

# ASSESSMENT OF URBAN LAND USE COVER CHANGES IN CIUDAD VICTORIA, TAMAULIPAS, MEXICO

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## ABSTRACT:

Ciudad Victoria, Tamaulipas witnessed population increase from less than 84,000 in 1970 to almost 250,000 in 2000, producing almost a 200% growth within the city. This expansion has changed the land cover of the urban area over the past three decades. This research quantifies land use and land cover change (LUCC) in Ciudad Victoria. The research is part of a larger study which focuses on human migration patterns and their impacts on land use within the state of Tamaulipas. This section of the research project utilizes both physical and cultural data sets. Satellite imagery from the mid-1970's, 1980's, 1990's and 2000 are processed in order to quantify LUCC in the area. The remotely sensed data set used includes North American Landscape Characterization Landsat Pathfinder Project (NALC project), data from Landsat MSS, Landsat TM, and more recent data from Landsat ETM+. In an effort to better understand the dynamics of land cover change through time, this research first explored a number of standard change detection techniques. In addition, to the image processing techniques which identify change, land cover characteristics were analyzed. This research was completed to identify the techniques that best isolate the changes in this urban environment. Remotely sensed data and results of change analysis are augmented by fieldwork and demographic data to help explain LUCC.

## 1. INTRODUCTION

World population multiplied at least ten-fold in the last four hundred years and now more than six billion people rely on the earth's resources. Conservative estimates place nearly an additional two billion people on our earth before we reach the end of this century's first quarter.

Undeniably, six billion humans use more resources, occupy more space, and cause more environmental change than the mere six hundred million souls of 1600. The evidence of human impacts on the environment appears in everyday discourse. Common perceptions that humans and their consumption negatively impact the environment rely on a growing body of scientific case studies. The pages of many academic journals are filled with case studies where expanding human populations degrade, displace, and extirpate natural flora and fauna.

The search for solutions that lessen human impact on the environment rides high on agendas in the developing world where natural population growth far outpaces growth rates in the developed world. Our emphasis on population and resource problems in the developing world also springs from our knowledge of documented trends and predictions that per capita consumption of resources will increase rapidly to levels approaching per capita consumption in the developed world. A focus on the developing world is also pertinent because problems there are not isolated to that region – environmental, economic, and political problems create massive migrant streams heading to developed areas of the world. We no longer live in a world of “us and them.” Rather, population and resource issues on one side of the globe impinge directly on livelihoods thousands of miles away. Millions of international migrants fleeing resource-poor lives drive this point home.

In this case study of a rapidly growing urban area in northeastern Mexico, then, we take the first step in

understanding the relationship between growing human population and their environment. Specifically, we look at the city of Ciudad Victoria in the state of Tamaulipas, Mexico. That first step entails documenting how much space an expanding population occupies and how that space is then used. In other words, we want to understand land use and land cover change.

This task of documenting and understanding how the growing populations of urban and peri-urban areas use their space and resources is important when viewed in just the slightly larger context of the Mexican State of Tamaulipas. A mere 50 km to the south of Ciudad Victoria lies the El Cielo Biosphere Reserve. Designated by the United Nations in 1987 under the Man and the Biosphere program, this reserve is a 356,872-acre site stretching from the eastern to the western slopes of the Sierra Madre Oriental. The reserve's biodiversity is among the highest in the world because it lies on the climate transitional zone between North and Central America. With elevations from 650 to 7,500 feet above sea level, El Cielo includes four distinct eco-systems: tropical jungle, mountain forest, pine-oak forest, and dwarf oak and heath forest. How will the growing population of Ciudad Victoria impinge upon the resources of this reserve? Yes, El Cielo is sufficiently removed from Ciudad Victoria to avoid the direct impacts of the growing city to the north. But what impacts will the demand for resources by residents of the city have on the reserve (e.g., firewood for lower income residents, lumber for construction, unique flora and fauna for household adornment, and simply increased visitation to the reserve by urban residents escaping the city)? This is an increasingly important question in the world today as we attempt to preserve the vestiges of biodiversity in the face of rising human use of the world's natural resources.

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In this research project, though, we take the first step in understanding the complex relationships between humans and their environment. We investigate the type of land cover change associated with a growing city in the developing part of the world and also explore the best methods to detect that change.

