

Land Cover Changes in Central Sonora, Mexico

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Abstract.— Remote sensing techniques have been demonstrated to be very effective tools to help detect, analyze, and evaluate land cover changes in natural areas of the world. Changes in land cover can generally be attributed to either natural or anthropogenic forces. Multitemporal satellite imagery and airborne videography were used to detect, analyze, and evaluate land cover changes in the central region of the Mexican State of Sonora. Observed land cover changes were analyzed in terms of the productive activity most likely responsible. The ecological consequences for the different impact intensity, area and percent of change are also discussed. Landsat MSS images were classified into five different land cover/land use categories for two time periods (1973 and 1992) and validated using airborne video imagery and fieldwork. About 85% of the entire land cover in the study area changed during that period of time. The Sinaloan thornscrub biotic community class had the highest rate of change; more than 28% of the original class evolved into other biotic categories.

The relationship between the land cover change with climatic patterns over the period of time considered is described. Future scenarios for watershed management in the region are analyzed.

Introduction

The term *Land Cover* relates to the type of feature present on the surface of the earth, including vegetation and nonvegetation features. The term *Land Use* relates to the human activity associated with a specific part of land and usually emphasizes the functional role of that land for economic activities (Lillesand, 1987; Campbell, 1987). Changes occurring in land cover and land use can generally be attributed to either natural or anthropogenic forces. Natural changes relate to both seasonal and annual variations in climatic conditions and are often reflected by variations in natural land cover; natural changes can also be related to fire. Changes resulting from anthropogenic forces are the result of human modification of the environment (Pilon et al., 1988). Geographic information systems (GIS) and remote sensing techniques are powerful tools in the analysis of temporal changes in land cover or land use, because spatial information from two or more time intervals can be compared more readily than by non computer-

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based methods. Since the earliest Landsat imagery appeared in 1972, paired images from subsequent dates have been used to detect land cover and land use changes in the landscape (Iverson and Risser, 1987).

In the study area, both the nature and intensity of land use patterns are changing. Agricultural activities and human population have increased in recent years. This growth suggests that the demand for urban and agricultural water will continue to expand. The exploitation of the underground water table and the expansion of agricultural activities in this region present a serious threat to the wildlife and vegetation dependent on the soil and water resources.

A better understanding of the historical land use change should provide additional knowledge of the conditions of the region. Therefore, the principal objective of this study was to estimate the land cover and land use changes that occurred in an area located in central Sonora between 1973 and 1992 using remote sensing and GIS techniques.

Methods

The study area is located in the central part of Sonora, Mexico, between North latitudes 28° 00' 00" and 29° 30' 00", and West longitudes 109° 30' 00" and 112° 00' 00" (figure 1).

Change detection in land use class areas was determined using Landsat MSS data processed with the remote sensing program ERDAS version 8.3.1 produced by Erdas, Inc., and the ArcView program version 3.1 developed by ESRI. The scenes used in this study were acquired from the North America Landscape Characterization (NALC) project through the EROS Data Center of the U.S. Geological Survey in Sioux Falls, SD. The scenes are from April 1973 and May 1992. The subsets defining the 1973 and 1992 study areas were extracted from the original scenes using ERDAS and the satellite imagery processing equipment available at the Remote Sensing Center, Office of Arid Lands Studies, University of Arizona.

The satellite imagery were atmospherically corrected and geographically registered before the classification process. By performing an unsupervised classification, five different land cover classes were determined according to the Brown and Lowe (1994) standard. The criteria

Results and Discussion

The classification categories identified in the 1973 and 1992 images were Madrean evergreen woodland, Sinaloan thornscrub, Plains of Sonora subdivision (Sonoran desertscrub), water bodies (dams and reservoirs), and farmland. The application of the image differencing technique to the two images shows that more than 85 % of the area changed classifications during that time. Madrean evergreen woodland, agricultural areas and Sonoran desertscrub decreased 28%, 24.3% and 31.4%, respectively. Water bodies and Sinaloan thornscrub classes increased by 13% and 25.0% respectively. Among the five classes analyzed in this study, Sonoran desertscrub was the least stable class, while agricultural areas comprised the most stable class.

Because desert vegetation is soon modified by climatic changes and considering that precipitation in the study area is the only factor of the environment which can cause a rapid change on vegetation (Cloudsley, 1977), it is presumed that most of the changes were due to natural causes. About 24% of the area changed as a result of direct human activities such as agriculture. These anthropogenic changes occurred as a result of Mexican government policies to generate jobs and improve the regional economy by financing clearing of natural areas for grazing pastures and farmlands (SARH, 1989).

