



2005 April — Vol. XIV, No. 2

FEATURES

EOM April 2005 - FEATURES

Using Feature Extraction To Monitor Urban Encroachment

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There are growing concerns about the effects of urban encroachment near military installations. Urban encroachment impacts both the civilian population and the military installation. Urban growth and development infringing upon a military installation — in this case Fort Benning, Georgia — negatively influences the installation's ability to conduct training and maintain combat readiness and hinders the viability of the installation itself. The objective of this study was to monitor urban encroachment affecting Fort Benning. A secondary objective was to utilize an efficient, more automated approach to extracting urban features from satellite imagery. This effort supports the long-term baseline ecosystem monitoring plan under the Strategic Environmental Research and Development Program (SERDP), the Ecosystem Management Project (EMP), and the Ecosystem Characterization, and Monitoring Initiative (ECMI).

Feature Analyst (version 3.4), assisted feature extraction software developed by Visual Learning Systems, was used in this study to monitor the extent and location of urban expansion occurring near the installation. Landsat 7 Enhanced Thematic Mapper (ETM) data used to complete the Fort Benning land-cover classifications, were already available and, though maybe not optimal for this type of analysis, were assessed for suitability in urban extraction. The 28.5-meter ETM data were acquired during leaf-off conditions for the years 1999, 2001, and 2003. To monitor urban growth over time, a trend analysis was performed based on urban delineations from these two-year time intervals

beginning in 1999 and continuing to 2003. This article describes the procedures used to extract characteristic urban features from the available satellite imagery and evaluates urban growth over time.

Background

The space-based X-Ray telescopes on the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellites (GOES) and ground-based optical and radio telescopes operated by the United States Air Force (USAF) have just detected an extremely powerful solar flare on the face of the sun.

Urban encroachment and its negative impacts are not just problems for military installations. In general terms, forest fragmentation caused by urbanization and sprawl poses one of the most significant, permanent threats to southern U.S. forests. As a result, this trend has the potential to be the biggest single threat to forest sustainability in the South over the next twenty or more years. The population of the United States has roughly doubled between the late 1950s and 2000, and the population of the South has grown at an even faster rate. The share of the U.S. population living in the South grew from 30.7 percent in 1990 to 32.5 percent in 2000. "By the year 2040, about 31 million forested acres are expected to be converted, concentrated primarily along the coast, in the Piedmont, and around major metropolitan areas." (Southern Forest Resource Assessment — Summary Report, by D.N. Wear and J.G. Greis, 2002. General Technical Report SRS-53 Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.)

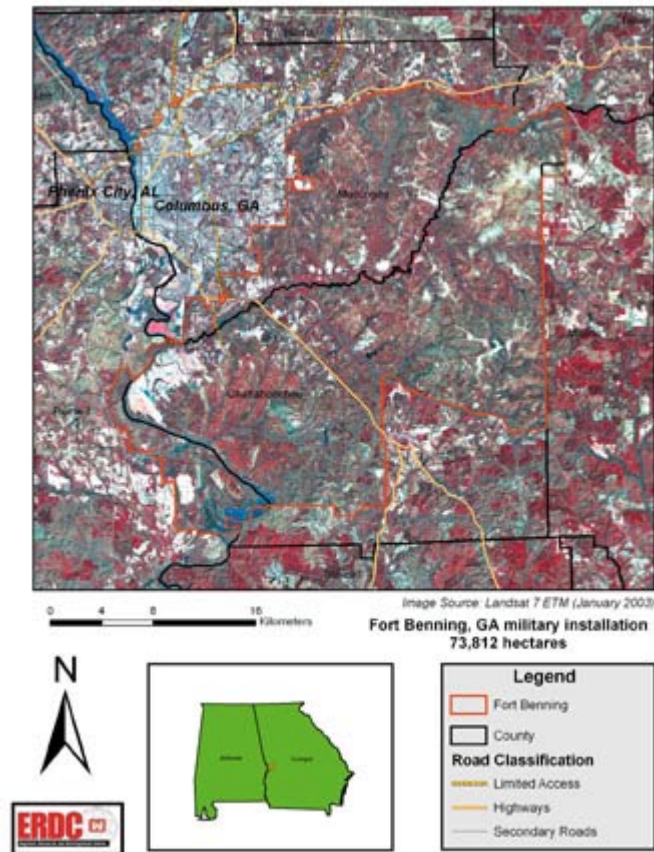


Figure 1 Location of Study Area, Fort Benning, Georgia

In addition to impeding military operations and causing deforestation of natural ecosystems, increased urban growth can provide pathways for invasive species, diminish some aspects of biodiversity (by threatening and endangering species), and accentuate the risk of catastrophic wildfire at the wildland-urban interface, and could ultimately influence future water supplies.

