

Development of Functional Ecological Indicators of Suburban Sprawl for the Northeastern Forest Landscape

Principal Investigator: Austin Troy

UVM, Rubenstein School of Environment and Natural Resources

atroy@uvm.edu

Aiken Center, RSENR, University of Vermont, Burlington, VT 05405

Collaborators: USDA Forest Service Northeastern Research Station, Vermont Forum on Sprawl

Graduate Research Assistant: Katrin Moffroid

Completion date: June 2006

- Developed new methodologies for mapping and characterizing suburban sprawl in the Northeastern Forests

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.

<<http://www.uvm.edu/envnr/nsrc/>>

Project Summary

While urban development is by definition detrimental to the natural environment, land must be developed to house people and provide places of employment and recreation. “Urban sprawl” is a term used to describe an inefficient pattern of development where the impacts are high relative to services provided. Various authors have attempted to define indicators of sprawl in terms of its social and economic impacts, but few have attempted to operationalize indicators of sprawl related to environmental impact. One of the challenges to this is that what defines sprawl environmentally will vary by ecosystem. The purpose of this project was to develop environmentally functional and spatially-explicit indicators of suburban and ex-urban sprawl that are specific to the Northeastern Forests and that considered per capita impacts. Using existing empirical research, in combination with extensive mapping and spatial analysis efforts, these indicators were used to track the environmental impact of development relative to the number of people housed and employed. Hence, while areas of dense development result in a high impact, their per capita impact is actually low. On the other end of the spectrum, extremely sparse, rural development also has a minimal impact, even on a per capita basis. However, in between those extreme, impact per capita increases. This study attempted to understand the nature of that impact curve (see figure 1) and where certain development patterns fall along that curve. This was done through a synthesis of studies of the impacts of urban development on environmental indicators (habitat fragmentation, biodiversity and water quality) within the Northeastern context. Based on this resulting information, we created two maps for Chittenden County, Vermont. The first was descriptive, showing per capita impact and where densities and arrangements are most and least efficient, based on weightings of population density, soils, topography, hydrography and natural communities. A number of different weighting schemes and threshold values were tried and the resulting maps compared. The second map was prescriptive, showing what level of density that should be required to offset the environmental impacts of conversion at each undeveloped location. It accounted for the fact that certain conversions (e.g. intensive agriculture to subdivision) are less harmful than others (e.g. unfragmented forest to subdivision). These areas were then compared to the prescriptive planning districts from the 2006 Chittenden County Regional Plan.

Background and Justification

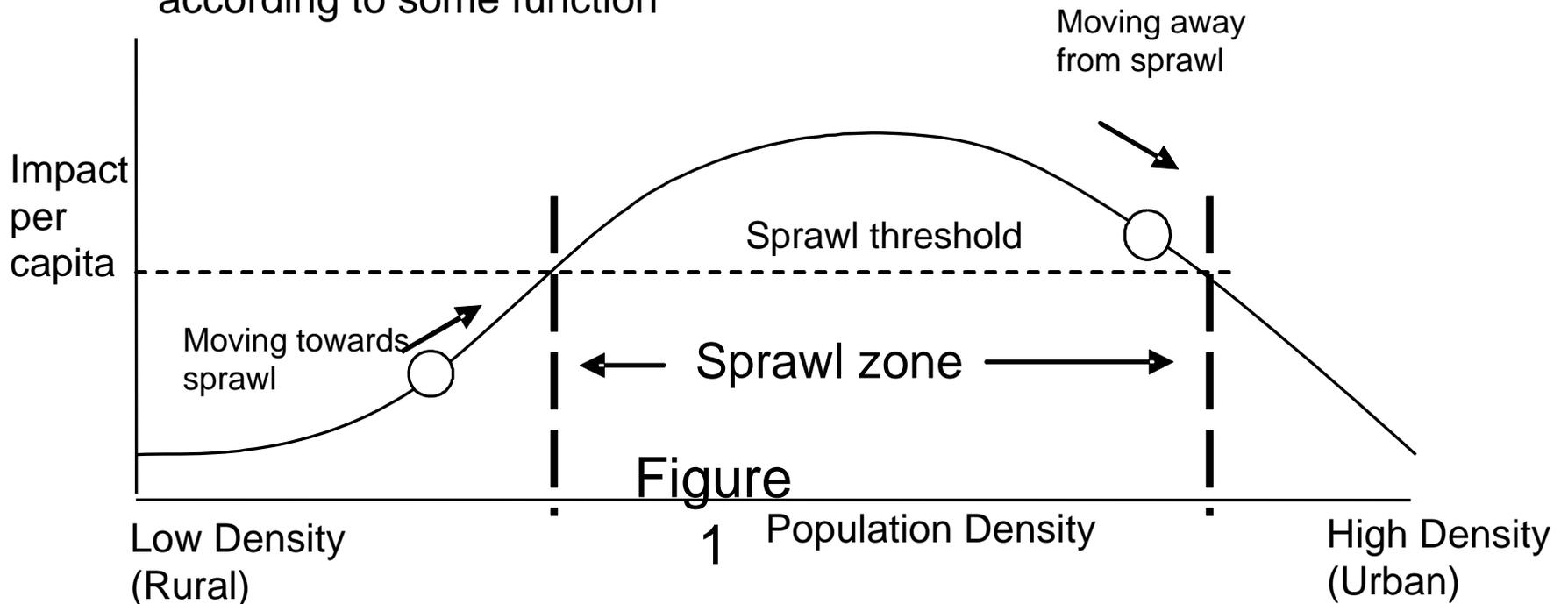
- With management of sprawl emerging as a policy priority, it is important that we know what it is and where it is, so we can have agreement as to when it is a problem (Galster et al 2001)
- Particularly important in Vermont where exurban/suburban uses area increasing; population is low, but residential land use per capita is high
- 78 percent of Vermonters polled believe that sprawl is a problem within the state; 61 percent think that action is needed
- Sprawl is notoriously hard to define; definitions confound causes and consequences
- A few recent studies have indicator-base definitions: Galster et al (2001), Carruthers and Ulfarsson (2003), Hasse and Lathrop (2003).
- Definitions usually mix environmental, social, economic, structural and aesthetic indicators
- No definitions purely defines sprawl indicators in terms of ecological impact; one reason is that each ecosystem requires different set of indicators
- An environmental sprawl definition must look at footprint per capita

References cited:

- Carruthers, J. I. and G. F. Ulfarsson (2003). "Urban sprawl and the cost of public services." Environment and Planning B: Planning and Design 30(4): 203-522.
- Galster, G, R Hanson, H. Wolman, S Coleman and J. Reihage. 2000. Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept. Housing Policy Debate 12(4):681-717.
- Hasse, J. and R. Lathrop (2003). "Land resource impact indicators of urban sprawl." Applied Geography 23(2-3): 159-175.