## 2. STUDY AREA

### 2.1 Cuidad Victoria, Tamaulipas

Capital city of the state of Tamaulipas is Ciudad Victoria with a population close to 250,000 residents. The city is strategically located in the center of the state in a valley lying at the foot of the Sierra Madre Oriental range. The city has an elevation of 320 m (1050 ft) and covers a little over 12 km x 12 km. The major land use land cover change (LUCC) from agricultural to urban via residential and commercial developments. This is one of the fastest growing cities in Mexico. The city population has continued to increase with an explosion from less than 84,000 in 1970 to almost 250,000 in 2000, producing almost a 200% growth within the city.

## 3. DATA AND METHODS

### 3.1 Data

The data used for the project were obtained from Tropical Rain Forest Information Center (TRFIC). This included North American Landcover Data (NALC) Triplicate data generation of 60 m Landsat MSS scenes covering the urban boundaries and south to include El Cielo Biosphere Reserve. In addition to the three MSS scenes, a more recent Landsat ETM+ scene was acquired (Table 1).

Sensor	Acquired Date	General Date
MSS	May 27, 1973	1970
MSS	March 14, 1986	1980
TM	April 7, 1992	1990
ETM+	Dec 9, 2000	2000
DEM	June 29, 1995	

Table 1. North American Landscape Characterization and Landsat ETM+

Although these scenes were taken with different sensors on different platforms, the data were geographically reference to a Universal Transverse Mercator (UTM) ground coordinate grid of 60 m. The referencing is part of the NALC Triplicate Processing Steps, specifics provided at <http://edc.usgs.gov/products/satellite/nalc.html>. The ETM+ scene was purchased as LIG format which was geographically referenced to the UTM coordinate grid. The NALC data was clipped to remove the embedded headers. All scenes were atmospherically corrected using ATCOR3 which removed the haze and most topographic effects. Additionally, the 2000 ETM+ image was resampled to 60m using nearest neighbor. Ciudad Victoria area was clipped from each of the scenes (Figure 1).

Other supporting data were population data for the census years of 1970, 1980, 1990, and 2000. These were used for comparative study of area and population estimates based on DML OSP (Pick, J. B., et al. 1989; INEGI, Sutton et. al. 2001). In addition, field visit is scheduled March 2005 to gather reference data.

## 3.2 Methodology

The methods explored in this research include change detection technique of image differencing, image classification, and principle component analysis. A

### 3.3 Change Detection Techniques

**3.3.1 Image Differencing:** Image differencing is based on subtracting two different time periods of the same location or scene. It is a simple process of subtracting the two different times pixel by pixel to create the difference image. In this case, a difference image was created between the Normalized Difference Vegetation Index (NDVI) images. The difference image from 1970 to 2000 shows the reduction of vegetation in the urban growth area. There was an increase in NDVI values (vegetation health) surrounding the urban areas, which may be attributed to the 2000 being a winter scene.



Figure 1: Difference Image between 1970 and 2000

**Image Classification:** In order to look at the changes in different LULC between the four decades each scene was classified into four classes. A NDVI layer was added to each scene for a total of five layers for the classifications. An unsupervised classification (Isodata) of four class was run on the urban subset images. All classes were assessed using the Transformed Jefferies test, to verify that they were spectrally different and separable. The four classes were interpreted to be representative of Urban, Modified, Pasture, and Forest. These were spectrally separable however the land use were mixed. The basic pixel counts through time are shown in Table 2.

	1970	1980	1990	2000
Urban	7590	8037	8407	10803
Modified	12431	13646	9544	16603
Pasture	13441	12235	21922	12687
Forest	8768	8312	2357	2137

Table 2: Pixel Count for Unsupervised Classification of subset images.

A supervised classification was preformed. The selected five class were tested for their separability and they were separable. However, this method of classification was not valuable as there were no training sites. The selected training areas were interpreted from the images. Since there field work will be done later one this method may be revisited with valid ground data to use as the training sites.

