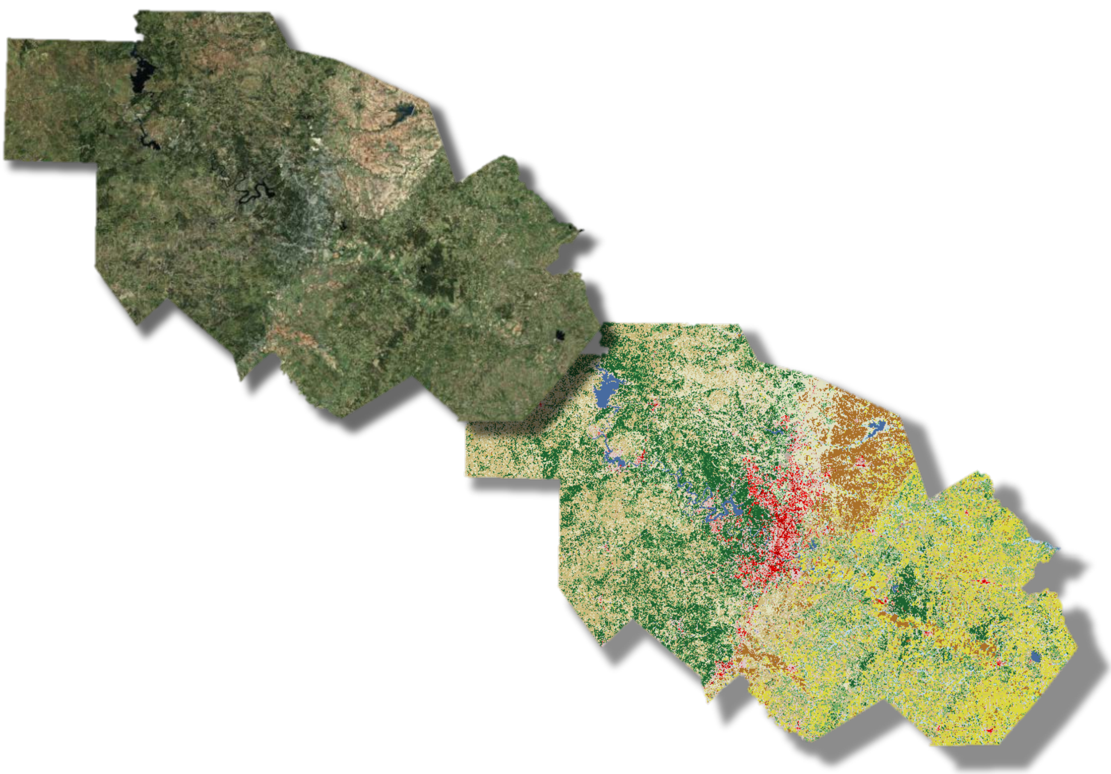
The Impacts of Urbanization In and Around Austin, Texas

An ArcGIS Study characterizing the changes in land use in Austin Texas



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1. INTRODUCTION

Austin is a small city in central Texas and is home to the University of Texas main campus as well as a several other smaller universities. Austin has been one of the fastest growing cities since 2000 and has seen a 20% increase in population since then, from 656,562 to 790,390 people. It is important then to consider how recent and long term land development has and can affect the area.

The effect of urbanization has become a common place sight. Where it was once common to see cattle grazing; now stand endless rows of houses. How does this type of change take place? How is land converted from one use to another? With the development of remote sensing technologies the reflectance and spectrum given off by a region of land can be identified by its use or impervious cover. Repeating this observation over a large space of land can give a map coded by land use.

Beyond giving insight in to the spread of cover and the change of one land use into another, this data can lead to an understanding of how land use impacts the environment. Environmental impact studies can be linked with this information and a correlation between the remote data and the field data can be drawn.

ArcGIS presents a platform to interpret this data using the program's ability to rasterize data and carry out complex calculations relating raster data sets with one another. These comparisons can give rise to a complex understanding about how land use has changed in and around Austin Texas.

The first goal of this study is to examine what the distribution of land use categories are around Austin Texas. This is done using the multi-resolution land characteristics (MRLC) national land cover data set (NLCD) which is separated into modified Anderson land categories (Anderson 1976; http://www.mrlc.gov/nlcd06_leg.php). This data is trimmed to represent the area of interest around Austin Texas as seen in figure 1. Additionally the local subwatersheds can be overlaid and the region cropped even further to fit to the subwatersheds. Using this restriction, an understanding of which subwatersheds have the most impervious land can be found using the percent developed impervious

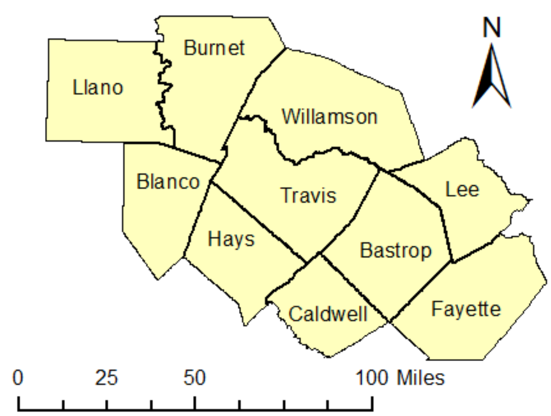


Figure 1. Layout of Region

land data set (PDIL).

This study shows how land has changed in the given region between the years 1992, 2001 and 2006. The study goes on to provide a simple way of calculating a cover-change product at both the two digit and one digit level. These distributions are further refined to show only cells that are labeled as developed cells to understand the expansion of developed regions with in the space. These areas are then studied at the subwatershed level by analyzing percent developed imperviousness, a characteristic that has been linked to impacted watersheds (Brabec 2002; Booth 1991).

