Quantification of Forest Cover Change in the Pawcatuck River Watershed:

A Multi-Method Analysis

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December 2013

NRS533

Class Project

Introduction:

The detailed study of landscape pattern and change involves aggregating together several different methodologies and technologies. The field of remote sensing has resulted in the technology which allows for the ability to characterize and quantify the mosaicked patches of land, consistently altered by biology, climate, ecology and human interaction. Specific methods of landscape assessment result from this use of remote sensing to process ground cover imagery. The core steps to these methodologies as based on the analysis of different image dates as well as varying spatial, temporal and spectral scales. The overreaching purpose of these types of analyses is to assist in studies which work to build connections between landscape change, land use and land cover and the ecological processes taking place within the land.

Forest cover change in particular, especially decline in cover, can have many implications when it comes to landscape structure. “There has been a rising interest in developing and evaluating alternative methods of forest management to mitigate the current trend of deforestation and forest degradation (Gautam, 2004).” In the eastern part of the U.S. it had been predicted that forest cover would decline after a peak in cover around 1970 resulting from post-settlement agricultural abandonment (Drummond, 2010). Current declines in forest cover can be attributed to population increases as well as urban sprawl, increased land use and silviculture (Drummond, 2010). This reduction in cover is just the next phase to the ever changing system that is the landscape. Several consequences are predicted to develop over time due to increased reduction in forest communities. These include loss of soil nutrients, reduced carbon sequestration, loss of habitat and erosion just to name a few.

Deforestation has many ramifications on the productivity and quality of watersheds and systems which they encompass. “Deforestation changes hydrological, geomorphological, and biochemical states of streams by decreasing evapotranspiration on the land surface and increasing runoff, river discharge, erosion and sediment fluxes from the land surface (Coe, 2001).” The reduction in tree abundance leaves the hydrologic system vulnerable due to these factors. Increased erosion results from the root system surrounding streams and rivers to be removed. This increased erosion leads to more likelihood of flooding and increased stream velocities.

In order to create a more developed link between forest cover loss and changes and watershed dynamics, it is necessary to determine accurate quantifications of each part of this pattern-process relationship. It is not enough to perceive connections and use that as a basis to make decisions about land management practices or attempt to bring assumptions into decision making into the political world and other non-environmental sectors of society. As scientists we need to work diligently to make accurate conclusions about what we are researching and correctly comprehend the technologies we work with and methods we employ.

Objective:

Throughout this class we have read and assessed several studies which have worked with the inaccuracies which results from the use of remote sensing technologies and methods, particularly the processing of terrestrial imagery in relation to scale error. Through the analysis of several publications it became clear that, "An important unifying concept in dealing with heterogeneity and integrating ecological and geographical sciences is scale (Wu, 2004)." As well as remote sensing scientists, "The best imagery is the one whose resolution or pixel size, corresponds most closely to the grain of the landscape, where we define grain as the finest spatial resolution at which observations are made and which constitute ecological meaningful information (Csillag et al. 2000)" However, as part of the class we did not have the opportunity go into potential error that compared methodologies, specifically quantification of land cover change using varying processes.

Being that there is such great room for error in imagery scale selection, especially error that in itself is difficult to define and quantify I wanted to go about a comparison of methodologies where differences could be quantified. The purpose of this study was to perform a change cover analysis by processing land cover imagery from two different dates in determination of forest cover change. This quantification was done using two different GIS methods and results were compared.

Methods:

Data:

1. National Land Cover Dataset from 2001
2. National Land Cover Database from 2006
3. RIGIS Rhode Island Watershed layer

Software:

1. ArcMap10
2. Forest Fragmentation Tool: Add-On from the Center for Land Use Education and Research (CLEAR)

Procedure:

1. Pre-Processing of NLCD 2001 and 2006
   a. Extraction of Pawcatuck River Watershed (HUC 10) from each NLCD landuse/cover image
   b. Reclassification of NLCD subsets into non-forest (class 1) and forest (class 2) using forest as Anderson Level 1 forest classes of deciduous forest (41), evergreen forest (42) and mixed forest (43).
   c. Separation of the HUC 10 layer into each of its nine HUC 12 watersheds. Each is created to be its own selectable layer

2. ArcMap10 Processing
   a. Use of Raster Calculator to multiply NLCD re-class and each HUC 12 watershed to result in nine selectable layers of non-forest and forest rasters for each NLCD date.
   b. Conversion of pixel sums to area of forest in square meters for each NLCD data.
   c. Calculation of difference between dates of 2001-2006.

