# AN OBJECT-ORIENTED CLASSIFICATION OF AN ARID URBAN FOREST WITH TRUE-COLOR AERIAL PHOTOGRAPHY

Jason S. Walker [1,*] & John M. Briggs [1]

[1] School of Life Sciences, Arizona State University, PO Box 874601, Tempe, AZ 85287-4601
jasonwalker@asu.edu

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**ABSTRACT:**

In order to adequately model ecosystems services of the urban environment, it is necessary to accurately inventory urban vegetation abundance and spatial distribution. An object-based, methodological design for estimating urban vegetation structure within the metropolis of Phoenix, Arizona using remote sensing techniques on high-resolution ($0.6m^2$) aerial photography was derived utilizing a hybrid of image segmentation and spectral classification. Within the arid urban environment, vegetation is controlled at a very fine scale and is best analyzed at extremely high spatial resolution. Since at a local scale the urban environment is composed of discretely heterogeneous patches, it is necessary to quantify landscape pattern at this scale. An object-oriented approach was taken utilizing a segmentation algorithm that transposes imagery into distinct polygons by incorporating a combination of spectral properties and neighborhood characteristics. This segmentation process was parameterized to isolate vegetation patches with a minimum diameter of 2m, which incorporates typologies from shrubs to large trees. Once segmentation was completed, the image was then analyzed and classified based on the cadastral and topological characteristics. Accuracy assessment of land cover classification was then conducted at 200 random points throughout the metropolis. The intent of this methodology is to allow for regular monitoring of vegetation change at a broad extent with fine resolution in the Phoenix basin**.**

## 1. INTRODUCTION

True-color aerial photography has been regularly used through photointerpretation as a method for groundtruthing coarser scale imagery, typically from satellites. Many of these imaging systems have much greater spectral resolution than aerial photography, which is used in the discrimination of many different types of land cover. Until recently, analysis of many fine-scale ecological phenomena have had limited functionality due to coarse spatial resolution of these imagery. A prime example is classifying urban vegetative cover. We are primarily interested in urban forest structure within the entire metropolitan region of Phoenix, Arizona encompassing over 200 $km^2$. Urban forest structure is controlled at a discretely heterogeneous scale, which is dominated by a combination of land use planning and individual decision making. Thus we proposed using imagery with very high spatial resolution. Private remote sensing satellites have begun to provide high-resolution multi-spectral imagery, such as IKONOS© and Quickbird©. However, accessibility to these imagery can be quite cost prohibitive if researchers are interested in a very large study area. True-color aerial photography, with filters representing red (650 nm), green (510 nm), &

blue (475 nm) are typically cultivated for use in the real estate market allowing agents to assess the layout of neighborhoods. High resolution is necessary for creating quality images sought after by this market. Another noteworthy advantage of this type of imagery is they are considerably more cost-effective relative to satellite imagery. In addition extensive analyses of multiple cities could be done on with these imagery, as they are collected in most medium to large cities and collected on average of once per annum, and up to 3x for quickly developing cities, such as the Phoenix metropolitan.

The key disadvantage of using these imagery for vegetative analyses is the absence of the near infrared band typically used to calculate common vegetation indices, such as Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI). However, we feel this is not detrimental as these fine scale data can be aggregated to be able to compare with these more common procedures estimating vegetation density.

## 2. METHODS

### 2.1. Imagery

True-color aerial photography of the entire Phoenix metropolitan and outlying rural areas was obtained from Landiscor©. Imagery was collected in April 2004. The sensor was flown at an altitude of 6,100 m producing an image with approximately 0.61 m resolution. The images were obtained orthorectified as a single tile into North American Datum of 1983 State Plane, Central Arizona.

