

Effects of Urbanization on Ecological Services in a Semi-Arid Region of the United States

Year 2 Project Report

NASA Land Cover-Land Use Change Program (NRA-00-OES-08)

Project Team

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Abstract

Changes with land cover and land use are closely integrated with water processes at the land surface. Nowhere is that more apparent than in the Edwards aquifer region of south-central Texas. The Edwards aquifer covers approximately 4,350 square miles in parts of 12 counties in Texas and includes San Antonio and Austin, the nation's eighth and nineteenth largest cities, respectively. Water is discharged at several natural points and through hundreds of pumping wells, particularly municipal supply wells in the San Antonio region and irrigation wells in the western extent. Because of its highly permeable nature in the fresh water zone, the Edwards aquifer responds quickly to changes and extremes of stress placed on the system. The semi-arid climate and highly variable rainfall in the region create large differences in recharge and discharge rates from year to year.

Population growth in this region has been high with county population increases (1990 – 1999) ranging from 11.1% in Kinney County to 72.6% in Williamson County. While this growth has directly increased the demand on the aquifer, of greater significance has been the impact on the region's ecological services. Of particular interest is the dynamic between water resources, carbon sequestration, and wildlife habitat. For example, reduction of brush and other woody plants in the Edwards aquifer recharge zone has been shown to increase water resources in the artesian zone, where the water is discharged for public use. However, the elimination of woody plants reduces wildlife habitat. Additionally, the increased biomass of woody plants sequesters more carbon than the grasslands that would replace them, so brush removal reduces sequestration of carbon. Clearly the goals of increasing water availability, increasing carbon sequestration, and increasing wildlife habitat are in conflict. Policy instruments have addressed these conflicting goals individually and as a result have failed to achieve a sustainable balance between them.

The overall goal of the research is to determine the impacts of past land cover and land use change (LCLUC) on regional ecological services and to apply that knowledge to evaluate public policy instruments to enhance these services in the future. Specific ecological services targeted are water resources, vegetation for carbon sequestration, and refugia for wildlife habitat. A strong multi-disciplinary research team has been assembled to accomplish this goal through evaluation of LCLUC in the region from LANDSAT satellite images, determination of the changes in ecological services arising from LCLUC, utilization of spatial information from these analyses to establish and evaluate different policy instruments to control LCLUC, and optimization of policies to maximize ecological services through management of LCLUC. The outcome of this research will be an understanding of LCLUC and the effects on ecological services in a semi-arid region, a determination of the effectiveness of policies to enhance ecological services, and an optimization of ecological services through policies that appropriately manage LCLUC.

Keywords: (1) Research Fields: Historical Land Use; Image Processing; Urbanization; (2) Geographic Area/Biome: North America; Savanna; Semi-arid; (3) Remote Sensing: LANDSAT; (4) Methods/scales: GIS; Regional Scale; Time Series Analysis;

Questions, Goals, and Approaches

NASA ESE Scientific Questions

This project is addressing three of NASA’s ESE scientific questions:

Where are land cover and land use changing, what is the extent and over what time scale?

Juniper and mesquite encroachment in rangelands in the drainage area and urbanization has been shown to have a significant effect on aquifer recharge. **Change detection** of LANDSAT images will be used to determine the amount and rate of brush encroachment (**carbon sequestration**) and urbanization (**human dimension**) in the region over the past 30 years. (25% effort)

What are the causes and what are the consequences of LCLUC?

The consequences of LCLUC in the aquifer drainage and recharge zones on surface water hydrology and aquifer recharge will be modeled for each watershed in the region so that an overall impact on **water availability** can be determined. (25% effort)

The consequences of LCLUC on ecosystem services (e.g. **carbon** sequestration, **water** availability, **wildlife** refugia) will be evaluated from a socio-economic basis. The **social science** basis is essential in establishing effective strategies to optimize brush control programs with respect to water quantity and carbon sequestration concerns. (25% effort)

What are the projected changes of LCLUC and their potential impacts?

