Forest Fragmentation in Connecticut:
What Do We Know and Where Are We Headed?

James Hurd, Jason Parent and Daniel Civco
Laboratory for Earth Resources Information Systems
Center for Land use Education and Research
Department of Natural Resources Management and Engineering
University of Connecticut
Box U-4087, Room 308, 1376 Storrs Road
Storrs, CT 06269-4087

Mary Tyrrell
Yale School of Forestry and Environmental Studies
Yale University
205 Prospect St.
New Haven, CT 060511

Brett Butler
Forest Inventory & Analysis Program
USDA Forest Service, Northern Research Station
160 Holdsworth Way
Amherst, MA 01003

Introduction

At last year's Connecticut Forest Forum, there where several excellent papers that reviewed the history and trends of the forests in Connecticut: what we need to know, what we need to watch out for, and some things that we can do about it. This paper takes a next step in that dialogue as we attempt to summarize what we know about the condition of Connecticut's forest based on the few projects that have studied forest fragmentation in Connecticut. It is not the definitive word by far, but it is a compilation of the best data we have and should provide some valuable information as we continue to better inform and educate ourselves about the condition of Connecticut's forest.

Just What Is Forest Fragmentation

Let's get it out of the way. If you asked 100 people you would probably get 100 slightly (or sometimes drastically) different explanations of what forest fragmentation is. In this paper, we define forest fragmentation as "the process of dividing large tracts of forest into smaller isolated tracts surrounded by human modified environments." (Society of American Foresters). Basically, this is the process of removing trees and replacing them with another land cover that is not likely to go away anytime soon (think roads, buildings, yards, golf courses, etc.). To expand on this a bit, we searched the web for other definitions of forest fragmentation. The following is some of what we found. Forest fragmentation is:

- the breaking up of large, contiguous forested tracts into smaller or less contiguous tracts.

  (Southern Research Station, U.S. Forest Service, www.srs.fs.usda.gov/sustain/data/authors/glossary.htm)

- the splitting of forestlands into smaller, detached areas as a result of road building, farming, suburban development, and other activities. This can isolate wildlife populations, and may result in forested areas too small to meet the habitat requirements of some species. Wildlife corridors help to remedy this problem.

  (School of Forest Resources and Conservation, University of Florida, www.sfrc.ufl.edu/Extension/ssfor11.htm)

- "Islands" of forest habitat that are disconnected from other forests by agricultural lands, transmission lines, roads, developments, etc.

  (Texas Cooperative Extension, texaspinestraw.tamu.edu/glossary.html)

- the subdivision of large natural landscapes into smaller, more isolated fragments. Fragmentation affects the viability of wildlife populations and ecosystems.

  (Maryland, Department of Natural Resources, www.dnr.state.md.us/forests/gloss.html)

- the change in the forest landscape, from extensive and continuous forests of old-growth to mosaic of younger stand conditions.

  (StreamNET, Portland, OR, www.streamnet.org/pub-ed/ff/Glossary/glossaryforest.html)

- Islands of forest habitat that persist on the land when the intervening forest has been removed.

  (Department of Forest Resources, Clemson University, www.clemson.edu/extfor/publications/fortp19/definitions.htm)

Fragmentation *versus* Parcellation

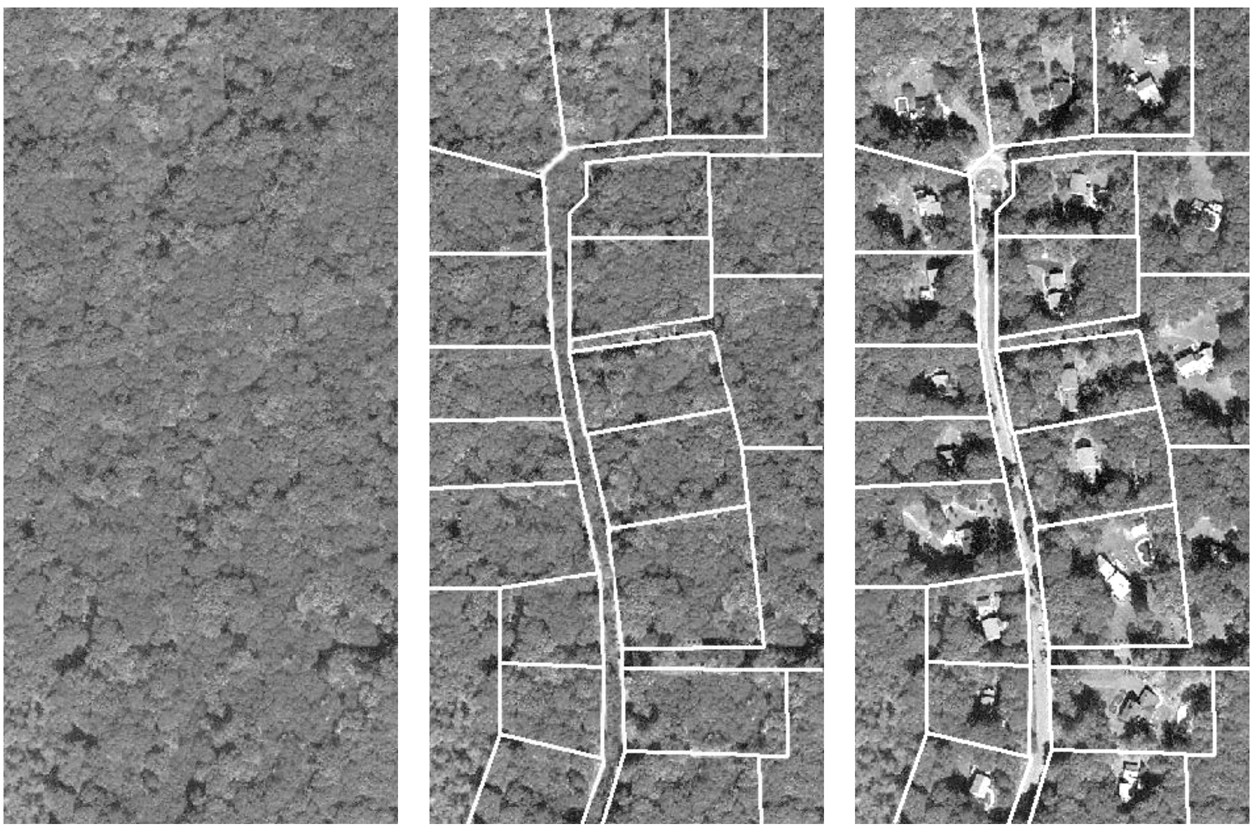
It is important to make the distinction between *fragmentation* and *parcellation*. An excerpt from the Yale Forest Forum Review[1] states it well:

