GIS IMPROVED OBJECT-BASED CLASSIFICATION FOR LAND USE/COVER CHANGE DETECTION IN A HUMAN ALTERED DECIDUOUS FOREST ENVIRONMENT

Erick Sánchez Flores
Researcher professor
esanchez@uacj.mx
[a] Universidad Autónoma de Ciudad Juárez
Henry Dunant 4016, Zona Pronaf,
Ciudad Juárez, Chih. 32310, México
esanchez@uacj.mx

Rolando Díaz Caravantes
Graduate student
Department and Geography and Regional Development
The University of Arizona, Tucson, AZ 85721, USA
diazrol@email.arizona.edu

Javier Chávez [a]
Researcher professor
jchavez@uacj.mx

Alfredo Granados Olivas [a]
Researcher professor
agranados@uacj.mx

ABSTRACT

Object-based image analysis has extended mapping capabilities by incorporating, within the traditional spectral mix input, the spatial and textural attributes of homogeneous sets of pixels, from which, individual objects can be derived from a digital image. With the increasing availability of high resolution imagery, the object-based approach has empowered analysts with the ability to detect individual features with very well-differentiated characteristics from their surroundings. Applications of this type have become very popular for feature extraction, mostly in urban-related or other human-influenced environments, where geometric characteristics of the features of interest allow easier detection. High resolution image analysis for land/use cover classification purposes, however, faces several difficulties when trying to take advantage of the object-based approach, due to the very high spatial variability of physical elements on the surface. This is especially true in natural environments where temporal variability adds another level of complexity to the classification process. In this study, we use GIS techniques to improve the classification capabilities of a feature extraction algorithm for land use/cover change detection in a deciduous forest environment in the municipio of Alamos, Sonora, Mexico. The land use history of this area includes intense grazing and agriculture activities, which builds on the temporal complexity of its natural deciduous communities. After using a supervised classification approach on a 1998 aerial photography and a 2007 high resolution image, GIS techniques including vector *editing*, *generalize*, and *dissolve* were applied to improve the assignment of classes for change detection. Results show a general improvement of 22% in accuracy assessment of GIS edited vector classifications depending on the original segmenting and merging parameters. Despite being a time consuming process, this approach shows an effective way to improve object-based classification for land use/cover in dynamic natural areas.

INTRODUCTION

Increasing availability of very high spatial resolution remotely sensed data in the last ten years has broadened the variety of applications for land monitoring and mapping, especially in the urban remote sensing area (Gamba and Dell´Acqua 2007). Spatial refinement allowed by greater resolving power in these new sensors has augmented the amount of detail available for analysis. Greater detail, however, has also increased the spatial internal variability of the information contained in observation units (Thomas *et al*, 2003), making the traditional pixel based information extraction processes more complex. The object-based image analysis approach has extended mapping capabilities by incorporating the spectral and spatial attributes of homogeneous sets of pixels to the traditional spectral mix input to derive individual segments from a digital image. These image segments correspond to the approximations of real world objects which can be characterized by shape and texture (Benz *et al*, 2004). Incorporating both spectral and spatial image information emulates the process of visual image interpretation, with the advantage of an automated classification routine (Laliberte *et al*, 2004).

With the increasing availability of high resolution imagery, the object-based approach has empowered analysts with the ability to detect individual features with very well-differentiated characteristics from their surroundings (Carleer and Wolff 2006). Despite the numerous advantages for feature extraction, very high resolution image analysis for land/use cover classification purposes faces several difficulties when trying to take advantage of the object-based approach, due to the very high spatial variability of physical elements on the surface. This is especially true in coupled natural/human-influenced environments where temporal variability adds another level of difficulty to the classification process. In this study, we analyzed land use/cover change in a rural area using very high resolution images to detect changes between 1998 and 2007. We used the information extracted from remotely sensed data and applied GIS techniques to improve the classification capabilities of a feature extraction algorithm. After describing the aims of this paper, we explain the data and methods applied and follow with a discussion of the results of the exercise.

DATA AND METHODS

For this study, we used an object-oriented supervised-classification approach to extract land use/cover classes from very high resolution imagery in a recently protected rural deciduous forest environment in Sonora, Mexico. Classification results were then processed with standard GIS tools to improve the overall classification accuracy and to detect land use/cover change between 1998 and 2007.