2. METHODS

2.1 DATA

Data for this study was retrieved from several locations. The main body of the data used was taken from Multi-Resolution Land Characteristics Consortium (MRLC). This data uses adapted Anderson land-use categories as described above. The data can be found at http://www.mrlc.gov/index.php.

Additional masks used to cut the data into regions of interest are found at the CAPCOG information clearing house at http://www.capcog.org/information-clearinghouse/geospatial-data/. The data used in this study were the polyline data sets supplying the counties boundaries and the polyline data set identifying the subwatersheds in the counties.

2.2 DATA TREATMENT

To prepare the data for the study several layers of manipulation were performed. This includes rasterizing the polyline data and creating different masks with which to extract different regions from the total land use data file.

2.2.1 RASTERIZATION OF POLYLINE DATA

Both data sets downloaded from the CAPCOG site were provided as polygons. To be able to perform calculations within a region of the total MRLC data set it was first necessary to convert both these data sets to raster form. This is done using to polygon to raster tool in the spatial analyst tool box. The unrastered and rastered versions of the two data sets are show below in figure 2 a and b.

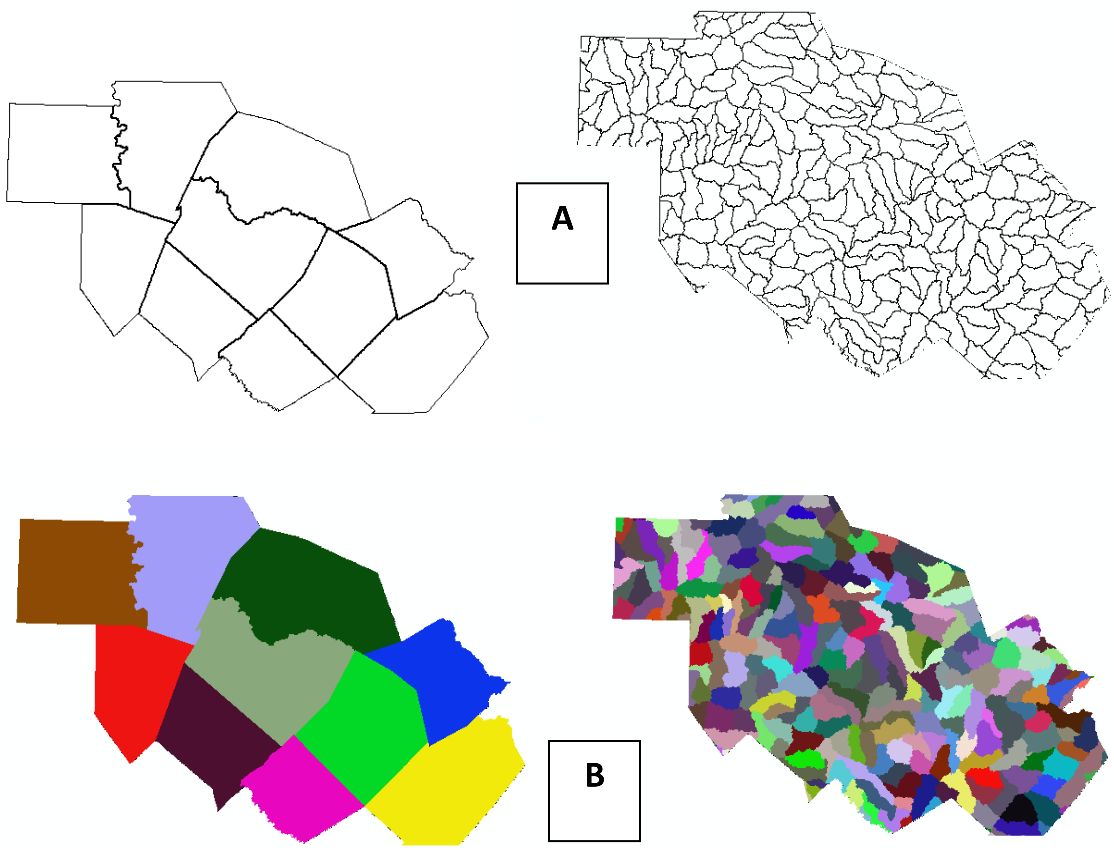


Figure 2 A and B. A) denotes the polygon data set that includes county name and area B) the rasterized version which only includes a single value, representing each county or catchment

It should be noted that at this point that before converting to a raster, should one wish to use only a small region within the specified vector data set, that sub-feature may be selected using the select feature and the selected features may be exported. This new data set can then be converted into a raster data through the same process as defined above. This is shown below for a watershed near the city of Austin. When this data is exported, the newly exported data set can be reprojected using any of the coordinate systems of the available data sets. Below in figure 3 is shown a selected set of subwatersheds converted into a raster. The county raster was reprojected using the "reproject" tool. In doing so the coordinate system is changed to match that used by the larger raster land use file. This demonstrated an alternative method for reprojecting the data.

Data available from the CAPCOG information clearing house was available projected using the Lambert Conformal conic and the NAD 1983 Texas State Plane for central Texas. This was reprojected to the Albers equal area conic used by the NLCD and the PDIL.

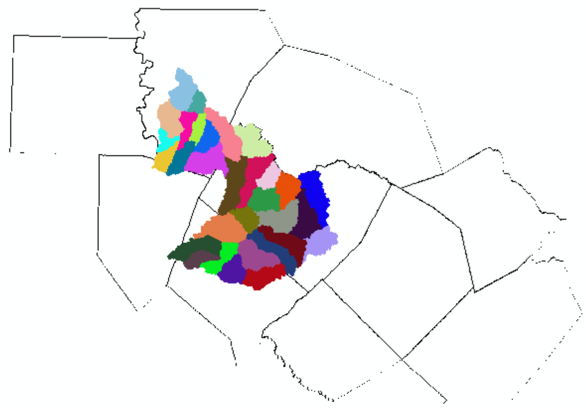


Figure 2. Extracted mask of subwatersheds

2.2.2 CLIPING OF CONTENTAL LANDUSE DATA SET

MRLC data was available as a contiguous data set. This makes working with the data set computer taxing. Using the “Clip” tool in ArcGIS, the extent of the total NLCD could be clipped to an area that had the same extent as the county data set making the data much easier to work with.