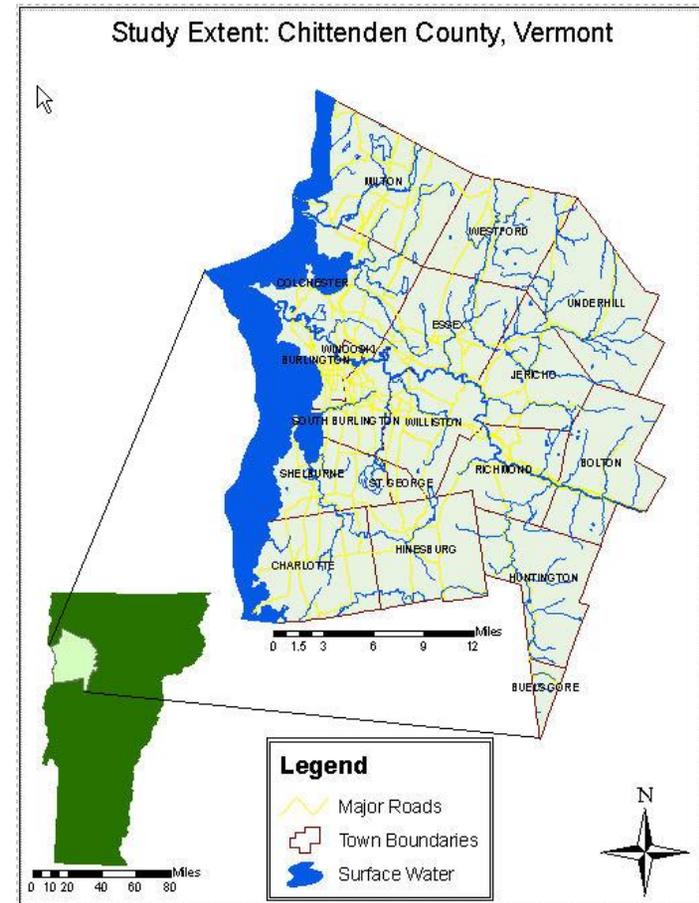
Hypothetical sprawl impact curve

- In the environmentally-based definition of sprawl, impacts of development are high relative to the population served
- Highly dense cities create significant impacts, but the large number of people served keeps the per capita impact low. On the other end of the spectrum, extremely rural development patterns also have fairly low impacts per capita (at least in terms of their residential component). However, in between these two extremes impact per capita increases according to some function



Project purposes

- *Phase I:*
 - Create an ecologically based index of sprawl specific to the Northern Forest based on environmental impact of development and population density
 - Estimate thresholds for categorizing “sprawl”
- *Phase II:*
 - Create a map to show what the estimated impact would be of new development in undeveloped areas
 - Critically evaluate prescriptive planning areas under the 2006 County Plan and recommend improvements based on results
- Study area: Chittenden County, Vermont