### 2.2. Object Oriented Approach

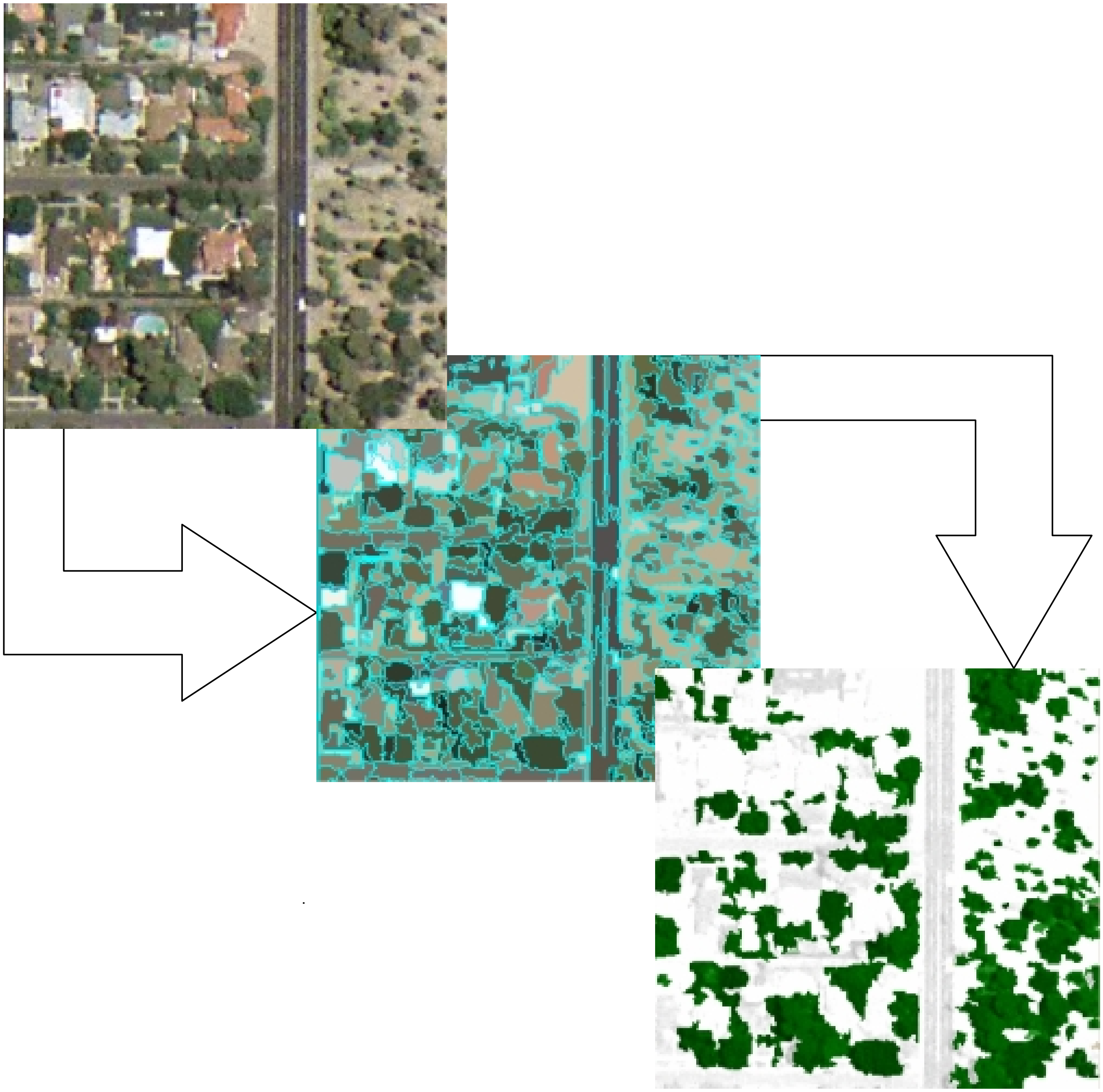
An object-oriented approach is ideal for conducting an analysis of vegetation cover with this imagery, as the resolution of imagery is greater than most vegetation. Classification of individual pixels is a very common and useful method for analyzing broad scenes with coarse resolution (i.e. Landsat). These imagery are plagued with sub-pixel mixing of fine-scale phenomena within a single pixel. It is theoretically and empirically possible to obtain compositional information about that pixel (Ridd 1995, Foody 2000). However, important spatial relationships are lost during sub-pixel analysis (Blaschke & Strobl 2001). An object-oriented approach initially completes a process of image segmentation effectively creating polygonal objects representing spectrally homogeneous units at a specified scale (Blaschke & Hay 2001). These objects can then be analyzed and put into a classification scheme in order for landcover extraction (Fig. 1).

### 2.2. Segmentation

Before classification can occur, the image must be apportioned into basic units for analysis. New technology allows for an object-oriented approach through a procedure of segmentation, which subdivides the entire image into regions at a user-defined scale, in essence creating patches as the fundamental unit of analysis (Definiens 2004). The proper level of segmentation is determined by the size of the object in question. This approach takes into account within-pixel spectra values as well as neighborhood characteristics making possible the extraction accurately shaped real-world objects as the basic units for analysis. Vegetation is typically dominated at a very fine resolution. Thus, the imagery was segmented at the respective scale parameter with weighted emphasis on the red and blue band, which visually appeared to segment vegetation best.