> "Forest fragmentation, parcelization (parcellation), and land use conversion are complex phenomena resulting from dynamic interactions between the natural landscape and society's ever-increasing demands on the land. 'Fragmentation' occurs when large expanses of forests are converted into smaller tracts of forest

[1] Forestland Conversion, Fragmentation, and Parcelization: A summary of a forum exploring the loss of forestland and the future of working family forests. Yale Forest Forum Series Publication, Volume 3, Number 6, 2000. http://environment.yale.edu/documents/downloads/0-9/03.06.pdf

> surrounded by other land uses, causing a disruption in continuity of the natural landscape. The term 'parcelization' is used to describe changes in ownership patterns whereby large forested tracts are divided into smaller parcels, which may or may not remain contiguous forest."

To visualize this, take a look at Figure 1. On the left is a continuous tract of forest land owned by a single individual. Not fragmented, and not parceled! In the middle is an example of a forest tract that has been parceled with each parcel (outlined in white) owned by a different individual. As shown, the forest is still intact and connected. Not fragmented, but parceled. On the right, the parcels, owned by different individuals, have been developed resulting in the removal of trees and replaced with buildings, driveways, and lawns. The forest is now disconnected. Fragmented and parceled! As can be seen by this example, fragmentation is the physical removal of trees and the breaking apart of continuous forest tracts. Parcellation does not always result in fragmentation, but does increase the likelihood that the forest will become fragmented. If someone goes to the trouble of subdividing their property into smaller parcels, it is likely going to be for development. If not fragmented, parcellation does make forest management and forest



Continuous forest tract, single owner parcel.	Continuous forest tract, multiple owner parcels.	Discontinuous forest tract, multiple owner parcels.
Not Parceled and Not Fragmented.	Parceled but Not Fragmented.	Parceled and Fragmented.

Figure 1. Comparison of forest fragmentation versus parcellation.

access (e.g., for recreation) more difficult because you now have to deal with more then one owner with each having their own idea of how to manage their property. In addition, an owner of a smaller lot is less likely to be able to pay for a professional forester to mange their property for harvesting or wildlife management.

What We Know About Connecticut's Forest

What do we know about the forests in Connecticut? Below we summarize results from a few studies of the forested landscape in Connecticut. The first two studies looked at current trends in forest fragmentation. Basically they answer the question "*where are we now?*" The last two studies try to project the future based on current land use and regulations. Basically they answer the question "*where are we going?*" These should serve as valuable resources as we inform and educate ourselves about the condition of Connecticut's forest and how we might want to change the way we conduct land use decision-making.

Facts About Connecticut's Forests*: Based on the USDA Forest Service's Forest Inventory and Analysis Data:* I doubt anyone would argue that Connecticut's forested landscape is integral to the state's ecological and social character. The forests provide the state's citizens with clean water and air, places to recreate and seek serenity, backdrops for their homes and everyday lives, and raw materials for forest products and firewood.

During the 19th century agricultural land use was at its peak and forest land cover was less significant in the state. Since then, and until relatively recently, the area of forestland reverting from agricultural land has outpaced the area of forestland being converted to other uses (think development). As such, there has been a net increase in the area of forestland. Now, development (and other conversions) is predominating and there is a net loss of forestland. Currently, forests cover 58% of the state's land area (1,770,000 ac ± 90,000 ac)[2] Although Connecticut is the 4th most densely populated state (702.9 people/sq mi)[3], it is also the 13th most densely forested.[4]

Although commercial (and non-commercial) forestry activities are still occurring, a predominance of the "harvesting" is due to land use conversions. The general lack of active forest management has resulted in a relatively even-aged forest across the state with an increasing number of large, mature stands. There is a general lack of early successional habitat in Connecticut as is the case in many other parts of the northeast. The state's average stand volume (2,001 ft^3/ac) is the 10th highest in the nation.

The fate of most of the state's forests lie in the hands of private individuals and corporations. Approximately 56 percent of the forestland in the state is owned by families and individuals. There are about 100,000 of these owners with holdings that range in size from 1 to more than

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[2] USDA Forest Service. 2006. Connecticut's Forest Resources, 2005. U.S. Department of Agriculture, Forest Service, Northern Research Station. (http://www.fs.fed.us/ne/fia/states/ct/ct_summary_2005.pdf)

[3] http://en.wikipedia.org/wiki/List_of_U.S._states_by_population_density.

[4] Smith, W. B., et al. 2004. Forest resources of the United States, 2002. St. Paul, MN, U.S. Department of Agriculture, Forest Service, North Central Research Station. Gen. Tech. Rep. NC-241. 137 p.

1,000 acres. An additional 21 percent of the forestland is owned by various corporations and associations.

In 1998 the U.S. Forest Service, Forest Inventory and Analysis program used photo-interpretation to assess forest fragmentation in Connecticut.[5,6] Using a systematic set of points covering the state, forest patch size, distance to nearest edge, distance to roads, and types of adjoining land uses were recorded.

The most common forest patch size was between 250 and 1,250 acres (Figure 2a). The highest percentage of large patches was found in the northeast part of the State *(i.e.,* Litchfield County; 17% of the points were located within forest patches of at least 2,500 ac).

The southwestern part of the state (i.e., Fairfield County) was the most fragmented. Not coincidently, it had a very high population density (>1,400 people/sq. mi.) and a high proportion of developed land (39% residential). More than 20% of the forestland in this area was in patches of 2.5 acres or smaller.