3. Forest Fragmentation Tool Add-On
   a. Download of forest fragmentation tool from CLEAR
   b. Adding tool to ArcMap10 toolbox.
   c. Using tool to individually process NLCD rasters re-classed by non-forest and forest.
   d. Use of Raster Calculator to multiply NLCD forest fragmentation outputs and each HUC 12 watershed to result in nine selectable layers of non-forest and forest rasters for each NLCD date.
   e. Conversion of pixel sums to area of forest in square meters for each NLCD data.
   f. Calculation of difference between dates of 2001-2006.

4. Comparison of Processes
   a. Calculation of absolute value of the difference in resulting forest cover in square meters for each process.

Discussion:

The purpose of this project was to compare the use of essentially different tools in the quantification of the same data. My general hypothesis was that there would be very little difference in the end results of each process due to the use of exact data extents and similarity in processing. Both processes resulted in the quantification of forest cover change in each of the nine HUC 12 watersheds of the Pawcatuck River Watershed. Inputs to each method was the NLCD 2001 and 2006 dataset which I reclassified by forest and non-forest using the re-class tool in ArcMap10. Each of the resulting forest and non-forest layers of the HUC 12 watersheds were created using the raster calculator tool in ArcMap. Differences in methods resulted from the forest and non-forest NLCD 2001 and 2006 layers being processed through the forest fragmentation tool. The output to this tool is a classification of the forest as patch, edge perforated and core forest.

I was quite surprised to examine the results of each method and notice significant differences between results for the change in forest cover for each HUC 12 watershed. As seen in the *Map of Different in Forest Cover Change between Both Methods* (Appendix 10) change between both methods was very inconsistent. Not only was there variance in amount of change between each HUC 12 watershed but there was also variation in direction of change (Appendix 5 and 8). In determining what resulted as forest in the forest fragmentation output, all categories of forest (Appendix 6) were combined. This tool can have many other uses and is specifically meant for quantification of varying types of forest cover as opposed to aggregation of entire forest area which is what was done in this project.

This project, while not overly complex, reiterates the need to validate results. The use of the remote sensing and GIS process is meant as an additional tool in the research of creating connections between all of the living and non-living pieces which interact and create the heterogeneous landscape. There are always going to be factors which cause for error and as remote sensing scientist we must do our due diligence to be aware of these errors and include mitigation in our planning and creation of methodologies.

Conclusion:

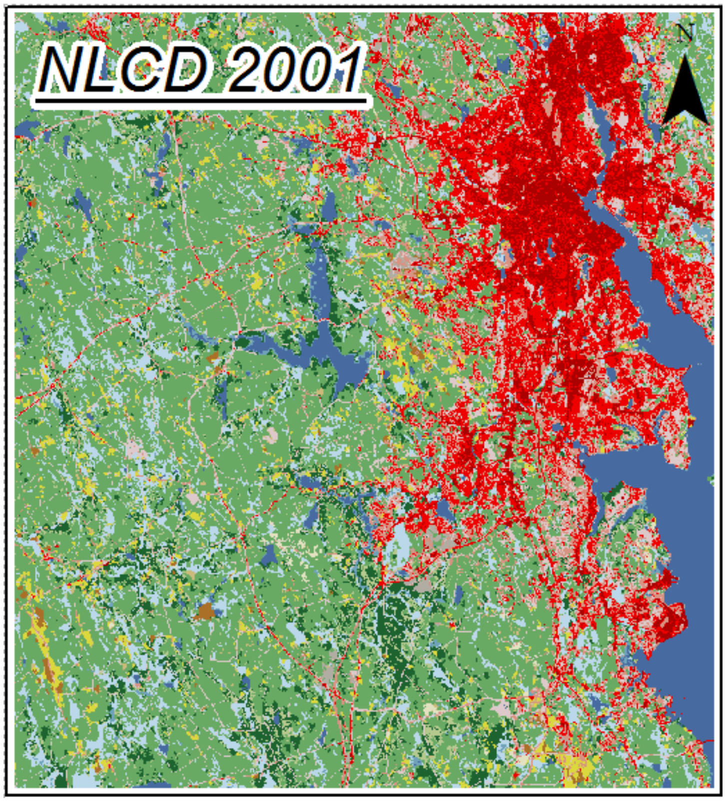
Statistical computations of the difference between methods was not done during this project. Going further I would like to examine these differences in outputs more closely to determine statistical variations and key areas of varying classifications. I believe the benefits of land change quantification continue to hold true. These processes create for the ability to quantify change and determine trends in land use and land cover over a large scale. However, we must always be aware that there will be error resulting when we attempt to make conclusions about the landscape through the use of scaled imagery and technologies which cannot include all factors that exist in the real world. As we move on to continue to analyze the world in which we interact we must keep this concept at the forefront of our research and continue to refine and improve our technologies and methodologies.

