Incorporating Land Use Change Into Army Basing Analysis

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ABSTRACT

Base Realignment and Closure (BRAC) 2005 determined stationing options for Army units given an Army installation's limited resources (facilities, lands, and ranges) and a unit's resource requirements. One factor considered within BRAC analysis was a measure of the extent that surrounding communities *have* "encroached" on a military installation. Urban and suburban development along an installation's immediate perimeter is a type of encroachment that potentially constrains military operations and training. The Army established the Total Army Basing Study (TABS) to develop a comprehensive and comparable analysis of Army installations as input into the BRAC decisionmaking process. This TABS analysis included a comparison of land use changes (from non-urban to suburban or urban) in the perimeter lands surrounding military installations. In addition, an encroachment trend was projected to 2020 for the sites in the analysis. We describe the TABS land use change analysis approach, examine analysis results for three military installations, and then compare the results at one of these three sites to results from an alternate land use change analysis method that was used at that same site. The authors' analysis and results were incorporated into the Army's candidate recommendations for the 2005 BRAC process.

BACKGROUND

Over recent decades, military installations and ranges were making concessions to their surrounding neighbors by moving ranges away from their boundary areas and/or curtailing night operations. The 1990s experienced a very rapid pace of urban expansion and an accumulation of legislative constraints on military training to protect species habitats and culturally valuable areas. These factors increased concerns regarding the loss of range capability at many military installations across the nation. As a result, installation range managers and military land use researchers began presenting the concern about loss of military use capability in various forums (Goran and Deal 2002; Goran and Westervelt 2003), and news articles started appearing in local and national newspapers (*USA Today* 2003).

To help installations and communities visualize these changing land use patterns over time, the staff at the Construction Engineering Research Laboratory (CERL) of the Engineer Research and Development Center (ERDC) in Champaign, IL (one of the Corps of Engineers' research laboratories), developed several map series as a set of products from its sustainable training lands research program. Figure 1, for example, shows a series of maps for the Camp Pendleton, CA, region that illustrates local area development (land use) changes every 20 years, from 1940 through 2000 (Timlin et al. 2002). This type of land use change in the vicinity of military bases is one factor that Defense defines as encroachment.

ENCROACHMENT DEFINED

In 1997, the Secretary of Defense created a Senior Readiness Oversight Council (SROC) to help ensure readiness of the Services. Shortly after its creation, the SROC identified encroachment as a major concern, and defined it as "external factors that inhibit the accomplishment of necessary training and testing." The SROC highlighted encroachment as "one of the primary issues affecting range sustainability and therefore, readiness" (Office of the Secretary of Defense [OSD], 2001). One of the key SROC encroachment factors is the urbanization of the lands surrounding military ranges. "Population growth near military ranges has led to competition for space and increased concern for health and safety" (OSD, 2001). Other factors identified as encroachment concerns include: endangered species and critical habitat; cultural resources; frequency spectrum; maritime sustainability; land and airspace restrictions; air quality; clean water; wetlands, and airborne noise (DoD, 2004).

Many Army installations were originally built in somewhat remote locations. But over the decades, the local communities began growing in population and spatial extent, usually extending a zone of urbanized area along roads leading toward the installations. When populations settle near military installations, the residents are often disturbed by the noise, air traffic, and perceived safety issues.

Encroachment is a hindrance to Army training. The Army faces increasing

APPLICATION AREAS:
Readiness and Training
OR METHODOLOGIES:
Forecasting Time Series, Categorical Data Analysis

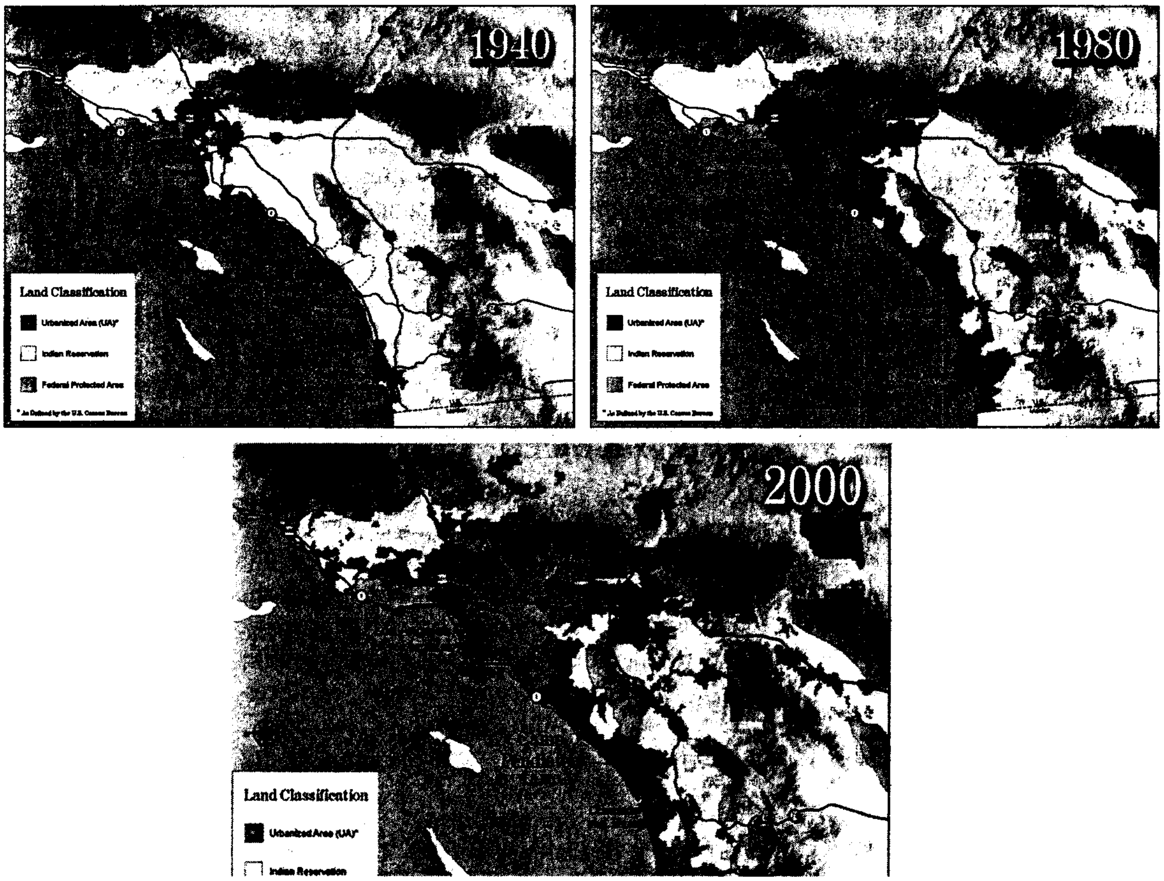

Figure 1. Land use change around Camp Pendleton, CA.

competition for the use of critical training land, airspace, and water resources necessary for weapon testing and unit training to maintain readiness. For Soldiers to train as they fight, it is essential to the Army and the country that these critical military land resources remain accessible for the successful completion of military missions (e.g., training, testing operations, and industrial base functions). Population growth, urban expansion, and increased traffic on the seas and in the skies are often competing factors for the availability these resources, especially in the vicinity of military ranges and flight routes.