Most forestland in the State (68%) was within an eighth of a mile of another land use (*i.e*., forest edge) (Figure 2b). Nearly nine out of ten acres (86%) were within a quarter of a mile. The most common land use adjacent to forestland was agricultural land (60%) followed by developed land (24%).

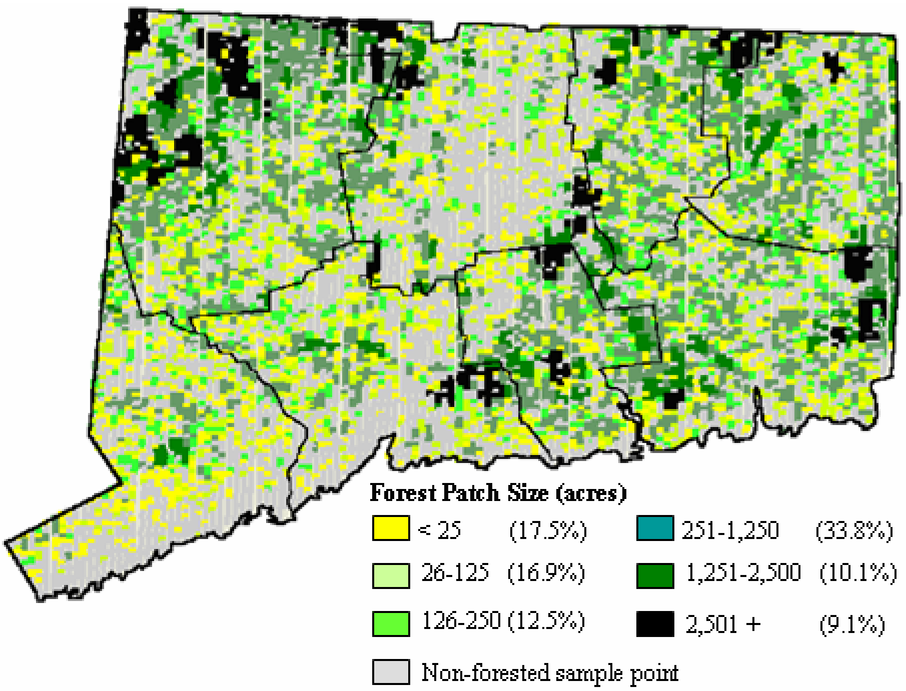
Connecticut's Changing Landscape*, University of Connecticut, Center for Landuse Education And Research (CLEAR)* – The Connecticut's Changing landscape (CCL) project looks at the change in land cover in Connecticut since 1985 (at roughly five year increments 1985, 1990, 1995, and 2002)[7]. The basis of the project is to identify land cover in Connecticut and characterize the change in land cover over time. At a minimum, this allows us to quantify how much of each land cover we have in Connecticut and what types of land cover we are gaining and losing over time. Beyond just quantifying changes in land cover, we can focus on specific aspects of the landscape, like forests and forest fragmentation.

Since land cover plays such an important role in the analysis of forest fragmentation for this study, we want to briefly touch on land cover and how our land cover maps were developed. There are many methods for developing land cover maps. These can range from hand drawing land cover boundaries on paper from a high resolution aerial photograph to advanced computer processing of digital imagery. The process we used falls under the latter category and comes under the discipline of remote sensing. Remote sensing is the science of acquiring information without physically coming into contact with the objects being studied. Specially designed sensors on satellites collect solar radiation reflected off features on the earth's surface. Different

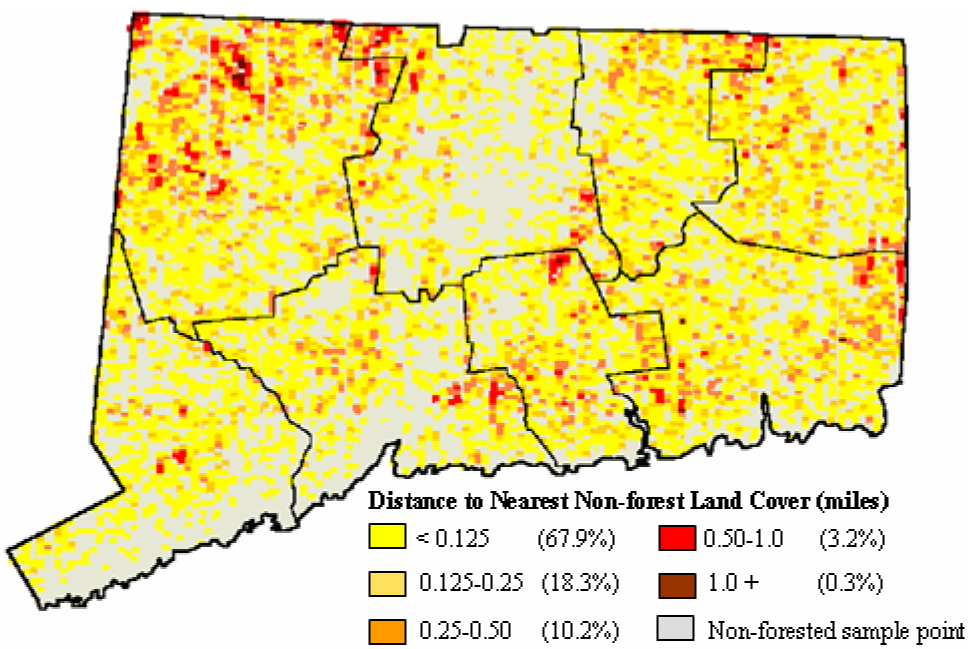
[5] Riemann, R. and Tillman, K. . 1999. FIA photointerpretation in Southern New England: a tool to determine forest fragmentation and proximity to human development. Res. Pap.

[6] Wharton, E. H., et al. 2004. The forests of Connecticut. Newtown Square, PA, U.S. Department of Agriculture, Forest Service, Northeastern Research Station: 35 p.

[7] Land cover mapping using satellite remote sensing data from 2006 is underway.



2a. Average size (acres) of contiguous forest patch at each sample point.



2b. Average distance (miles) from each sample point to the nearest non-forest land cover.