Study Area

Fort Benning is located in west central Georgia, south of the city of Columbus, Georgia, and east of Phenix City, Alabama. Fort Benning is situated in the Upper Coastal Plains physiographic province — a low, flat region characterized by well-drained, gentle rolling hills and poorly drained flatwoods (Figure 1). The installation covers approximately 73,812 hectares.

Semi-automated Urban Delineations

Feature Analyst was used to perform semi-automated urban delineations from three sets of time-series Landsat 7 data, collected December 1999, January 2001, and January 2003. It was assumed that leaf-off conditions would provide an unobstructed viewpoint from the satellite platform and thus be more suited to extracting urban features from the imagery. The acquisition of these data at specified time intervals allowed for urban

growth to be assessed over time.

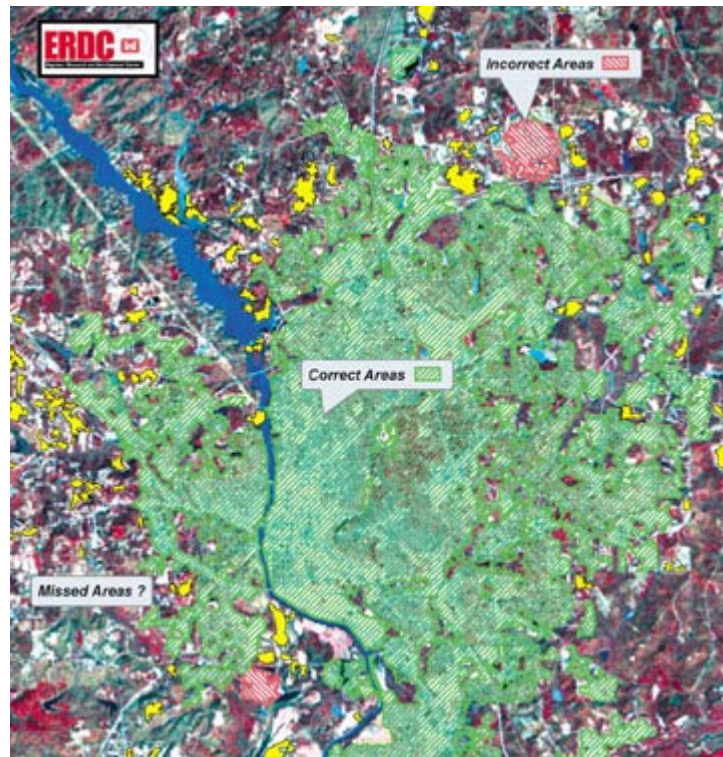


Figure 2 Correct, incorrect and questionable areas were identified to enhance clutter removal.

Feature Analyst is adaptive software that responds directly to the analyst's input, or training. Therefore, the results are greatly dependent upon the quality of the input data. Training sets — output as ESRI shapefiles — are digitized by the user to produce "ideal" examples of each feature to be extracted. These training sets are then input into the software for feature extraction to take place. The heuristic learning algorithms of the Feature Analyst software utilize textural information, shape, spatial context, size, and anticipated extent of coverage, in addition to spectral information, to extract features of interest. Because of this, coarse-resolution imagery, such as the Landsat product used in this study, may not be optimal compared to a more suitable high-resolution product, such as QuickBird or IKONOS. Nonetheless, one objective of this study was to evaluate the effectiveness of using readily available satellite imagery for use with sophisticated feature extraction software such as Feature Analyst.

To capture urban growth near and around Fort Benning, polygon training sets representing urban features (buildings, houses, streets, etc.) were manually digitized using the Landsat 7 ETM satellite imagery. The primary urban expansion impacting Fort Benning is that of the metropolitan areas of Columbus, Georgia and Phenix City, Alabama. Therefore, this Region of Interest (ROI) was clipped from the image scene to extract features only within this chosen area. Variable-sized representative samples were digitized throughout the ROI for two reasons. First, the different size polygons will

adequately represent the various feature shapes in the image. Second, it is important to select areas across the extent of the image to reduce the potential effects of shadows. The completed training sets were then used as input to the learning phase of the routine. By selecting a feature type that most closely represents the target feature, in this case buildings, and by choosing the spatial resolution closest to that of the imagery, the initial extraction process was completed for each of the target urban feature classes. However, many more iterative processes are needed to render satisfactory results.

As a result of the first iteration, clutter — in the form of small polygons — was removed from the dataset by aggregating the undesirable features together. Aggregating effectively removes "island" polygons as well as small holes within the resulting polygons. To further refine the clutter removal process, a series of correct (positive) and incorrect (negative) examples were identified (Figure 2). Areas of missed urban features were also identified during this phase of the process. This helps the software to learn from any mistakes that may have been made during the initial classification and was initiated several times to produce desirable results. Because of the coarse resolution of the Landsat imagery and the inability to effectively use pixel size to extract key features, manual editing had to be implemented to eliminate areas of confusion, i.e., areas that resemble urban features, such as bare ground and highway construction. Once satisfactory results were obtained, the residual polygons were smoothed to eliminate the jagged-edge appearance.