### 2.3. Object Discrimination / Classification

For classification to be meaningful, these segmented patches must be locally trained by *in situ* classification. A sample study area was established in northern Tempe as a proxy for the metropolitan, since most dominant types of landscap-



ing are present, mesic yards to desert landscaping and bare soil. One hundred sampling points were randomly distributed in the study area and then assessed and classified as either "woody vegetation" or "other" through groundtruthing using a GPS unit with sub-meter precision. These plots were cross referenced with true-color imagery and the classified segments were isolated creating a sample library. This library serves as the foundation for image classification. A principal components analysis was then conducted to ascertain the most appropriate features to discriminate between the two classes. Interestingly the shape metrics contributed nothing to the analysis. This is likely due to the fine scale segmentation necessary for analysis of individual trees. If one increases the scale parameter too high then pixels are aggregated above the resolution of much urban vegetation. Three features contributed to the best discrimination power: mean value of the blue band, the mean value of the red band, and the ratio of the mean value of the green band to the standard deviation of the green band. The parameters of these features were then scaled to enhance the classification accuracy.

## 3. RESULTS

### 3.1. Testing Set

Within the sampling study area of northern Tempe, 500 points were randomly generated. *In situ* groundtruthing was then conducted with a GPS unit with sub-meter precision to determine classification. Access was prohibited at 55 sites and thus no classification was assigned to those points. Of the remaining points, 197 were classified as "woody vegetation" if there was a shrub or tree at the location with a diameter greater than 2 m. The "non-woody" category included other locations with all other land cover classifications, 248 in all, and vegetation less than 2 m.

### 3.2. Error assessment

The image was classified and then compared with the testing set, generating an error matrix (table 1). The error matrix effectively illustrates the general robustness of the classification errors. Errors of inclusion, commission errors, are very small for objects classified as woody with only 2 out of 175, but are larger for the non-woody classification.).

| | | | |
|---|---|---|---|
| | **Referenced as:** | | |
| **Classified as:** | **Woody** | **Non-woody** | |
| **Woody** | 173 | 2 | 17 |
| **Non-woody** | 24 | 246 | 27 |
| | 197 | 248 | |
| | **Woody** | **Non-woody** | |
| **Producer's accuracy** | 0.88 | 0.99 | |
| **User's accuracy** | 0.99 | 0.91 | |
| **Overall accuracy** | 0.94 | | |
| **KIA** | 0.88 | | |

Table 1. Error matrix showing ground reference data versus the image classification of urban woody vegetation; and classification error assessment statistics.

This matrix can be used to compute more meaningful accuracy assessment measures (table 1) , such as producer's accuracy, user's accuracy, & overall accuracy (Story & Congalton 1986, Congalton 1991). The producer's accuracy estimates the probability that a point in the groundtruthed reference library was correctly classified. Thus, 88% of the objects classified as "woody" and 99% of the object classified as "non-woody" agreed with the reference collection. User's accuracy provides an estimated probability to how well the classification of the segmented objects correctly predicts the proper class. Thus the user of the classified image can be 99% certain that an object classified as "woody", and 91% certain that an object classified as "non-woody", is correctly classified relative to the objects on the ground.

Overall accuracy is calculated by summing the correct classifications and dividing by the total, in effect giving how many object were correctly identified, 94% in this classification. The Kappa statistic, 0.88 for this classification, is preferred over overall accuracy as it takes into account the probability that classification and reference may agree by mere chance, and is typically a preferred estimate of general accuracy (Congalton & Green 1999).

## 4. DISCUSSION

We have clearly shown that common aerial photography is capable of being used to classify the urban forest in an accurate and repeatable fashion. It is our hope that this process is equally as valuable in more mesic urban environments. It does appear that classification of other objects of interest may be difficult, as many of the impervious surfaces, roads and roofing material are constructed of nearby geologic materials which make discrimination among natural and man-made difficult (Stefanov 2001). Additionally, discrimination among different man-made items (i.e. roads & buildings) has proven difficult due to the similarity of source materials.

## 5. CONCLUSIONS

Aerial photography, especially with very high spatial resolution, has shown great promise in classifying Phoenix's arid urban forest in this paper. Additional error assessment will be conducted to analyze the accuracy nuances between types of vegetation and canopy size. With the promise of strong robustness of this classification procedure, spatially explicit data will now be able to be collected across the Phoenix metropolitan in order to analyze other ecological phenomena that occur within the city, such as human impacts of urban forest coverage and animal diversity patterns.

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