The effectiveness of programs to manage brush removal will be evaluated with respect to the needs of the landowners and other stakeholders in the region. The **human dimension** is critical to establish optimal solutions to rangeland management. (25% effort)

Project Goals

This is an ambitious project with multiple components. In order to develop and test the methodology, second year efforts have been focused on two watersheds in the region; Sabinal River and Leon Creek. The goals were (1) develop image processing methods and GIS data fusion for classification of urbanization areas, (2) evaluate the effects of landcover changes and urbanization on the watershed using the SWAT model, (3) develop auxiliary soils data from the SSURGO database for the region and (4) distribute and evaluate the stakeholder questionnaire.

Table 1. Project Timeline from the proposal - Year 2

Quarter/Year	Activity	Status
3 rd Quarter 2002	2 nd Year of the Project	
	Collect additional LANDSAT images	Complete
	Parameterization of SWAT	Complete
4 th Quarter 2002	Test neuro-fuzzy methods for land cover classification	Complete
	Develop stakeholder questionnaire	Complete
1 st Quarter	Distribute stakeholder questionnaire	Complete

Quarter/Year	Activity	Status
Quarter 2003	SSURGO preprocessor for ArcView	Complete
2 nd Quarter 2003	Preliminary evaluation of questionnaire responses for test watersheds	Complete
	Calibration of SWAT model for San Antonio	In progress
	Development of image classification methods for urban areas	In progress

Because of the flooding that occurred in the Edwards Aquifer region in July of 2002, all of the counties contained in the study area were declared Federal Disaster areas. While this did not impact our work with historical data and with the stakeholder questionnaire, it did create some delays in field surveys and the collection of ground truth data.

Approach and Methods

The approach to this study has relied on close interdisciplinary cooperation between engineers and social scientists. There are three major efforts under way (1) determining land cover classification and land cover change from LANDSAT data (led by Lacey), (2) modeling the effects of urbanization on recharge to the Edwards Aquifer (led by Haan), and (3) surveying landowners and stakeholders to determine attitudes and management options for brush control (led by Kreuter and Conner).

Progress

Our second year efforts have continued to focus on two watersheds in the region; Sabinal River and Leon Creek. Sabinal River is an area where land use is primarily farming and ranching but is undergoing significant changes in land ownership and land use. Traditional agricultural activities are being supplemented or replaced by recreational uses (e.g. leased hunting) of the land. This project will explore the implications of these changes on brush removal programs and landowner incentives. Leon Creek is located in the northwest of corner of San Antonio (Bexar County) and extends into Bandera County. It is an area that has undergone extensive urbanization over the previous 15 years.

Determining Land Cover Classification and Land Cover Change from LANDSAT Data

In order to delineate the Sabinal River watershed, elevation data in the form of 30-meter digital elevation model (DEM) files were obtained from the Texas Natural Resource Information System (TNRIS). The hydrology extension in ArcGIS was used to fill sinks, determine flow direction, calculate flow accumulation, and identify sub-watersheds, based on the DEM files. Land cover classification was accomplished through the use of Matlab. Sections of MRLC data were coupled with corresponding Landsat 7 ETM+ bands. Training data were chosen from within the same image set but not from within the delineated watershed. Only image bands 3 and 4 were used due to the high correlation among the other band combinations. A 3x3 window was passed over each pixel to incorporate adjacent pixel effects. An averaged pixel dataset is produced for each training and test band. The genfis2 subtractive clustering algorithm in the Matlab

Fuzzy Logic Toolbox was used to create a set of fuzzy rules. When the genfis2 algorithm was applied to the training dataset, 7 fuzzy rules were produced. Adaptive Neuro-Fuzzy Inference System (ANFIS) was then used to optimize the fuzzy rule set. Once a final fuzzy inference system (FIS) was created, the image data within the watershed boundary were evaluated. After the classified dataset was produced, it was imported into ArcGIS for validation against the existing MRLC dataset for the watershed. Validation was accomplished by differencing the original MRLC dataset and the classified dataset that resulted from the FIS. An example of the ANFIS classification is shown in figure 1.

