Land Cover and Soil Properties of the San Marcos Subbasin

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Project Background

In Central Texas, just south of the Austin area is the city of San Marcos. The watershed which comprises this city and some of its surrounding area is the San Marcos Subbasin. This subbasin was chosen for this study because it was used in previously exercises in Dr. David Maidment's Geographic Information Systems in Water Resources course at the University of Texas at Austin. Some of the analysis done on this subbasin include: geographic properties of the subbasin such as the area of HUC12 subwatersheds within the basin, the length of streams of within the subbasin, the area and the ratio of the length of the streamlines to the area, or the drainage density, of the San Marcos subbasin. Meaningful spatial analysis dealing with the topography, elevation and precipitation was also preformed in the course. It only made sense to continue working with this subbasin after knowing all the above-mentioned information. However, the areas in which this project is focused are the soil characteristics of the subbasin as well as the land and vegetative cover.

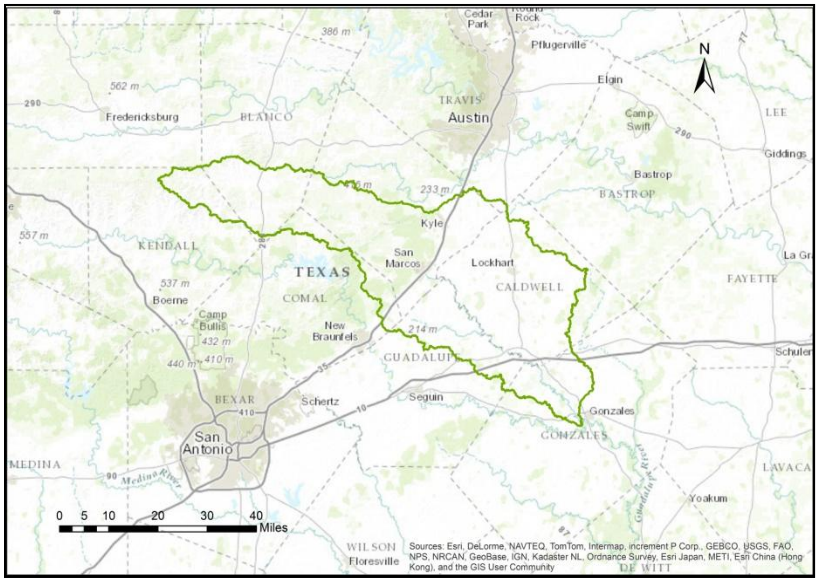

Figure 1: San Marcos Subbasin

Data Sources

Although this is a rather small region in Central Texas, there are readily many sources with vast ranges of data used for all different purposes. The soil data used in this study was downloaded from the ArcGIS Online's SSURGO Soil Data Downloader (beta). The downloader is a very user friendly system and sends map packages that are formatted to open easily into ArcGIS. The land cover data was downloaded from the USGS National Land Cover Institute, specifically the Landsat 5 Topography Mission. This data is easily accessible as long as you have a registered USGS account and there are not too many requests for data ahead of you in the queue. There were several images taken over many days for this particular area, a number of those were downloaded from the website and then uploaded in ArcGIS. From this point, only very few included all of the San Marcos Subbasin within a single image, which were the images chosen for the analysis within this project. A digital elevation map was downloaded from the National Elevation dataset.

Methods

Vegetation Index Calculations

The first step in this project was to load the Landsat 5 TM images into ArcGIS 10.1 and format their coordinate system in order to match the location of water bodies in the Landsat images and the ones found in the National Hydrography Dataset. Once the coordinates were correct, the next step was to begin to calculate the Normalized Difference Vegetation Index (NDVI). The reason NDVI was chosen is because remotely sensed spectral vegetation indices are widely used and have benefited numerous areas of study in their assessment of water use, plant health, plant stress and crop production to name a few. The interest of the project is to look at the relationships between the vegetative cover and the other more general properties of the subbasin such as the soil distribution and the stream network.