BASE REALIGNMENT AND CLOSURE

The Defense Base Closure and Realignment Act of 1990 provided the DoD with an approach to address the changing needs of military installations (DOD, 1990). Originally inspired by the reduction of forces associated with the end of the Cold War in 1989, there were multiple rounds of Base Realignment And Closure (BRAC) during the 1990s (1991, 1993, and 1995). Even after these rounds, the DoD sought another opportunity to address surplus and non-optimal use of facilities and lands to improve its overall basing strategy. In response, Congress approved a new round of BRAC for 2005.

DECISION PROCESSES WITHIN BRAC

In the BRAC 2005 legislation, Congress stipulates eight criteria for BRAC decisions. The first four criteria represent Military Value (MV), which must be the primary consideration for BRAC 2005 recommendations (DOD

2005). The Army BRAC Report echoes that "Military Value was the primary consideration in making closure and realignment recommendations" (DoD 2005). Thus, all proposed closures and realignments start with MV analysis; the BRAC Commission evaluates each proposal by how well it supports MV as well as the force structure plan. Military value is determined by a set of attributes that comprise a comprehensive and comparable view of an installation for military uses.

The Total Army Basing Study (TABS) completed an analysis to determine the list of BRAC installation recommendations based on the law and the installation's characteristics (DOD 2005). TABS also completed a research effort to develop a MV model that met the BRAC criteria for certification of source data, analytical approach and for comparability across these installations using lessons learned from past modeling, and addressing current defense objectives. Part of this effort included interviews with senior Army and Defense leaders to obtain their views on BRAC 2005 objectives, priorities, challenges, and transformational or cost-savings opportunities. Combined, the internal research effort and interviews provided the basis for BRAC MV analysis. The encroachment application we describe was used for the Urban Sprawl attribute within the Army's MV analysis.

The 40 TABS-defined attributes that represent installation characteristics that differentiate installations, are measurable, and have certifiable data sources. (See Ewing et al. 2005 for a complete description of the Army's MV analysis and the Army BRAC Report.) Urban Sprawl was included in the "Future" capability category. This capability determines if the installation will be able to grow or if its mission will be compromised over time. Other attributes under the Future capability included: Buildable Acres, Brigade Capacity, Environmental Elasticity, Critical Facility Proximity, and Water Quality (Table 1). Each attribute was mapped to the DoD Criteria (DOD, 2005). Urban Sprawl was mapped to Criterion #1, which the Army referred to as Readiness and Criterion #3, also known as Surge.

TABS used the following Definition, Purpose, and Background for the Urban Sprawl attribute:

- *Definition*: A linear forecast to 2020 of urbanization, based on changes in land use from 10 years of historical data.
- *Purpose*: Evaluates land use changes and encroachment along the edges of Army Installations including 1-mile and 2-5 mile buffers around the installation.
- *Background*: Land use changes in the immediate vicinity of military installations can result in constraints being imposed on mission and resource management operations at these installations. Encroachment can compromise sustained and future training and testing missions at an installation (DOD 2005).

TABS needed a way to measure encroachment within a defensible, repeatable, and consistent method across installations to support their analyses (see Figures 2 and 3). TABS considered possible ways to approach the encroachment measure and contacted ERDC-CERL for suggestions. Major Army installations are included in this analysis, but there are a few installations from other Services, because this round of BRAC analysis included recommendations from each service for joint (multi-service) basing opportunities.

Table 1. Attributes for Future Capability.

Attribute Name	Attribute Description
Buildable Acres	Capability if internal expansion on an installation
Brigade Capacity	Current and future ability to support Army maneuver brigades
Environmental Elasticity	Ability to absorb additional personnel given environmental constraints
Urban Sprawl	Future expectations of encroachment around the installation
Critical Facility Proximity	Capability to support consequence management and homeland defense missions
Water Quality	Availability of water resources within the geographic region of the installation

TABS used ERDC-CERL's encroachment analysis to provide the basis for the Urban Sprawl attribute, including the definition above and a technical report (Lozar et al. 2005). TABS analysts had the encroachment analysis to support their review of different stationing actions.

MODEL DEVELOPMENT

Land Use Change Analysis

The methods chosen to model land use change around military installations needed to meet several OSD criteria (DOD 2005). First, the data sources had to be certified as reliable by the service audit agency. Second, the analysis approach had to be auditable by the service audit agency. Third, the data needed to be consistent and comparable for all installations; data at one site that could not be repeated at another site could bias the study and therefore could not be used. Fourth, the techniques to analyze these data needed to be clear, consistent, and comparable across all installations in the study set. Lastly, the data needed to be available from some existing sources, because time and financial resources were insufficient to acquire new data specifically for the purpose of an analysis of land use change.

The techniques developed by Timlin et al. (2002) and illustrated in Figure 1 provided excellent portrayals of land use dynamics in the vicinity of installations, but they were based on data from local maps and the Census Bureau's definition of populated areas. Local map sources, such as those used by Timlin, vary from one location to another across the country. In addition, the Census Bureau uses a threshold value that requires a certain density of residences in a census tract to meet the definition of populated area. However, installations are impacted by scattered low density housing along their perimeter creating a need to identify urbanized areas in the vicinity of an installation — no matter how low the density of dwelling.

Lozar et al. (2003) modified the approach of Timlin et al. (2002), primarily by adding

Figure 2. CONUS installations in the TABS analysis.

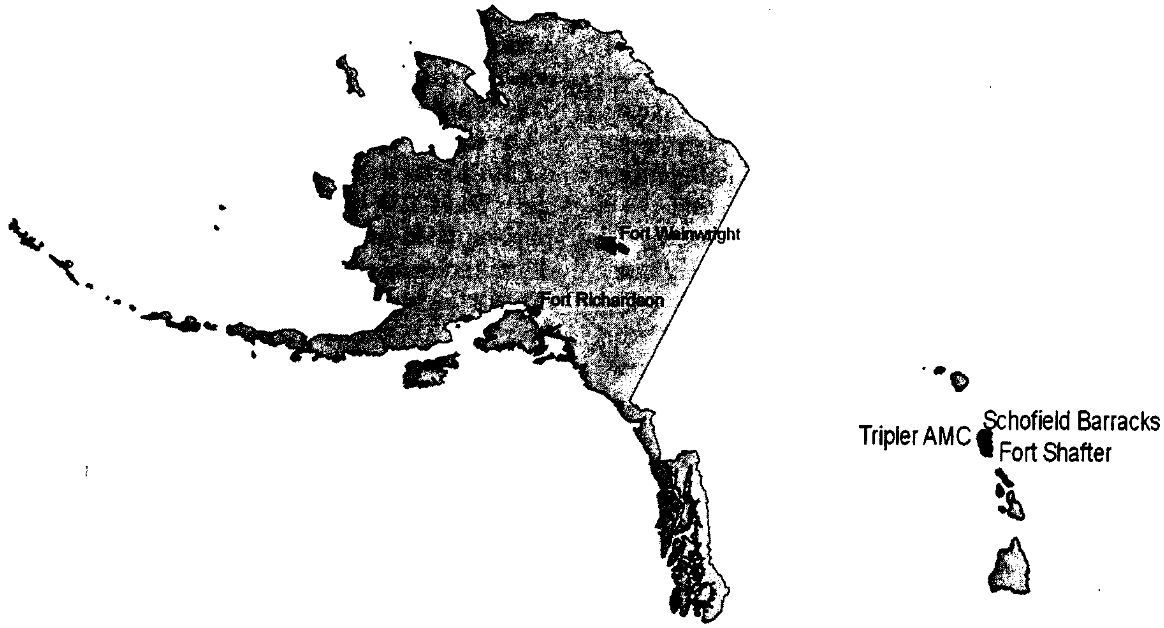

Figure 3. Alaska and Hawaii installations in the TABS analysis.

satellite imagery to their analysis. The Lozar approach identified any change in residential development in the installation vicinity, and supplemented national Census bureau data with both local maps, county records, and a variety of satellite imagery sources. This approach was valuable for an analysis of individual installations, but did not meet the consistency criteria, because the availability of acceptable quality satellite imagery and local data varies from site to site. A new data source was needed to meet the required consistency, comparability, and auditing standards.

