

A Remote Sensing Based Urban Tree Inventory for the Mississippi State University Campus

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Abstract

A unique urban tree species identification project for the Mississippi State University campus was undertaken in the Spring of 2002. A collaborative effort between the MSU Forestry Department, Landscape Architecture Department and the U.S. Forest Service was initiated in an attempt to automate tree species identification from high-resolution multi-spectral imagery. Traditional image processing approaches to tree identification failed to accurately classify trees into unique classes due to differential crown illumination, crown shadowing, and spectral confusion with other vegetation types. Feature Analyst enabled extraction of tree crowns from other landscape features. After tree crowns were delineated from other vegetative cover types, a traditional image processing approach yielded excellent results for delineating Pine, Hardwood, Cypress, and Other tree species.

Keywords: Remote Sensing, Feature Analyst, High-resolution, Multi-spectral, Urban, Forestry

Introduction

A collaborative project between Mississippi State University and the USDA Forest Service was undertaken to identify tree species in an urban environment. The major project goals included (1) identifying major species associations from remotely sensed data, (2) determining the efficacy of using remote sensing data for tree species identification, and (3) assessing the cost/benefit of employing student labor for training and ground validation of remote sensing results.

Identification of major species associations required finding answers to several questions:

- What tree species can be identified from high-resolution multi-spectral remotely sensed data;
- What are the remote sensing skills needed for accurate species identification; and
- What image processing techniques can help overcome the problems of high-resolution imagery like differential crown illumination, crown shadows, and distinguishing trees from other woody vegetation?

Determining the efficacy of using remote sensing data for inventorying urban tree resources required finding answers to:

- Can remote sensing techniques save time and money compared to traditional 'field-based' inventories; and
- How well do 'traditional' image processing classification procedures work?

Assessing the cost/benefit of employing student labor for training remote sensing classification processes and ground validation of remote sensing classification results led to asking these questions:

- Do students make good 'field crews';
- What is the learning curve for learning to use tree measurement tools;

Methods and Materials

The study area included approximately 50% of the Mississippi State University campus. The campus was divided into 12 roughly equivalent areas and 3 students per area (36 total students) were assigned to do field sampling.

Students were trained in the use of GPS receivers and tree locations were differentially corrected using the GPS receivers and a ground station. Field data sheets were prepared and field collection data included tree species, differentially corrected GPS tree locations, crown ratio, crown density and diameter at breast height (d.b.h.).

GeoVantage, Inc.¹ provided high-resolution (.5m and 1m) multi-spectral remote sensing data over the MSU campus. The data bandwidths were:

- 440-460 nm (blue)
- 540-560 nm (green)

¹ GeoVantage, Precision Navigated Imagery, P.O Box 147 Pine Street, Swampscott, MA 01907

640-660 nm (red)
830-870 nm (NIR)

Classification of high-resolution multi-spectral imagery for individual tree species presents several challenges when using standard image processing techniques. Challenges include differential crown illumination and shadows within individual crowns.

Several standard approaches to species classification were tested including using lowpass filtering and band transformations prior to an unsupervised classification approach. Figure 1 illustrates the result of an unsupervised classification process using 50 initial classes. Multiple classes within a single crown resulted from this approach. Post-classification aggregation of classes failed to control within species variance in single species.

Only marginal classification improvement was obtained through the use of pre-classification data transformations including low-pass filtering, textural analysis, Normalized Difference Vegetation Index (NDVI).

At this point in the project a decision was made to attempt a different approach to tree species classification using Visual Learning Systems' **Feature Analyst**^{TM 2} software. Feature AnalystTM is based on hierarchical machine learning technology. The benefits of this machine learning approach over standard supervised image classification techniques, such as the maximum likelihood method, are the ability to improve feature classification using inductive learning techniques (Al-AbdulKader, et. Al).

A hybrid classification technique was developed using Feature AnalystTM and standard image processing techniques. Figure 2 shows the flowchart of processing steps used in the hybrid classification technique.