Study area

For this study, we selected the ejido La Labor de Santa Lucia (La Labor), located in the southeastern part of the Mexican state of Sonora, in the municipality of Alamos (Figure 1). This mountainous area, situated in the western foothills of the Sierra Madre Occidental, occupies an approximate extension of 27.6 sq. km. with an elevation ranging from 260 to 572 masl. La Labor is located within the natural protected area (NPA) “Sierra de Alamos-Río Cuchujaqui”, issued in 1996 with supporting financing of the Global Environment Facility (GEF) (World Bank, 1997) and currently administrated by the National Commission for Natural Protected Areas (CONANP).

The natural value of this area is recognized because it represents the northernmost distribution of the Low

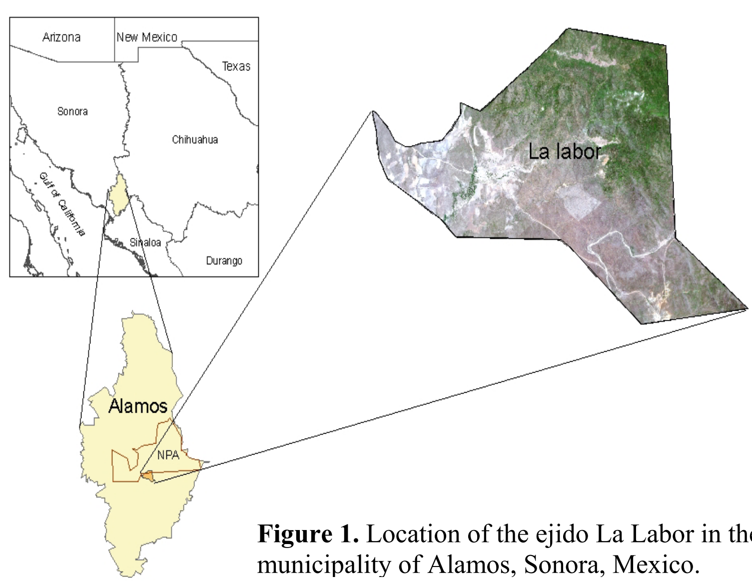

Figure 1. Location of the ejido La Labor in the municipality of Alamos, Sonora, Mexico.

Deciduous Forest and is located in the transition zone between the Neoartic and Neotropical biogeographic regions, with about 1,100 species of vascular plants (World Bank, 2004).

Conditions of occupation and land use in La Labor have been determined mostly by the practice of small-scale seasonal agricultural and extensive cattle breeding, with the U.S. beef market as the principal destination of the production. Another important activity in La Labor is the exploitation of *L. involucrata* “vara blanca” (Felger et al, 2001), a local species that is in high demand to make stakes that support growing plants, such as tomatoes and grapes, in Northern Mexico.

Remotely Sensed Data

For this study, we used a 1.5m panchromatic aerial orthophoto collected in May 1998 (AP98) and a 2.44m multispectral QuickBird image collected in July 2007 (QB07). The 1998 observation date occurred two years before beginning the formal administration of the natural protected area, while the 2007 observation date occurred after seven years of operation. According to these collection dates, phenological differences due to seasonality can still be considered minimum due to the late onset of the rainy season in 2007. The QB07 dataset was first pan-sharpened and resampled to 1.5m to match spatial resolution of the AP98 dataset. Both datasets were georreferenced to UTM zone 12 N WGS84 and co-registered for positional consistency with an RMS of 0.47m Since we used a post-classification comparison approach, no other spectral o radiometric normalization was applied.

Object-based Supervised Classification

For this study, we first used a feature extraction tool to identify individual regions with homogeneous land use/cover type. For this purpose, after testing different segmentation levels, we selected 53.1 for AP98 and 49.7 for QB07. These segmentation parameters ensured a good delineation of individual objects representing the main land use/cover types in the area. Given the high spatial resolution of the images, the objects extracted initially were merged using a merging λ threshold of 81.3 for the AP98 and of 77.6 for the QB07, to iteratively merge adjacent segments based on a combination of the spectral and spatial information contained in the extracted segments (Robinson et al, 2002). This process helped to reduce over-segmentation by integrating small objects into larger homogeneous segments. We computed spatial, spectral, and texture attributes from the extracted segments to serve as the basis for the supervised classification.

Based on our field knowledge, we selected ten representative land use/cover classes present in both dates in La Labor to train a 3K Nearest Neighbor algorithm that performed the supervised classification in the two datasets. This algorithm considered the Euclidean distance from the target to the three closets neighbors in an n-dimensional space defined by the spectral and spatial attributes to assign each segment into a particular class. This method was selected because it is much less sensitive to outliers and noise in the dataset and performs better than traditional nearest-neighbor classifiers because the K nearest distances are used as a majority vote to determine the target membership class (Schowengerdt 2007).