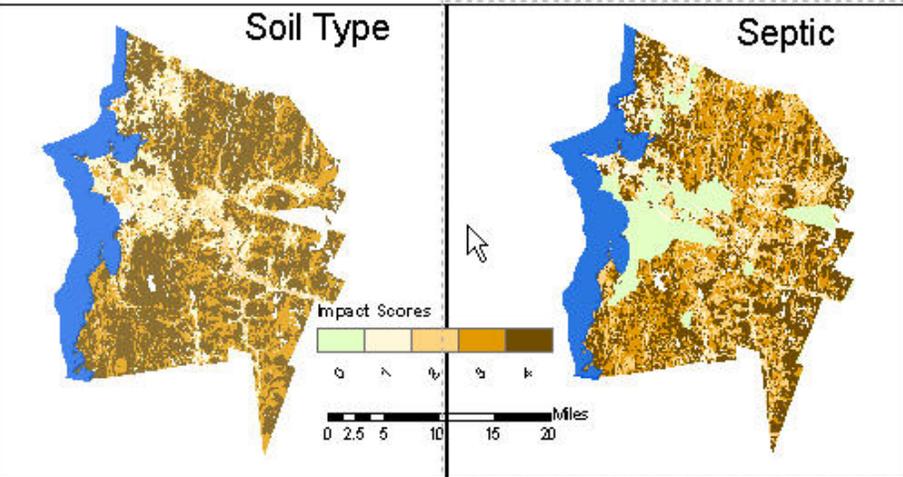
Phase I Methods

Phase I. Descriptive Map

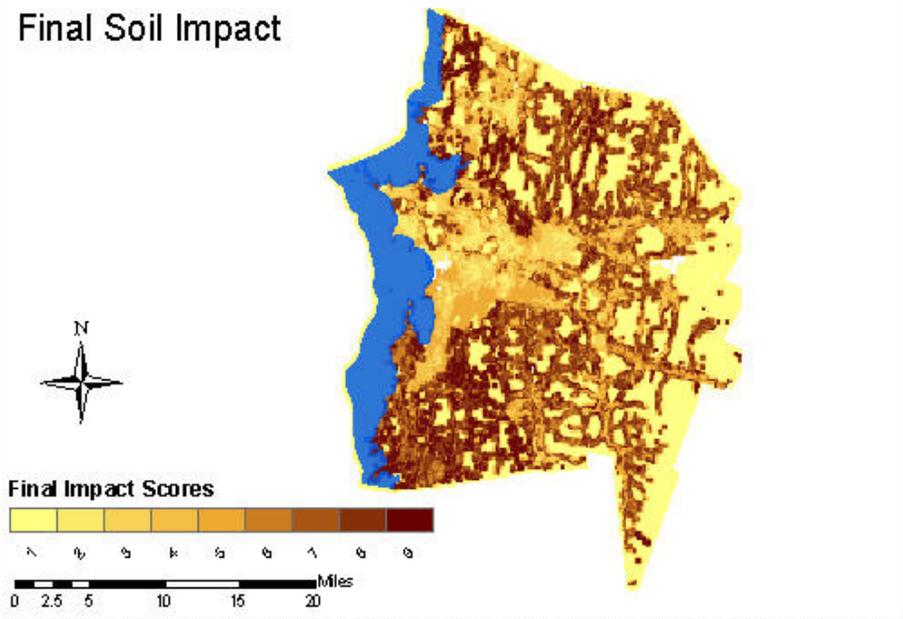
- 1) Conduct extensive literature review on ecological impacts of urbanization to develop impact indicators
- 2) Map impact indicators for currently developed areas
 - Impervious Surface, Forest Fragmentation, Distance to Water, Commute Time, Slope, Soil Type, Residential and Commercial Density
- 3) Map residential and commercial density by individual structures
- 4) Weight indicators to determine current impact
- 5) Divide total impact by residential and commercial density
- 6) Conduct analysis at fine resolution

Sample Indicator: soils

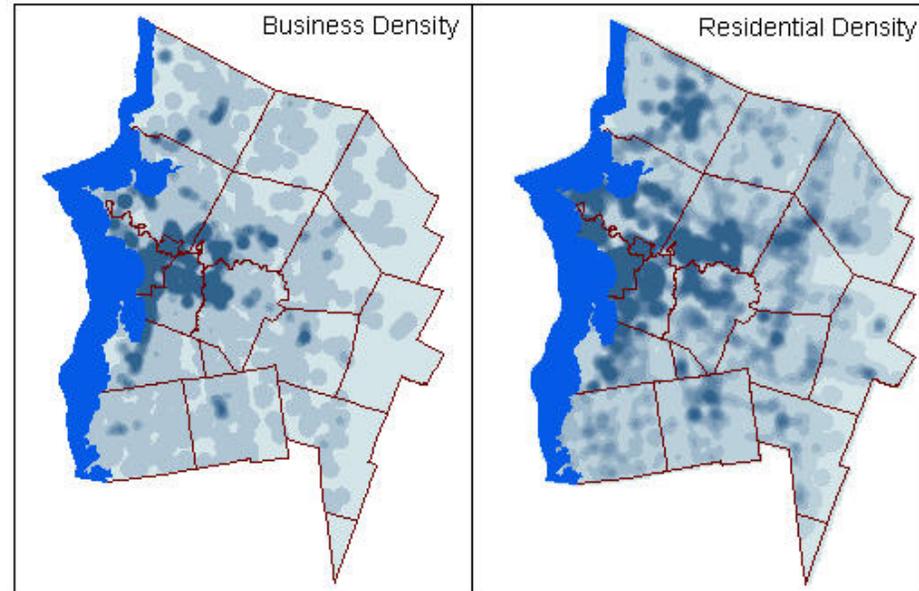
Soil Impact Scores for Hydrogroup, Septic, and Overall