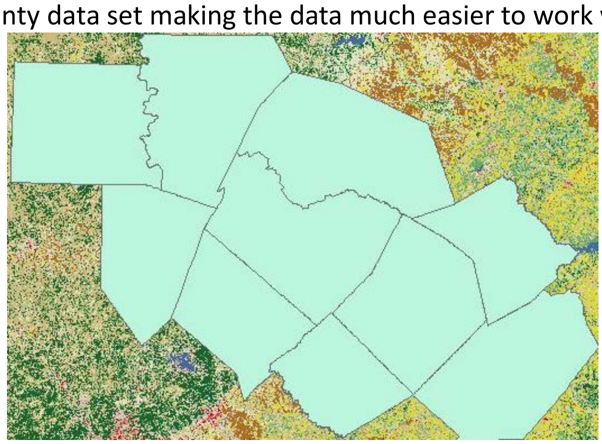
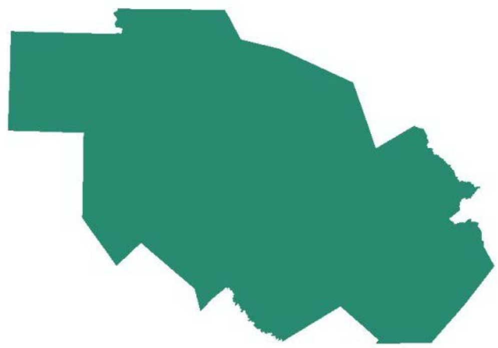


Figure 3. Clipped region overlaid by counties

2.2.3 MANIPULATION OF RASTER COUNTY AND SUBWATERSHED TO TEMPLATES

To carry out analysis on the data sets, it was necessary to match the shape of the land use data to that of the counties data set, essentially applying the shape of the counties as a cookie cutter to extract only the data of interest.

To carry out this operation the raster version of the counties data set was set so that all values were equal to 1. While there are simpler ways to do this, the counties raster data set was multiplied by 0 and then a value of 1 was added to it, using the map algebra tool in Arch GIS. Using the raster calculator tool, the county raster with value 1 is then "converted" through a simple multiplication (1 * land use value) and the land use mask is extracted.



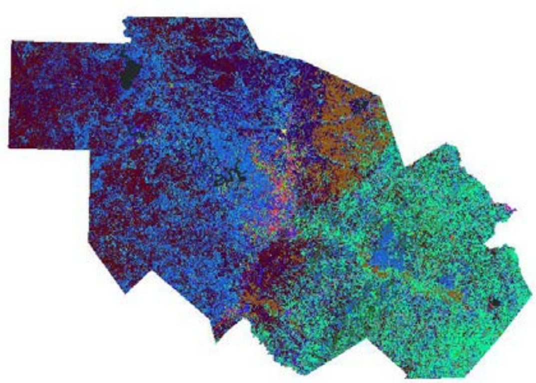


Figure 4. Top: Counties raster with all grid cells equal to 1. Bottom: Extracted land use

The above figure can then be used to study the land use either by county or for the region. In this study only the latter is analyzed. To make the extracted land use more visually appealing, the color scheme from the original data set was saved and applied to each of the cuts from each time period.

2.2.4 LAND COVER CHANGE PRODUCT

One of the initial goals of this project was to represent how land use changed over time. This required the "difference" of the land use to be compared from each time represented. To do this two approaches were taken. First the total change product for the 2001-2006 image sets was computed using the 2 digit values. To carry out this operation the map algebra tool was used. The string of code used a conditional such that if the year 1 value = the year 2 value the value was given a 0, if not then then the original data was multiplied by 100 and the second year was added to it. In using this approach the value of the previous land class was preserved. This can be seen in eqn. 1.

Eqn 1: Con("2001counties" == "2006counties", 0, "2001counties"*100+"2006counties")

Where 2001 counties was the clipped 2001 land use data for the region and 2006counties was the land use for 2006 for the region.

A similar approach was taken to reduce the values to single digit land use classes. This allows for the land use class change to be studied at a higher level. In this case only the first digit of the category was kept. The values were changed using the "Reclassify tool". The map algebra code is provided in eqn 2.

Eqn 2: Con("2001counties1v" == "2006counties1v", 0,"2001counties1v"*10+"2006counties1v")

The change products were not used to show visually the changes. Instead only the new value was kept, this can be seen in eqn 3.

Eqn 3: Con("2001counties1v" == "2006counties1v", 0," 2006counties1v")

In this case the only grid cells that have changed will be represented with a land use code. The end result of both analyses allowed the data to be exported to excel for further manipulation. In this case only the 2 digit and 4 digit land use data was examined. In excel the data could be tested using if then statements and truncation of other digits to rescue previous or current land use categories. In this way the area could be studied examining inter or intra land use category changes.

2.2.5 URBAN DEVELOPMENT ANALYSIS AND A NOTE ABOUT 1992 DATA SET

One of the initial goals of this study was to examine the progression of urban area over time. It should be noted that the 1992 data set does not use the same land use categories and it is therefore not recommended that it be compared directly with the 2001 and 2006 data sets. This is also impart due to the changes in equipment sensitivity since the 1992 data was collected. Instead other analysis is recommended using the raw spectral data when comparing. However, because there was little issue at the first level of the category, the land was analyzed for urban development. In this case the 1 digit raster of each time period was converted to display only those cells considered developed impervious land. This was done using a conditional statement. An example is provided below for the 2001 data set. To modify the 1992 data set for an imperfect look at the urban changes from this period the category 85 was changed into a 2 and 61 into 8. These values seemed to match up somewhat when inspecting the rasters. This result is purely investigational and is improper for any formal publication.