GIS Classifications Processing

Classified datasets were converted to vector format and incorporated into a GIS environment. Taking advantage of the increasingly stronger linkage between remote sensing and GIS, which provides data integration capabilities and map overlay techniques (Lang and Blaschke 2006), we applied a series of GIS processing tools to improve the classification accuracy. Given the large number of resulting polygons in each classified dataset; we first applied the GIS tool aggregate to combine same class polygons within 5, 10, 20 and 40m threshold distances. Based on the best performing aggregate parameter, we then use the eliminate tool to merge polygons smaller than 3, 18, 72 and 288m^2 with neighboring polygons with largest shared border. After selecting the best performing eliminate parameter, we applied the smooth line tool to improve the overall cartographic appearance of the polygons' boundaries. Finally, we edited manually those features not detected correctly through the process.

Accuracy assessments of the original and GIS processed classified datasets were performed with a randomly distributed 113 point sample collected independently in field during the 2007 summer season, and calculated in the form the Kappa coefficient. Collection of this field sample was supported by the field knowledge of local villagers. Once we selected the appropriate level of generalization based on the accuracy assessment; the two classified datasets were compared by creating a difference map and computing a change matrix to identify the percentage of change occurred in the area between 1998 and 2007.

RESULTS AND DISCUSION

Object-based land use/cover classification of the AP98 and QB07 datasets resulted each in the following 10 classes: Agriculture (AG), Dwelling (DW), Road (RD), Mesquite (MQ), Deforestation (DEF), Deciduous Forest (DF), Dense Deciduous Forest (DDF), Sparse Deciduous Forest (SDF), Grassland/Secondary Vegetation (GSV), Overgrazed Deciduous Forest (ODF). According to the selected segmenting and merging parameters classification from AP98 was composed of 135,830 polygons while classification from QB07 was composed of 191,735 polygons. After applying the aggregate GIS tool with the different parameters, we found that polygons aggregated within a distance of 20m performed the best, improving classification accuracy from 0.355 to 0.437 Kappa coefficients in AP98 and from 0.387 to 0.478 in QB07. Based on the Aggregate 20 datasets we further improved classification accuracy up to 0.587 in AP98 and 0.603 in QB07 when applying the eliminate tool to merge polygons smaller than 288 sq. m., smoothing polygons' boundaries and editing manually (Figure 2). This means an overall accuracy improvement of 23.2% and 21.6% for AP98 and QB07 respectively.

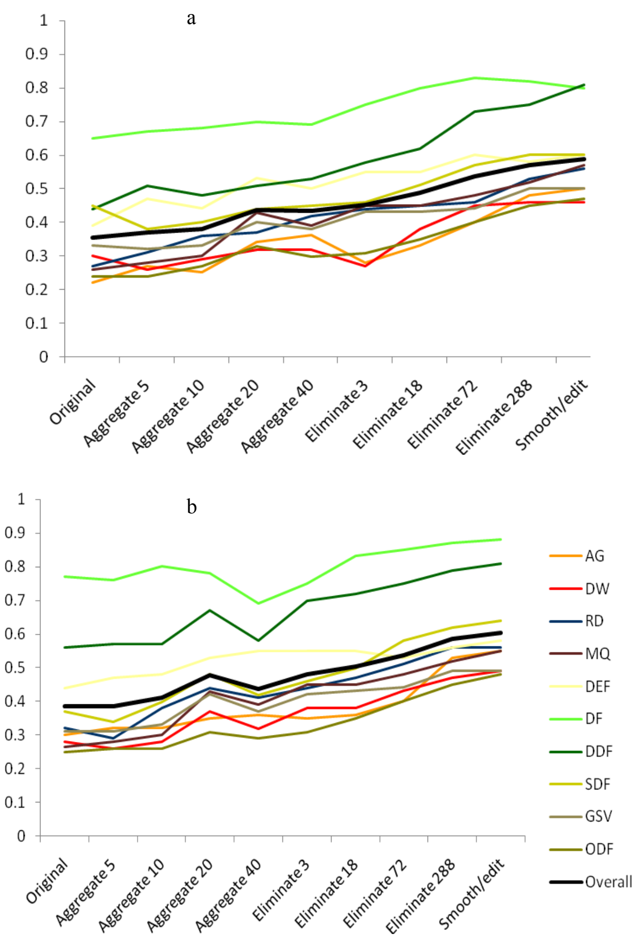

Figure 2. By class and overall Kappa coefficients for each of the GIS tools applied to the AP98 and QB07 datasets.