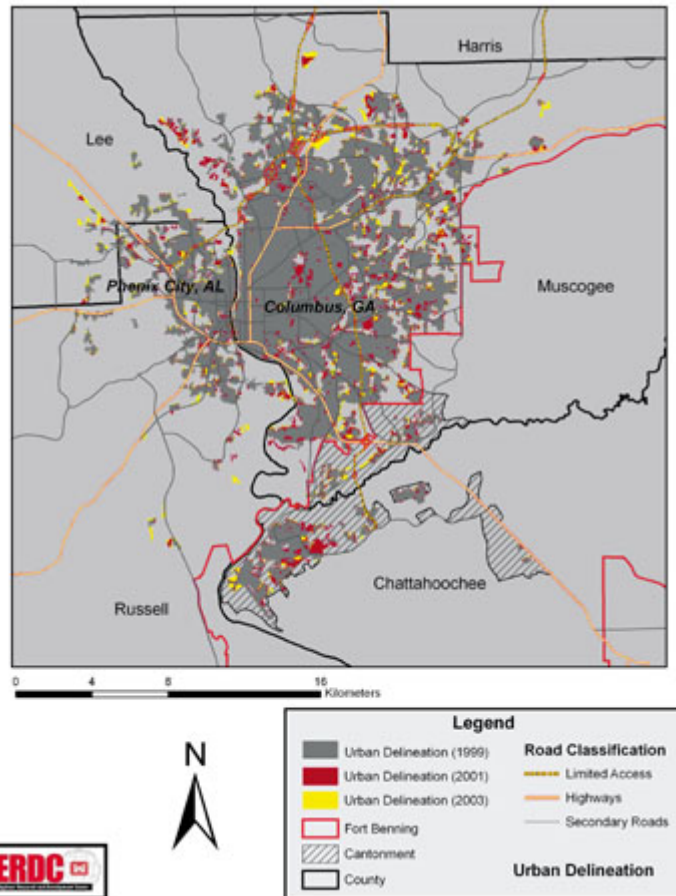


Figure 3 Urban Expansion over time (1999-2001- 2003)

Year	Total Area (ha)	Growth Percentage
1999	15,246	-----
2001	15,644	2.54%
2003	16,101	2.83%

Results

Urban features were extracted from the satellite imagery for the past three collection years. Figure 3 illustrates the urban expansion over time (1999-2001-2003) for the metropolitan areas affecting Fort Benning. To remain consistent with prior urban growth estimates, urban features within the cantonment areas of Fort Benning were included with the final delineation estimates for all years. The results (represented as total area in hectares) were then analyzed to correspond to the urban growth impacting Fort Benning. There has been a steady increase in urban growth since 1999. Table 1 summarizes the growth estimates as well as the percentage of growth from the first initial estimate in 1999 to the present in 2003. Urban growth has increased roughly 2.5 percent from 1999 to 2001 and slightly more at 2.8 percent from 2001 to 2003.

Conclusion

The assisted feature extraction method utilized in this project demonstrates the advantages of the Feature Analyst software to provide the user with an easy way to extract urban features from satellite imagery without using the traditional image processing techniques. Other advantages of using the feature extraction software are that it is incorporated into ArcGIS 9.0, it is quite user-friendly, and it produces results quickly.

The completed output (ESRI shapefile) from Feature Analyst can be easily compared to previous years in order to effectively determine where urban encroachment is occurring. This approach appears to be very helpful and efficient in a decision support system, especially for generalizing urban growth and its potential impacts. The feature extraction software provides the user with a quick and easy method to extract single features from the satellite imagery. However, using high-resolution satellite imagery, as opposed to coarse-resolution, may provide more precise estimates when using semi-automated feature extraction software such as Feature Analyst to extract detailed urban features. For reasons similar to those that make high-resolution imagery unsuitable for input into traditional pixel-based clustering and classification algorithms, coarse-resolution imagery may not be the best input for sophisticated feature extraction software that relies on a finer spatial context based on pixel size. 🌐

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This article is based on Automated Procedure to Monitor Urban Encroachment Over Time on Fort Benning Military Installation, by S.S. Jackson and S.G. Bourne, An SERDP Technical Notes Collection, ERDC/EL TN ECMI, U.S. Army Engineer Research and Development Center, Vicksburg, Missouri, 2004. www.wes.army.mil/el/ Citation of trade names does not constitute an official endorsement or approval of the use of such products. (ESIP Federation).