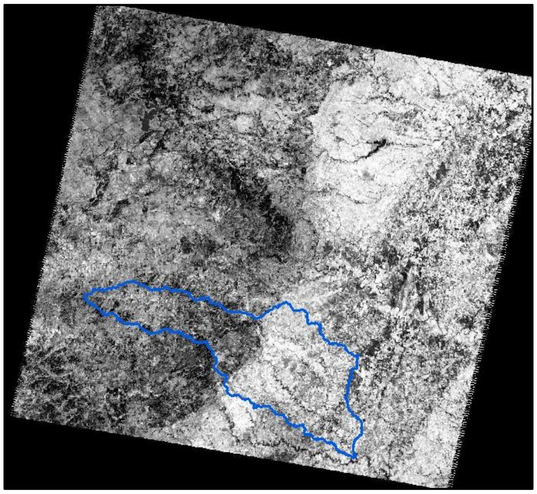

Figure 2: Landsat 5 Thermal Image

The next step, was an attempt at using the ArcGIS function to calculate the NDVI directly. It was an attempt because in order for this function to work correctly, the Landsat 8-bit digital number (DN) thermal image must be unwrapped into all seven bands, each compromised of a different wavelength of light reflected by the surface. In order to understand exactly what all this transformation entailed, independent research was done to find exactly how to unpack the single image. The first step that was required was to transform the Landsat 5 TM data into Landsat 7 ETM+ sensor data because they are calibrated differently. This calculation would need to be performed for every point of data included in the raster data set. This was accomplished by using the Raster Calculator Tool in ArcGIS. The equation given by Vogelmann et al. (2001), shown as Equation 1, was used with an accompanying table of the slope and intercept for each band not shown. After converting to the Landsat 7 ETM+ sensor data, it was then decided to calculate the radiance. Again, this was done for all seven bands over the entire raster set .using the Raster Calculator. The equation used for this calculation is shown as Equation 2, given by Chander et al. (2009), and once again the accompanying table is not shown. Now that the radiance is known for all seven bands, the reflectance is the final conversion need before the NDVI can be calculated. Equation 3, again given by Chandar et al. (2009) is used. The values of the earth-sun distance, *d*, and $E_{sun,\lambda}$ are found in tables from Chandar et al. as well. θ_{SE}, is the sun-elevation angle specific to the Central Texas area, and found in the header text file that was downloaded with the images. During this final conversion, there were several small negative

$$DN7 = (\text{slope}_\lambda * DN5) + \text{intercept}_\lambda$$

Equation 1: Landsat 5 to Landsat 7

$$L_\lambda = (\text{gain}_\lambda * DN7) + \text{bias}_\lambda$$

Equation 2: Landsat 7 to Radiance

$$R_\lambda = \frac{\pi * L_\lambda * d^2}{E_{sun,\lambda} * \sin(\theta_{SE})}$$

Equation 3: Radiance to Reflectance

numbers that were created, since quantitatively negative reflectances make no sense, those numbers were set to zero.