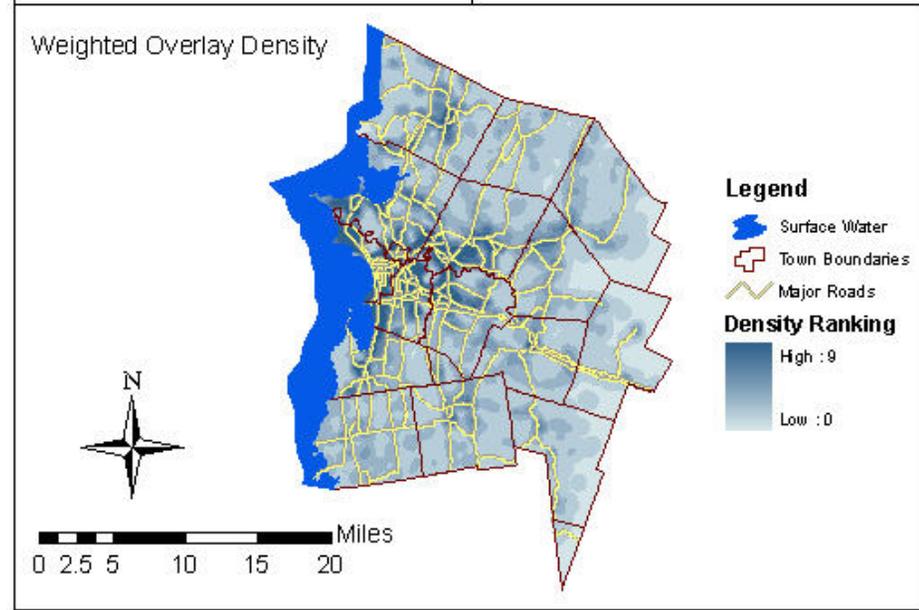
Final Soil Impact



Density layer



Weighted Overlay Density



Phase II Methods

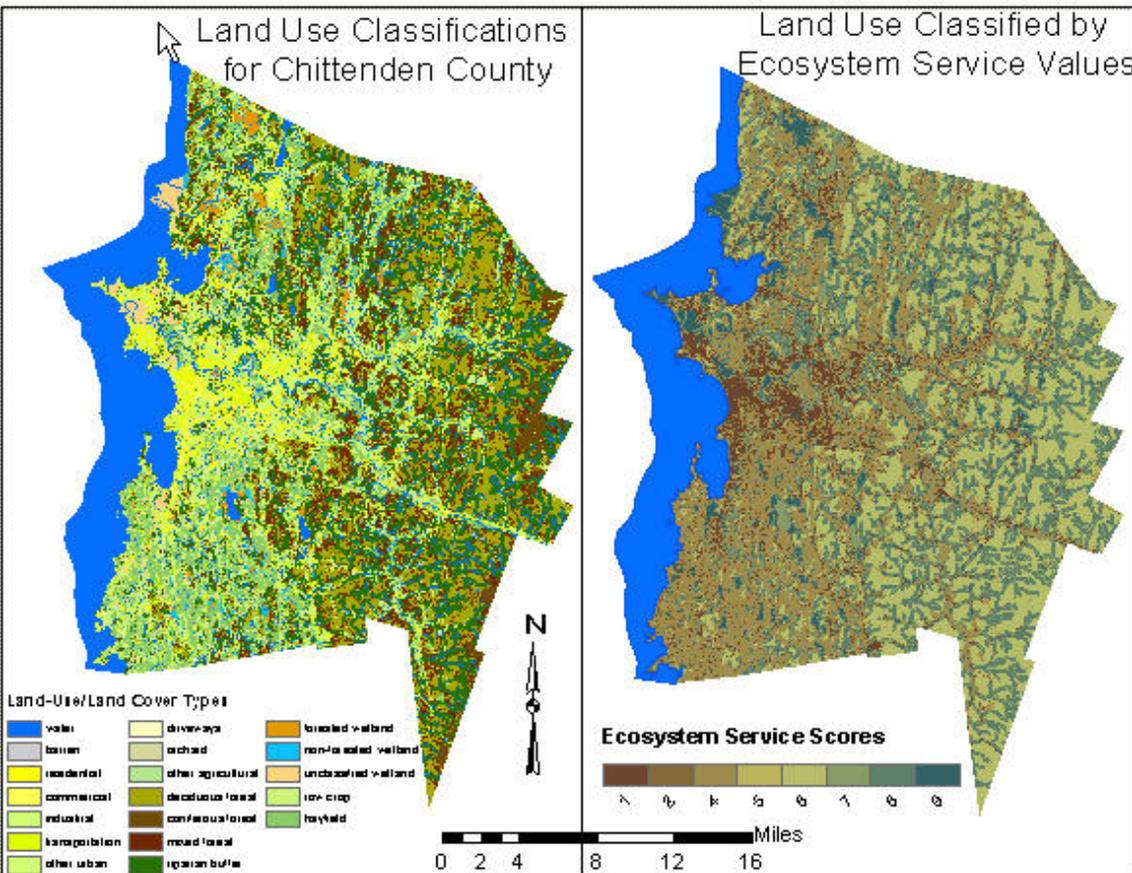
- 1) Map a different set of indicators for entire County :
 - Ecosystem Service Values, Impervious Surface, Forest Fragmentation, Distance to Water, Distance to Conserved Land, Distance to Development, Slope, Soil Type
- 1) Weight indicators to determine potential impact
- 2) Overlay CCRPC Planning Areas on prescriptive map
- 3) Evaluate existing boundaries and make recommendations

Phase II: Ecosystem Service Values

Services provided by Ecosystems that increase human welfare should be documented as economic gain

Methods

- Land Use enhanced from Landsat 30m image
- Ecosystem Values from <http://ecovalue.uvm.edu>
- Natural log of value was used for impact score

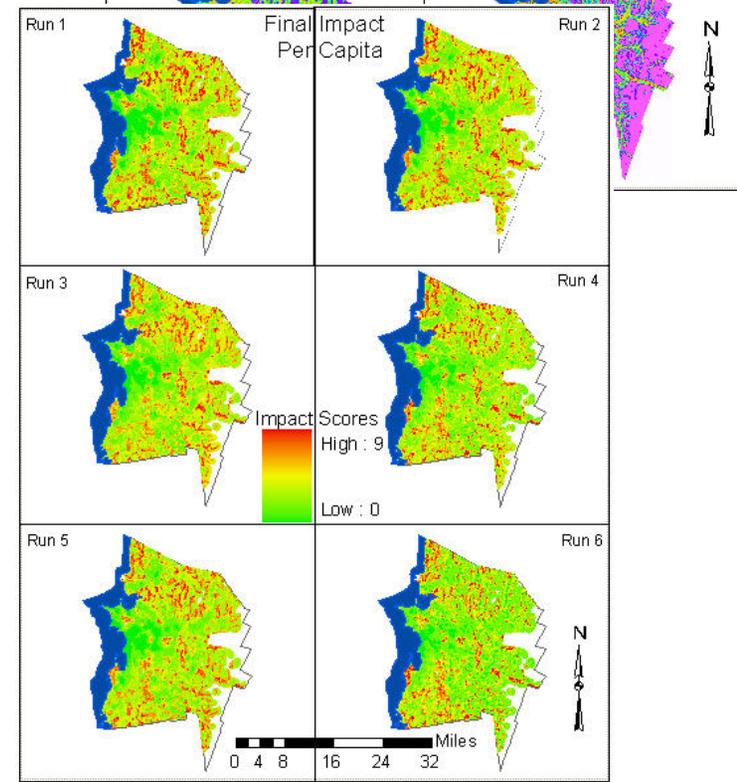
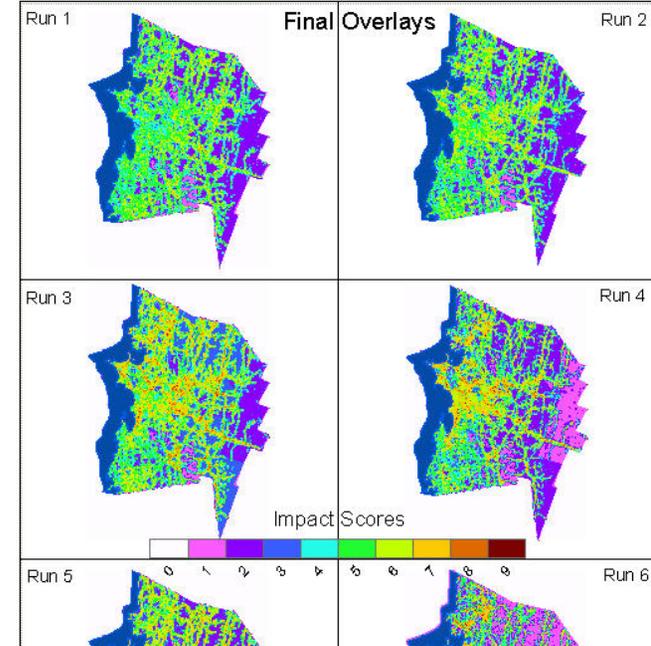