There are several steps involved in using Feature Analyst software to maximum effect. Among these is careful attention to digitizing features of interest in a variety of locations and with a variety of spectral reflectance. Numerous polygons were digitized for each tree species represented on the MSU campus. These polygons represented a range of species and spectral conditions including coniferous and deciduous trees. Single trees were chosen for polygons wherever possible and a wide range of age classes were represented. Another important characteristic of the Feature Analyst software is the 'input representation'. It is possible to uniquely define the shape of the area to be sampled for feature extraction via the 'input representation'. For this project the 'Manhattan' representation seemed to give the most consistent results for extracting trees from all other reflective surfaces. Problems of differential crown illumination and crown shadows that were largely unresolved using traditional image processing techniques were significantly reduced when Feature Analyst was used to extract individual tree crowns. Figure 3 illustrates how Feature Analyst enabled extraction of a single crown for the same tree that standard image processing yielded 6 separate classes.

² Visual Learning Systems, P.O. Box 8226, Missoula, MT 59807

After successfully partitioning of trees from other landscape components, a tree ‘mask’ was applied to the multi-spectral imagery and just trees were subset from the imagery for further ‘standard’ image processing. Problems of differential crown illumination and shadowing still existed within individual tree crowns, but image spectral variance was significantly reduced by eliminating all other reflective surfaces from the imagery. The problem was now reduced to reducing within-species variance while maximizing between-species variance.

Approximately 90% of the field plots were used to generate signatures for a supervised classification approach while the other 10% were used for classification accuracy assessment. Controlling spectral variance within species required the use of multiple training fields within single tree crowns. The classification philosophy stressed the collection of small training fields with low variance that would yield numerous output classes that could be aggregated post-classification classes by species.

Results

Results of the classification and aggregation process were tested using a cross-validation approach and a traditional contingency table analysis. Overall classification accuracies were better than 80% for 4 species groups including Pines, Hardwoods, Cypress, and Other. The ‘Other’ class included big leaf ornamental hardwoods like Royal Paulownia and American Sycamore.

Early efforts at classification using standard image processing methodologies yielded lower accuracies for fewer species groups (Pine and Hardwood). Implementation of Feature Analyst derived tree masks provided significant improvement over those earlier efforts that concentrated on using a combination of lowpass filters and band transformations to reduce within-species variance.

High-resolution remotely sensed data was shown to be a viable alternative to a ‘ground only’ inventory of urban areas where differentiating broad species groups is the primary objective.

Conclusions

Combining Feature Analyst feature extraction capabilities with standard image processing techniques resulted in better classification accuracies and differentiation of more species groups than standard image processing techniques alone. The ease of use and gentle learning curve of Feature Analyst makes it a viable tool for student use on M.S. and Ph.D. projects.

High-resolution remotely sensed data was shown to be a viable alternative to a ‘ground only’ inventory of urban areas where differentiating broad species groups is the primary objective.

On the whole, students provided a good resource for field data collection although some measurement error and incorrect species identification contributed a small amount of uncontrolled variation in the classification process.

An M.S. project currently underway has implemented Feature Analyst to extract catfish (aquaculture) complexes from other water in the Mississippi Alluvial Floodplain. Since aquaculture acreage is determined from the water plus the levees, extraction of the levees and water as a single class is impossible using traditional image processing techniques. Figure 4 shows the result of the feature extraction and figure 5 shows the input representation that was most successful for extracting aquaculture complexes.

Literature

K.A. Al-AbdulKader, J.S. Blundell, and W.H. Farrand. *Marine Habitat Mapping Using High Spatial Resolution Multispectral Satellite Data*. Saudi Aramco Journal of Technology. Fall 2002. <http://www.vls-inc.com/reviews/Reviews.html>