In 2003, the Undersecretary of Defense for Acquisition, Technology and Logistics initiated an effort to provide data to support the BRAC 2005 analyses. This effort, titled the Installation Visualization Tool (IVT), was intended to provide a computer-based capability to view installation characteristics. The U.S. Air Force Geobase program coordinated the IVT effort and developed a comprehensive quality assurance and quality control process (Office of the Secretary of Defense, Installations and Environment, Business Transformation, Defense Installation Spatial Data Infrastructure [DISDI] website: http://www.acq.osd.mil/ie/bei/disdi.htm). The Headquarters Air Force Geo Integration Office under the Office of the Civil Engineer prepared a detailed plan to support the consistent preparation, evaluation, documentation, and use of the IVT mapping capability across the military Services in support of BRAC 2005 (Headquarters Air Force Geo Integration Office, 2003).

The IVT's key contribution was a visual data capability to supplement the Service's BRAC analyses and to help analysts visualize the implications of alternative stationing options. The IVT program consists of eight layers of data:

1. Installation boundaries
2. 100-year floodplain boundaries
3. Accident Potential Zones (APZs) on and around runways and other landing zones
4. Noise Zones at various decibel levels
5. Wetlands boundaries
6. Explosive Safety Quantity Distance (ESQD) areas
7. Five-meter orthorectified imagery of the areas beyond the base, and areas underneath military training routes and special use airspace
8. One-meter orthorectified imagery of the installation and areas within 1 mile of the installation.

For our purposes, the orthorectified imagery, from the IKONOS platform (Geoeye, 2007), provided an important data source. The 1- and 5-meter imagery was acquired by Space Imaging, Inc. and provided to the Services through the National Geospatial Intelligence Agency's Commercial Imagery Program.

Although this IKONOS imagery was available for all installations, it represented only one point in time (roughly 2001-2003) for each location. To determine the trend over time, we needed at least one additional data source. Two options existed: the U.S. Geological Survey's National Land Cover Datasets (NLCD), which provides an interpretation of land cover for the entire continental United States (through a partnership of Federal agencies called the Multi-Resolution Land Characteristics Consortium [http://www.mrlc.gov/index.asp]), and the Census Bureau data, which could be used as an additional source of information on local population and land use. We used both sources, but the NLCD data provided the primary data for the second point in time (approximately 1992), except in Alaska and Hawaii where only Census data were available.

To provide useful comparisons of land use change, the ERDC-CERL analysts defined study areas of 1 mile and 5 miles from the installation boundaries. The technique involved the use of Environmental Systems Research Institute (ESRI) Geographic Information System (GIS) software, plus Leica Geosystems' ERDAS IMAGINE imagery analysis software, to:

1. Create the perimeter zones around each base
2. Join together separate image panels into a unified mosaic
3. Perform a two-step classification of the IKONOS imagery to generate a two-class (urban and non-urban) interpretation for each of the IKONOS images (Lozar et al., 2005).

Initially, the image classification resulted in some false classifications when non-urbanized areas were classed as urban. To improve the classification results, analysts used image manipulation techniques, including road data (because of the association of urbanized areas with roads) and masks to "screen out" non-urban areas. The visual clarity of the IKONOS imagery provided a consistent visual reference to ensure that the classification properly reflected conditions on the original IKONOS imagery. The 1-meter and 5-meter resolution of the IKONOS imagery allowed for visual detection of all built structures.

The NLCD data, used for a temporal comparison with the IKONOS imagery, provides a 30-meter resolution. These 30-meter grid cells do not include visual evidence of structures; however, all grid cells in the NLCD are classified according to modification of the Anderson classification system (described on the U.S. Geological Survey [USGS] website at: http://landcover.usgs.gov/). The source data for NLCD is Landsat satellite imagery at 30-meter pixel resolution. Although there are dozens of land and land cover classes in the three levels of the Anderson system, only developed areas were considered urban in this analysis.

Developed Areas

Developed Areas are characterized by a high percentage (30% or greater) of constructed materials (e.g., asphalt, concrete, buildings, etc.).

Low Intensity Residential — includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30 to 80% of the cover. Vegetation may account for 20 to 70% of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

High Intensity Residential — Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20% of the cover. Constructed materials account for 80 to 100% of the cover.

Commercial/Industrial/Transportation — Includes infrastructure (e.g., roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential. (source: USGS website at: http://landcover.usgs.gov/).

The NLCD's developed areas were then compared with the urban classification from the IKONOS imagery; first visually, to ensure the classifications were visually logical, then using ESRI grid cell analysis capabilities. Tables helped to provide a quantitative comparison of the extent of the urban area in the 0-to-1 mile perimeter and the 1-to-5-mile perimeter of each installation in the study (see Table 2 for an example), at the time of the NLCD imagery source (approximately 1992), and at the time of the IKONOS source (2001-2003).

The extent of urbanization difference between these two sources (NLCD and IKONOS analysis) provided a trend in urbanization over time, which was projected in summary tables for the region surrounding each base, to the year 2020.

This trend was calculated from a limited timeframe (circa 1992 to circa 2003) during which suburban expansion and scattered suburban development was, in many parts of the United States, unusually high. However, this same pace of land use change has continued into the first decade of the 21st century. Projecting this trend to 2020 involves some uncertainty in predictions because the factors causing this trend will change over this timeframe. However, a key value of the projection in this analysis is not the specific projection for any one site, but the comparison of projections, using a consistent trend approach, across all the sites in the study.

The method described above was applied to all of the installations in the study, except for those in Alaska and Hawaii, where the NLCD data were not available (Figures 2 and 3 show the installations in the TABS analysis). In Alaska and Hawaii, we used urbanized areas data from the Bureau of the Census 2000 census, plus road data from the U.S. Geological Survey and National Geospatial Agency for the 1992 timeframe (to align with the date of the NLCD data). This method yielded comparable data for the "trend" analysis.

SELECTED RESULTS

This study involved nearly 100 installations, mostly Army but also a few other Services' installations. Results from Fort Benning, GA; Fort Hood, TX; and Marine Corps Air Ground Combat Center at 29 Palms, CA are summarized in this article. These three major installations represent different parts of the nation, different military missions, and have significantly different perimeter development patterns.