References:

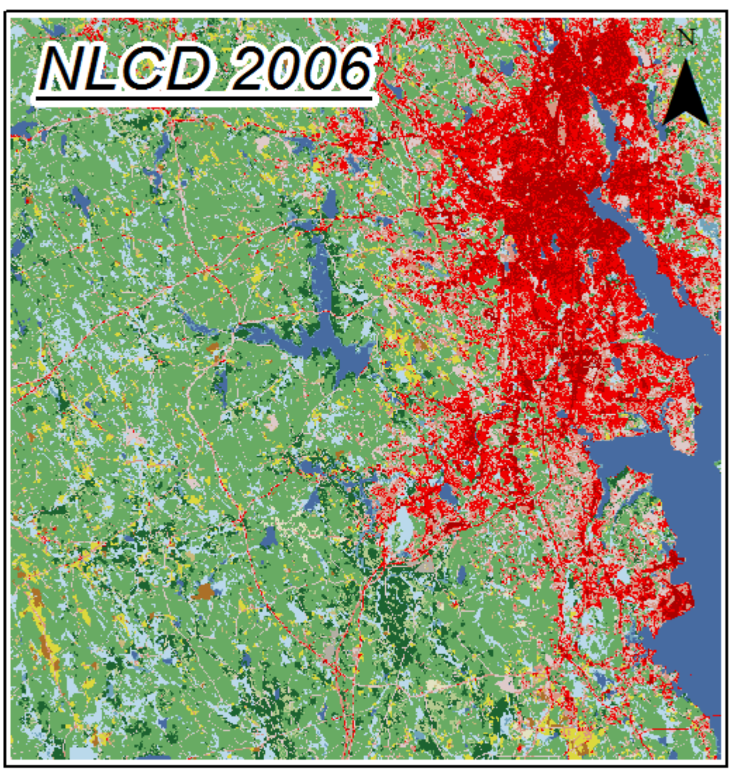
- Coe MT. The effects of deforestation and climate variability on the streamflow of the Araguaia River, Brazil. Biogeochemistry. 2011-09; 105:119-131.
- Csillag, F., M J. Fortin, and J. Dungan. On the limits and extensions of the definition of scale. 2000. Bulletin of the Ecological Society of America, 81: 230-232.
- Drummond, Mark A., Thomas R. Loveland. Land-use Pressure and a Transition to Forest-cover Loss in the Eastern United States, *BioScience,* Vol. 60, No. 4 (April 2010), pp. 286-298 Published by: University of California Press on behalf of the American Institute of Biological Sciences
- Gautam, Ambika P., Ganesh P. Shivakoti and Edward L Webb. Forest Cover Change, Physiography, Local Economy, and Institutions in a Mountain Watershed in Nepal, Environmental Management, Vol. 33, No. 1, pp. 48-61.
- Wu Jianguo. Effects of changing scale on landscape pattern analysis: scaling relations. 2004. Landscape Ecology, 19:125-138.
- NLCD 2001 Data http://www.mrlc.gov/
- NLCD 2006 Data http://www.mrlc.gov/
- RIGIS Data http://www.edc.uri.edu/rigis/data/

Appendix:

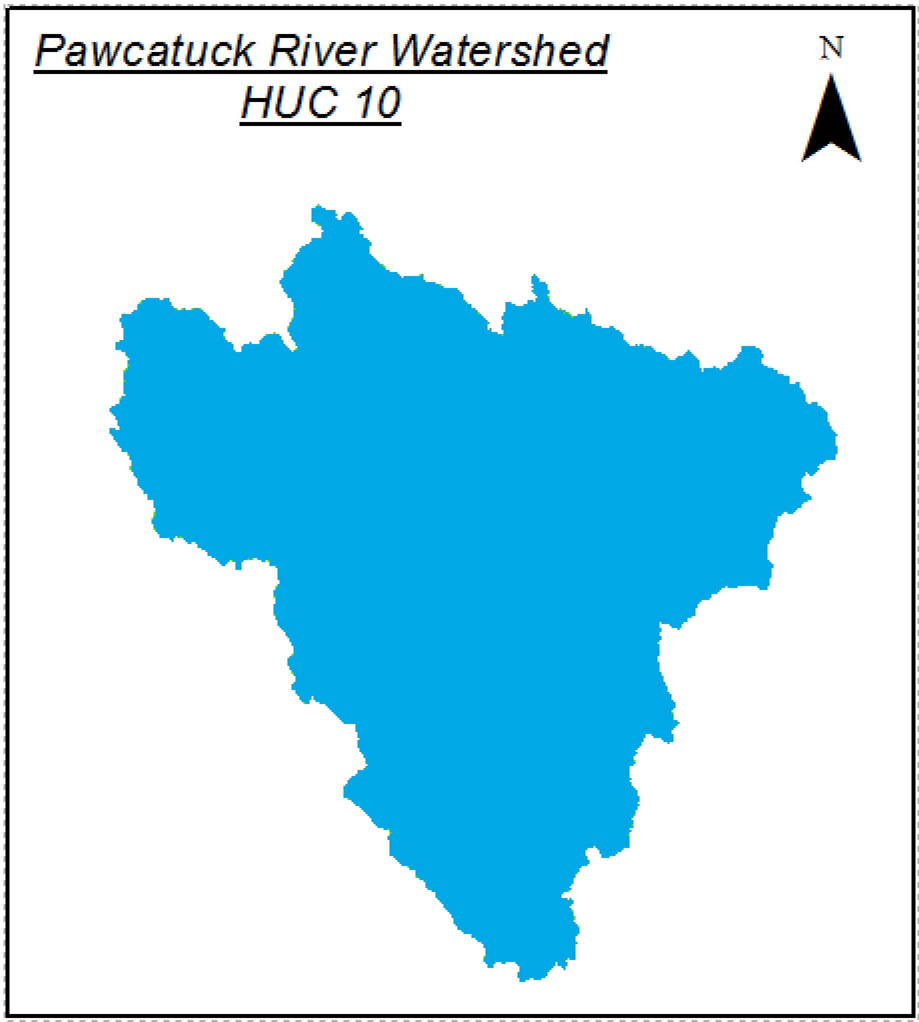
1. NLCD 2001 Raw Imagery



2. NLCD 2006 Raw Imagery



3. RIGIS Data: Pawcatuck River Watershed HUC 10

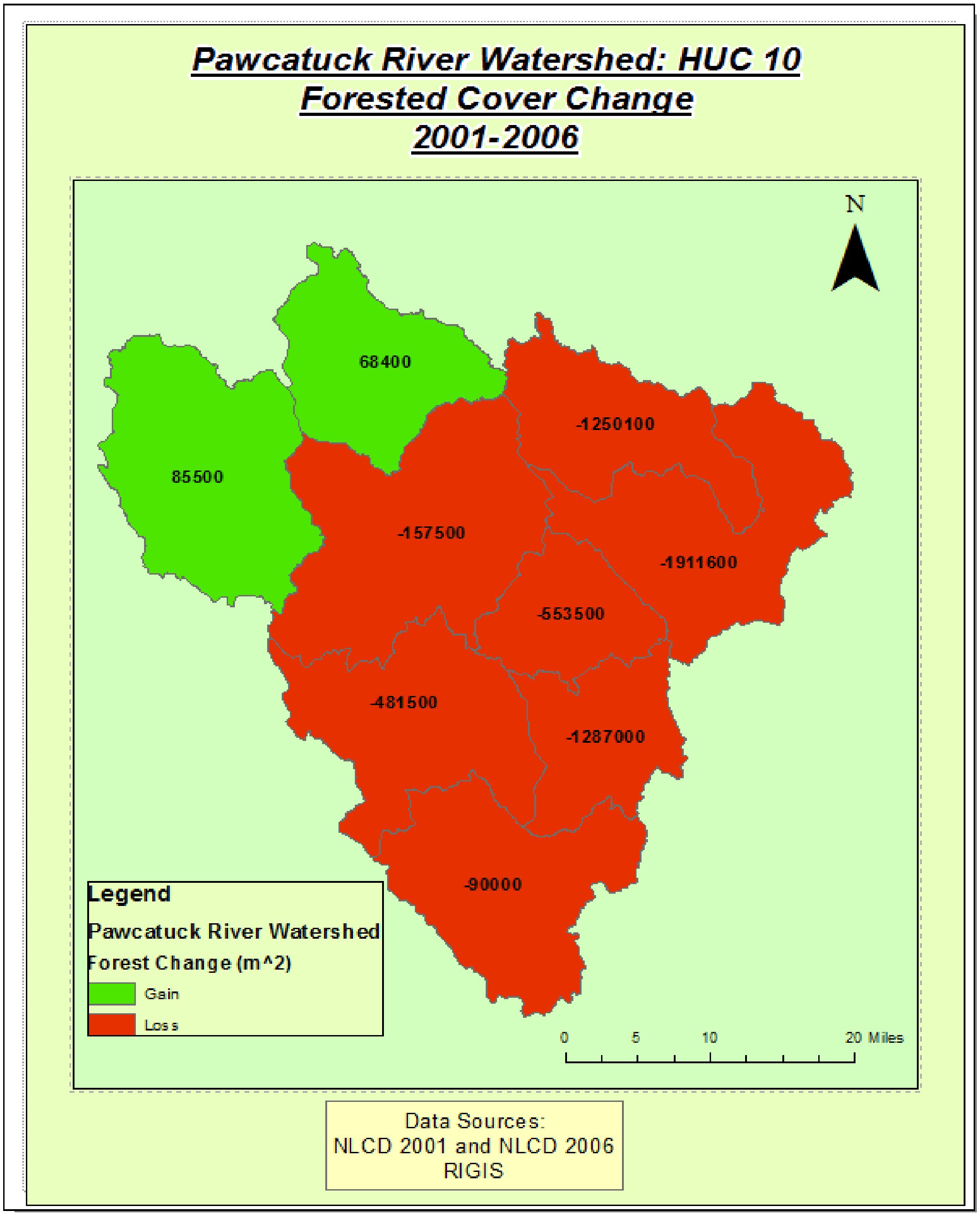


4. Table Results of Process 1 using ArcMap10

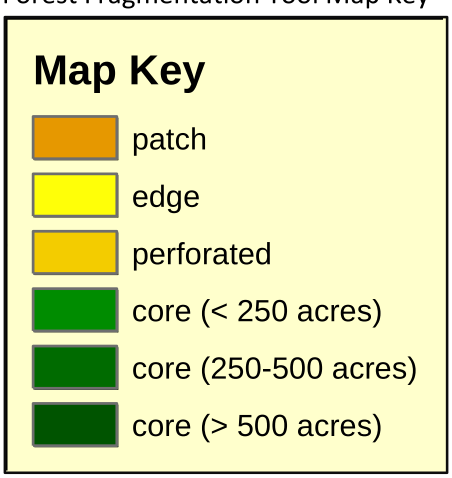
Forest Cover Change (2001-2006) Using ArcMap10

HUC10 Watershed	2001 Area (m^2)	2006 Area (m^2)	Difference (2006-2001) (m^2)
1	40554000	40622400	**68400**
2	61290900	61376400	**85500**
3	16125300	14875200	**-1250100**
4	65079900	64922400	**-157500**
5	14417100	12505500	**-1911600**
6	19492200	18938700	**-553500**
7	48639600	48158100	**-481500**
8	10673100	9386100	**-1287000**
9	53705700	53615700	**-90000**

