Developing Vegetation Density, Topography and Watershed Layers for a GIS of Government Canyon State Natural Area, Texas

Erika Christine Cohen
Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695
Faculty Sponsor: Thomas G. Drake, North Carolina State University

Lela Prashad
Department of Geosciences, Trinity University, 715 Stadium Dr., San Antonio, TX 78212
Faculty Sponsor: Glenn C. Kroeger, Trinity University

INTRODUCTION

Government Canyon State Natural Area (GCSNA) is a 5838 acre area of land, located in Bexar County, Texas (Fig. 1) that overlies the karst recharge zone of the Edwards Aquifer. It is currently being prepared to open to the public as a State Natural Area (SNA) in the year 2000. By designating this area as a SNA, the primary focus in any plans is conservation of the recharge features, and environment, not recreation. In June 1998 the Texas Parks and Wildlife Department (TPWD), Edwards Aquifer Authority, and the San Antonio Water System agreed on a usage plan for the GCSNA. Developed camping and facilities will be restricted to the 700 acres at the south end of the GCSNA. There will also be nine miles of equestrian trails on this lower end of the GCSNA. The remaining area will be open to mountain bikers, hikers, and primitive camping. Horses will not be allowed in this undeveloped area because there is concern that they disturb an endangered bird found in this part of Texas, the Golden Cheeked Warbler, from nesting. There are no streams in Government Canyon that are consistently full so it is likely that camping and picnicking in the GCSNA will not become popular and that the park will be mainly used by mountain bikers and equestrians.

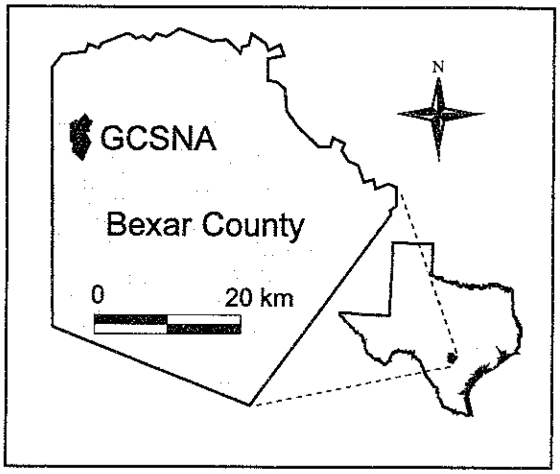

Figure 1. Location of the Government Canyon State Natural Area (GCSNA) in Bexar County, Texas.

The Edwards Aquifer is the main source of water for San Antonio, the eighth largest city in the nation. Water from the aquifer is used for drinking, agriculture, industry, and recreation. Water pumped out of the aquifer is pure and is not significantly treated. It is becoming increasingly difficult to keep the aquifer from being polluted because of urban development in the recharge zone. Nearly 88% of Government Canyon lies in the recharge zone while the area around the GCSNA is already being developed.

The GCSNA lies across the Balcones fault zone that separates the Texas coastal plain from the Texas hill country. One of the Balcones faults, the Haby Crossing fault, divides the GCSNA into two geologic and topographic regions. The upthrown block to the north of the fault exposes the Cretaceous Edwards Limestone and the Cretaceous Glen Rose Formation. Upper Cretaceous Austin Chalk, isolated blocks of Edwards Limestone and the Pleistocene Leona Formation are exposed on the downthrown block south of the fault. The Edwards Limestone is a macroporous limestone that, in the subsurface, houses the Edwards Aquifer. Recharge of the aquifer in the park occurs where the Edwards Limestone is exposed along the Haby Crossing fault. North of the fault, the topography is a dissected plateau while south of the fault, the topography is relatively flat.

The TPWD had constructed a GIS that included roads, trails, streams, cultural features and two and five-meter vector contour data. The two-meter data was for the flat area south of the Haby Crossing fault and the five-meter data was for the entire GCSNA. The contour data was provided by surveyors contracted by the TPWD. All TPWD GIS layers used UTM Zone 14 coordinates based on a NAD83 datum. Our goal was to extend their GIS to include more complete topography, watershed, and vegetation layers. We built an enhanced digital elevation model (DEM) by combining data from USGS 7.5 minute DEMs and surveyed contour data. From this enhanced DEM, we derived hydrology data for the GCSNA. We then generated a vegetation density layer using multispectral satellite imagery.