Results: Weighted Overlay

- Each impact layer normalized on ten digit scale
- Ran sensitivity analysis with multiple weights for different indicators
- Different weightings schemes were based on different findings in literature
- Followed same basic pattern with different ranges
- Resulted in different versions of final impact per capita

Weights used in Overlay (Percent Weighted)

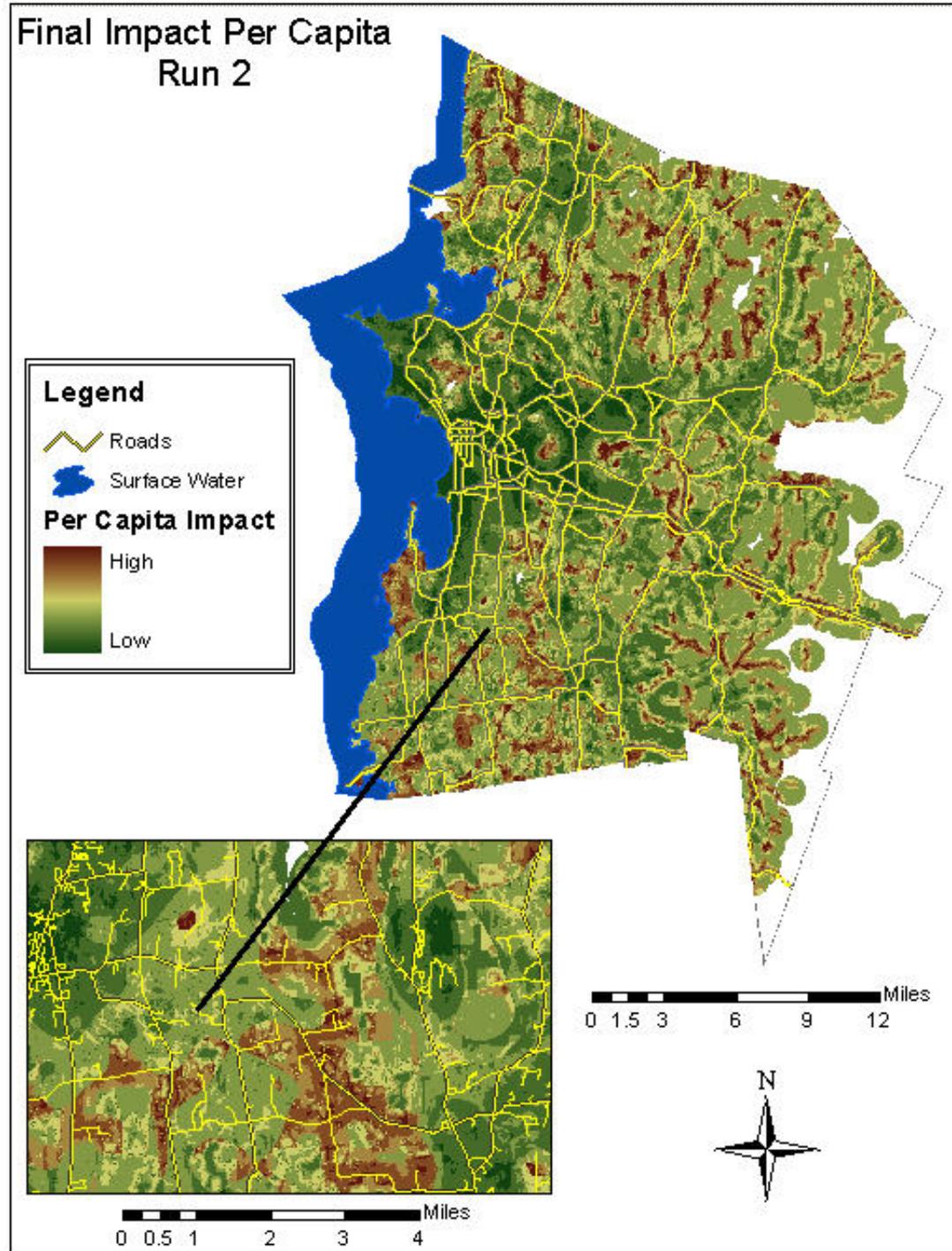
| Layer | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Run 6 |
|----------------------|-------|-------|-------|-------|-------|-------|
| Impervious Surface | 17 | 25 | 25 | 40 | 20 | 50 |
| Forest Fragmentation | 17 | 25 | 25 | 40 | 20 | 50 |
| Driving Time | 17 | 15 | 25 | 10 | 20 | 0 |
| Water Buffers | 17 | 15 | 25 | 10 | 20 | 0 |
| Soils | 16 | 10 | 0 | 0 | 20 | 0 |
| Slope | 16 | 10 | 0 | 0 | 0 | 0 |



Results:

Per capita impact map

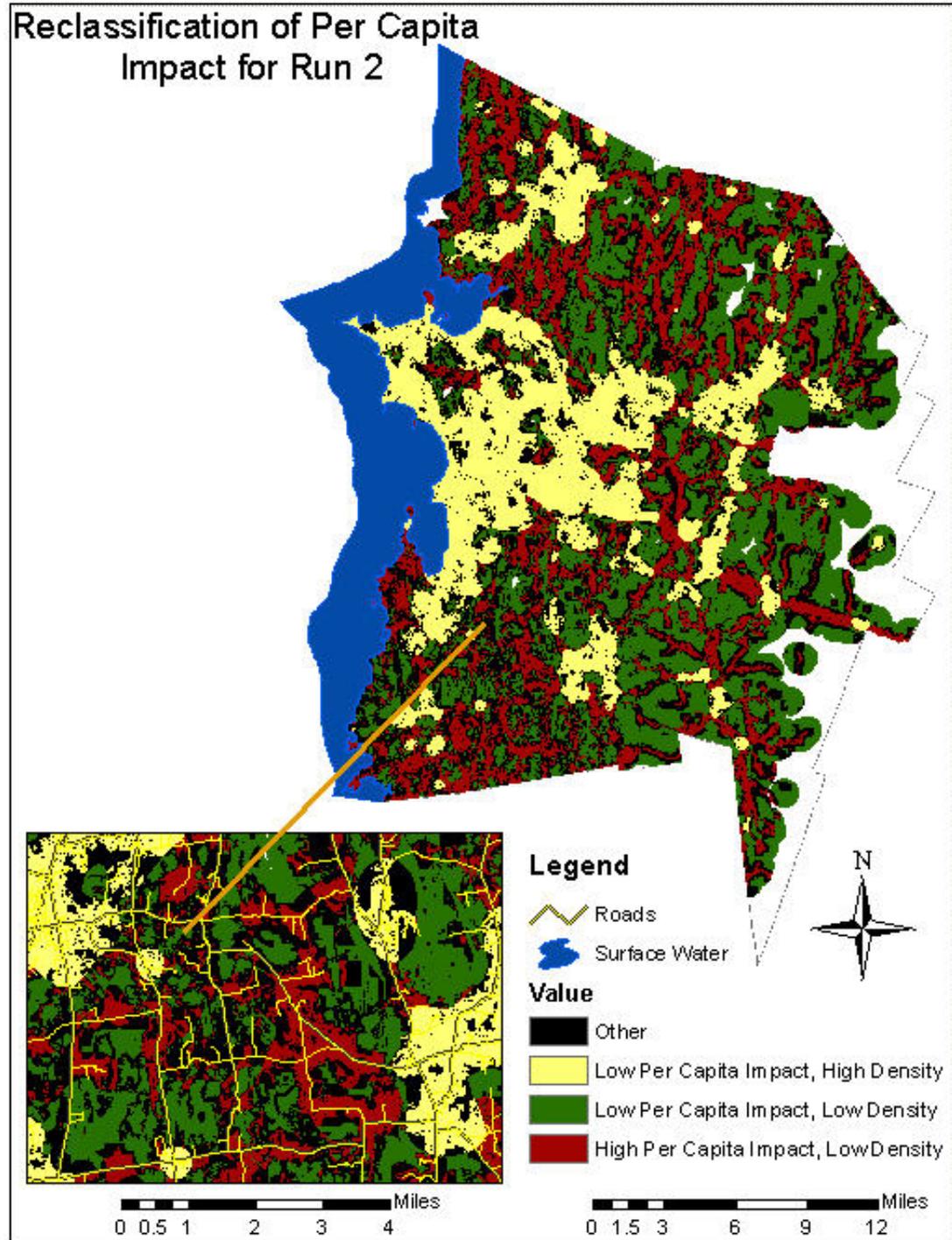
- Each of the six runs shows similar pattern of per capita impact, but we chose to focus on run 2, which represents “happy medium” of weights



Results: Categorization

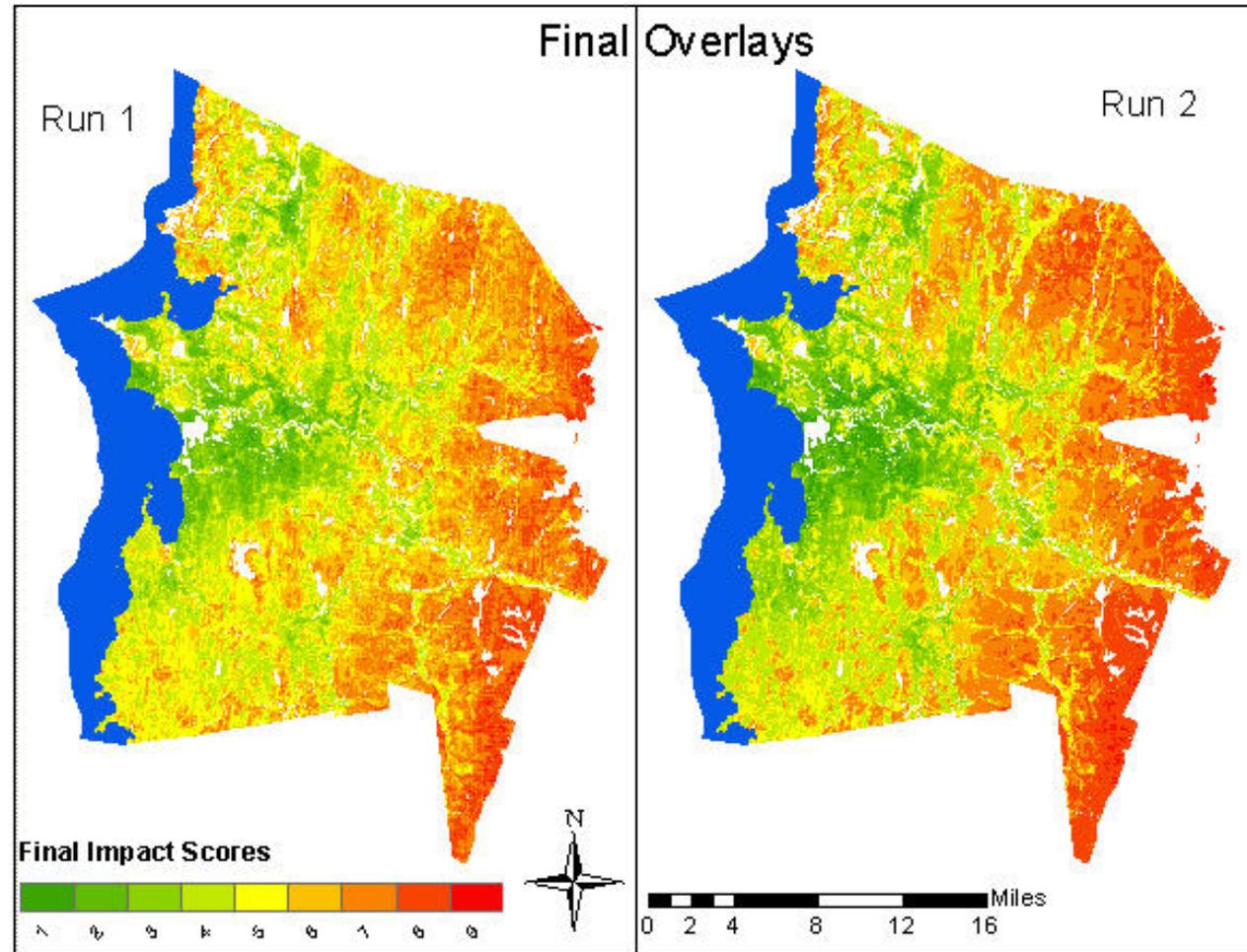
- Applied threshold values (3 and 5) to run 2 impact map to categorize areas as “urban” (high impact, high density>> low per capita impact), “rural” (low impact, low density>> low per capita impact) and “sprawl” (high impact, low density>> high per capita impact)
- Show that areas around existing urban and village centers are categorized as low per capita impact. On average, suburbs farther from centers classed as sprawl.

