Quantifying Landscape Elements in a Semi-Arid Region: A GIS-based Approach

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Project 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.

Project Objectives

(1) Develop the LANDSAT image library for the region

(2) Develop image classification methods for identification of brush species and urban areas

(3) Develop the watershed modeling data inputs

(4) Identify and interview stakeholders in the study areas

(5) Develop the survey questionnaire

(6) Develop the landholder data necessary to distribute and evaluate the questionnaire.

Progress Towards Project Objectives

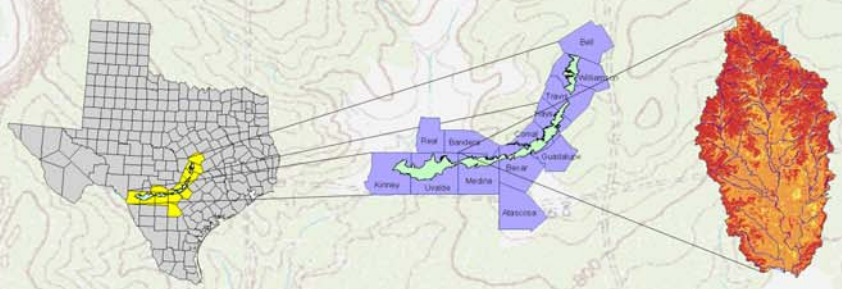
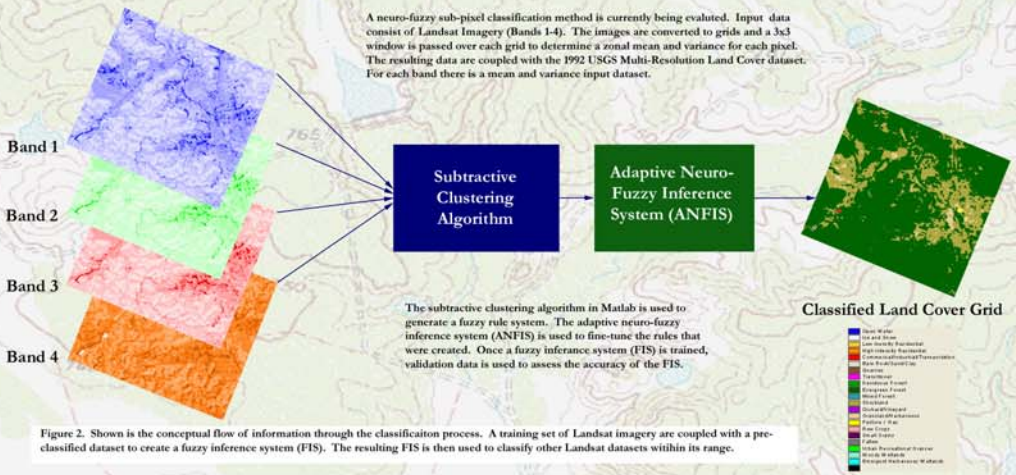


FIgure 1. (a) The State of Texas is shown with the counties of the Edwards Aquifer highlighted, (b) The counties of the Edwards Aquifer are extracted for closer examination (Real county is included since it contributes flow into the recharge zone. The recharge zone of the Edwards Aquifer can be seen in green, (c) The delineated Sabinal River Watershed made up of Real, Bandera and Uvalde counties.

A neuro-fuzzy sub-pixel classification method is currently being evaluted. Input data consist of Landsat Imagery (Bands 1-4). The images are converted to grids and a 3x3 window is passed over each grid to determine a zonal mean and variance for each pixel. The resulting data are coupled with the 1992 USGS Multi-Resolution Land Cover dataset. For each band there is a mean and variance input dataset.



The subtractive clustering algorithm in Matlab is used to generate a fuzzy rule system. The adaptive neuro-fuzzy inference system (ANFIS) is used to fine-tune the rules that were created. Once a fuzzy inferance system (FIS) is trained, validation data is used to assess the accuracy of the FIS.

Figure 2. Shown is the conceptual flow of information through the classificaiton process. A training set of Landsat imagery are coupled with a pre-classified dataset to create a fuzzy inference system (FIS). The resulting FIS is then used to classify other Landsat datasets withihn its range.

Classification Status

The highest accuracy that has been achieved by using this method is 67.8%. The average accuracy value is 54.5%. Accuracy is determined by subtracting the classified land cover dataset that is produced by the FIS from the original dataset for the region of interest. Figure 3 presents the original and developed land cover classificaiton for an Landsat 7 image subset of the Sabinal River Watershed on April 4, 2000.

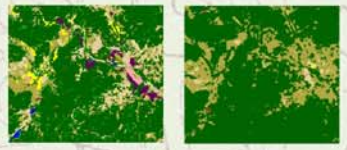


Figure 3. (a) 1992 USGS Multi-Resolution Land Cover dataset, (b) Classified dataset from FIS. Legend shown at bottom.

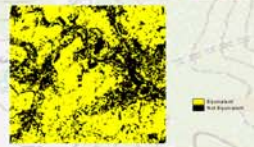


Figure 4. Differential between original dataset and dataset classifed by FIS.

Next Steps

While the final land cover classification did not accurately reflect the validation datasets, work is continuing on this approach. Possible sources of error may include not enough training data or incorrect membership function selection. Alternative band mean and variance combinations may still yield more accurate results.

A pre-processor replacement for the subtractive clustering algorithm may be considered. The primary reason for considering alternatives is the potential to develop a more representative fuzzy rule set that can then be optimized using ANFIS.

Heterogeneity within the training dataset may be causing problems. To further study this problem, input datasets will be changed to homogeneous sets of land cover. The FIS will be trained with these datasets and the results compared. Accuracy is expected to improve.

Once the methodology for the neuro-fuzzy sub-pixel classification method is fully tested for the Sabinal River watershed, the effort will be extended to include all of the watersheds in the Edwards aquifer region.