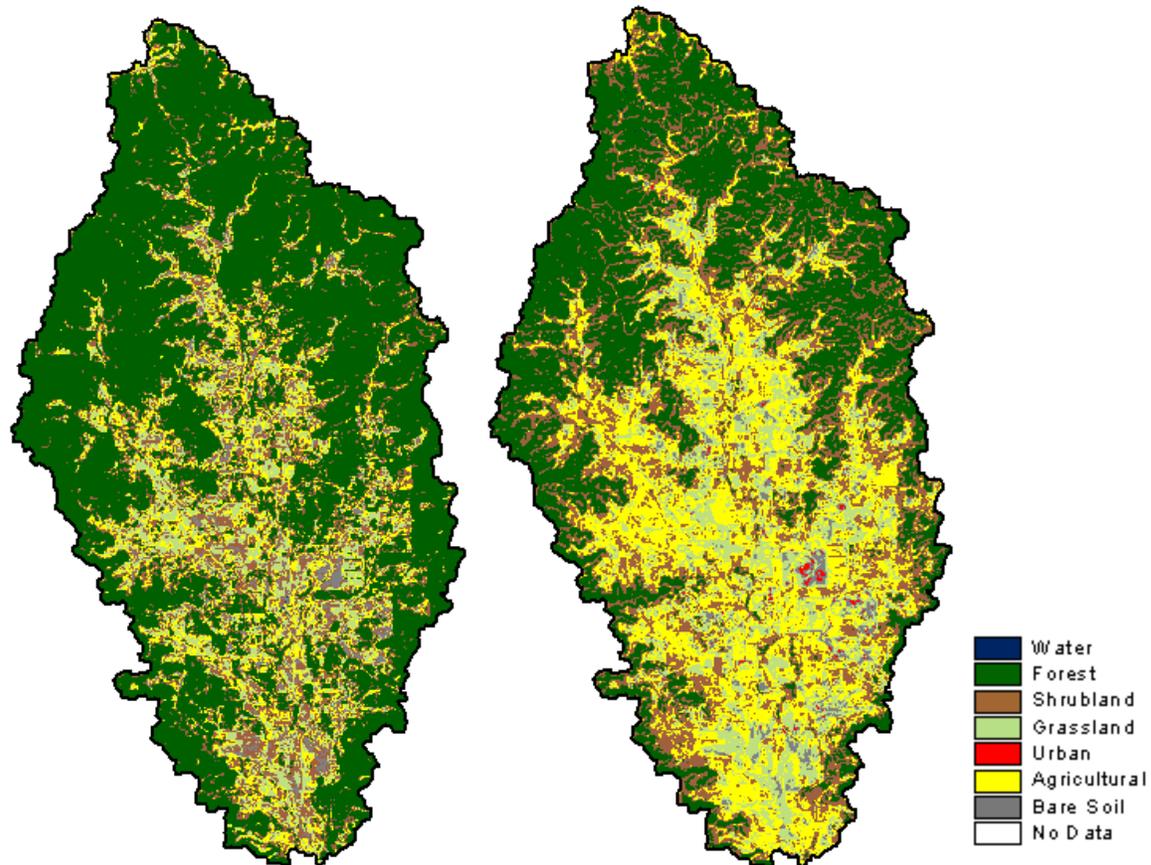


Figure 1. Comparison of December 14, 1999 to April 4, 2000 classified images for the Sabinal watershed using ANFIS.

The ANFIS land cover classification method demonstrated an acceptable overall accuracy (85% or greater) and it did show promise with respect to forest, shrub land, and grassland, which were most often correctly classified in both images. However, it performed less well on urbanized areas and consequently an alternative method of classification of urban areas is under development.

Modeling the Effects of Urbanization on Recharge to the Edwards Aquifer

The Leon Creek Watershed, located in western San Antonio was modeled using the Soil Water Assessment Tool (SWAT) model. Land use classification datasets were derived

from LANDSAT satellite imagery to estimate the change in land cover from 1985 to 2002. These datasets along with stream flow data and precipitation records were used as inputs to the SWAT model to estimate aquifer recharge in order to calibrate the parameters of the model. Once the calibration is complete, the SWAT model will be used to evaluate the effects of additional urbanization changes in the San Antonio area.