Fort Benning

Fort Benning, GA, is the home of the Infantry School and is also a force projection base. The installation, created at the time of World War I and enlarged during World War II, is located primarily to the south and east of the city of Columbus, GA, in Muscogee County. A small section of the installation is across the Chattahoochee River in Alabama. Fort Benning is entirely surrounded by privately held land; essentially all of the land surrounding the installation is susceptible for transition in ownership and a change in land use. Fort Benning has a large and growing population of Soldiers and civilian employees. With a population over 180,000, the city of Columbus provides urban amenities for the Fort Benning population and also accommodates a rapidly growing and diversifying economy. The Census Bureau (http://quickfacts.census.gov/qfd/states/13/13215.html) reports that the Muscogee County

Table 2. Percent Change in Developed Area on Perimeter of Military Bases.

Base Perimeter Region	Private Land Percent in Perimeter	Percent Total Developed Circa 1992	Percent Total Developed Land Circa 2003	Percent Change Per Annum 0-to-1-Mile Perimeter	Percent Change Per Annum 2-to-5-Mile Perimeter
Ft. Benning, GA	100	7.15	25.63	3.06	2.48
Ft. Hood, TX	96	4.35	7.47	0.65	0.70
29 Palms, CA	30	0.33	1.44	0.02	0.13

population grew at rate of 3.9% from 1990 to 2000.

The NLCD data classified 4,154 acres as developed area in the 0-to-1-mile perimeter, and 17,484 in the 1-to-5-mile perimeter surrounding the installation. From the IKONOS imagery, 21,870 acres in the 0-to-1-mile perimeter and 77,342 acres in the 2-to-5-mile perimeter were interpreted to be developed. These acreage values correspond to just over 7% of urbanized land in 1992 and about 25% of urbanized land by 2003 (Table 2).

The developed area growth trend, per annum, was 3.06% in the 0-to-1-mile perimeter and 2.48 % in the 1-to-5-mile perimeter. These growth rates are higher than the average across installations, which is just under 2% per annum. Figure 4 shows the Fort Benning region. Within the 0-to-1-mile perimeter darker shading represents the pre-1992 developed areas, while lighter shading shows the areas developed between 1992 and 2003. Within the 1-to-5-mile perimeter darker shading represents the pre-1992 developed areas, while lighter shading shows the areas developed between 1992 and 2003.

Note the growth of the city of Columbus right up to the northwestern boundary of Fort Benning, and the extensive scattered development, especially along roads, around every portion of the base perimeter.

Fort Hood

Fort Hood, TX, is primarily a unit training and force projection installation. The installation hosts two active military divisions (1st Cavalry Division and 4th Infantry Division

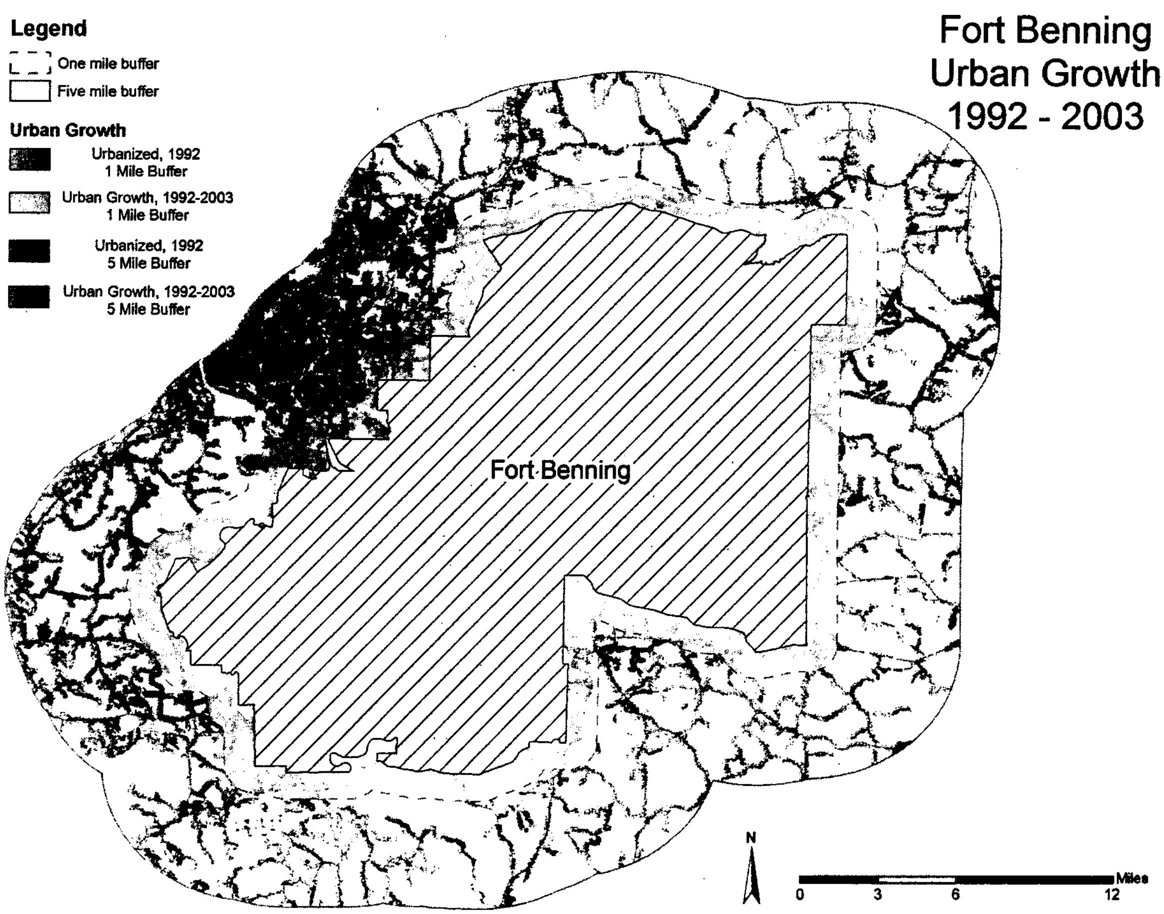

Figure 4. Urban growth near Fort Benning, GA.

[Mechanized]), and covers 339 square miles. The units stationed at Fort Hood are some of the first to be deployed in times of war. The installation straddles Bell County (237,974 acres in 2000 with a population growth rate of 4.5%) and Coryell County (74,978 acres with a population growth rate of 0.3%). Killeen and Copperas Cove are the major towns near the base, both to the south in Bell County (http://www.hood.army.mil/fthood/info/About_fort_hood.htm).

Fort Hood is also surrounded by private land, except for Belton Lake, a Corps of Engineers' Reservoir directly east of Fort Hood. The installation partially surrounds the lake to the west, north, and south. A significant percentage of the installation's boundary is public land and therefore this land is unlikely to be subject to an increased rate of land use change.

The status of Fort Hood is quite different from Fort Benning. Figure 5 shows extensive growth around both Killeen and Copperas Cove, and both urban areas have extended, during the 1992-2003 timeframe, into the 0-to-1-mile buffer region (lightest shaded area).

However, the scattered development around both the 0-to-1-mile and 1-to-5-mile perimeters of the installation is relatively sparse compared to Fort Benning.