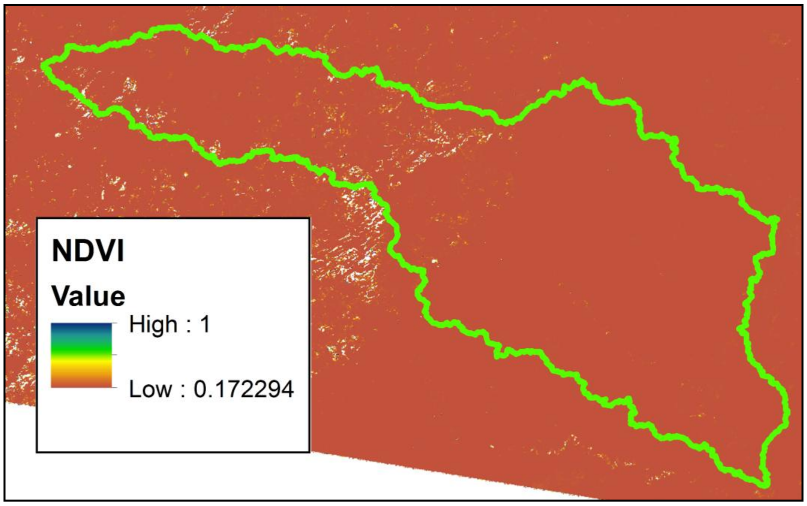

Figure 3: NDVI

Then NDVI was then calculated, shown here in Figure 3. The result of the NDVI shows that almost the entire entire subbasin has less that 25% of vegetative cover, which is accurate, however, the goal of this project is to look at the cover and its relationship to streams and soil, for which a more diverse view of the vegetative cover is needed. In areas, such as this one, with low vegetative cover and a diverse soil distribution is useful to look at the Soils-Adjusted Vegetation Index (SAVI), which attempts to correct the NDVI for soil brightness. The SAVI for the San Marcos Subbasin is shown in Figure 4. It is a much better representation of the area, and now it is possible to look at relations between land cover and other properties of the basin.

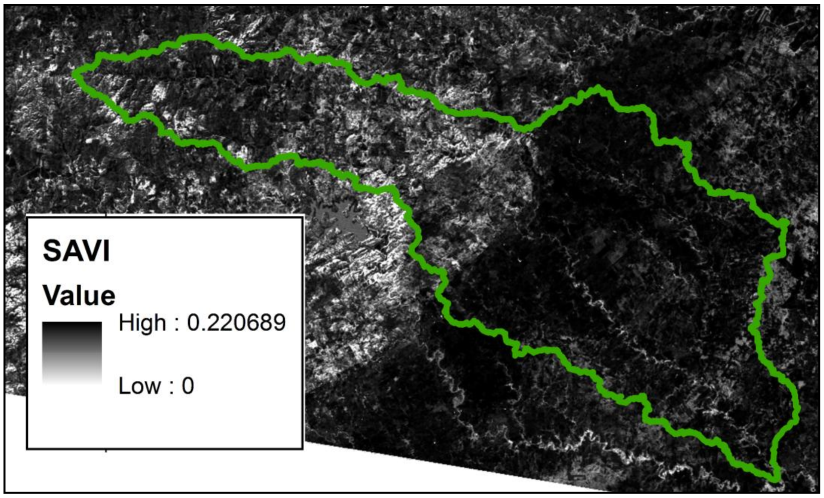

Figure 4: SAVI

Two Relationships were found looking at the SAVI. The first relationship, which seems rather obvious and makes sense is that there tends to be more vegetative cover along stream banks. It makes sense that since there is an abundance of water, normally, and it is easily accessed by the plant roots that there is more growth near streams, this is shown in Figure 5. The second relationship that was discovered was dealing with the geology of the watershed. Noticeably, the Edwards Aquifer occupies some of the area beneath the San Marcos Subbasin. By overlaying the aquifer boundary on top of the SAVI data set, it is evident that there is less vegetative cover over the Edwards Aquifer. In order to understand why this occurred, it was then decided to look at the soil distribution over the subbasin, with an emphasis on the types of soils that are found above the Edwards Aquifer.

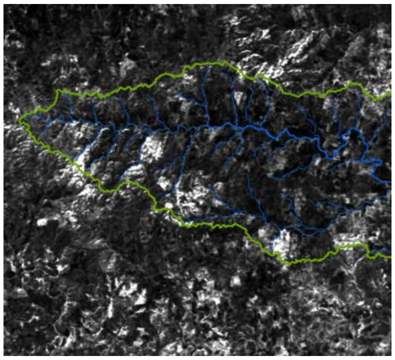

Figure 5: SAVI and Streams

Soil Characteristics and Relationships

The next part of the San Marcos Subbasin that this project analyzed was the soil distribution and if there were any correlations between soil types and the streams as well as the vegetative cover and soil types. As mentioned above, there was evidence that the Edwards Aquifer was influencing the vegetative cover above, the actual theory of this study is that there are only certain types of soils found above the aquifer and they, not the aquifer, are what is responsible for the lower vegetative cover in the area.