A SSURGO Pre-Processing Extension for the ArcView Soil and Water Assessment Tool

Soils represent a fundamental abiotic parameter in defining the characteristics of an ecosystem. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) produces the most detailed digital spatial data sets that are publicly available. The Soil Survey Geographic (SSURGO) Database contains basic attributes for the continuous coverage of soils across the United States. In its standard format, the SSURGO data set is incompatible for use within the ArcView Soil and Water Assessment Tool (SWAT). A modified version of the State Soil and Geographic (STATSGO) Database is the template soils data set used by ArcView SWAT. A methodology has been developed by the Texas A&M University Blacklands Research Center (BRC) and USDA/NRCS that adjusts a SSURGO data set to fit the modified STATSGO format. While this method accomplishes the conversion task, it is very time consuming. It also makes use of third-party software during the conversion process that may not be available to all users. An ArcView geographical information system (GIS) extension can automate all of the tasks similarly involved in the BRC-USDA/NRCS method. A SSURGO 2.0 dataset pre-processor extension for the ArcView SWAT model has been developed in order to incorporate this more detailed soils data into estimates of the effects of land cover on recharge to the aquifer. An example of the improved data is shown in figure 2.

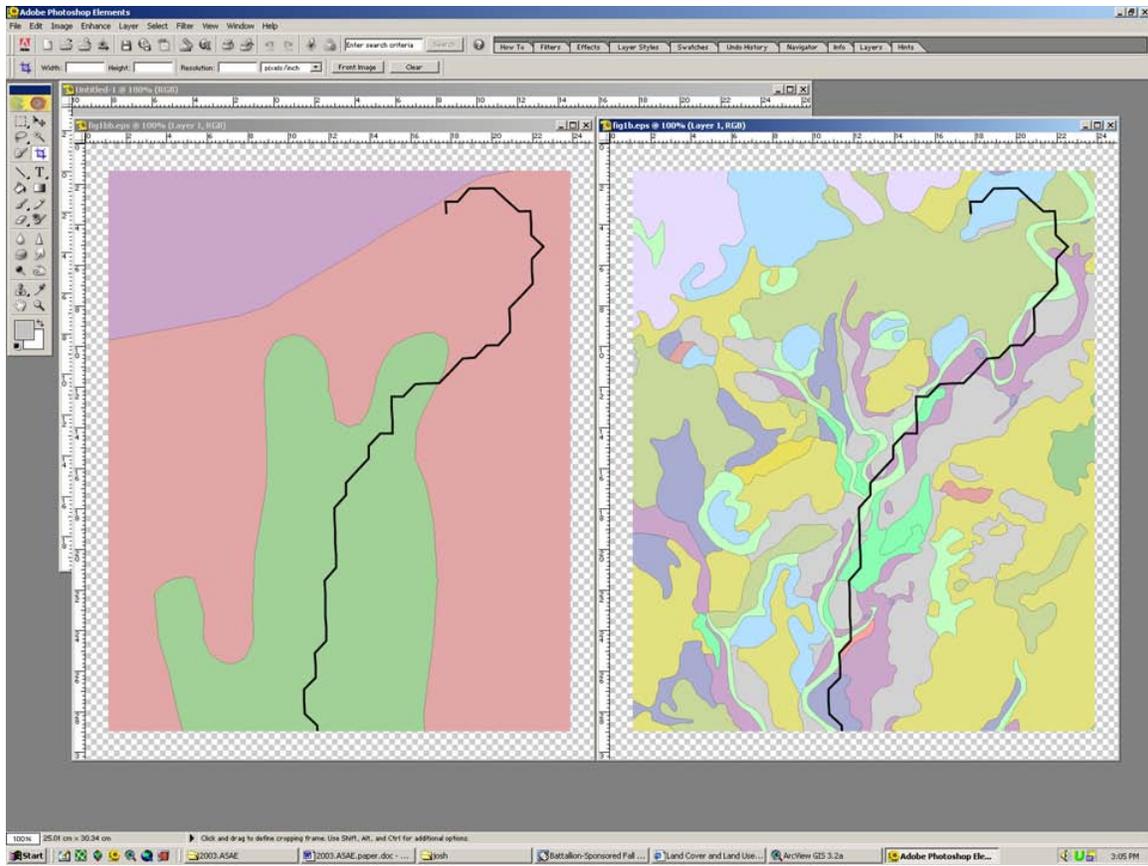


Figure 2. Comparison of STATSGO data to SSURGO data for the Leon Creek watershed in Bexar County, Texas.