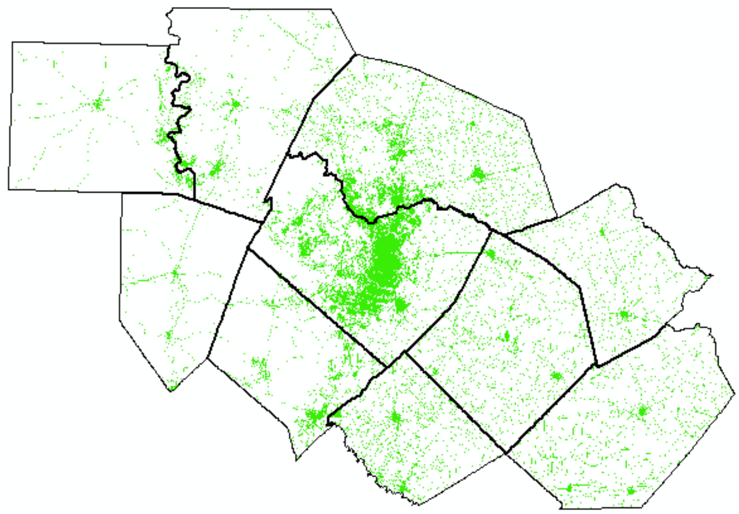


Figure 5. Single value urban only mask, 1992

2.2.6 SUBWATER SHED ANALYSIS

To further study the impact of urbanization the rasters of the subwatersheds described in section 2.2.1 were converted so that all grid cells had a value of 0. In this case the raster was then added to the imperviousness grid calculated in 2.2.5 and the result gave a grid representing the developed imperviousness land in the selected subwatershed. Several subwatersheds were selected to study this relationship. An example of this calculation is given below showing the resulting raster of a watershed in the region as representing the urban development in it.

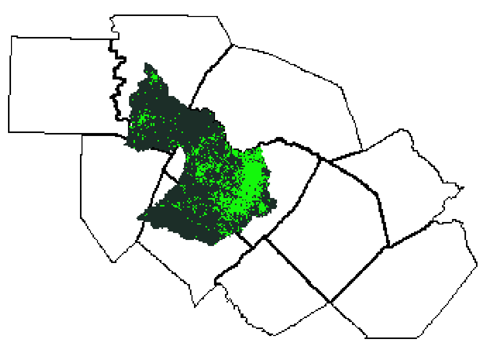


Figure 6. Extracted imperviousness in a watershed

3. RESULTS

The main goals of this study were to produce a distribution of the land use for the Austin area region using the NLCD. The second goal was to create an understanding of how land use has changed in the region. While there are many different directions that this could be taken such as forestation, zoning etc.; the central question in this study is how did developed land cover change? Lastly this final question is applied as it relates to water quality. As stated previously, numerous studies have shown that as the percent developed impermeable land cover increases it can lead to issues in watersheds. This final point is considered in the region under investigation.

The initial goal was to understand the distribution of land use in the Austin region. Below is the land use for the region in the period analyzed in this study. A spatial representation of each of these years is presented below in figure 7. It is interesting to note the obvious increase in road ways leading out of the region.

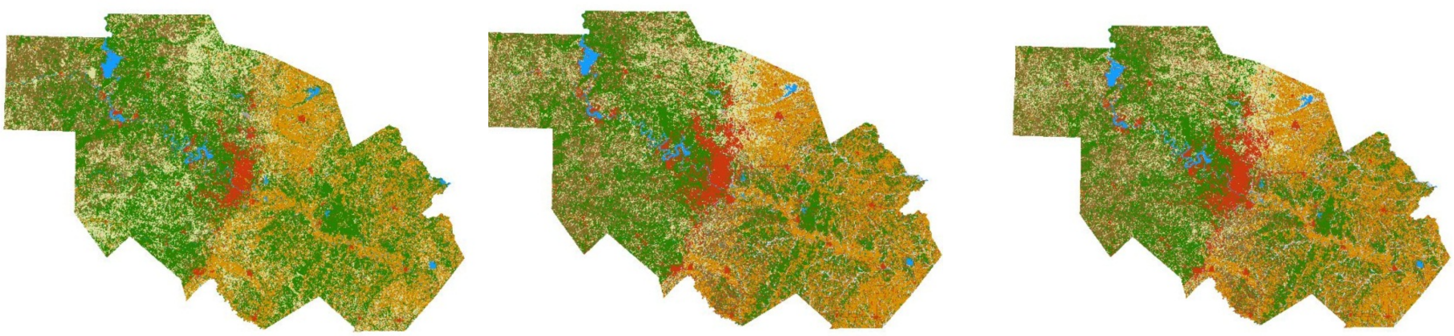


Figure 7 Single value land use in the region. Left most image is 1992 and proceeding to the right, 2001, 2006

While it is not proper to compare the breakdown of the 1992 data with the 2001 and 2006 an attempt at the break down of the 1992 data is provided alongside that of the 2001 and 2006 data in figures 8-10. These values have been attempted to be converted into surrogates for the values presented in the 2001 and 2006 data however this is not exact and should not be considered beyond a thoughtful query (MRLC Website).