METHODS

Digital Elevation Models A major goal of our project was generating an enhanced DEM. The construction of our DEM involved three steps: obtaining and mosaicing the USGS DEMs, generating a high resolution DEM from the surveyed contour data inside the park, and merging the two data sets to create one DEM.

First we obtained the Helotes and San Geronimo 7.5 minute quadrangle DEMs from the USGS EROS data center. We imported them into ArcView by converting the DEMs into grid format with the Spatial Analyst Extension which adds raster GIS capabilities to ArcView. USGS DEMs are classified into three levels of accuracy. Level one DEMs are created by scanning National High Altitude Photography and can have a vertical root mean squared error (RMSE) of up to 15 meters. Level two DEMs are processed for consistency in data and systematic errors are taken out. Level 2 DEMs are augmented with data from hypsographic and hydrographic data digitizing and have a maximum vertical RMSE of one-half contour interval. Level three DEMs are derived from Digital Line Graph hypsography and hydrology. These are the most accurate DEMs with a RMSE of less than one-third contour interval. (USGS, 1993). GCSNA overlaps two 7.5 minute quadrangles. A level two DEM was available for the San Geronimo quadrangle, while only a level one DEM was available for the Helotes quadrangle. There is obvious digital noise in the Helotes quadrangle, especially south of the Haby Crossing Fault where the topography is essentially flat. We mosaiced these two DEMs even though they were of different qualities because we were going to augment them with the high accuracy five-meter contour data.

We created the equivalent of a level three DEM from five-meter contour lines inside the park. The process involved two steps: making a triangular irregular network (TIN) and converting the TIN to a grid. A TIN is, "a surface representation derived from the irregularly spaced sample points and breakline features. These points are connected by edges to form a set of non-overlapping triangles used to represent the surface" (ESRI, 1997). We created the TIN by using ArcView's 3D Analyst extension. The surveyed contours were used as "soft" breaklines (no sharp break in slope) in generating the TIN. Next, we converted the TIN to a grid using the convert-to-grid option in ArcView's 3D Analyst extension. This operation resamples the TIN surface at regularly spaced points. We chose a 10 meter cell size for the resampled grid. The finished product is a grid or raster layer in the GIS (Fig. 2a).

Before merging the USGS DEM mosaic with our derived DEM, the USGS DEM mosaic was transformed from the NAD27 to the NAD83 datum. The datum shift was approximately 20 meters south and 30 meters east. Next, we performed several tests on the match between these two representations of the topography within the boundary of the GCSNA. Registration was tested by comparing drainage paths on the two surfaces and by visually comparing contours of major topographic features from each DEM. A difference surface was calculated to check for any overall elevation mismatch. Finally we used the merge operation in the ArcView Spatial Analyst Extension to simultaneously resample the USGS DEM mosaic at 10 meter cell size and replace coincident cells with the values from the contour derived DEM within the boundary of GCSNA.

Drainage Analysis Once we had merged the DEMs, we generated a watershed layer for the GIS, encompassing the GCSNA and the surrounding two quadrangles. The first step in creating the watershed was to fill any sinks in the DEM. Using the Spatial Analyst extension to ArcView, we ran a script that identified any sinks in the data and changed the values in those cells to that of the lowest neighboring cell, creating a filled grid. Next, the flow direction from each cell was calculated using the filled grid. Finally, a watershed layer was calculated from the flow direction layer (Fig. 2b).

Imagery We obtained a SPOT XS multispectral scene of Government Canyon acquired on October 14, 1997. This scene had 20 meter square pixels and three spectral bands in the green (0.5-0.59 μm), red (0.61-0.68 μm) and near infrared (0.79-0.89 μm). The scene was system corrected so it was radiometrically correct but not georeferenced. We rectified and georeferenced the scene using a ground control point (GCP) process.