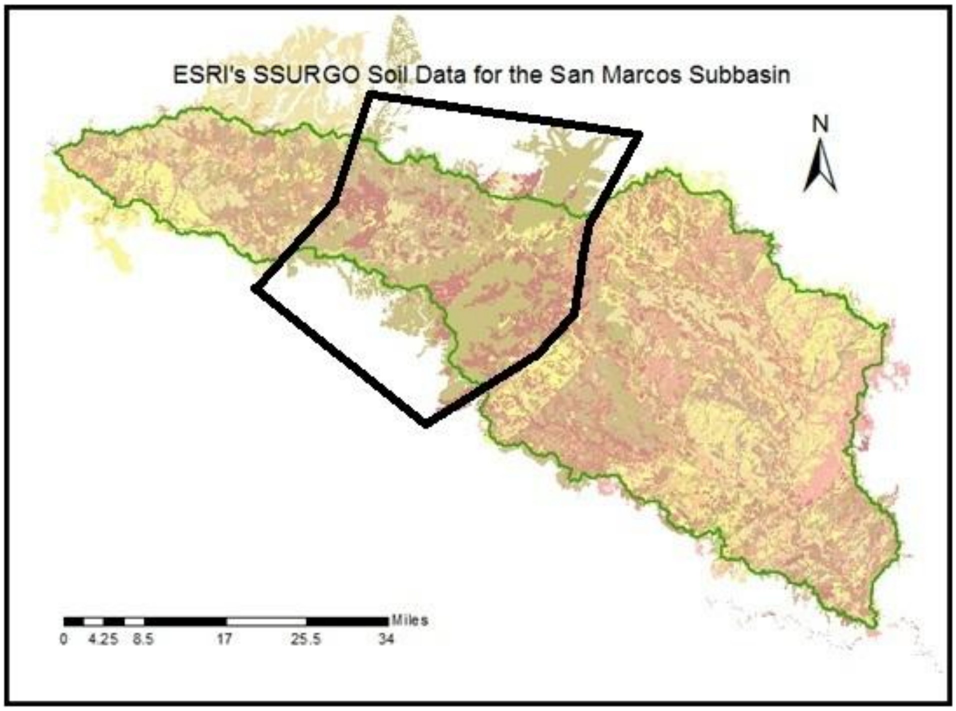

Figure 6: SSURGO Soil Data

Looking at the soil distribution of the subbasin, Figure 6, it is obvious there is a lot of diversity just in this smaller watershed. The next step was to compare the Edwards Aquifer boundary with the soil map for the subbasin. Focusing on just the area that is over the Edwards Aquifer, we can see that there are three different types of soil based on the soil map, and those soils all have the least depth to bedrock, making it difficult for plants to grow in this particular area. It also makes sense that there would be rock, since it can act as one of the confining layers of the Edwards Aquifer. The specific area of the basin with the Edwards Aquifer underneath it is displayed in Figure 6.

Taking a closer look at the soils found near the streams it then seemed necessary to look at each of the ten different classifications of soils in Figure 6. By creating a layer of each of the soils individually, and overlaying the National Hydrography dataset flowlines over each layer, and analyzing them individually it was then possible to see which soils were found near the streams most frequently. The most common soil found near or under almost 40% of the streams for the San Marcos subbasin is displayed in Figure 7 with a zoomed in view for one section of the watershed. The soil shown is comprised of moderately well drained clays, with 3 to 8 percent slopes along the areas containing this classification of soil. From this analysis, it is also clear that this type of soil contributes to plant growth and health, and possibly explains what we saw earlier with more vegetative cover near streams.