Reclassification of Per Capita
Impact for Run 2



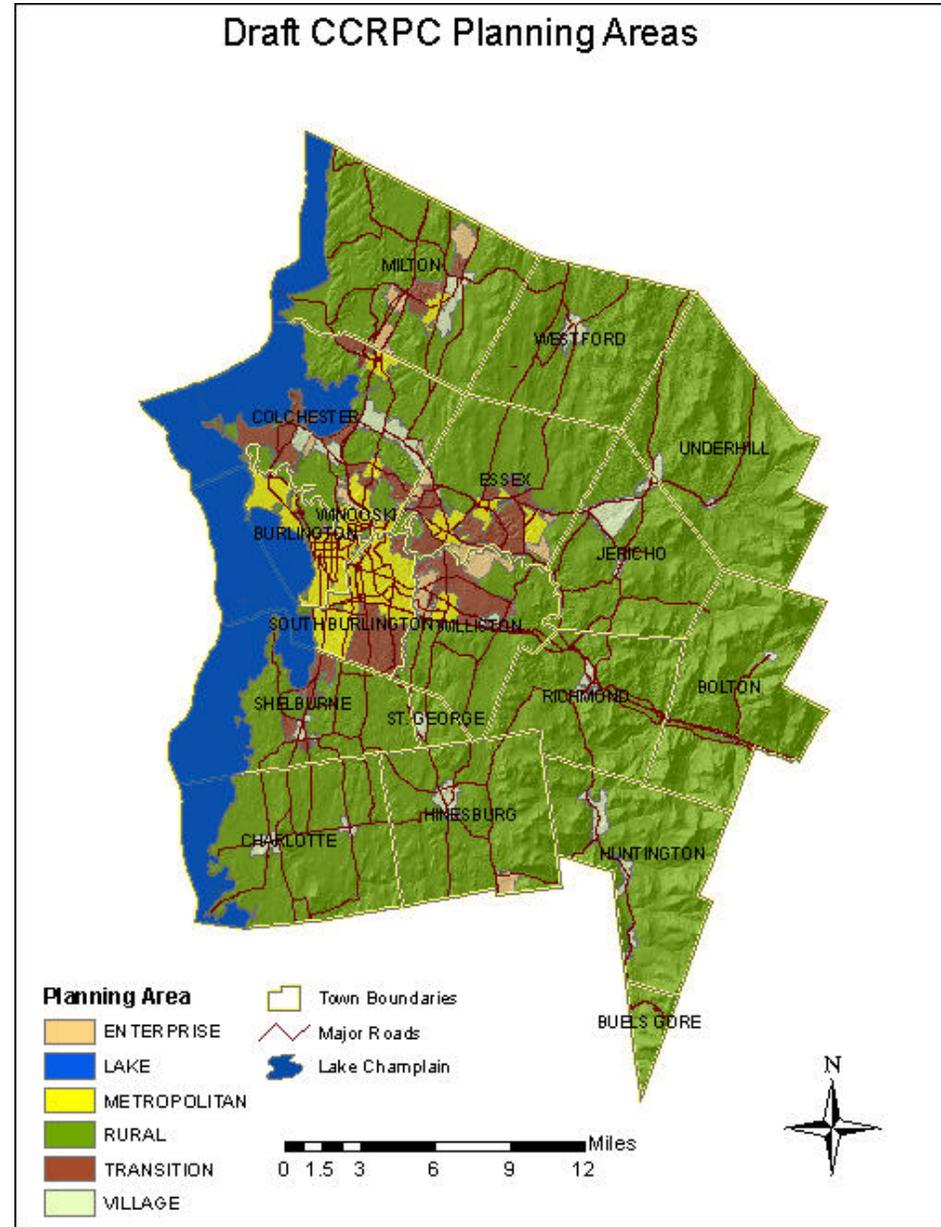
Results:Phase II

- Mapped weighted combination of second set of indicators to show where new development would likely have high ecological impact
- Shows low per capita impact near Burlington metro hub and village centers, increasing with distance in general