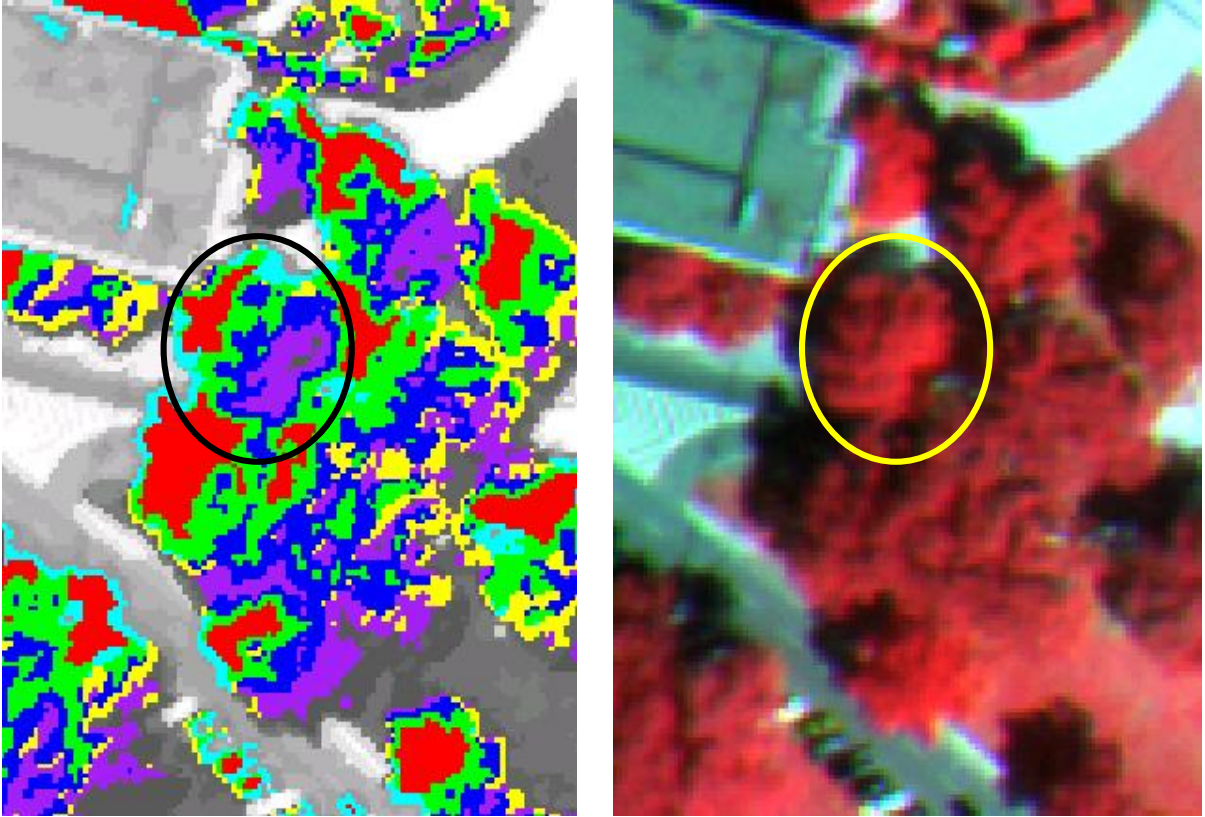


Figure 1. Results from an unsupervised classification of high-resolution multi-spectral data that yielded 6 distinct classes for an individual tree crown.

