Hierarchical image analysis of Phoenix's urban forest structure

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ABSTRACT

This is an object-based, methodological design for estimating urban structure, specifically vegetation, using remote sensing techniques on high-resolution (0.6m²) aerial photography utilizing a hybrid of image segmentation and spectral classification. Color imagery can be analyzed and classified spectrally, albeit limited relative to multispectral imagery. The advantage of analyzing color imagery is that it is typically collected a much higher resolution than multispectral imagery and is commercially available for many entire metropolitan regions. Objects within the urban ecosystems are typically restricted to specific scales. Therefore, it becomes necessary to be able to analyze objects at their respective scales. For example, vegetation is controlled at the local scale within the urban environment and is best analyzed with high resolution data, whereas it is appropriate to analyze land-use structure at much coarser resolution. Data synthesis among objects of mismatched scale is problematic for many pixel-based remote-sensing techniques as all objects are classified at the same scale, the resolution of the pixel. A hierarchically-networked, object-oriented approach takes into account within-pixel spectra values as well as neighborhood characteristics making possible the extraction of real-world objects, proper in shape, as the basic units for analysis and can be synthesized across scales. This is realized through a combination of data-driven (bottom-up) methodologies and knowledge-based (top-down) classification. This technique is in the process of being analyzed for accuracy to allow for regular monitoring of vegetation change at broad scale with fine resolution in the Phoenix basin.

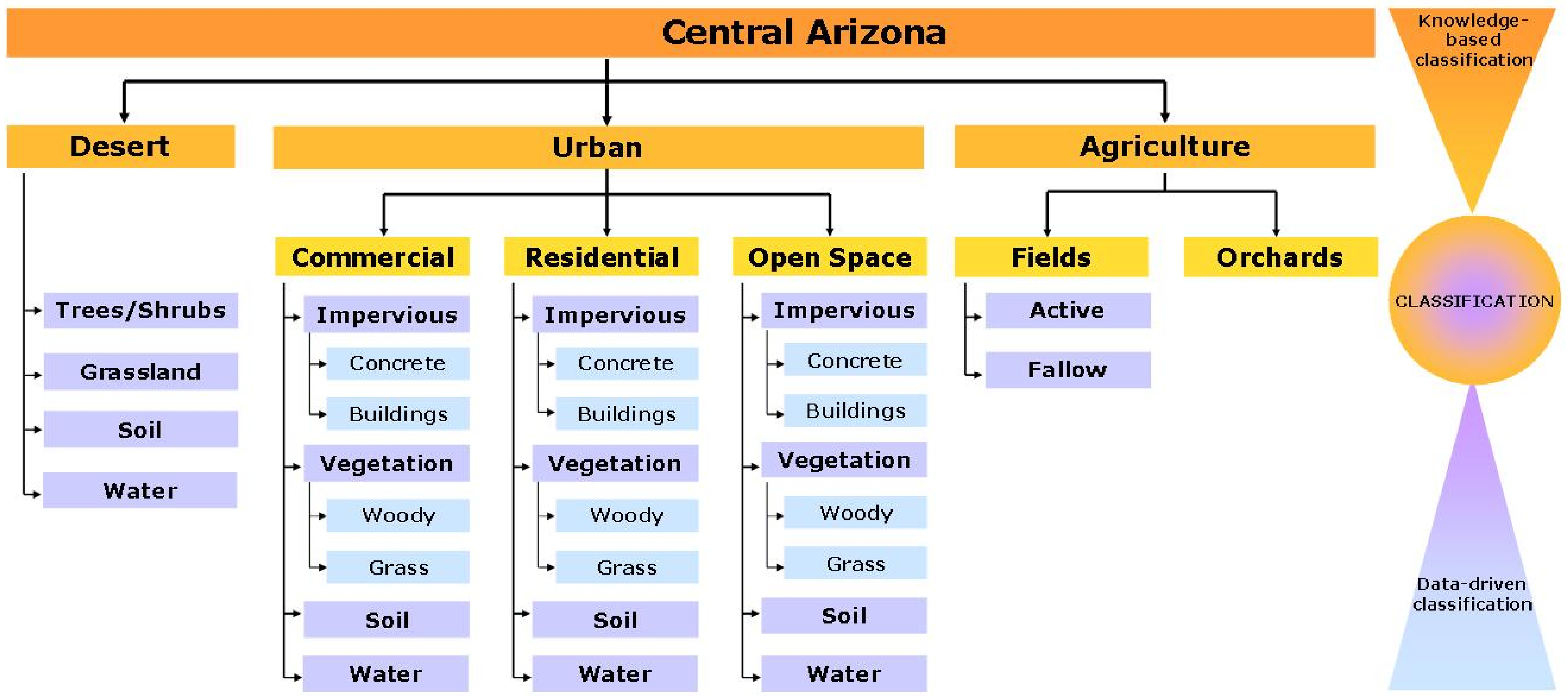
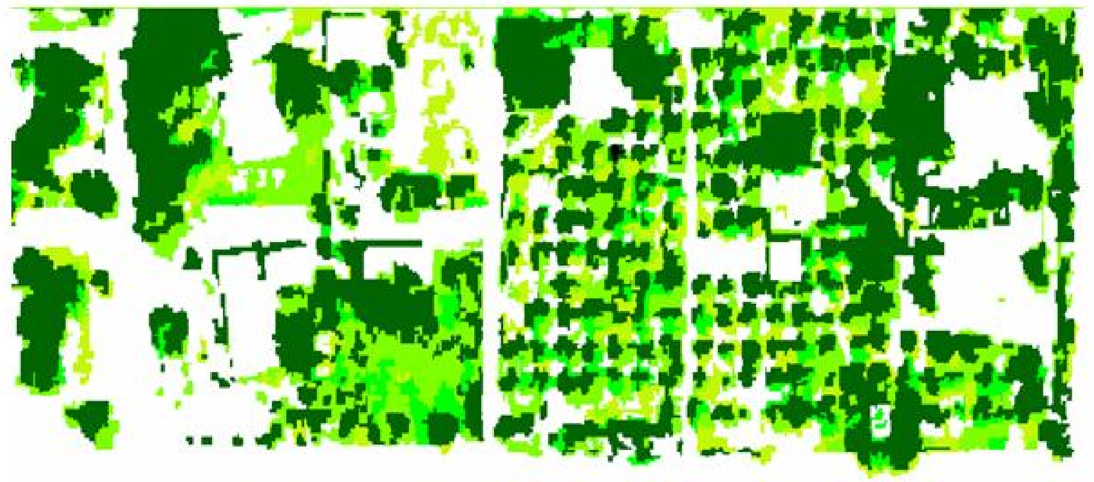