Table 2 indicates the rate of change: 0.65% per annum in the 0-to-1-mile perimeter, and 0.70 % per annum in the 1-to-5-mile perimeter. Overall, urban land use in the 1-to-5-mile buffer around Fort Hood increased from 4.35% in 1992 to 7.47% in 2003.

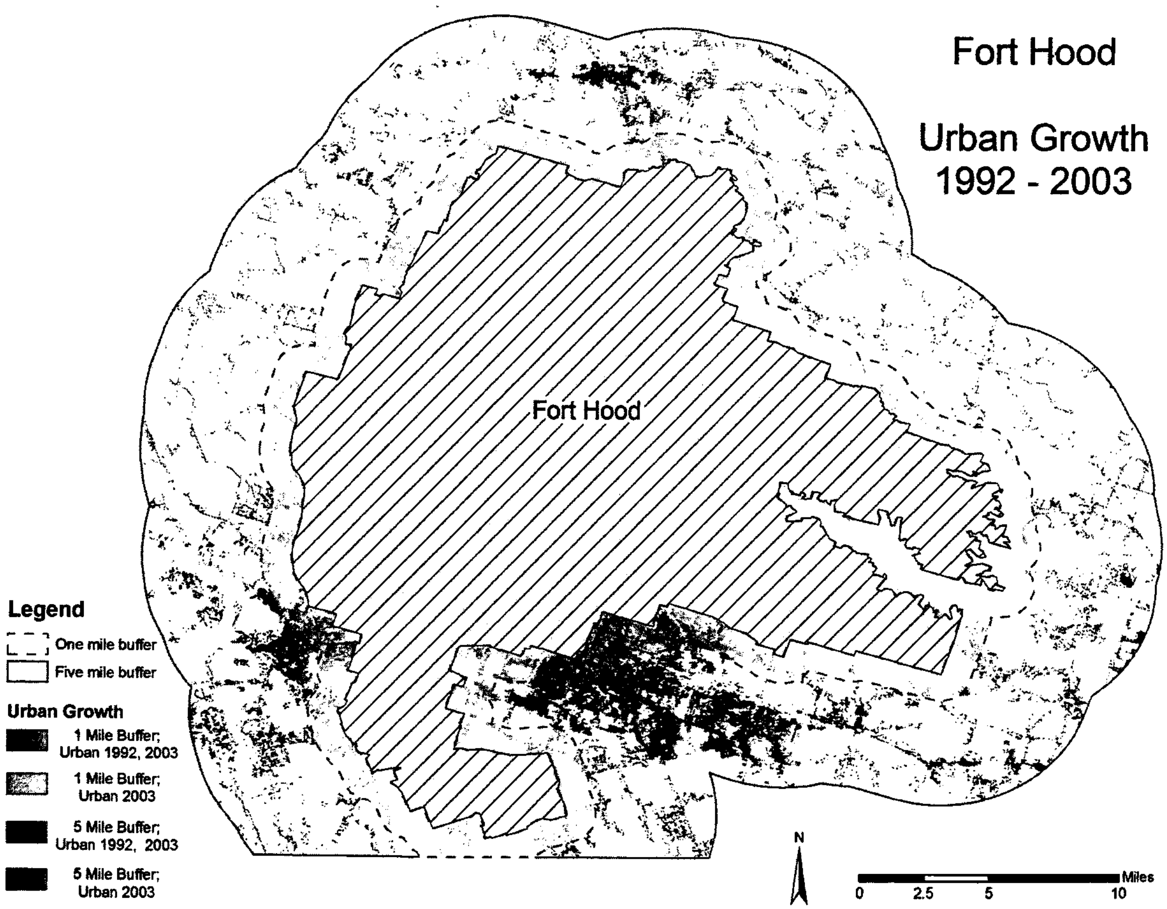

Figure 5. Urban growth near Fort Hood, TX.

29 Palms

The Marine Corps Air Ground Combat Center (MCAGCC) at 29 Palms, CA, serves as an important training center for Marine Corps units that rotate through the Center for exercises, just like Army units do at the nearby National Training Center at Fort Irwin to the north. This Marine installation is located in the very large San Bernardino County, with the town of 29 Palms just to the south of the base.

The perimeter of the MCAGCC is just under 70% federal land; thus there are limited regions of the installation perimeter where land use has been subject to change during the time of this analysis. The total urbanized area (1.44%) around the perimeter of MCAGCC was low in 2003 (year of the IKONOS imagery for MCAGCC), and the rate of change from 1992-2003 was 0.02% per annum in the 0-to-1-mile perimeter and only 0.13% per annum in the 1-to-5-mile perimeter. Although Figure 6 shows some land use change in the vicinity of the town of 29 Palms, the "risk" of perimeter land development constraining future operations at 29 Palms is quite low, relative to Fort Benning, Fort Hood, and the majority of installations included in this TABS analysis.

COMPARISON OF RESULTS FROM DIFFERENT METHODS (FORT BENNING, GA)

Performance analysis of any method requires testing, and ideally, in the case of spatial studies, ground truthing. Unfortunately, ground truthing over many square miles is often an inefficient form of assessment, requiring more time and resources than available. To evaluate the above method, we conducted a comparison