Preliminary Stakeholder Survey Results for the Sabinal Watershed

In order to ascertain the willingness of landowners within the western portion of the Edwards Aquifer to enroll in brush management and other land management activities as well as learn more about their attitudes regarding brush cover and ecological services, questionnaires were sent to 600 landowners of Bandera, Kerr, Medina, Real, and Uvalde counties in April and May 2003. A total of 248 usable surveys (defined as having no more than 2 blank pages) were returned and analyzed. Only landowners owning 50 or more acres, per local county appraisal districts documents, were sent questionnaires. The county breakdown of those received were Bandera – 59 surveys, Kerr – 59, Medina – 57, Real – 20, and Uvalde – 53.

The mean and median property sizes for landowners of the five counties were 1,028 and 222 acres, respectively. The mean and median amounts of land for which the respondents made land improvement decisions were 1,046 and 228 acres, respectively. One-half of respondents earned 2% or less of their total income from land activities, and 42.2% had a total household income of over \$100,000. The greatest source of property income was from the sale of livestock which was roughly double the income from hunting enterprises.

Landowners placed high importance on grass and forage production and low importance on heavy brush. The willingness to enroll in land management practices can be partly explained by the large amount of heavy cover reported (average of 36.5% of respondent's property) and the low value landowners placed on heavy cover for all brush types (oak, juniper, mesquite, and mixed brush). However, respondents indicated they would prefer higher levels of oak and mixed brush compared to juniper and mesquite.

Landowners were most interested in land improvement projects that use best management practices for grass cover, increased water flow by reducing brush cover, and that provided for wildlife habitat. Respondents were less interested in programs in which they were required to perform. There was more interest in programs with public compensation compared to those without funding.

Roughly three-fourths of landowners would be willing to enroll in a cost-share program. The minimum cost-share required to entice at least 40% of landowners is 70% while a cost share of 80% will attract 61.2% of landowners.

Next Steps

The project will continue to follow the original timeline as shown in Table 2. Once the methodology is fully tested for the two watersheds, the effort will be extended to include all of the watersheds in the Edwards aquifer region.

Table 2. Project timeline - Year 3.

Quarter/Year	Activity
3 rd Quarter 2003	Analyze landowner responses for implementation of alternative policy instruments Evaluate alternative classification methods for urban areas. Expand classification to the entire Edwards aquifer recharge region
4 th Quarter 2003	Optimize brush and urbanization management strategies. Estimate costs of implementing alternative policy instruments that incorporate appropriate landowner incentives
1 st Quarter 2004	Determination of optimal combination of policy instruments for enhancing ecosystem services and social welfare
2 nd Quarter 2004	Final Report prepared Final publications prepared and submitted

Conclusions

The second year of this project has seen the team successfully implementing all aspects of the project. Some key findings are:

- Adaptive neurofuzzy classification was successful on forested and grass land areas but was not as successful on urbanized areas.
- An ArcVIEW GIS preprocessor for the SSURGO soils data has been successfully developed and tested and will be made available on the Texas A&M University LCLUC web site (<http://lcluc.tamu.edu>)

- A stakeholder questionnaire was successfully tested in one watershed in the western part of our region of interest. Preliminary analysis of the data suggests that there are potential management strategies that could offset the impact of urbanization on the surrounding rural areas.

Publications

- Peschel, J., R. E. Lacey, P. K. Haan and U. P. Kreuter. 2002. Quantifying land cover features of the Sabinal river watershed using ANFIS. *Eos Trans. AGU*, 83(47), Fall Meet. Suppl., Abstract H22D-0918, 2002, Moscone Center, San Francisco, CA.
- Branyon, R., P. Haan and R. E. Lacey. 2003. Modeling the effects of urbanization on recharge to the Edwards aquifer. ASAE Annual International Meeting, Las Vegas, NV, ASAE.
- Peschel, J. M., P. Haan and R. E. Lacey. 2003. A SSURGO pre-processing extension for the ArcView Soil and Water Assessment Tool (SWAT). ASAE Annual International Meeting, Las Vegas, NV, ASAE.