The goal of our georeferencing was to transform the scene into a UTM zone 14 projection based on a NAD83 datum. To do this, we warped the scene using a set of ground control points (GCPs) around the perimeter of, and inside of, the GCSNA. We chose GCP locations that were clearly identifiable on the image and were also easily accessible on the ground (Figure 4). Because of the large 20m pixel size, we could use major intersections of roads and highways in and around the GCSNA as our GCPs. We went to these intersections and measured their positions using a Pathfinder Pro-XRS Global Positioning System (GPS) unit. We acquired positions to submeter accuracy using real-time differential correction information broadcast by the OmniSTAR satellite service. The GPS produced geographic coordinates (latitude and longitude) based on the WGS84 datum. We used a program called Geographic Calculator to convert these to UTM zone 14 coordinates based on a NAD83 datum

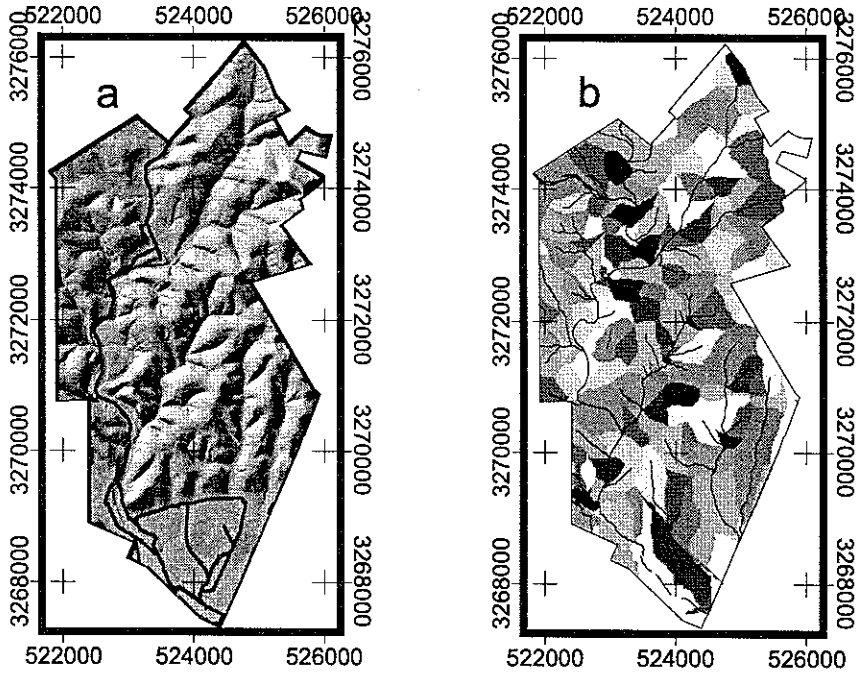

Figure 2. a. Hillshaded rendition of the DEM generated from 5 meter contour data. Here roads and drainages can be seen. **b.** Watershed layer derived from our DEM shown with drainages from the TPWD GIS. Both maps are in UTM Zone 14 projection, NAD83 datum. Coordinate grid shows UTM northings and eastings in meters.

In order to rectify and georegister the scene with our GCPs, we used a software program called Geographic Transformer. In this program the UTM coordinates were assigned to the pixels in the image corresponding to the GCPs. With 14 GCPs, we warped our scene using an overdetermined second order polynomial transformation. The georegistered scene was then imported into our GIS. We checked the registration of the scene with GIS against road and drainage layers provided by the TPWD. There were no significant deviations.

Although vegetation reflects strongly in the green portion of the visible spectrum, it has a much larger reflectivity peak in the near infrared. Since this is one of the bands of radiation recorded by the SPOT satellite, it was possible to calculate an image that represented density of vegetation. We calculated a Normalized Differential Vegetation Index (NDVI) image using a software package called ER Mapper. An NDVI is a thematic image of estimated vegetation density calculated with the algorithm (near infrared – red)/(near infrared + red). This band ratio normalizes for the overall brightness of the spectrum and emphasizes the difference between red and near infrared reflectivity that characterized green vegetation. In the resulting NDVI image, dense vegetation can be seen in bands that follow the contours of the hills (Fig. 3). This is due to the fact that the Glen Rose Limestone is composed of two interbedded lithologies, a dense resistant limestone, and a more shaley lithology which is easily eroded and therefore conducive to soil development. The shaley layers also act as aquitards and direct the lateral flow of groundwater. Dense vegetation is also observed in a narrow band along the Haby Crossing fault.