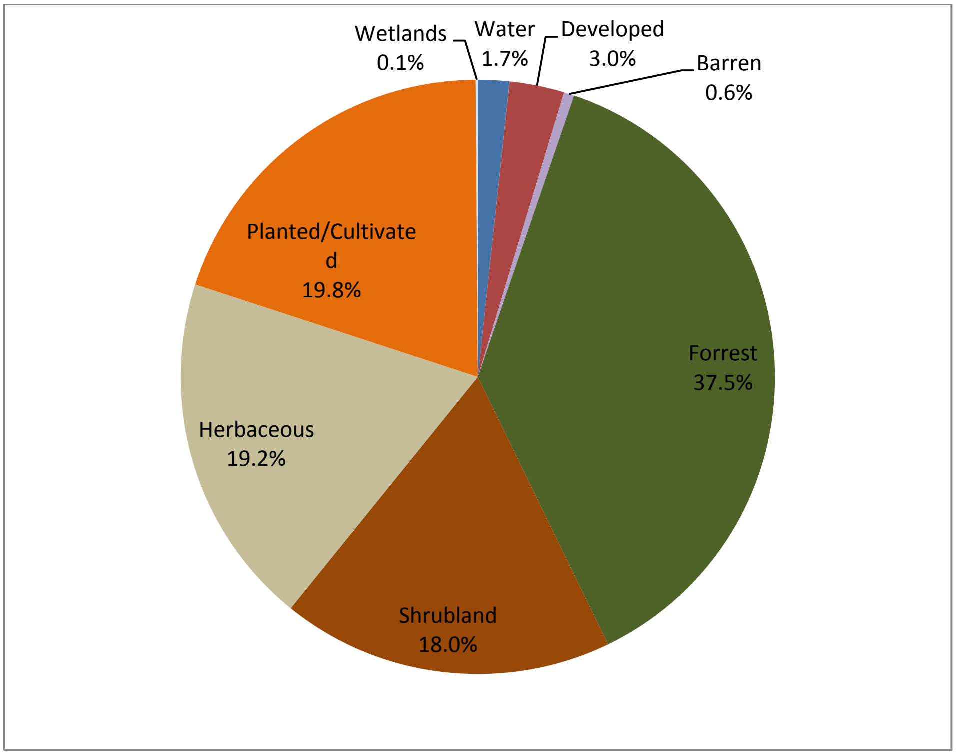


Figure 8. 1992 Converted breakdown Distribution

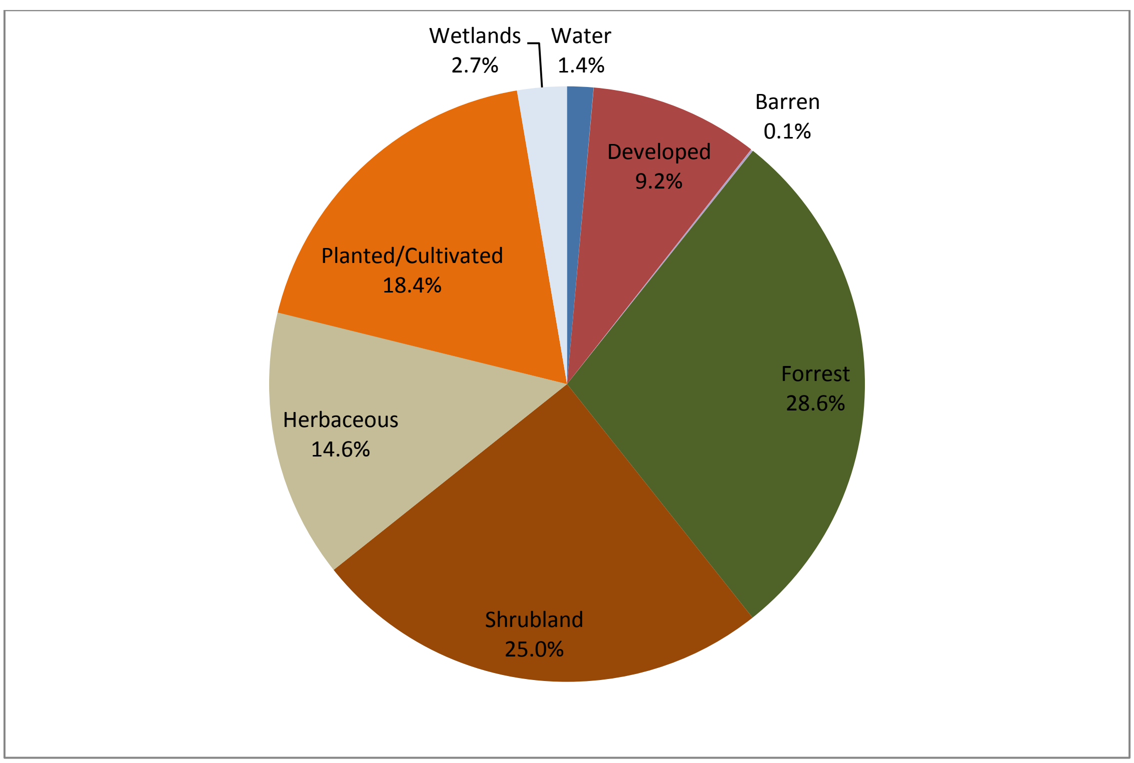


Figure 9 2001 Land use breakdown and distribution

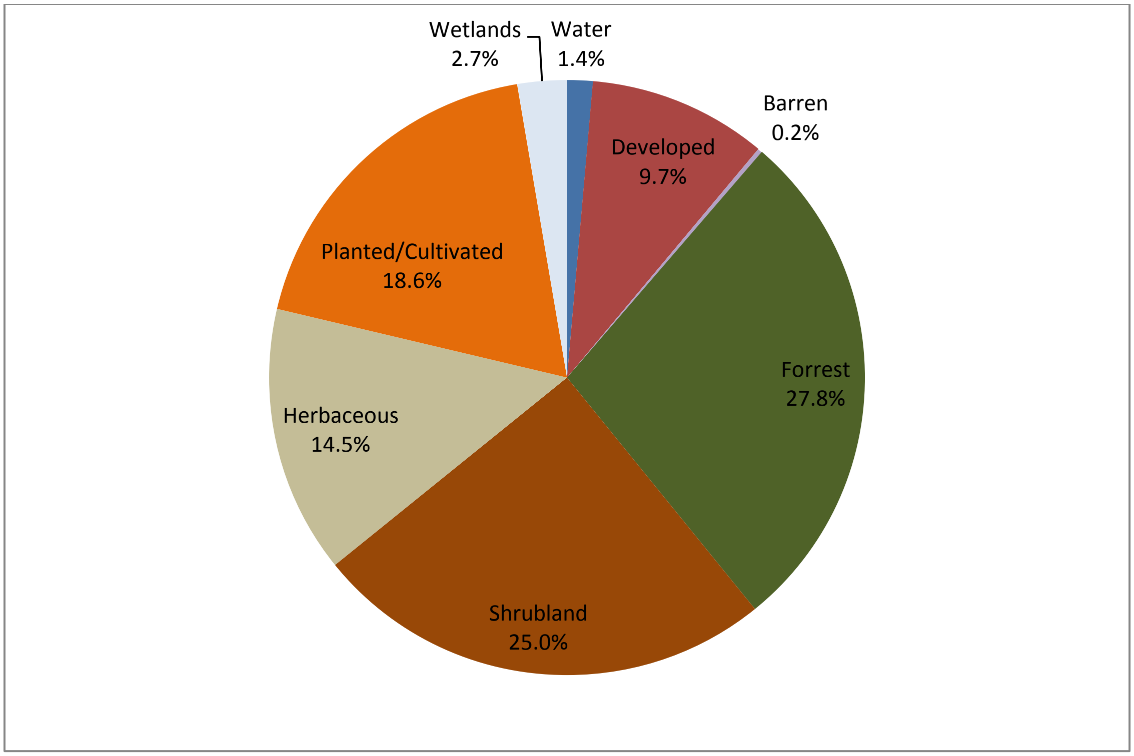


Figure 10. 2006 Land use breakdown and distribution

In these figures it can be seen that the developed land use is increasing. While it may not be completely accurate to examine the 1992 as presented it does give some sense of the loss of forest cover. To further understand how the land use changed, the 2001 and 2006 change product is evaluated. For this the one digit change product was examined. Note this will only give inter-category change. If a land value changed within its category the change is negated in this observation. The distribution of change is given below. This graph shows the change by number of 30m x 30m grid cells.

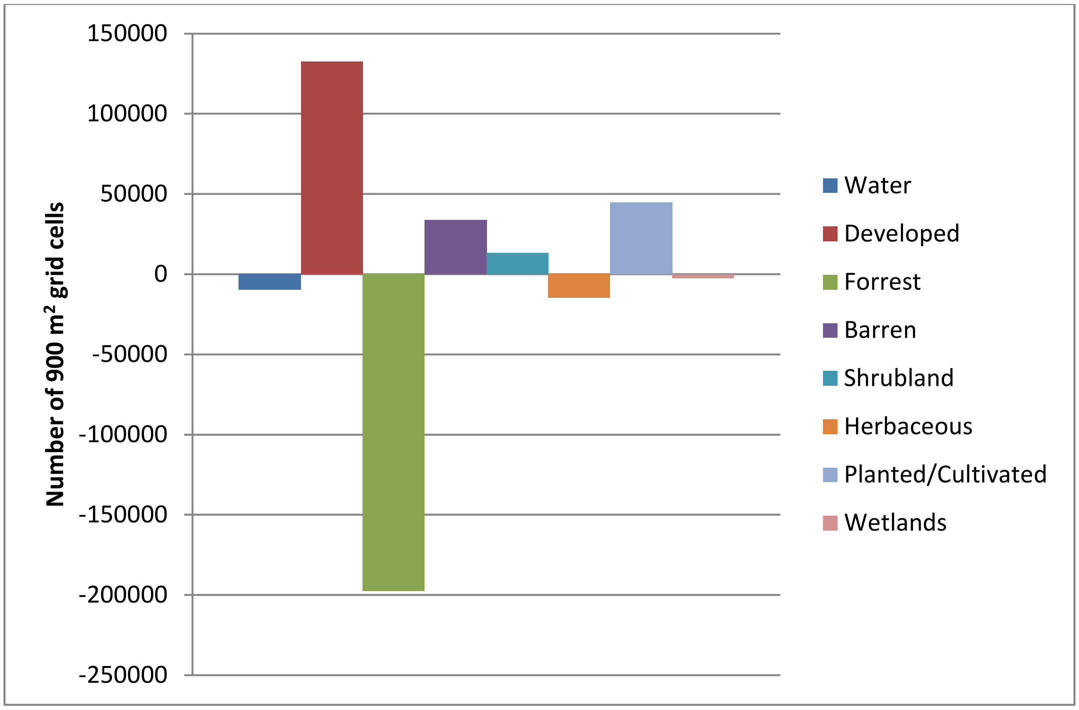


Figure 11. Change in Grid cells between 01 and 06

Further, the change product was analyzed using the full two digit value, leading to a 4 digit value overall. This was carried out using only the raw data because the number of code combinations are confusing to present graphically. The further analyses lead to the following results:

- 2.12% was inter-category change
- 0.04% was intra-category change
- 92% of the intra-category change was an increase in developed impermeable land
- 22.6% of inter-category change was an increase in developed impermeable land

To better understand where the change occurred maps of the change product are shown for bother inter and inter/intra changes. After using a conditional to reassign all values greater than 0 (a binary conversion) such that all change product cells have the same value, the inter-category change could be subtracted from inter/intra category change using eqn4. In this case if both cells were changed between the years (a value of 1) then the resultant was that they had a value of 0, and were equivalent to no change. The results are shown in figure 12.