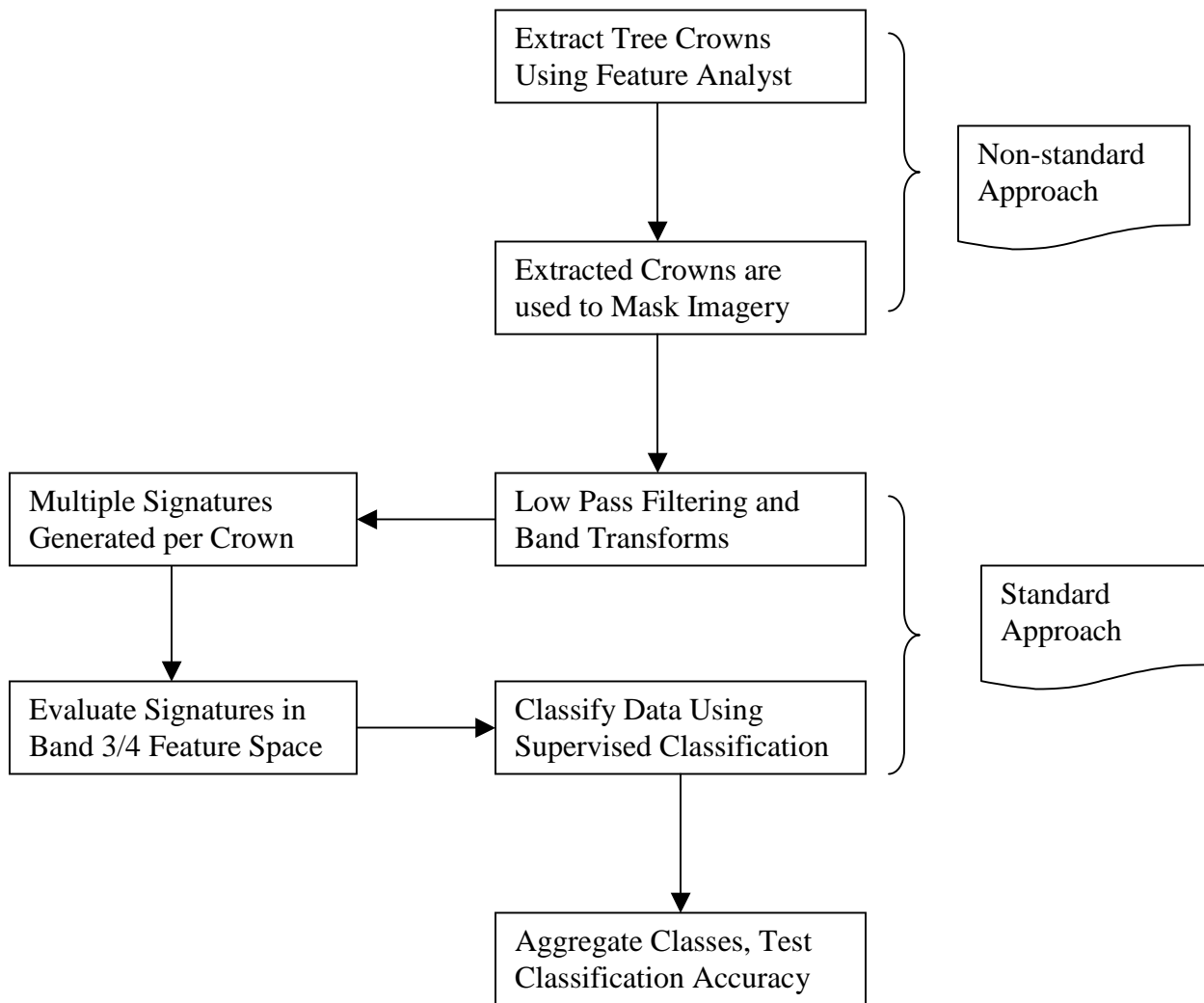


Figure 2. Flowchart of Image Processing Steps

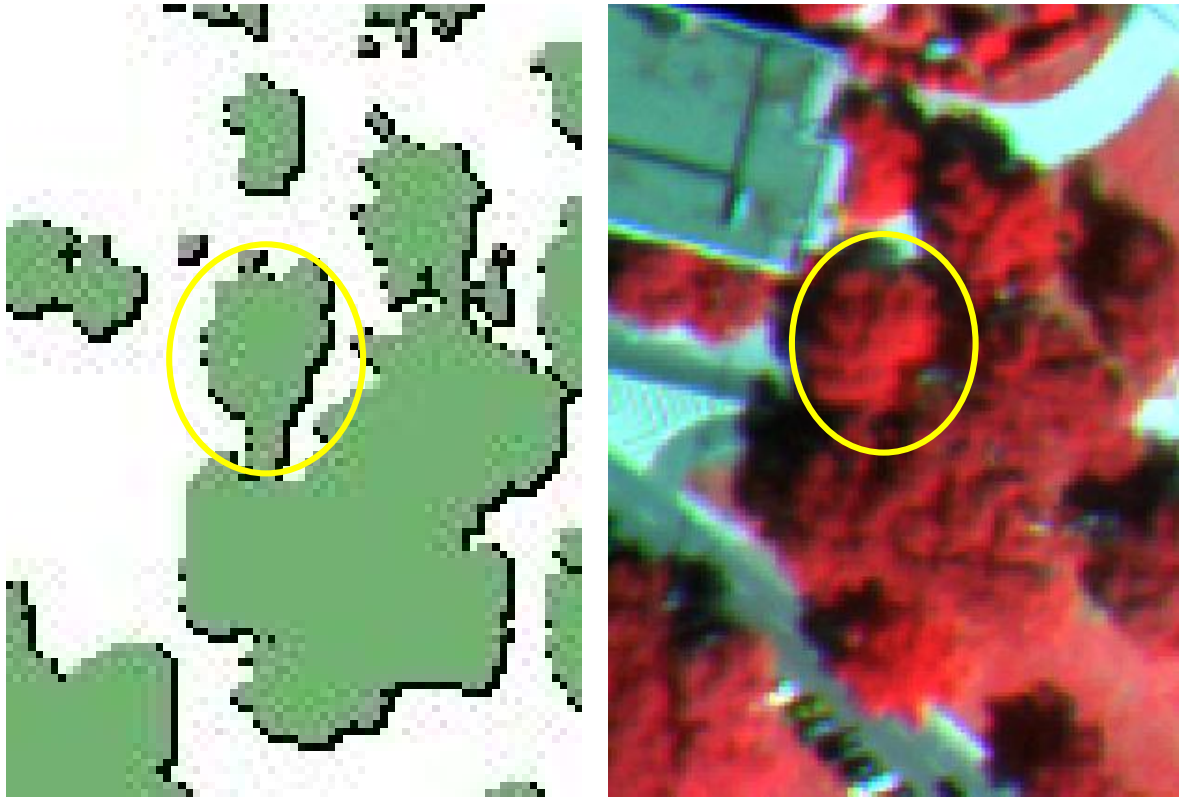


Figure 3. Results from Feature Analyst 'feature extraction' of high-resolution multi-spectral