5. Map of ArcMap10 Results



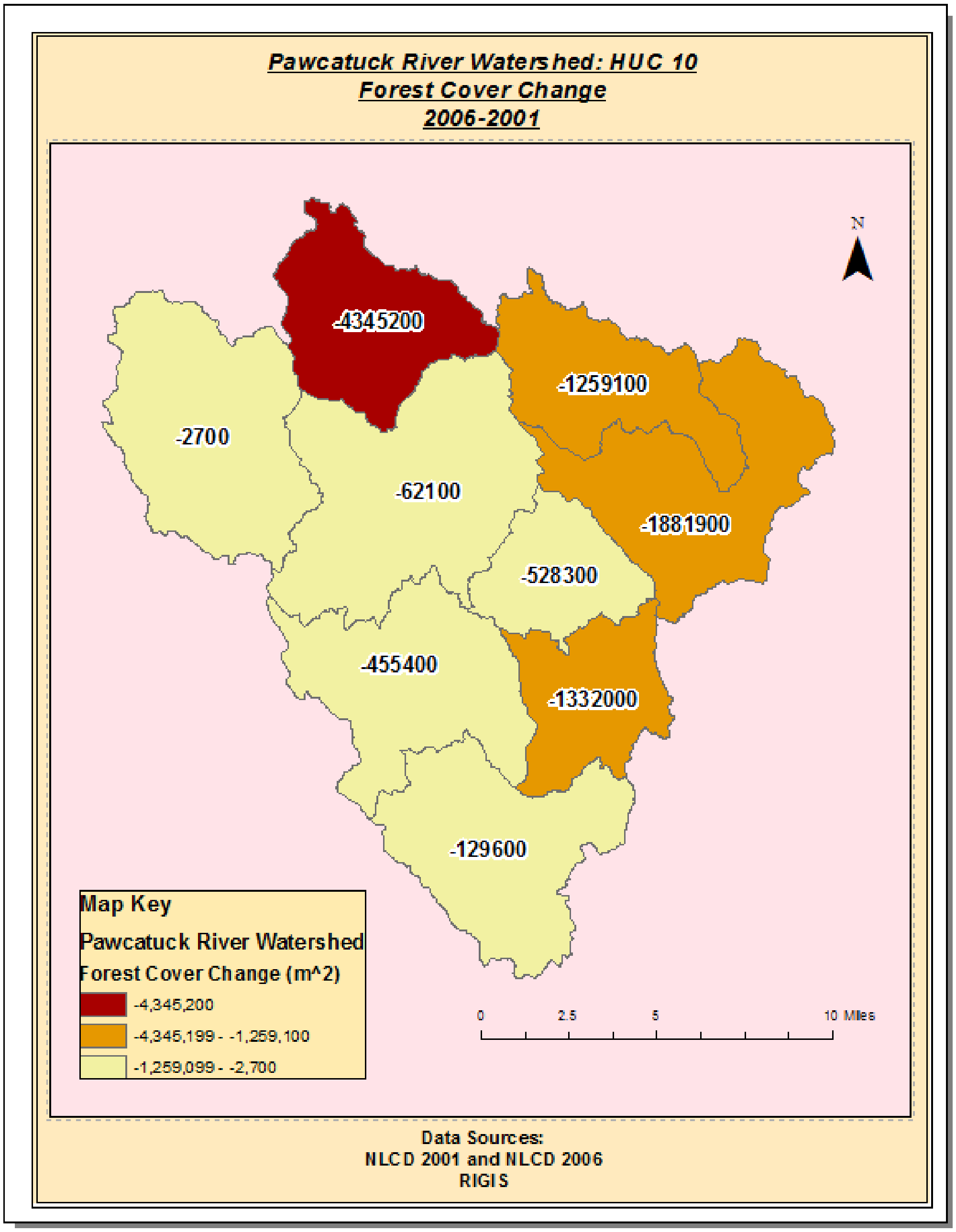
6. Forest Fragmentation Tool Map Key



7. Table Results of Process using Forest Fragmentation Tool

Forest Cover Change (2001-2006) Using CLEAR Forest Fragmentation Tool			
HUC10 Watershed	**2001 Area (m^2)**	**2006 Area (m^2)**	**Difference (2006-2001) (m^2)**
1	40689900	36344700	**-4345200**
2	61394400	61391700	**-2700**
3	161465100	14886000	**-1259100**
4	65043000	64980900	**62100**
5	144322500	12540600	**-1881900**
6	19497600	18969300	**-528300**
7	48654900	48199500	**-45400**
8	10704600	9372600	**-1332000**
9	3756100	53626500	**-129600**

8. Map of Forest Fragmentation Tool Results



9. Table of Difference in Both Methods

Difference in Methods			
HUC10 Watershed	**ArcMap10 (m^2)**	**Forest Fragmentation Tool (m^2)**	**Difference (Absolute Value) (m^2)**
1	68400	-4345200	**4413600**
2	85500	-2700	**88200**
3	-1250100	-1259100	**9000**
4	-157500	62100	**95400**
5	-1911600	-1881900	**29700**
6	-553500	-528300	**25200**
7	-481500	-45400	**26100**
8	-1287000	-1332000	**45000**
9	-90000	-129600	**39600**

10. Map of Different in Forest Cover Change Between Both Methods