2005 Assessor Parcel Data from Maricopa Assessor Office. The study area of this research is the City of Phoenix, Arizona. Based on existing information, urban open spaces in Phoenix include civic, open space, recreational/cultural and vacant lands.
Sample site in Phoenix, Arizona is empirically investigated to test new theoretical concept for urban open space (Figure 1).

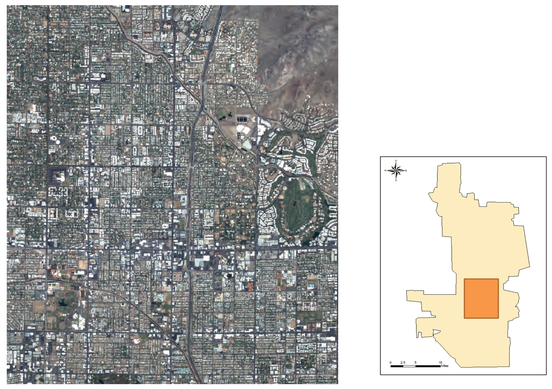

Figure 1. Sample Site in Phoenix, Arizona

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.

$$U = \{x, \mu_U(x) \in [0,1]\ x\ \in M\}$$

$\mu_U(x)$: *a membership function; represents the fuzzy state of greenness and publicness of an urban open space, characterized by parameter x*
$\mu_U(x) = 0$: *means an urban open space is not totally green (or does not have full social functions)*
$\mu_U(x) = 1$: *means an urban open space is totally green (or have full social functions)*
$\mu_U(x) =$ *between* 0 *and* 1: *denotes partial greenness (vegetation cover) and publicness (social function)*

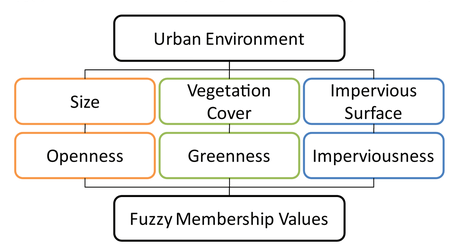

Figure 2. Fuzzy Membership Values

Producing Fuzzy Membership Values:

1) The size of openness is calculated from the areas of parcels and buildings. Size does not indicates parcel area but the area of openness as follows:

Openness =
Parcel Area - Building Area

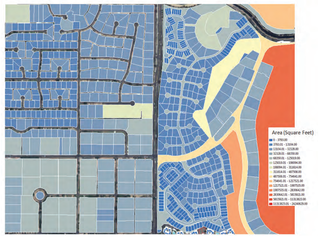

Figure 3. The Size of Open Area

2) The areas of greenness and impeviousness are calculated from remote sensing classification outputs. Object-oriented classification method is used to extract vegetation cover and impervious surface.

Figure 4. Object-oreinted Classification Output

The fuzzy membership values are produced based on fuzzy set application rules shown in Figure 5.

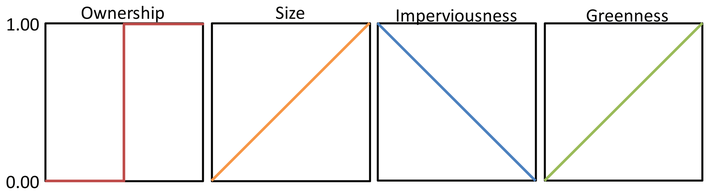

Figure 5. Fuzzy Set Application Rules

Urban Open Space Mapping:

Urban open spaces are mapped with binary and fuzzy apporaches. First, binary approach can be applied to show each type of urban open space as shown Figure 6 Left. Fuzzy mapping for urban open spaces (Figure 6 Right) shows comprehensive characteristics of previously considered attributes (Ownership, Size, Imperviousness, and Greenness). This provides better representation for the characteristics and quality of both private and public spaces in cities. Figure 7 shows the final output for urban open space mapping using fuzzy set approach.

Figure 6. Urban Open Space Mapping with Classical (Left) and Fuzzy (Right) Approaches

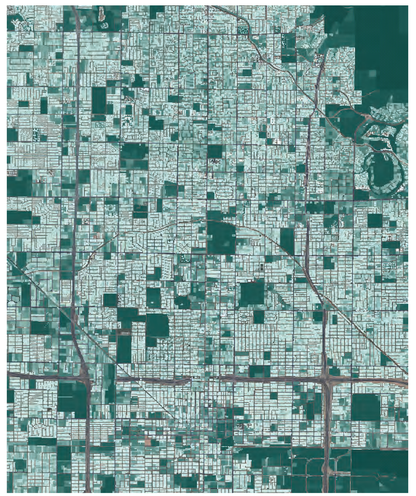

Figure 7. Final Urban Open Space Mapping for the Sample Site in Phoenix

Research Summary and Future Implementation:

This research provides a new view to understand urban open spaces using fuzzy set theory. This approach can be a solution to examine the characteristics and quality of urban open spaces in arid cities and to understand their benefits and functions for urban environment. Thq quality of urban environment should be assessed with not only public open spaces but also other residential and commercial landscapes. This approach needs to be evaluated to confirm the benefits of urban open spaces in arid cities. The evaluation will show how the theoretical perspective developed in this study allows for detailed and appropriate analyses for urban open space research.

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