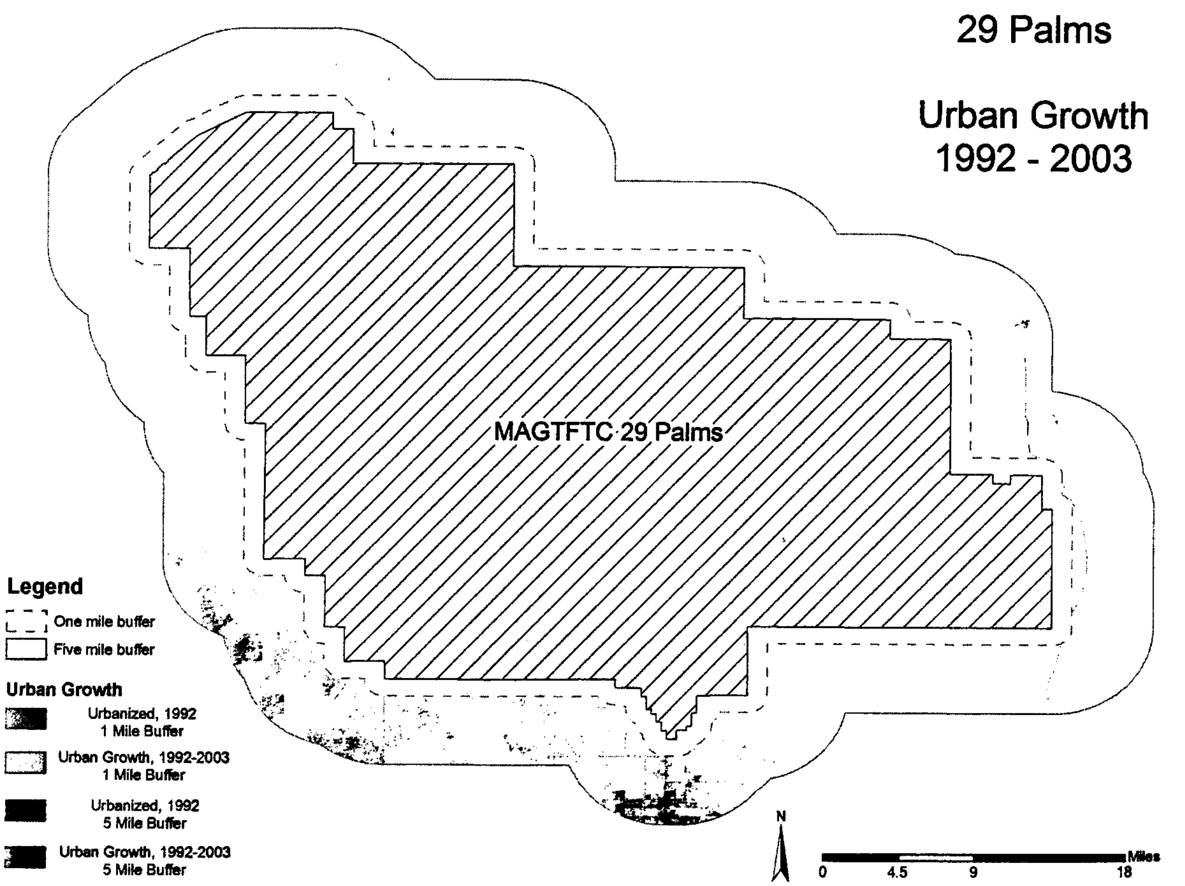

Figure 6. Urban growth near MCAGCC 29 Palms, CA.

with a similar urban encroachment method that has been accepted in the past as a viable method. The DoD's Strategic Environmental Research and Development Program (SERDP at: http://www.serdp.org/) supported an image analysis procedure to monitor urban encroachment over time near Fort Benning, GA (Jackson and Bourne 2005). The basis of the monitoring is similar to the method described above with the IKONOS and NLCD data (i.e., the TABS method). Jackson and Bourne delineated urban land use from Landsat satellite imagery and analyzed growth over time. The delineation differs from the TABS method in terms of the imagery source and scale, the software selected for the analysis, the analysis approach, and the span of years considered. Both analyses share a data point in 2003, and cover roughly the same geographic area. A comparison of results provides insight on the value of the TABS method when compared to the method employed by Jackson and Bourne.

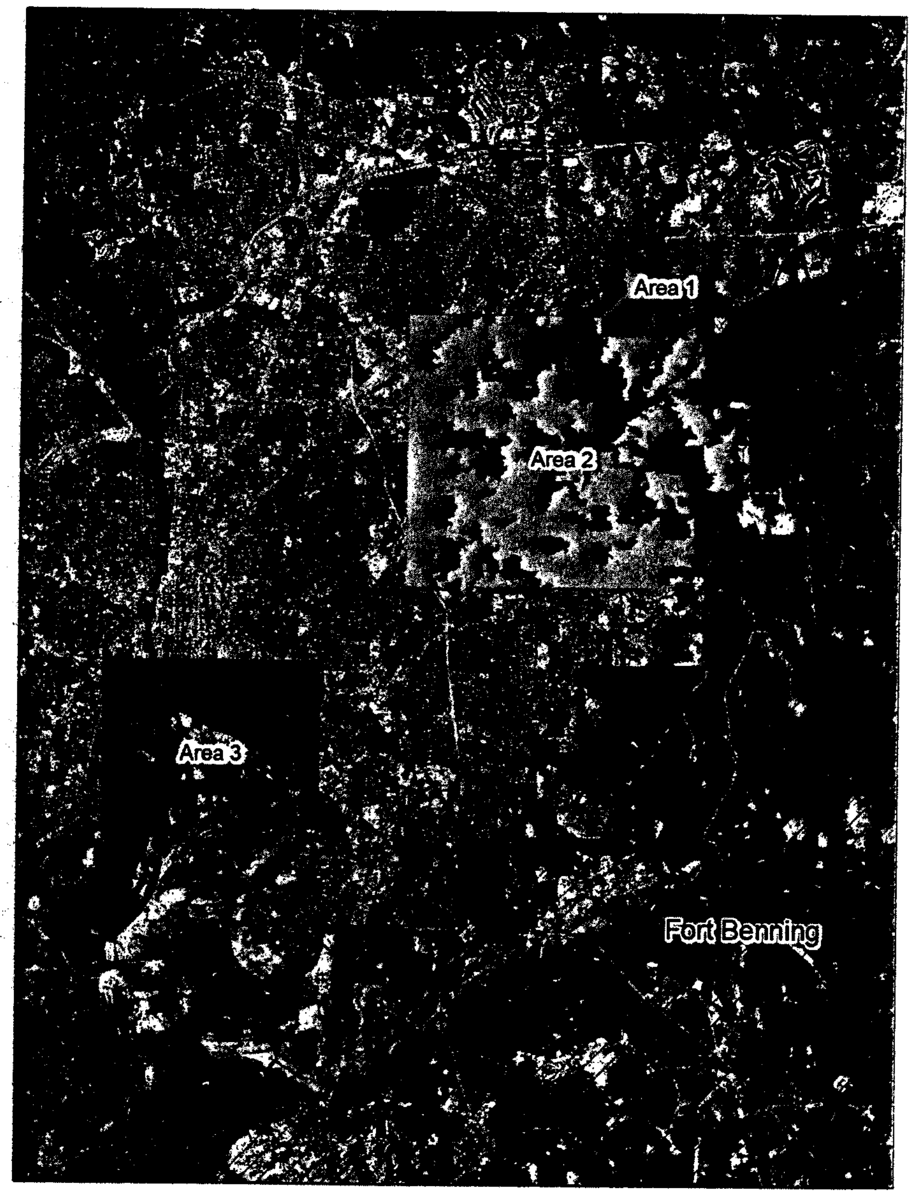

Figure 7. Selected comparison areas near Fort Benning, GA.

Jackson and Bourne used Feature Analyst, a feature extraction software package (Visual Learning Systems), to identify urban features in the landscape near Fort Benning. With Feature Analyst, a user digitizes ideal examples of features for extraction, called training sets, and the tool analyzes the rest of the imagery and selects similar features. The heuristic learning algorithms of the software utilize textural information, shape, spatial context, size, anticipated extent of coverage, and spectral information to extract features. In this case, polygon training sets of variable size representing urban features (buildings, houses, city streets, etc.) were manually digitized from Landsat 7 Enhanced Thematic Mapper (ETM) satellite imagery. Further steps of refinement included limiting areas of interest, identifying correct and false extraction examples through multiple iterations, and eliminating areas of confusion (areas that resemble urban features such as bare ground and highway construction). A GIS layer of software-identified urban polygons was the final result.

There is a significant area of overlap in the ground surface coverage between the two studies; selected regions from these overlap areas were used for comparison. Figure 7 shows three example comparison areas where both studies identified urbanization. The subsequent three figures (Figures 8, 9, and 10) magnify those examples and show differences in the identification results from both analyses using 2003 data.