Figure 1. Hierarchical classification scheme for image analysis of Central Arizona-Phoenix. Initially a knowledge-based, top-down approach is used to classify broad land use classes identified by the Maricopa Association of Government. This allows the data-driven, bottom-up approach to be utilized more accurately by applying localized knowledge which is attuned to the specific land use class. For example, the likelihood that any given object in the desert is a building is very low. However, in residential neighborhoods the ability to recognize and classify buildings is mandatory. Therefore, parent classes are able to pass down class descriptors to their respective child classes, allowing for more precise classification.

KNOWLEDGE-BASED CLASSIFICATION

Appropriating accurate land-use allows for a localized-knowledge classification in order to define local scale phenomena during image analysis of aerial photography. The advantage of this approach is that objects of like classes can be analyzed with common semantics, increasing the final degree of accuracy in classification.



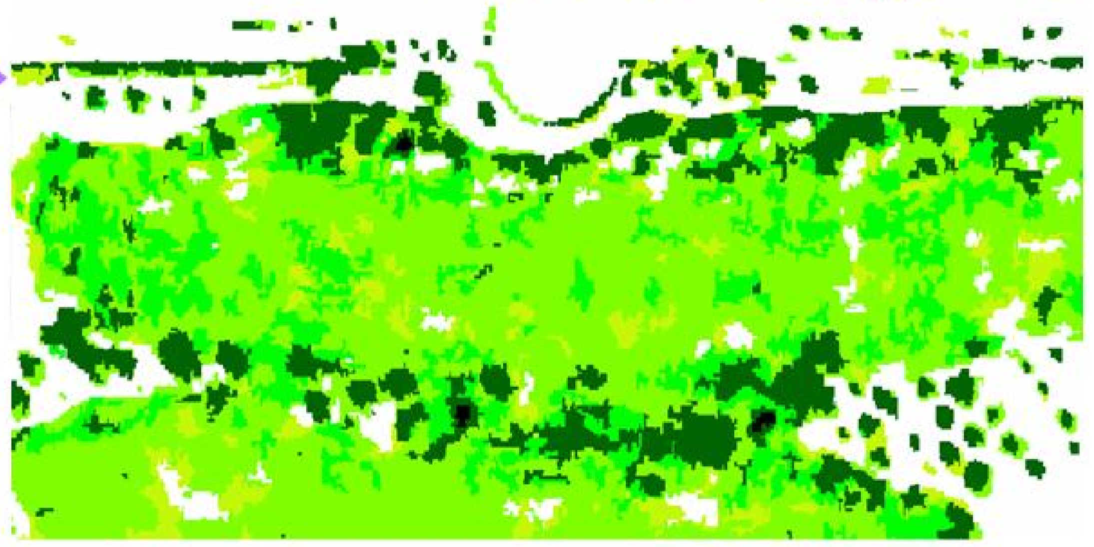


IMAGE CLASSIFICATION

The spectral library in concert with the localized knowledge based on landuse type is used as the statistical foundation for a supervised classification of the segmented image.