Figure 2. Analysis conducted by the US Forest Service looking at sample plots using aerial photo interpretation (U.S. Forest Service. 2004. The Forests of Connecticut)

amounts and wavelengths of radiation are reflected from different types of materials. For instance, water reflects solar radiation very differently from a parking lot, and coniferous trees reflect differently from deciduous trees. Unlike you, however, the satellite's sensor doesn't know what it is "seeing"; it just collects data. Interpreting these images to produce land-use and land-cover data is done on computers with the aid of specially designed image processing software.

For the CCL project, we utilized Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Mapper (ETM) satellite imagery. This sensor captures reflected solar radiation in the blue, green, red, near-infrared, middle infrared and another middle infrared (plus thermal) portion of the electro-magnetic spectrum at 30-meter spatial resolution (think of the image as a grid, and each grid has a reflective value for each portion of the electromagnetic spectrum listed above, for an area that covers 30x30 meters of the earth's surface). The reason for using this imagery for this project was because there exists a fairly extensive archive (back to 1982 when the first TM sensor was launched), there are enough spectral bands to distinguish among most features on the earth's surface, a single Landsat scene covers most of the Connecticut area of interest, and the file size is easily manageable. Several image processing techniques were used to generate the final classification. The specifics are beyond the scope of this paper, but rest assured, the utmost care was taken to create a classification that is as reasonably accurate as possible (given the source data characteristics and time). The classification scheme consists of developed (further divided into high, medium, and low density), turf & grass, other grasses & agriculture, deciduous forest, coniferous forest, water, non-forested wetlands, forested wetland, tidal wetlands, barren, and utility right-of-ways (which was digitized directly from the Landsat image where visible in the imagery). For the table below, which shows the area of land cover for each date, the categories were condensed as follows: **Forests** (deciduous forest, coniferous forest, forested wetland), **Anthropogenic Features** (developed, turf & grass, other grasses & agriculture, utility right-of-ways), **Hydrologic Features** (water, non-forested wetlands, tidal wetlands), and **Barren Land**.

Table 1. Connecticut statewide area of land cover for each of four dates.

	Connecticut Statewide Land Cover Area (acres)							
	1985	**%**	**1990**	**%**	**1995**	**%**	**2002**	**%**
Forests	2,004,624	62.96	1,948,208	61.19	1,920,105	60.31	1,886,426	59.25
Anthropogenic Features	1,024,426	32.18	1,072,874	33.70	1,095,507	34.41	1,126,908	35.39
Hydrological Features	132,603	4.16	136,388	4.28	134,694	4.23	132,192	4.15
Barren Land	22,239	0.70	26,422	0.83	33,585	1.05	38,365	1.20

Using this land cover as the basis for forest fragmentation analysis, a forest fragmentation model developed by Kurt Riitters and others[8] was modified to work with our Landsat derived land cover maps. This model generates categories that describe the type of forest fragmentation condition that exists for a given forest pixel based on an analysis *window* of a given size. These fragmentation categories are:

[8] Riitters, K., J. Wickham, R. O'Neill, B. Jones, and E. Smith. 2000. Global-scale patterns of forest fragmentation. Conservation Ecology **4**(2): 3. [online] URL: http://www.consecol.org/vol4/iss2/art3/

- Core forest - all the pixels in the surrounding window are forest.
- Perforated forest - most of the pixels in the surrounding window are forested, but some appear to be part of the inside edge of a forest patch, such as would occur if a small clearing or house was built within a continuous tract of forest.
- Edge forest - most of the pixels in the surrounding window are forested, but some appear to be part of the outside edge of forest, such as would occur along the boundary of a large urban area, or agricultural field.
- Transitional forest - about half of the cells in the surrounding window are forested and these may appear to be part of a patch, edge, or perforation depending on the local forest pattern.
- Patch forest – very few forest pixels are in the surrounding window and those that are contribute to a forest patch on a non-forest background, such as a small wooded lot within an urbanized region.

Table 2 provides the results of the forest fragmentation analysis applied to each date of land cover. It is important to understand that analysis windows of different sizes will produce different results. Smaller windows will capture higher frequency patterns at a more detailed level whereas larger window sizes will capture lower frequency patterns. Each window size will tell a different, but related story. Based on these results, we can begin to quantify and qualify current trends in forest fragmentation in Connecticut.

Table 2. Results of Connecticut statewide forest fragmentation model on four dates of land cover using three different analysis window sizes.

	Forest Area (acres)							
	1985	**%**	**1990**	**%**	**1995**	**%**	**2002**	**%**
Total Forest	2,004,624	62.96	1,948,208	61.19	1,920,105	60.31	1,886,426	59.25
9x9								
Core	726,810	36.26	664,024	34.08	623,264	32.46	576,764	30.57
Perforated	434,400	21.67	441,965	22.69	452,795	23.58	463,528	24.57
Edge	576,993	28.78	566,403	29.07	561,829	29.26	555,765	29.46
Transition	173,889	8.67	179,555	9.22	183,621	9.56	189,045	10.02
Patch	92,551	4.61	96,258	4.94	98,592	5.13	101,316	5.37
27x27								
Core	121,616	6.07	98,496	5.06	80,216	4.18	67,778	3.59
Perforated	340,010	16.96	331,101	17.00	324,851	16.92	308,100	16.33
Edge	1,192,640	59.49	1,149,963	59.03	1,134,322	59.08	1,115,968	59.16
Transition	240,063	11.98	249,760	12.82	257,289	13.40	265,171	14.06
Patch	110,273	5.50	118,875	6.10	123,415	6.43	129,405	6.86
81x81								
Core	2,287	0.11	348	0.02	296	0.02	261	0.01
Perforated	78,628	3.92	69,010	3.54	57,182	2.98	45,632	2.42
Edge	1,543,066	76.97	1,470,370	75.47	1,438,533	74.92	1,396,203	74.01
Transition	27,3265	13.63	289,958	14.88	299,870	15.62	313,936	16.64
Patch	107416	5.35	118,561	6.09	124,264	6.47	130,433	6.91

The most obvious statistic is the loss of forest over time from 1985 to 2002. During that period, Connecticut lost about 118,000 acres of forest. But what does that mean in terms of forest fragmentation? The results of the forest fragmentation model help to shed some light on the issue.