Figure 8 captures a small section of northeast Columbus, GA. In this comparison area, the TABS method identified 43.2% urban land in 1992 and approximately 76.3% urban land

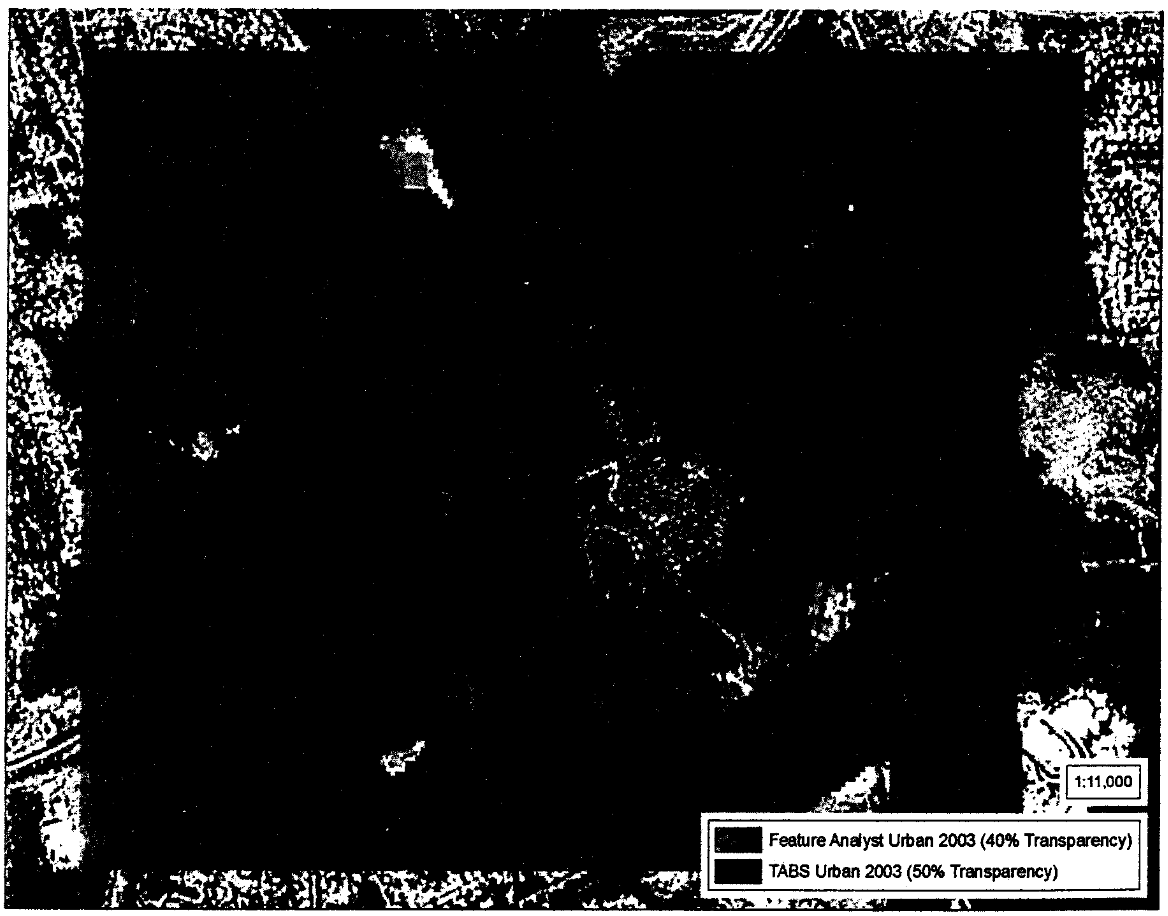

Figure 8. Comparison Area 1.

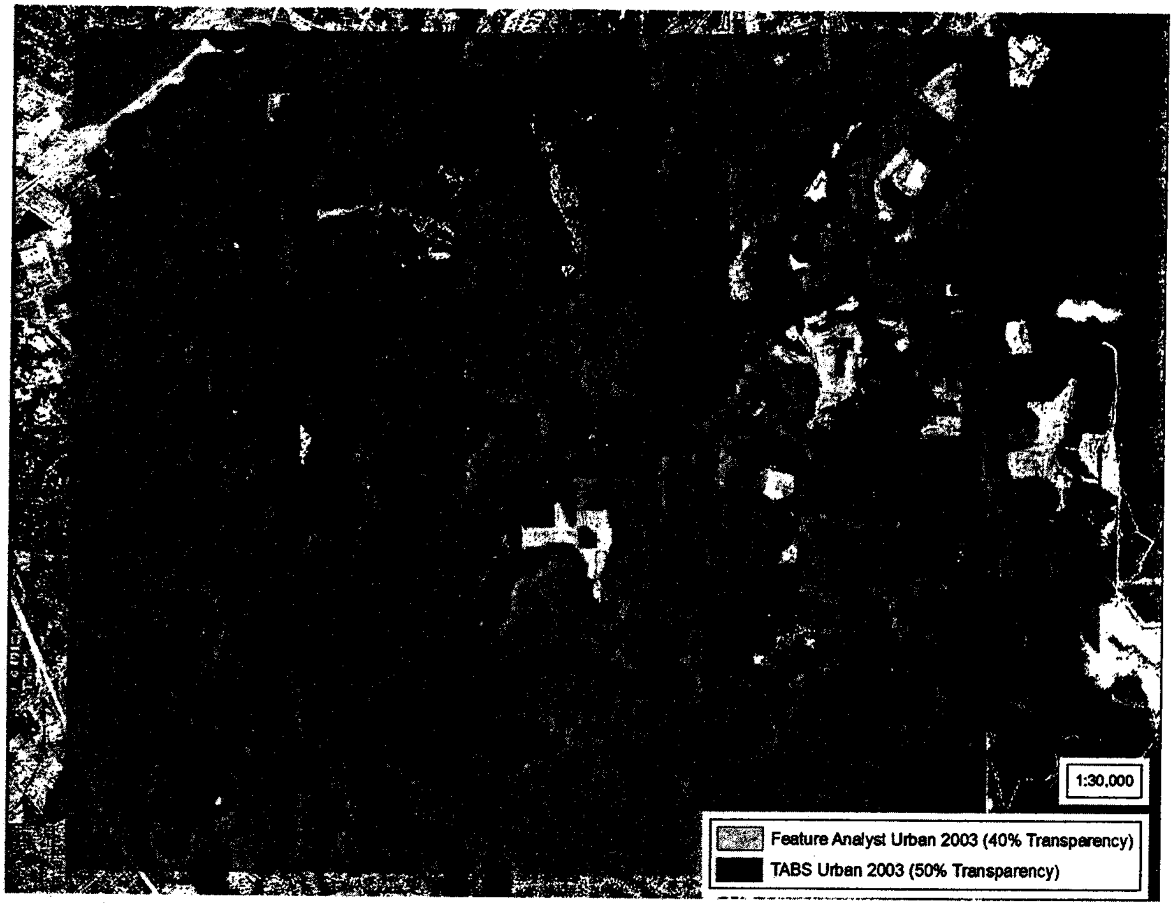

Figure 9. Comparison Area 2.

in 2003; Feature Analyst identified 49.2% urban land in 1999, and 50.7% urban land in 2003. Figure 9 is a large sample of central and northeast Columbus. Here, the TABS method classified 39.3% of the land as urban in 1992, and 73.1% of the land as urban in 2003; Feature Analyst found 46.6% of the area urbanized in 1999, and 52.6% of the area urbanized in 2003. Figure 10 is a moderately sized sample of southwest Columbus and Phenix City, AL. The TABS method found urban lands accounted for 31.3% of the area in 1992 and 64.2% of the area in 2003; Feature Analyst identified 48.3% urban land in 1999 and 50.0% in 2003.