Eqn 4. “o1o6cg4bi”-“o1o6cg2bi”

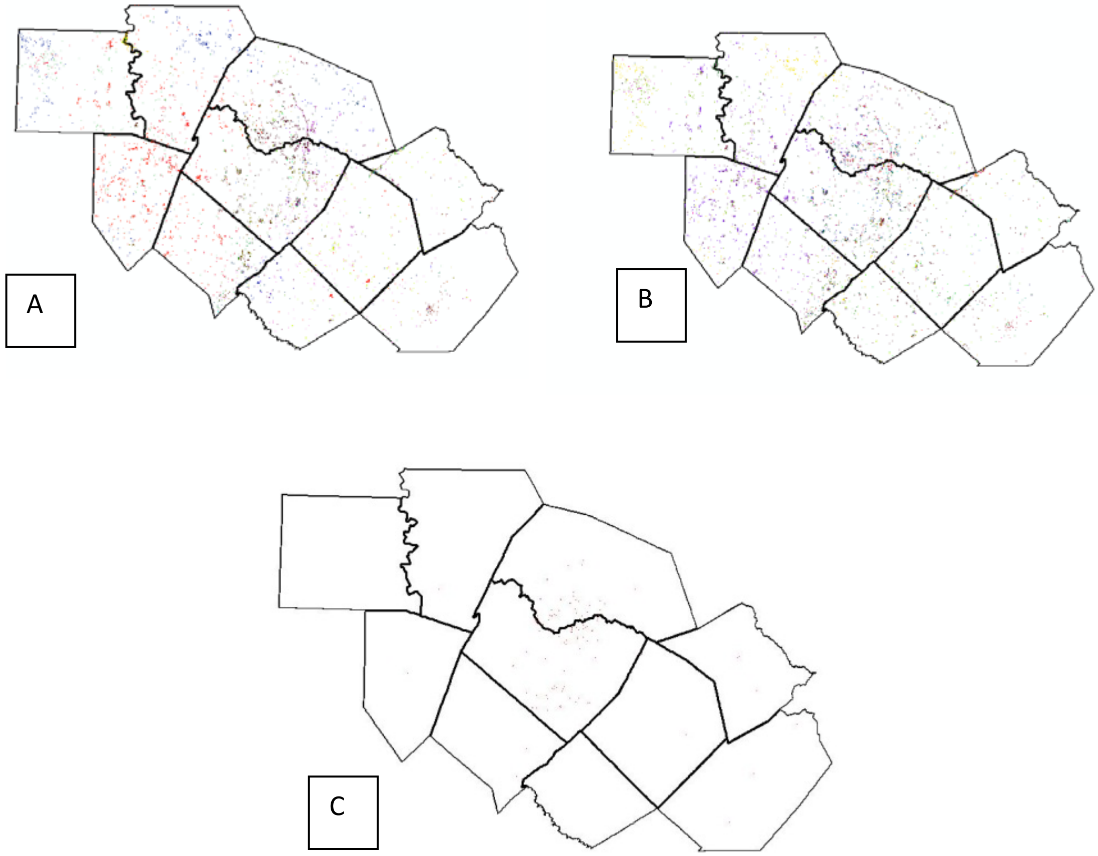


Figure 12. 2001-2006 Change products A) inter-category change B) inter/intra- category change C) intra-category change

URBAN GROWTH

To examine only urban growth, the land use rasters were changed to detail only those cells with a value of 2 (urban land). This over laying these maps with a changing color scheme as shown in figure 13, details how the cells with an urban category have changed over time. This figure has the 1992 values on top in blue, the green values in the middle representing 2001 and the red layer on the bottom as 2006. If a red cell is visible, it would indicate that this cell was not considered urban until 2006. This gives an idea of how the city has expanded.