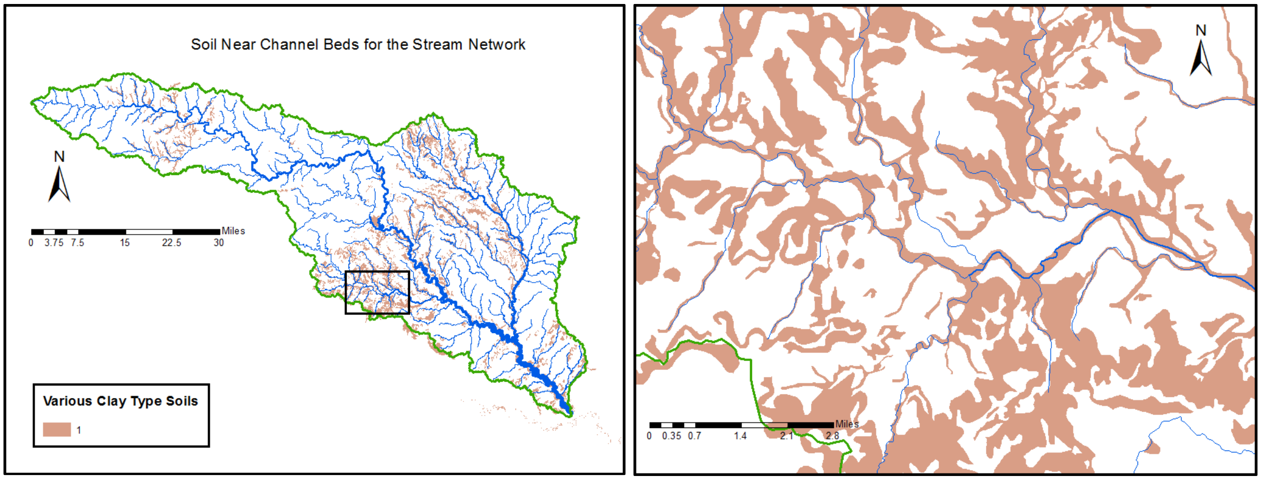

Figure 7: Clay Soils in the San Marcos Subbasin

It was then decided to look at the soil characteristics of the Lower Colorado Cummins Subbasin which is directly to the east of the San Marcos Subbasin, shown in Figure 8. The reason this basin was chosen was because it is in the same region and should exhibit some of the same soil characteristics. The Lower Colorado Cummins basin also has a much larger river, the Colorado, running through it, and it is not above the Edwards Aquifer allowing for several different comparisons between the two basins.

Performing the same type of soil analysis that was applied to the San Marcos subbasin, a different soil classification was found underlying the majority if the streams in the Lower Colorado Cummins subbasin. The types of soil found near approximately 37% of the streams were classified as gravelly sandy loams which are moderately well drained. This is different than that of the San Marcos subbasin, which mentioned above, was mainly clay type soils. It was very interesting upon taking a closer look at the Colorado River and which of the soils are found nearest to it. Shown in Figure 9 is a zoomed in view of the gravelly sandy loam soil. Near the center of the figure the soil winds around just like a flowline, and this particular looking flowline is the soil found near the Colorado River, we can even see the outline of the river.

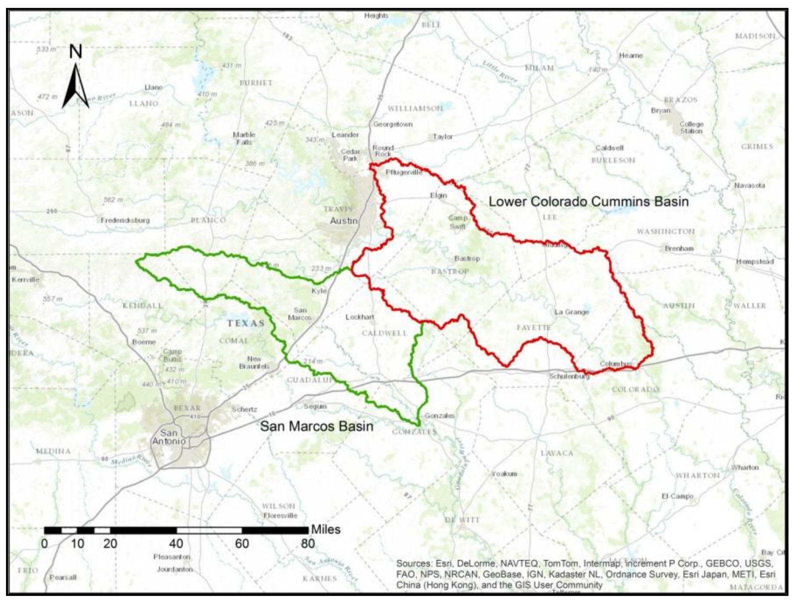

Figure 8: Lower Colorado Cummins Subbasin

The west-most parts of the Cummins basin were found to be very similar to the San Marcos basin, which is what we would expect since they share a border there. There were no such areas in the Cummins basin similar to the area above the Edwards Aquifer found in the San Marcos basin where only a few different types of soils were found. This reinforces the hypothesis that the aquifer is contributing the types of soils found in the same region