Examining the results of the 9x9 analysis window, core forest contains the largest percentage of forest cover (more than 30% for each date), but this is decreasing over time with about 150,000 acres of core forest lost between 1985 and 2002. Perforated forest is increasing in area as are transition and patch forest. Edge forest actually shows a decrease in area, but an increase in percent contribution to forest cover. What these results are showing us is that significant forest conversion in Connecticut is occurring away from existing developed areas. Significantly less core forest and more perforated forest identify a trend of urban sprawl where we are clearing small lots out of the larger forested landscape. In addition, the loss of edge forest area and an increase in transition and patch forest area indicate the breaking apart and shrinking in size of forest patches among and adjacent to already developed areas.

The 27x27 analysis window identifies an interesting pattern. Between 1985 and 2002 nearly half the core forest was lost, about 54,000 acres. Granted, there was not a lot of core forest to begin with -- about 6.1% of the forest area, due to the size of the analysis window -- but this again shows us that we are developing away from existing developed areas. Perforated forest is showing a decrease in area, likely a function of the analysis window size. Edge forest is the dominant forest feature comprising about 59% of the forest land cover. Transition and patch forest are increasing in area, again indicating the carving up of the forest around existing developed areas. What these results are showing us is that core forest is becoming a less dominant land cover feature as forest patches decrease in area.

Lastly, the 81x81 analysis window highlights how ubiquitous the non-forest features are in Connecticut. At this analysis window size, virtually no core forest exists. If you remember the definition of core forest, all the pixels in the analysis window must be forested. If even one pixel is not forested, the center pixel will not be considered core forest. Like the 27x27 analysis window, perforated forest is decreasing, edge forest is dominant, over 70%, and transition and patch forest are increasing, indicative of forest being converted to smaller and more isolated patches. Figure 3 provides results of the forest fragmentation model for each of the three analysis window sizes.

Impact of Roads on Connecticut Forests (2002 Land Cover) - Following research conducted at the national level[9] and a more localized evaluation in Massachusetts[10], we wanted to look at the potential impact that roads might have on the forest ecosystem in Connecticut. Using the 2002 land cover as the base map, and a roads layer provided by the Connecticut DEP, we measured the proximity of Connecticut forests to Connecticut roads. For a brief overview, in the national study it was found that about 20 percent of all conterminous U.S. land area was within 400 feet of a road. Conversely, only 18 percent of the land area was more than 3,300 feet from a road.

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[9] Riitters K.H. and J.D. Wickham. 2003. How far to the nearest road? *Front Ecol Environ* 2003 : 1(3), pp125-129.
[10] Forman, T.T. and R.D. Deblinger. 2000. The ecological road-effect zone of a Massachusetts (U.S.A.) suburban highway. *Conservation Biology*: 14(1) pp. 36-46.

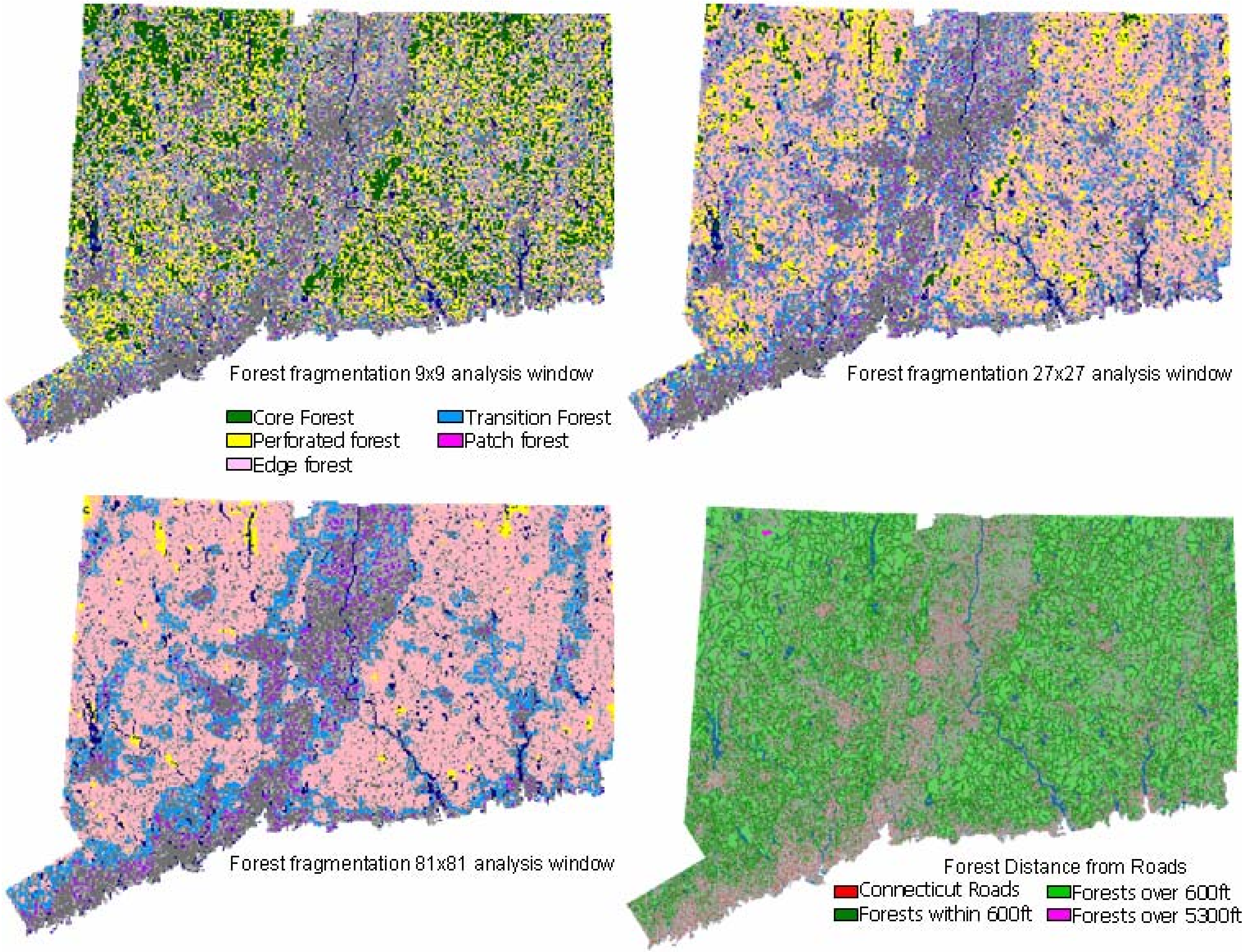

Figure 3. Results of the forest fragmentation model performed on 2002 land cover using different analysis window sizes and proximity of Connecticut forests to roads.