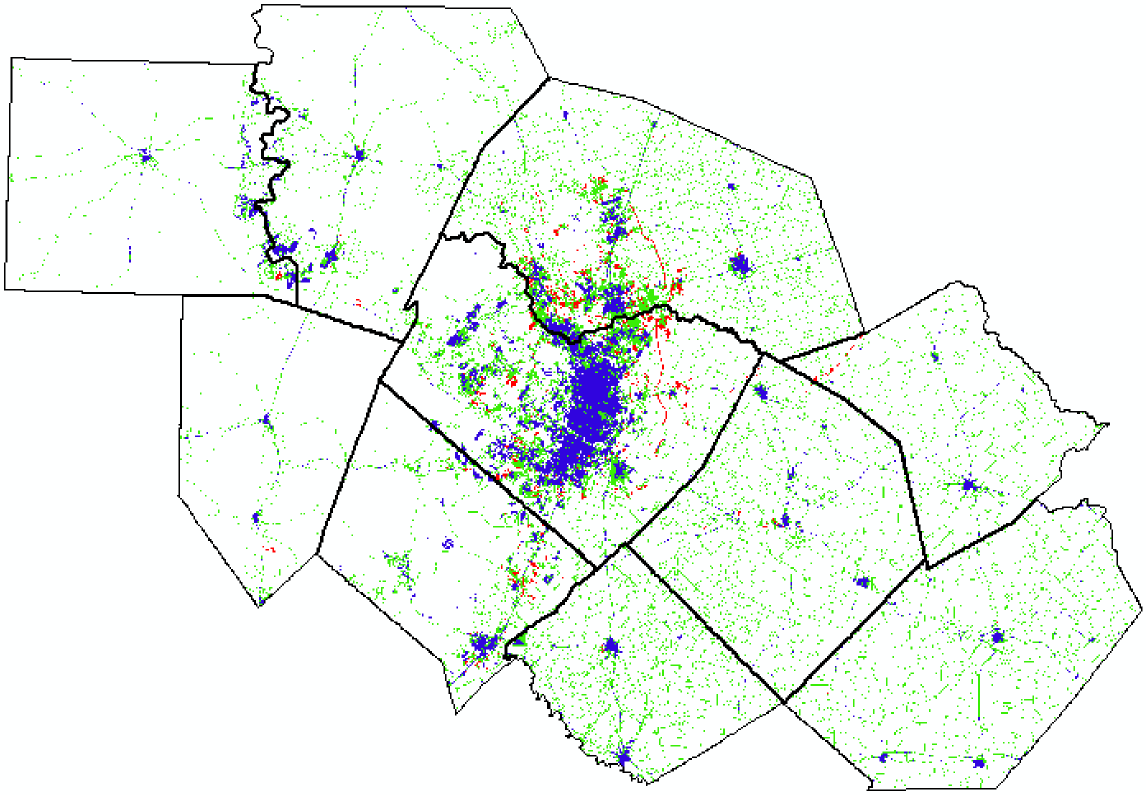


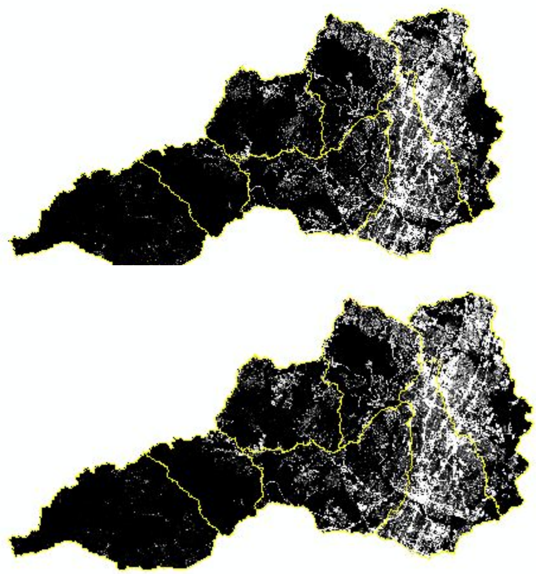
Figure 13. Combined urban growth. Blue values are 1992 data. Green is 2001. Red is 2006

WATERSHED AND SUBWATER SHED ANALYSIS

To further study the region and the impact of the urban development, an analysis of the impervious cover on subwatersheds was started. For this part of the project the sub City of Austin subwatershed was selected. This is in part due to the fact that it contains Bull Creek Park, a park with an impacted water body. The watershed was examined to map percent impervious cover relative to urban development. In figure 14 , it can be seen that the impervious land cover matches directly to the urban categorized land as wells as how the land use has changed over time.

Figure 14. Left to Right: Percent impervious, overlay of urban, 92-06 urban development

To understand how impervious cover has changed, the impervious area was cut out much like the urban development. Figure 15 details the percent impervious land cover change for the subwatershed between 2001 and 2006.



A. 2001 Impervious cover for the City of Austin subwatershed
   - 13.77% Impervious cover

B. 2006 Impervious cover for the City of Austin subwatershed
   - 14.55% Impervious cover

Figure 15. Imperviousness of city of Austin subwatershed

4. DISCUSSION AND CONCLUSION

The results of this study provide insight into how a city develops. In addition the study sheds some light into how a watershed develops due to urbanization. In looking at the breakdown and shift of the city, it is interesting to note that the major loss of land cover was forested land while shrub land stays mostly constant during this time period. Additionally, examining the development of new urban land, it is interesting to note that further development of same category (intra-category change) was minimal at best, at least relative to the imagining equipment. Examining the urban land scape changes gives some insight into how the city moves. If one examines the change products, figures 12 A and B, it is clear that there is a broad white spot in the center of the region. This broad white spot is the city proper. There is minimal change in this region while most of the development follows road systems to the north and south of town. A clear distinction between the 1992 data and the 2006 data is found in these figures. This highlights the incompatibility of the data sets and the increase in sensitivity of instrumentation more likely than actual urban growth in the outlying regions.

The city of Austin subwatershed is in excess of 10% total impervious cover. This is beyond limits specificed by numerous sources (Brabec 2002). What is not given in this percentage though, is the distribution of the impervious cover. As seen in the images in figure 15, this impervious cover lies farther to the east, so before understanding which streams are most impacted, an understanding of the distribution is necessary.

The growth of a city impacts the landscape in expands into. To properly understand how this growth can impact the ecosystem surrounding the city a complete knowledge of what the expansion is consuming is required. Modern tools such as GIS and remote sensing deliver the power to understand growth in a detailed fashion over a large area. Future work continuing off of the above study should continue and maybe with enough data points, a predictive plan could be built to understand which watersheds are at most risk to become impaired.

REFERENCES

1. Anderson, J.R. *A land use and land cover classification system for use with remote sensor data*. *Development* **2001**, (US Govt. Print. Off.: 1976).
2. Brabec, E., Schulte, S. & Richards, P.L. Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning. *Journal of Planning Literature* **16**, 499-514 (2002).
3. Booth, D., Urbanization and the Natural Drainage System – Impacts, Solutions, and Prognoses. *The Northwest Environmental Journal* **7**, 93-118 (1991)
4. MRLC Website: http://www.mrlc.gov/faq_lc.php (accessed on 11.20.11)

DATA

National Land Cover Data Set and Imperviousness Data Sets:

2006: http://www.mrlc.gov/nlcd06_data.php

2001: http://www.mrlc.gov/nlcd01_data.php

1992: http://www.mrlc.gov/nlcd92_data.php

Subwatersheds and Counties:

http://www.capcog.org/information-clearinghouse/geospatial-data/