Common to all three areas is a lower rate (approximately 20-30% lower) of urban identification in the Jackson and Bourne analysis. While there may be multiple reasons for this difference — one factor that likely contributes is the difference in pixel resolution of the underlying satellite imagery. As Jackson and Bourne (2005) note, the coarse resolution of Landsat ETM imagery (28.5 meters) substantially diminishes the ability to distinguish small ground features important in urban detection. The IKONOS imagery used in the TABS method (5 meters) has a resolution better suited for urban feature detection. As spatial resolution becomes finer, the proportion of pixels falling on the boundary of elements in the scene decreases. Boundary pixels contain a mix of elements within each pixel, and reducing the number of mixed pixels reduces confusion in the classification process, resulting in higher classification accuracy (Markham and Townshend 1981). Additionally, at a 5-meter resolution, an easy visual check can detect urban and nonurban classes. This visual checking

Figure 10. Comparison Area 3.

potential of the IKONOS imagery allows analysts to better estimate which spectral classes represent urban features, and after identification, determine the extent of urban area that may have been over- or under-represented. These classification differences are easily observed in Figures 8, 9, and 10, where the areas classified as developed (urbanized) by the TABS methods fingers out from the boundaries of the Jackson and Bourne developed classification. Visual inspection of these additional areas reveals the presence of urban features in these regions.

The studies also reflect differences in road classification. Jackson and Bourne did not use linear features like roads in their digitized training sets, so major roads and their immediate surroundings are not identified as urban features. The TABS method, though, specifically identified roads as areas where urbanization was likely to occur. These differences can be seen in Figures 8 through 10, where major roadways are identified as developed by the TABS method but not by Feature Analyst.

One additional check, a visual classification of the image in Figure 7 compared the TABS and the Jackson and Bourne results. Urban polygons were digitized by hand from visual interpretation of the 2003 IKONOS imagery. The polygon areas were summed, and 62.7% of the land was found to be urban. This amount lies between the Jackson and Bourne finding (50.7%) and the TABS result (76.3%). This analysis appears to confirm that the Jackson and Bourne study likely under-represented urban features — but also implies that the TABS analysis approach may over-represent urban features. The TABS analysis provided a comparison capability across installations in the study; the over-representation was consistent across these installations and was conservative in nature as far as the installation's ability to support additional army missions.

SUMMARY

TABS used this newly developed spatial analysis method to support and provide the basis for their Urban Sprawl attribute, 1 of 40 different attributes to determine an installation's Military Value. ERDC (Lozar et al. 2005) provided TABS quantitative information on the extent of urbanization, and the trend in change to urban land use. This approach also provided an audit trail needed within the context of a BRAC analysis. In addition to having the MV ratings, TABS analysts evaluating basing decisions also had the ERDC study available to augment their analysis as they determined the feasibility of stationing actions.

This effort ensured a consistent and defendable approach for examining and comparing encroachment across a varied group of installations and terrain and will be available in the years to come to further evaluate the encroachment phenomenon that impacts the Army's readiness.

The value of this study extends beyond the inclusion of this information for the BRAC analysis. These data will continue to help the Army identify enduring installations impacted by encroachment; and the analysis techniques provide improved methods for examining such data. New authorities in the 2003 Defense bill permit the Services to partner with local government and non-government organizations to take steps such as purchasing easements to preserve compatible land uses in perimeter lands at risk for conversion to developed areas. The TABS analysis provides a comprehensive and consistent source to identify areas at risk for development in the near perimeter of military installations. This information is also invaluable for communities and installations that participate in the Joint Land Use Studies (JLUS) program, sponsored by the Office of Economic Adjustment (OSD, 2002) and for the Sustainable Ranges program reports to Congress on the status of encroachment (Sustainable Ranges Program Office, 2005).

REFERENCES

Defense Base Closure and Realignment Act of 1990, Pub. L. 101-510, §2901(b), as amended through the National Defense Authorization Act of Fiscal Year 2003.

Department of Defense (DOD). February 2004. *Report to the Congress, Implementation of the Department of Defense Training Range Comprehensive Plan.*

DOD. May 2005. *Report to the Defense Base Closure and Realignment Commission, Vol. III, Department of the Army Analysis and Recommendations BRAC 2005.*

Ewing, P. L., Tarantino, W., and Parnell, G .S. March 2006. "Use of Decision Analysis in the Army Base Realignment and Closure (BRAC) 2005 Military Value Analysis," *Decision Analysis*, Vol 3, No. 1, 33–49.

Geoeye. 2007. *Geoeye Imagery Products: IKONOS.* Commercial product web page, accessible through URL: http://www.geoeye.com/products/imagery/ikonos/default.htm.

Goran, W. D., and Deal, B. M. September-October 2002. "Technologies to Help Installation Plan Across the Fence Lines," *Army AL&T*, 32–34.

Goran, W. D., and Westervelt, J. D. March-April 2003. "Fort Future, Preserving Room to Maneuver," *The Military Engineer*, No. 622, 43–44.

Headquarters Air Force Geo Integration Office under the Office of the Civil Engineer. December 2003. *Installation Visualization Tool Quality Assurance Plan Version 1.1*, 31.

Jackson, S. S., and Bourne, S. G. January 2005. *An Automated Procedure To Monitor Urban Encroachment Over Time on Fort Benning Military Installation*, Engineer Research and Development Center, ERDC/EL TN-ECMI-05-01.

Lozar, R. C., Ehlschlaeger, C. R., and Cox, J. 2003. *A GIS and Imagery Approach to Historic Urban Growth Trends Around Military Installations*, ERDC/CERL TR-03-9/ADA421209.

Lozar, R. C., Meyer, W. D., Schlagel, J. D., Melton, R. H., MacAllister, B. A., Rank, J.S., MacDonald, D. P., Cedfeldt, P. T., Kirby, P. M., and Goran, W. D. April 2005. *Characterizing Land Use Change Trends Around the Perimeter of Military Installations, Engineer Research and Development Center,* ERDC TR-05-4.

Markham, B. L., and Townshend, J. R. G. May 1981. "Land Cover Classification Accuracy as a Function of Sensor Spatial Resolution," *Proceedings of the 15th International Symposium on Remote Sensing of Environment,* Ann Arbor, MI.

Office of the Secretary of Defense, Installations and Environment, Business Transformation, Defense Installation Spatial Data Infrastructure (DISDI). access date October 2005. website: http://www.acq.osd.mil/ie/bt/ivt.htm.

Office of the Secretary of Defense. 2001. *2001 Annual Report to Congress.*

Office of the Secretary of Defense, Office of Economic Adjustment. August 2002. *Joint Land Use Study, Program Guidance Manual,* Arlington, VA.

USA Today. 2 December 2003. "Urban Sprawl Advances on American Military," Reuters News Service, 20A.

Sustainable Range Program Office. July 2005. *Implementation of the Department of Defense Training Range Comprehensive Plan,* The 366 Report, Department of Defense report to Congress, as required by Section 366 of the National Defense Authorization Act, FY2003.

Timlin, D., Johnson, D., and Deal, B. January 2002. Guidelines for Developing Historic Urban Growth Series for Military Installations Risk Assessment, ERDC/CERL TR-02-4/ADA408249.