Final GIS processed land use/cover classifications were composed of 723 and 874 polygons for AP98 and QB07 classifications respectively (Figures 3). From the accuracy assessment it is observed that aggregating polygons beyond the 20m threshold does not represent an improvement in the classification results for the particular conditions of these datasets. The eliminate tool shows a steady improvement in classification accuracy up to polygons smaller than 288m^2 Even though it is obvious this exists, no threshold was identified in this experiment using this tool. The boundary smoothing itself did not represent a significant difference in classification accuracy, most of the improvement in this step came from the manual editing we performed in some particular classes.

Deciduous Forest and Dense Deciduous Forest were the two classes with highest classification accuracies due in part their respectively dominant presence of 42.9% and 39.1% in AP98 and 31.3% and 57.6% in QB07. Overgrazed Deciduous Forest was the least represented class with only 0.023% and 2.5% for AP98 and QB07, respectively. This class also had the lowest classification accuracy in both datasets. Its Kappa coefficient, however, improved accordingly 23% for both dates.

Land use/cover change during the observation period showed a relatively stable environment with most of the classes increasing quantitatively no more than 2% from its original extent. This is important because of the expected increased in agriculture and deforestation in the southern portion of the study area, outside the natural protected area. The only two classes that showed a significant change were Deciduous Forest with an increase of 11.6% and Dense Deciduous Forest with a decrease of 18.5%. It is important to consider, however, that these differences may result from classification limitations due to the poorer spectral content in the AP98 datasets.

a b

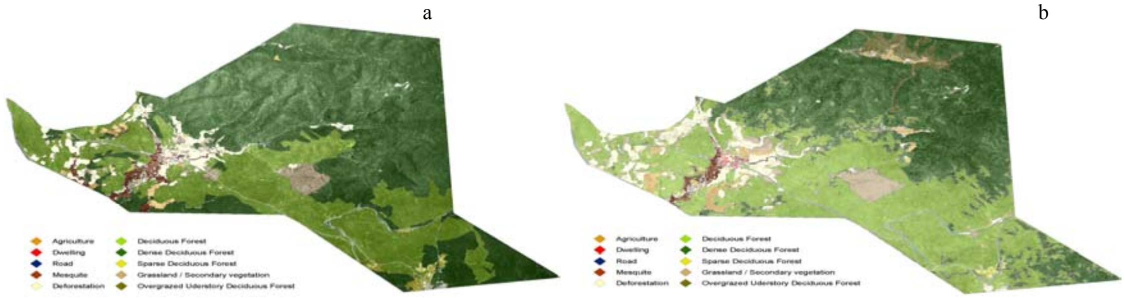

Figure 3. GIS improved object-basedl and use/cover from AP98 (a) and QB07 (b) datasets.

The relative qualitative changes occurring between both dates are shown in hectares in Table 1. Here is shown that Deciduous Forest, Dwelling, and Grassland / Secondary Vegetation were the most stable classes with 15.6, 23.2, and 25.1% of change between 1998 and 2007. We can also confirm that Deforestation only changed 32.6%, with most of that change occurring between classes like Agriculture and Sparse Deciduous forest, which may even have been the result of some seasonal influence in the spectral response of the datasets. Another related change is the increase in the Dwelling class, which occurred mostly in areas previously occupied by Deforestation. Perhaps one of the few important evidences of human-induced alterations in the area is the increase in Overgrazed Deciduous Forest to the expenses of Deciduous and Dense Deciduous Forest occurring mostly in the northern portion of La Labor, inside of the natural protected area (Figure 3b).

Table 1. Land use/cover change matrix from AP98 and QB07 GIS improved classifications.