imagery that yielded 1 class for an individual tree crown.

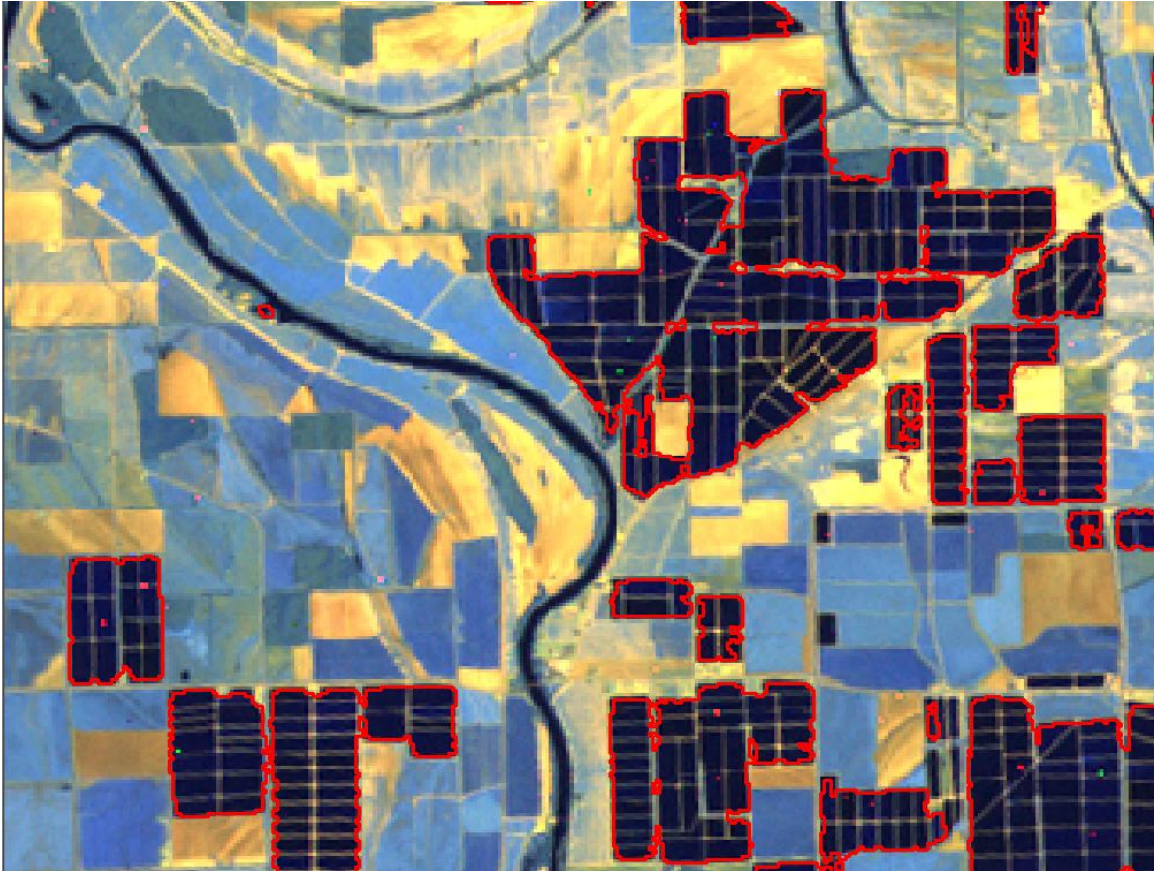


Figure 4. Aquaculture complexes including levees extracted from Landsat TM data without extraction of 'other water'.