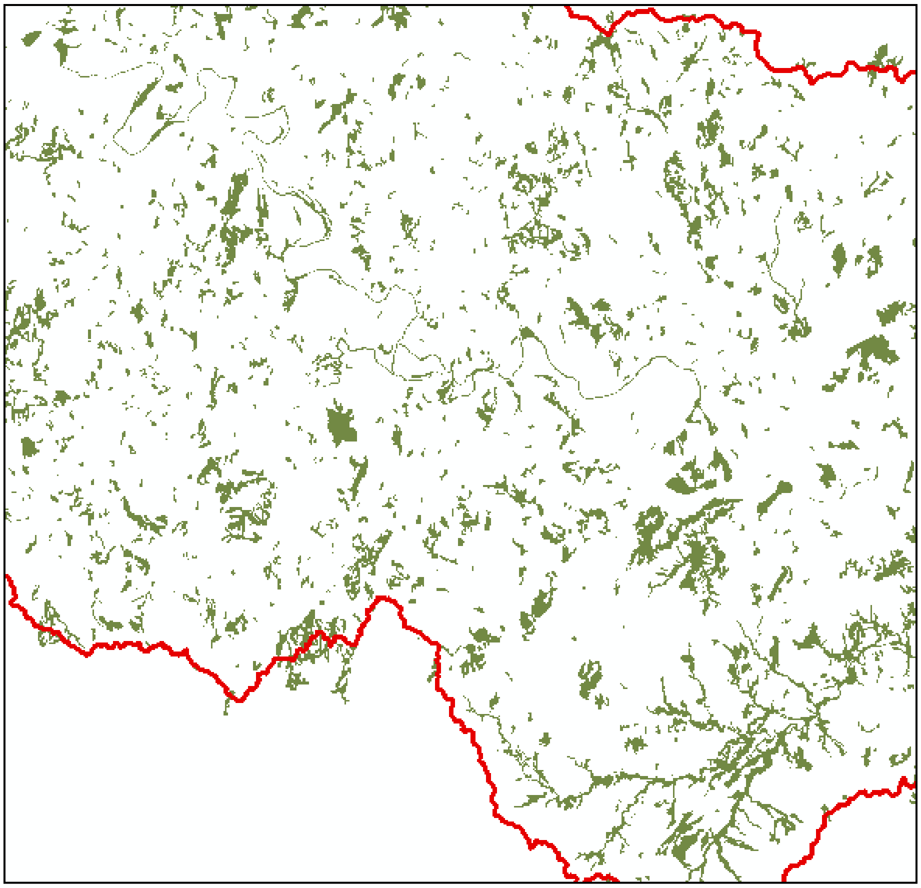

Figure 9: Sandy Loam in the Cummins Subbasin

Future Work

Future steps include looking at the rest of the soils and vegetative cover of the land above the Edwards Aquifer to see if there are similar findings of less vegetative cover and only specific types of soil that overlay the aquifer. Another avenue that would be worth pursuing would be to examine other subbasins in the surrounding area and looking at their soil and vegetative cover properties. It would be useful to look at a basin that has the Edwards Aquifer underneath it as well, possibly the Austin Travis Lakes subbasin to the north. It would be useful to compare these basins with the San Marcos and see if there are regional trends with and without an aquifer present. It would also be useful to look more closely at the soils above the Edwards Aquifer and study what is keeping these soils from displacing and why they are specific to the region above the aquifer. There is also interest in looking at the infiltration in the area surrounding the Edwards Aquifer, and how it varies with distance away from the aquifer.

Acknowledgements

I would like to give special thanks to Dr. David Maidment for teaching a very informative and vital class that has introduced me to several new things, particularly the variability and countless things that are possible with ArcGIS. I would also like to Dr. Ayse Airmak for her insightful presentations dealing with Landsat data and her help dealing with it.

Sources

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Elevation Data - viewer.nationalmap.gov/viewer

Hydrography Data - nhd.usgs.gov/data.html

Landsat Data - landsatlook.usgs.gov; glovis.usgs.gov

Soil Data - resources.arcgis.com/en/communities/hydro/index.html