However, this does not mean that all natural vegetation classes can be converted into croplands, since some areas are unsuitable for agricultural exploitation given their steepness, salinity, soil texture, or scarcity of water sources for crops irrigation. Although the anthropogenic changes obtained in this study do not represent a significant percent in terms of area, they are important in terms of environmental impact because they have generated a considerable number of ecological problems. The problems include: depletion of the groundwater table; disappearance of former perennial water bodies and streams that

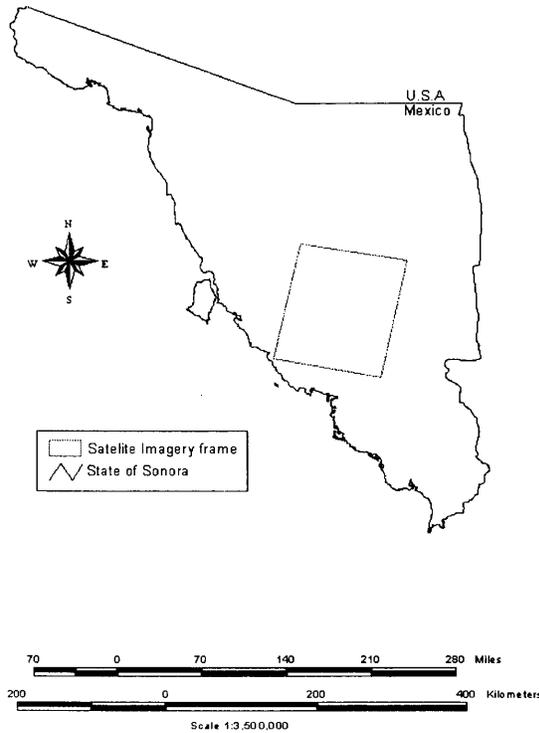


Figure 1. Location of the study area.

used to distinguish these land cover classes were based principally on feature reflectance values, topography, the association to other features on the image (i.e., a straight border on irrigated croplands), and video frames taken from flights over the study area.

Change analysis by image differencing (Jensen, 1986; Campbell, 1987; Singh, 1989) was used to detect land cover and land use differences between 1973 and 1992 (table 1). The subtraction process results in positive and negative values for pixels with reflectance value change and zero values for pixels with no change. In this study, subtracting the 1973 classification image from the 1992 classification image produced change detection values.

Table 1. Comparison of area and percentage occupied by different classes on 1973 and 1992 images and percentage of change between those years.

TYPE OF FEATURE	1973 year		1992 year		Percentage Change between 1972 - 1992
	Hectares	Percentage	Hectares	Percentage	
Water	6633	0.3	7647.8	0.3	13.3
Woodland	773979.48	34.3	556880.4	24.7	-28.0
Thornscrub	1048572.4	46.5	1397354.8	62.0	25.0
Croplands	19378.8	0.9	14661.4	0.6	-24.0
Desertscrub	408085.2	18.0	280104.5	12.4	-31.4
TOTAL:	2256648.8	100.0	2256648.8	100.0	

were sources of water and habitat for wildlife and plant species; reduction of the wildlife population species; modification and suppression of natural habitats and ecosystems; ecosystems pollution by extensive and intensive use of agrochemicals; and dispersion and introduction of weeds and non-native species into natural adjacent ecosystems.

In comparison to other life zones, the desert more readily displays ephemeral, highly variable land cover changes that may not be significant over longer time periods. An isolated rainfall event, for instance, may induce a short-lived, dramatic vegetation response that does not reflect a permanent land cover change. In environments like the study area, it is thus important to examine the changes that have occurred over longer time spans. The two dates of this study were chosen to make the substantial and lasting land cover changes of the intervening years evident.

In addition, extreme changes in precipitation patterns in some years could affect the vegetation land cover classes, resulting in spectral differences between two images that could be interpreted as a permanent land cover change.

Change detection error can thus result if the source imagery captures the response to either a short-lived, isolated climatic event or a more sustained, anomalously pronounced one. Therefore, it is recommended that change detection studies be made at many frequent time intervals (i.e., every five years). This will permit the creation of simulation models of the change processes, which will lead to a better understanding of how different factors interact to cause land cover class modifications.

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