Based on road statistics, spatial distribution of roads, road density, traffic volumes and so forth, it was estimated that impacts by roads could extend out as much as 500 feet from a road. That would impact about 15 – 22 percent of the conterminous U.S. land area. The study in Massachusetts found that the impact of roads could extend up to 1,000 feet from roads depending on the size of the road, adjacent land cover type and ecosystem. In summary, it was observed that you can expect a detrimental effect if more then 60 percent of the land area is within 1,200 feet of a road.

How does Connecticut compare? Looking at Table 3 and Figure 4 we can see that approximately 43 percent of Connecticut's forest is within 500 feet of a road and is most certainly going to be impacted somehow by the road network in the state. This could extend as far as 71 percent of the forest if we use the 1,000 foot threshold. In addition, since more then 60 percent of Connecticut forest is within 1,200 feet of a road we are likely to see some detrimental impact to the overall forest ecosystem. Again, these are generalizations, but sobering none-the-less.

Table 3. Proximity of Connecticut's forests to roads.

	Area (acres)	**% of CT Forests**
Forests within 100ft	132,205	7.2%
Forests within 500ft	799,007	43.2%
Forests within 600ft	930,205	50.2%
Forests within 1,000ft	1,321,094	71.4%
Forests within 1,200ft	1,453,456	78.5%
Forests over 5,300ft	854	0.05%

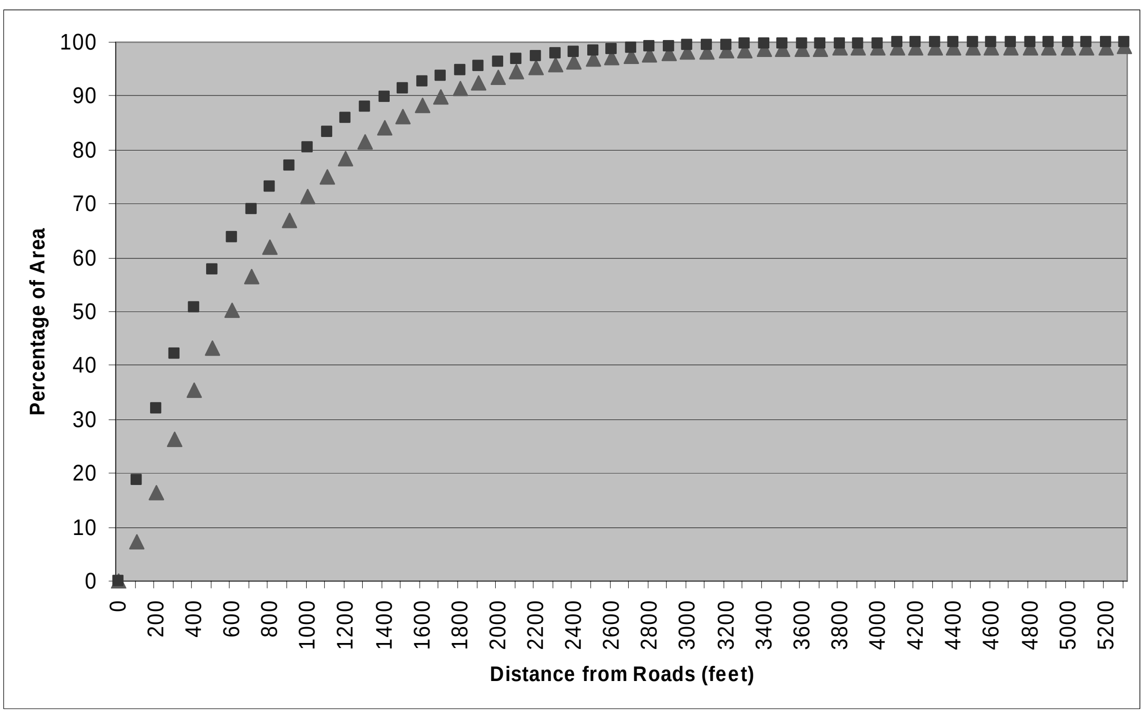

Figure 4. Proportion of total surface area of Connecticut (black squares) and forest area (grey triangles) as a function of distance from roads.

What Can We Say About the Future of Connecticut's Forest?

Dynamic Models of Land Use Change in Northeastern USA[11] *: Developing Tools, Techniques, and Talents for Effective Conservation Action* - This study covers most of the Thames River Watershed and adjacent towns, almost 1900 square miles of rural and forested land in northeastern Connecticut and south-central Massachusetts. An estimated thirteen percent of the watershed is permanently protected from development, either in the form of public land or conservation easements. Known as the "Last Green Valley[12]," it is one of the last largely rural areas remaining in the highly-developed section of the east coast between Boston and Washington, D.C. It is home to the Quinebaug Highlands, a 269 square mile region of mostly privately owned forestland, identified as one of Connecticut's Last Great Places by The Nature Conservancy; the 4,000 acre Norcross Wildlife Sanctuary in Massachusetts; the Yale Myers Forest, a 7,000 acre research and teaching forest; several state forests; and the Pawcatuck Borderlands, a 200 square mile area of largely contiguous forest along the Connecticut-Rhode Island border. The Quinebaug-Shetucket Rivers Valley was declared a National Heritage Corridor in 1994 to help with efforts to protect the unique history and rural character of this New England valley.