RESULTS

The DEM created from the five-meter contour data and the USGS DEMs were merged and aligned successfully. The TPWD can now work with a full DEM that includes the surrounding area. The slope and aspect layers were calculated for the park using our refined DEM to observe any correlation with vegetation. There was no correlation found. However, our NDVI image suggests that vegetation density is highly correlated with geology. The terraces of the non-resistant, shaley lithology of the Glen Rose Formation are highly vegetated whereas the more resistant limestone lithology is not. The GIS layers have been given to the Texas Parks and Wildlife Department for their use. Our GIS is also being used by the Trinity University Physics and Biology departments in studies on vegetation and solar radiation. Metadata for our new layers is being created.

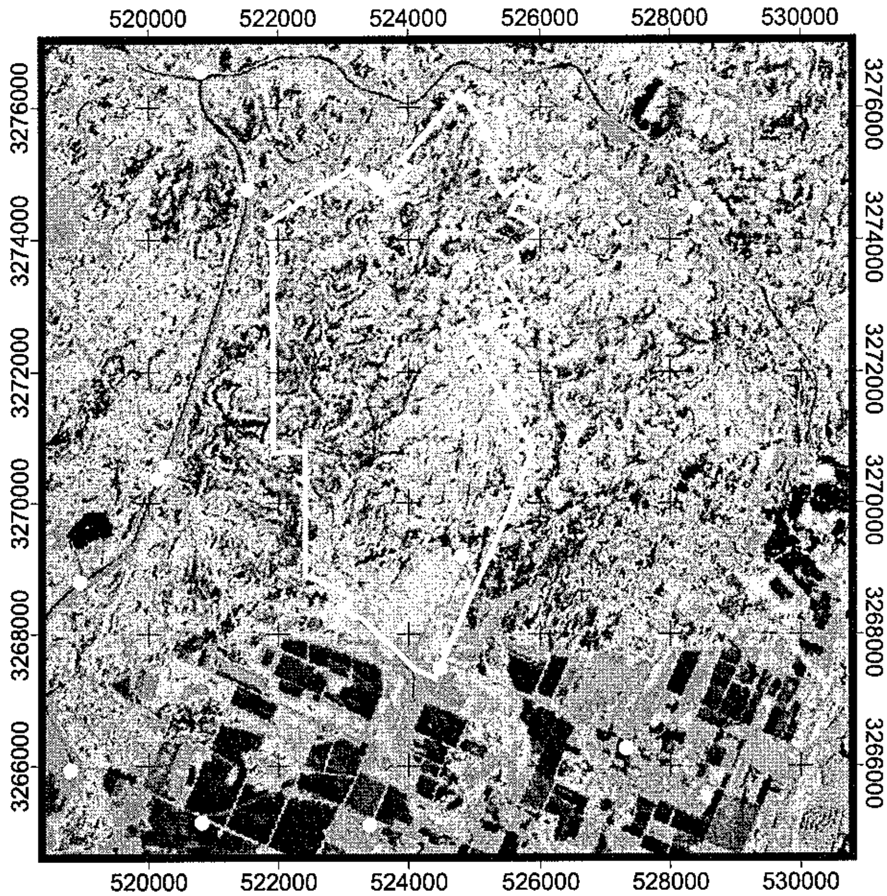

Figure 3. NDVI generated from SPOT XS imagery. Dense vegetation can be seen forming along contours on the shaley unit of the Glen Rose Formation and along the Haby Crossing Fault located near the south end of the GCSNA. GCPs collected to warp the image to the UTM projection are shown as white circles.

REFERENCES CITED

ESRI, 1997, ArcView 3D Analyst: 3D Surface Creation, Visualization, and Analysis: Redlands, California, Environmental Systems Research Institute, Inc., 118 p.

U.S. Geological Survey, 1993, Digital elevation models-data users guide 5:Reston, Virginia, U.S. Geological Survey, 48 p.