GROUND-TRUTHING

Once the entire image is segmented, the patches must then be locally trained for meaningful classification. Vegetation and other objects of interest were identified and mapped using a GPS unit. Pixels from these plots were isolated from the image creating a spectral library.

DATA-DRIVEN 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. The proper level of segmentation is determined by the size of the object in question. This is partitioned into a hierarchical network which allow multi-scalar analysis representing the data at different resolutions simultaneously.

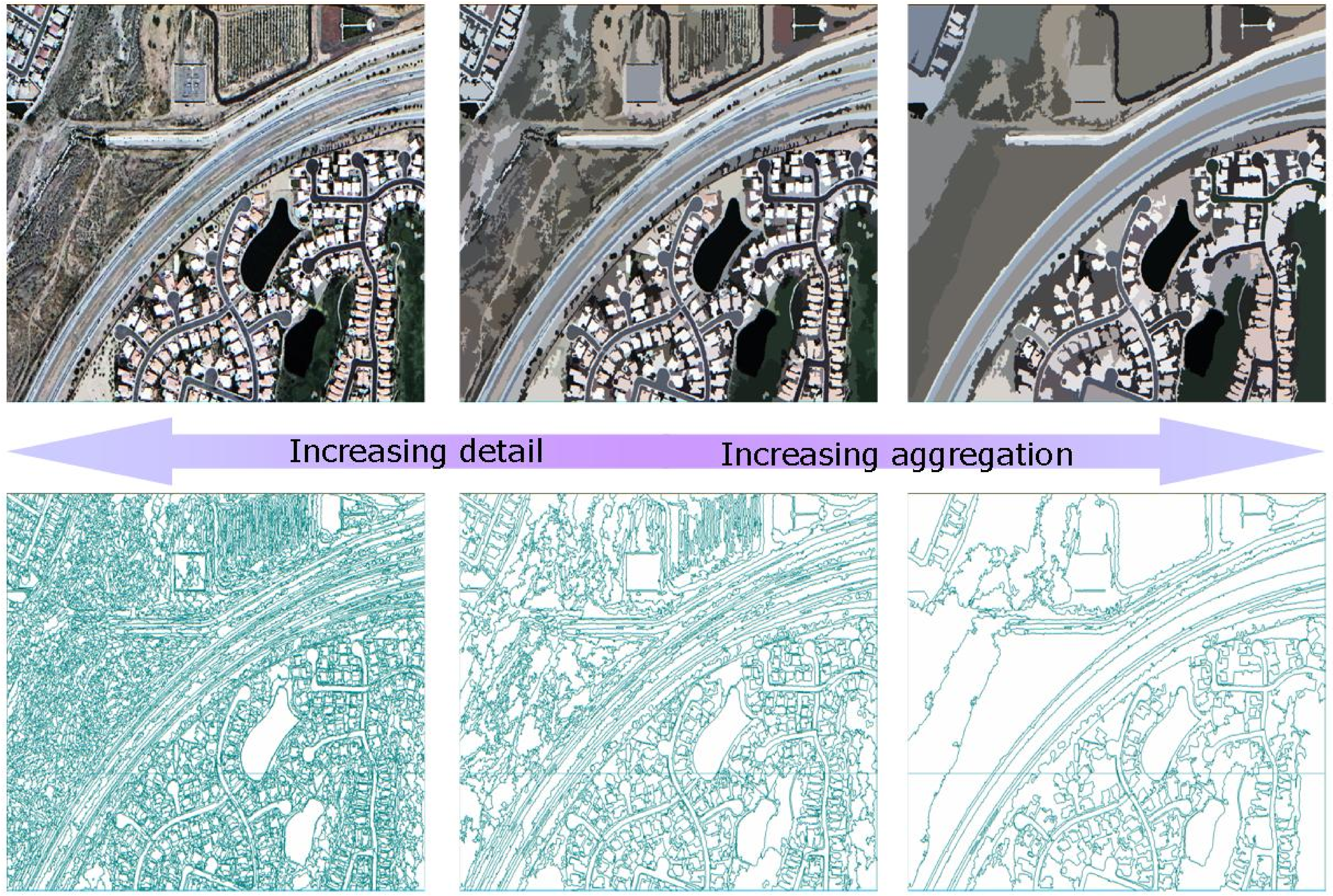


Figure 2. Image segmentation at varying scales. By analyzing spectral characteristics in concert with neighborhood dynamics, this process subdivides the image into discrete polygonal units at a user-defined scale. Classification is not done at this step. However once a classification is completed, it is possible to analyze objects of interest at their appropriate resolution, while simultaneously analyzing objects of other scales at their specific resolution.