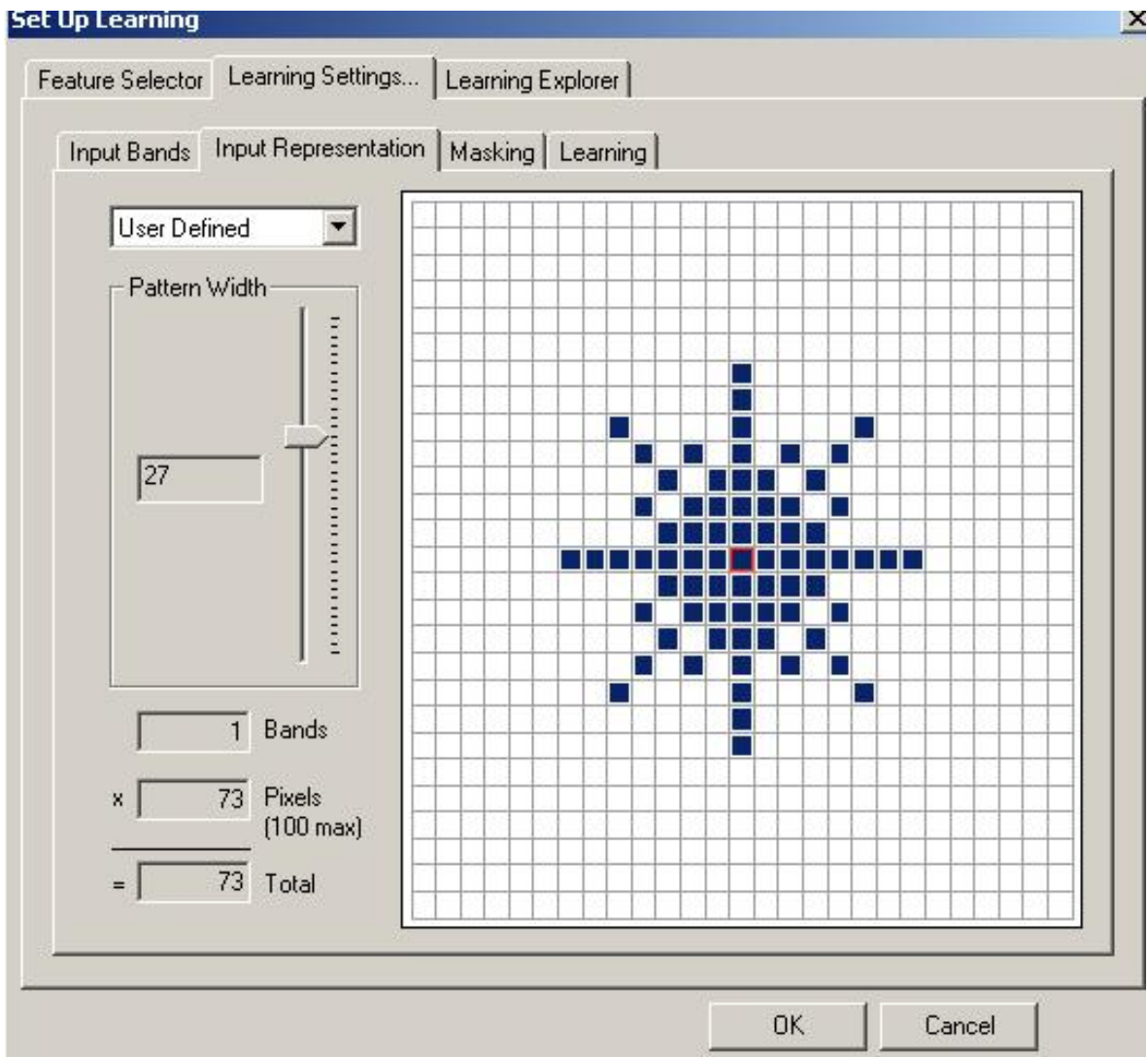


Figure 5. Input representation used for extracting aquaculture complexes.