		1998									
		AG	DW	RD	MQ	DEF	DF	DDF	SDF	GSV	ODF
	AG	10.2429	0	0.0774	1.1763	13.9491	3.7674	13.2687	0.1197	3.6639	0
	DW	0.126	0.8361	0.0702	0.4077	4.2462	0.0162	0.0135	0	0.0045	0
	RD	0	0.0333	7.9299	0.054	1.4625	9.3951	0	1.2555	0	0
	MQ	0	0	0.0027	27.5535	0.0927	0	0.0036	0	0	0
2007	DEF	8.3961	0.2205	0.8208	5.3604	88.839	37.4832	20.8935	3.6468	8.3448	0
	DF	0.4608	0	4.7772	6.6267	9.9	731.9691	418.5558	16.7193	0	0
	DDF	0.0477	0	0.4194	1.8747	4.311	44.2926	1028.1906	3.1743	0.54	0.0639
	SDF	0.342	0	0	4.8366	5.2803	30.3138	13.455	10.206	0.6552	0
	GSV	0.3933	0	0.1413	0.1377	3.5181	10.8369	30.8169	1.1547	39.2859	0
	ODF	0	0	0	0	0.2322	0	70.8534	0	0	0
	Total	20.0088	1.0899	14.2389	48.0276	131.8311	868.0743	1596.051	36.2763	52.4943	0.0639
	% Change	48.80	23.28	44.30	42.62	32.61	15.67	35.57	71.86	25.16	100

*units = hectares

CONCLUSIONS

In this work, we have demonstrated the effects of applying GIS processing tools in improving the accuracy of an object-based classification derived from very high spatial resolution remotely sensed data collected in a deciduous forest environment. Results showed a general improvement in classification accuracies of 22% after aggregating the original segmented into clusters of polygons located within a distance of 20m and eliminating isolated polygons smaller than 288m^2. Larger threshold distances did not show a further improvement in accuracy. The effect of eliminating larger polygons was not explored in the exercise. Despite being a time consuming process, this approach shows an effective way to improve object-based classification for land use/cover in natural dynamic areas. We recognize that accurate results are highly influenced by the minimum mapping units selected in the original datasets. Therefore, further explorations of processing thresholds might be needed to obtain optimum results.

Land use cover change detected through this protocol in La Labor showed a relatively stable environment during the 9-year period of observation. No obvious evidence of increased human-related activities was found not even in the outer limits of the NAP. There is also no evidence of improved natural conditions as a result of the starting operation of the protected area due in part to the short time period since its formal operation in 2000.

ACKNOWLEDGEMENTS

We thank the collaboration of Sandra Parra in the manual vector editing phase of the exercise. Many thanks also to David Adams for the revision of this manuscript.

REFERENCES

Benz, U.C., P. Hoffmann, G. Willhauck, I. Lingenfelder, and M. Heynen, 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information, *ISPRS Journal of Photogrammetry & Remote Sensing*, 58, 239-258.

Carleer, A.P., E. Wolff, 2006. Region-based classification potential for land-cover classification with very high spatial resolution satellite data, In *Proceedings of the 1st International Conference on Object-based Image Analysis*, Salzburg University, Austria, July 4-5, 2006.

Felger, R.S., M.B. Johnson, and M.F. Wilson, 2001. *The Trees of Sonora, Mexico*, Oxford University Press, 400 pp.

Gamba, P., F. DellÁcqua, 2007. Spectral resolution in the context of very high resolution urban remote sensing, In Q. Weng and D. A. Quattrochi (eds.), *Urban Remote Sensing*, CRC Press:Boca Ratón, 412 pp.

King, R. B., 2002, Land cover mapping principles: a return to interpretation fundamentals, *International Journal of Remote Sensing*, 23(18), 3525-3545.

Laliberte A.S., A. Rango, K.M. Havstad, J.F. Paris, R.F. Beck, R. McNeely, A.L. Gonzalez, 2004. Object-oriented image analysis for mapping shrub encroachment from 1937 to 2003 in southern New Mexico, *Remote Sensing of Environment*, 93 (1/2) 198-210.

Lang, S., T. Blaschke, 2006. Bridging remote sensing and GIS – What are the main supportive Pillars?, In *Proceedings of the 1st International Conference on Object-based Image Analysis*, Salzburg University, Austria, July 4-5, 2006.

Robinson, D., N.J. Redding, & D.J. Crisp, 2002. *Implementation of a Fast Algorithm for Segmenting SAR Imagery*, Australia: Defense Science and Technology Organization.

Schowengerdt, R.A., 2007. *Remote Sensing: Models and Methods for Image Processing, 3rd ed.*, Academic Press: San Diego.

Thomas N., C. Hendrix, R.G. Congalton, 2003. A comparison of urban mapping methods using high-resolution digital imagery, *Photogrammetric Engineering and Remote Sensing*, 69 (9), 963-972.

World Bank, 1997. Mexico, Protected Areas Program: Proposed Restructuring Project, Global Environment Division, Washington DC, U.S.

World Bank, 2004, Proposed Supplemental GEF Grant, Washington D.C., U.S.