**3.3.2 Principle Component Analysis:** A NDVI image consisting of a NDVI layer for each year. Each layer was stretched to 0-255 (8-bit). A PCA image was created with four component layers. These layers represented the variance within the NDVI values over the four decades. The fourth component represents about 10 percent of the variance. This component isolates the urban area.

**3.3.3 Polygons of Urban Areas:** An on-screen digitizing of the urban areas for 1970, 1980, 1990, and 2000 was performed. Using the unsupervised classification images as the base data polygons surround the urban areas were created in ArcGIS. These polygons were used to get the area. Although the area could be calculated using the pixel count the low resolution of the MSS created less than desirable results. It was decided that polygons would offer a more accurate area than the pixel counts. There is however a close relationship between the classified pixel counts and the digitized area.

#### 4. RESULTS

The difference image from 1970 and 2000 was created with all pixels that had at least a 10 percent change in NDVI value. The area that decreased by 10 or more is shown in Figure 2. This area consists of 4505 pixels which is about 30 percent higher than the changes in the pixel counts from the classified images (3212 pixels). The decrease in NDVI values is concentrated in the urban center; however, the agricultural areas had differences not due to LUCC but the acquisition dates.



Figure 2: Decrease in NDVI between 1970 and 2000.

The classified images showed a consistent growth in the urban area. However, the lack of reference data resulted in just using the images a qualitative and support data. The urban areas and population data were compared to the estimates produced by Sutton et. al. (2001). Figure 3 is a scatterplot of the natural log of the area of cities vs. the natural log of the population of cities. The square point represent Ciudad Victoria as measured by Landsat MSS and ETM from 1973 to 2000. The points represented by 'X's are the cities of Mexico as measured by the nighttime 'city light' composite derived from the Defense Meteorological Satellite Program's Operational Linescan System (DMSP OLS) circa 1995. Use of DMSP OLS imagery has been demonstrated as a means of estimating urban populations (Sutton 2001). Figure 3 shows that the same relationship can be demonstrated with Landsat imagery. The relationship using only four temporal points was  $\text{Ln}(\text{pop}) = 7.43 + 1.06 \text{Ln}(\text{Area})$   $R^2 = .91$ , whereas; the relationship using only the DMSP OLS derived points for all of Mexico's cities circa 1995 was  $\text{Ln}(\text{Pop}) = 7.27 + 1.03\text{Ln}(\text{Area})$   $R^2 = 0.72$ .

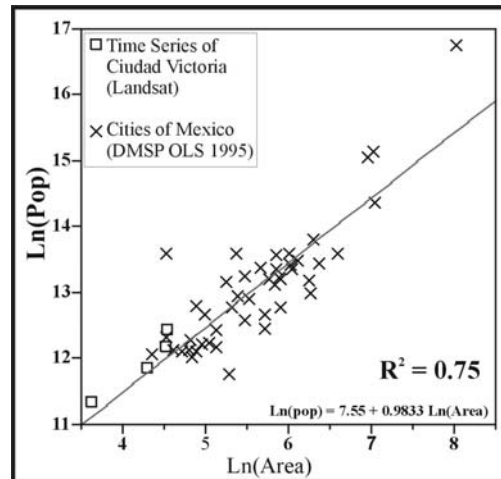


Figure 3: Scatterplot of Natural Log of Derived Urban Area and Natural Log of Population

#### 5. CONCLUSIONS/FINAL REMARKS

The objective of this project was to isolate the LUCC in Ciudad Victoria using the NALC data set. The change techniques were able to identify that there were major changes occurring in the city area. The difference image isolated the areas of decrease in NDVI which were greatest within the urban expansion. The classified images show promise once there is adequate reference data. There were significant differences between the spectral responses of the four classes. This indicates that once a supervised classification can be performed a quantitative analysis can be performed. The PCA images were also able to isolate the changes. Component 2 isolated the riparian area which went through modifications during the time period. Component 4 was able to isolate the urban area better than any of the other techniques. This component was the basis for a Urban mask which will be used in an expert system to aid in a supervised classification when performed. The most interesting results were with the high correlation to the outcome of comparing the population to either the DMSP OLS or Landsat derived urban areas. Ultimately, this study showed the need for multiple data sources when trying to identify the changes in LUCC. Using multiple sources of remotely sensed data to monitor urban growth has great potential.

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