This study was designed to test the ability of a dynamic simulation modeling tool—GEOMOD—to illustrate local and regional land use changes, both in the recent past and in the near future. GEOMOD, developed by researchers at the State University of New York College of Environmental Science and Forestry (SUNY ESF), predicts the rate and spatial pattern of land conversion based on past land use change.

Since fragmentation and parcellation are very difficult to quantify, especially over a large land area, we have used change in forest cover as a surrogate measure of the extent to which the forest has become fragmented and parcelled. This is a reasonable approach in the northeastern United States, where the situation with change in forest cover is not so much large extensive clearing of forestland, but a patch–by-patch clearing for development. Forest fragmentation—conversion of a large, continuous forest into a scattering of small patches—can be readily seen in satellite imagery. It may not, however, be visible from the local roads and thus often remains hidden from public view and consciousness. Parcelization is even less obvious, as property lines don't show on the land. Unless the new owners build roads and houses, the change may be difficult to discern.

Of the study area's 740,000 acres of forest not permanently protected from development, 7.4% has been lost since 1985. This may seem like a fairly low rate over 17 years, but it is the pattern that is most troubling. If the same trend continues, we project that the Thames Watershed and surrounding towns will lose an additional 64,000 acres of forest, scattered across the landscape, in the next 17 years. The forests are more fragmented as shown by the area-to-perimeter ratio which was 421:1 in 1985, dropping to 381:1 in 2002. However, our projections out to 2022 indicate that the future trend may result in an infilling of developed areas hence elimination of smaller forest fragments and a mathematically higher area-to-perimeter ratio, although the remaining patches would not be larger than they were in 2002.

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[11] http://research.yale.edu/gisf/ppf/dynamic_models/index.html

[12] To learn more about the Last Green Valley, visit http://thelastgreenvalley.org

Some towns remain virtually unchanged in forest cover, while others have lost 10–12 % of their forest. Considering only the land that is available for development, that is, excluding forestland permanently protected by government ownership or conservation easement, then the situation is even more dramatic. Fifteen towns have lost more than 10% of their unprotected forestland in the seventeen years between 1985 and 2002.

It is quite likely that these results overstate the amount of intact forest remaining. The land cover classification process (this study used the CCL four date land cover dataset), which uses 30-meter resolution satellite imagery, is much better at picking up concentrated development than low density rural development. For example, a housing subdivision with large lots and trees would show up as partial forest in the satellite imagery. However, this is no longer the same forested habitat for wildlife as a large tract of un-fragmented forest, nor is it a forest that can be managed for timber or other forest products.

The pattern of forest loss in this region is best predicted by distance from agricultural lands, soil type, and distance from urban areas. Population, casino development, and roads were somewhat less important drivers of land use change, as were most socio-economic factors analyzed. However, socio-economic factors, prior settlement patterns, and soil types are inter-related and thus probably co-dependent with the top three drivers.

Salmon River Watershed Example*: A University of Connecticut Master's Thesis Project* - Future changes to forest cover were simulated over a 30 year period for six Connecticut towns (Bolton, Colchester, East Haddam, East Hampton, Hebron, and Marlborough) that comprise a majority of the Salmon River watershed located in central Connecticut. Suburban development was assumed to be the major force driving forest change in this region. Locations of potential development were identified based on factors that were believed to influence the land's desirability for development (*e.g.*, soil type, proximity to existing roads). Areas that could not be developed, as indicated in the town zoning regulations, were excluded from the analysis (*e.g*.,. wetlands, flood zones, excessive slope, etc.). Specialized GIS software was used to simulate development by *populating* the study area with buildings in accordance with each town's zoning regulations and based on projected population growth. The buildings were assigned construction dates that reflected the desirability of their location – more desirable locations were assigned earlier construction dates. The 2002 CCL land cover map served as the starting point for the analysis and was modified using the simulation process to forecast land cover change to the year 2036. The forest fragmentation model was then used to quantify the types of fragmentation found in the forests of the simulated land cover map.

According to the simulation, overall forest cover in the area will decline by 3% over the next 30 years. Core forest will decline by almost 28% while perforated, edge, transitional, and patch forest will increase substantially (Table 4). Figure 6 compares forest fragmentation maps, for the study area, from the condition in 2002 to the predicted condition in 2036. The projected loss of interior forest and increase of the fragmented forest types are likely to be conservative

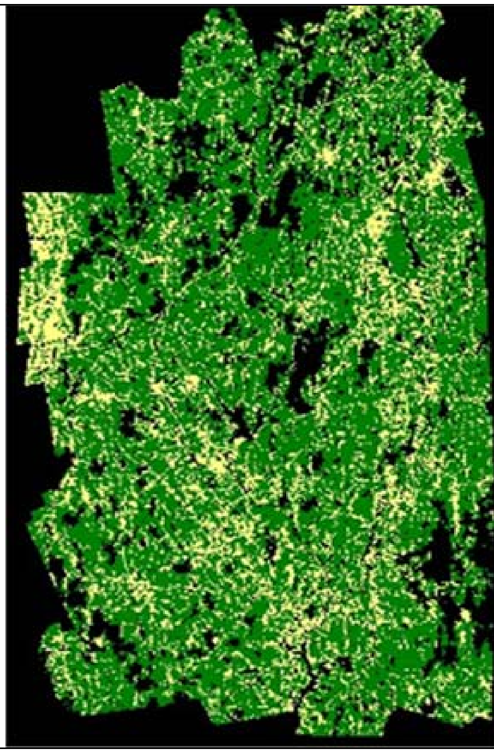
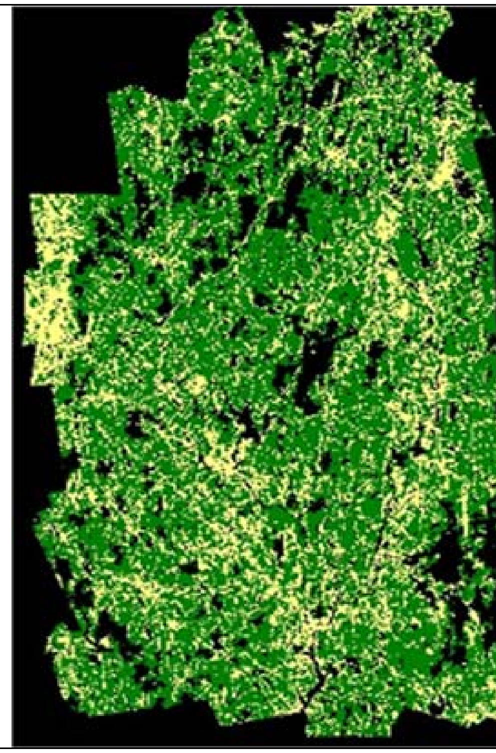
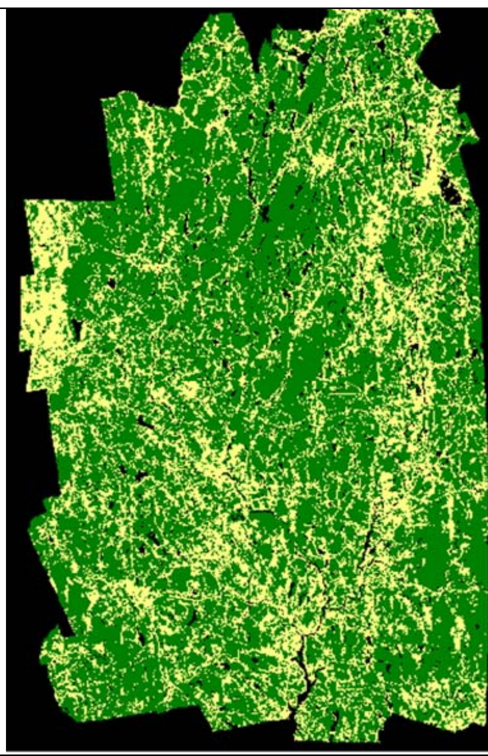
	
1985 (forest cover in green)	2002 (forest cover in green)
	
Predicted 2022 (forest cover in green)	*Risk* map

Figure 5. Current and projected forest fragmentation for the Thames River watershed in eastern Connecticut and risk map for future conversion from forest to development (red is most at risk to green least at risk).

Table 4. Forest fragmentation type change, in the study area, between 2002 and 2036.

Forest Type	2002 (acres)	2036 (acres)	Change (acres)	Change (%)
Core	55,887	40,423	-15,464	-27.7
Perforated/Edge	35,713	47,549	11,836	33.1
Transition	5,137	5,653	516	10.1
Patch	1,638	1,774	136	8.3

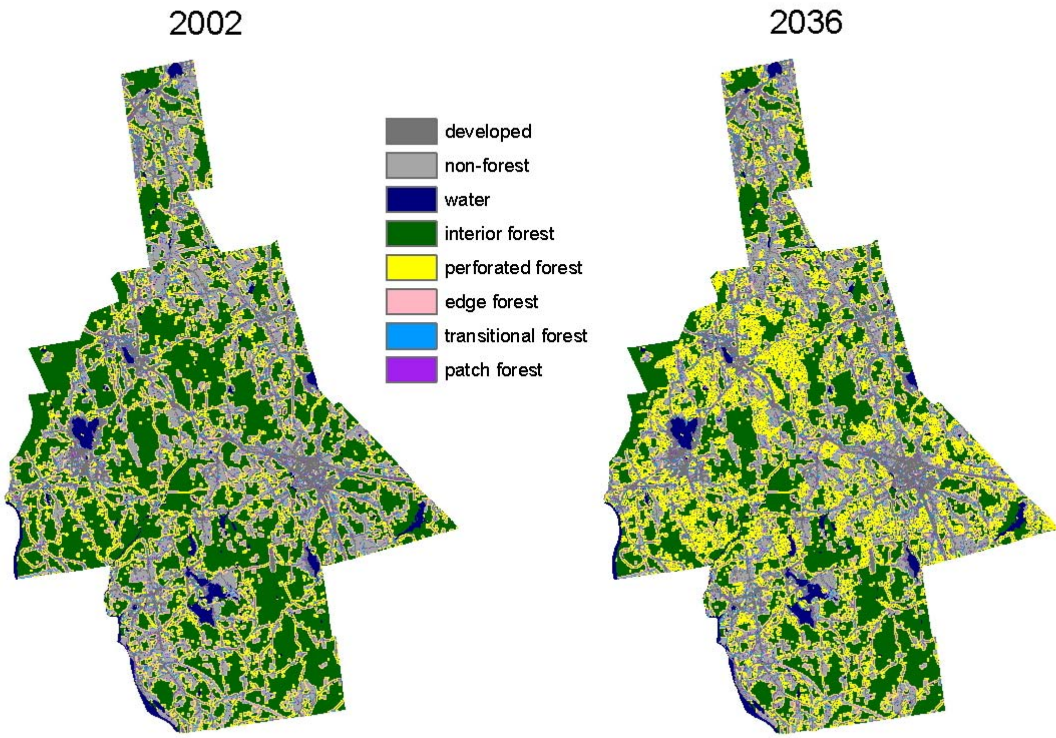


Figure 6. Forest fragmentation maps showing current forest fragmentation for 2002 and predicted forest fragmentation based on potential development for 2036.

estimates since the simulation did not account for future road construction. Despite any conservatism, the simulation forecasted a noticeable decline in total forest cover while the remaining forest became increasingly fragmented.

Where Do We Go from Here?

This paper just touches on some of the trends and predictions of forest fragmentation in Connecticut. Obviously other analysis can be done. We hope that what we have shown here highlights the issue of forest fragmentation in Connecticut. Yes, it may seem like we have a significant forest resource in the State, but we think we have clearly shown that the forest resource has been significantly impacted by our land use decisions. It rests with those interested in conserving Connecticut's forest legacy to begin to determine how we can mitigate the problem. To reinforce this, we offer one last visual (Figure 7). Is this the future of Connecticut?

Is This the Future of Connecticut?