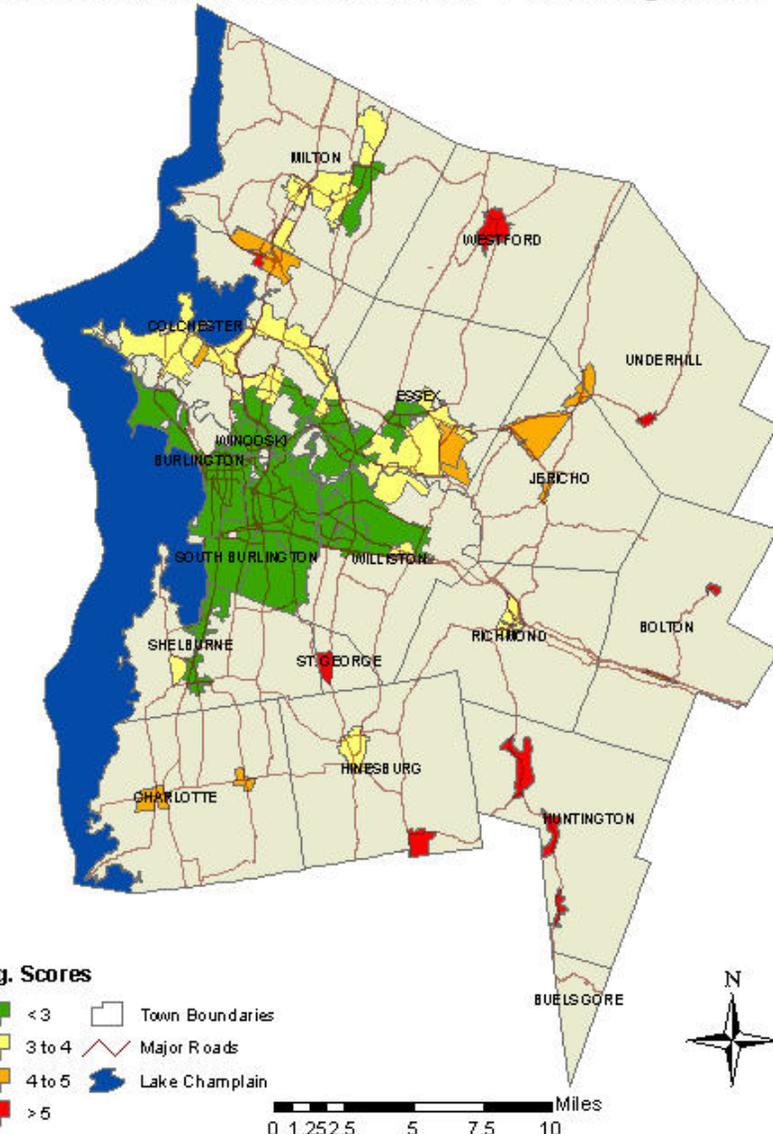
Phase II Results

- Overlaid impact map on map of Chittenden County Regional Planning Commission non-rural planning areas; these show areas targeted for continued growth, transition, village style development, etc.
- Took average potential impact score by planning area polygon (next slide)
- Areas designated metropolitan tend to have low average impact scores.
- Many village centers and some transitional areas have high average scores indicating that small amounts of additional development in these areas will have a big environmental impact if not zoned correctly
- Zooming in to the level of fine detail (next slide) shows heterogeneous potential impact scores; means that within a village area growth could be targeted to minimize the environmental impact if planned

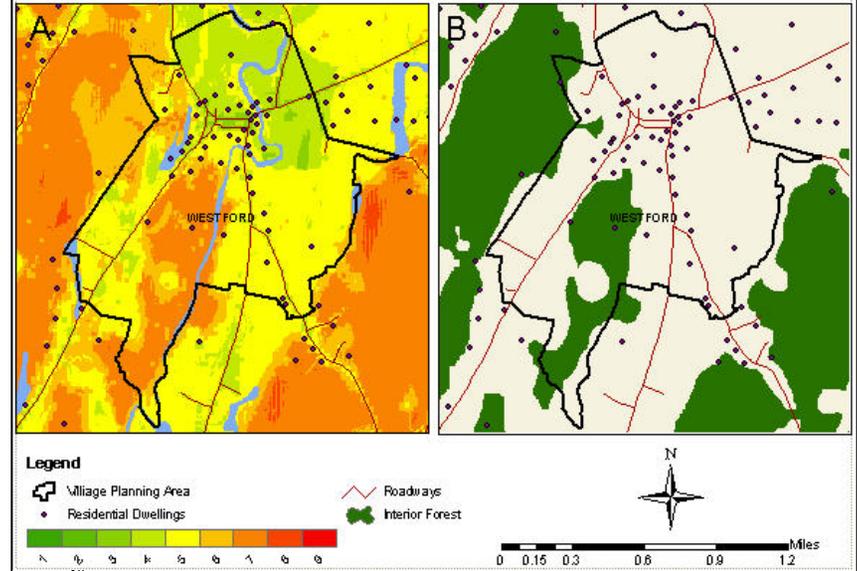


Results: Phase II

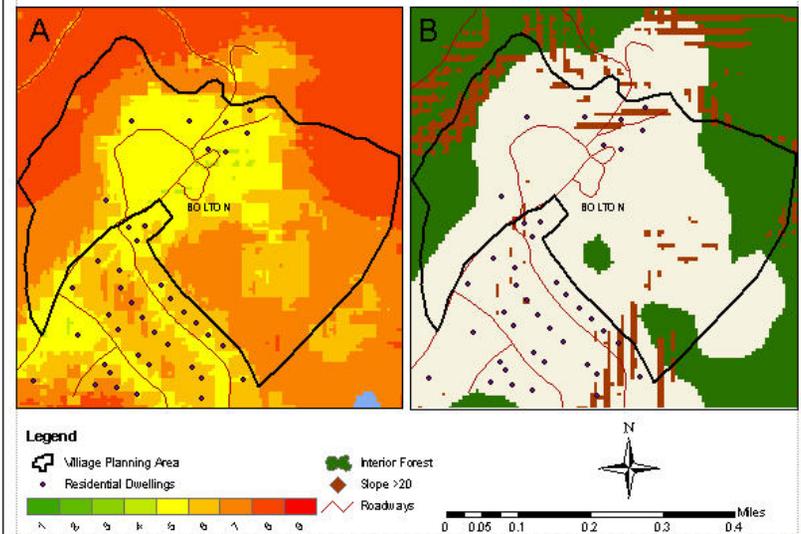
Classification of the Draft CCRPC Planning Areas



Planning Area Close-up: Westford



Planning Area Close-up: Bolton



Implications and applications in the Northern Forest region

- Sprawl is a priority issue for residents of the Northern Forest region
- The problem has been having a systematic and grounded approach for defining it
- Without such a definition it is extremely hard to do planning to avoid it
- This provides an approach that can be easily replicated using standardized public data sets and basic spatial analysis methods
- This could prove particularly useful to local planning and zoning departments as they re-zone, to RPCs as they update their regional plans, and to the state, in updating the statewide land use policies.
- Executive Director of Chittenden County RPC is aware of project and will be debriefed on results
- These results will also be shared with staff of other RPCs.

Future directions

- This research will contribute to a new project being conducted by PI for US Department of Transportation, in which integrated land use/transportation simulation model is being run for Chittenden County, in collaboration with the County's RPC and Metropolitan Planning Organization (MPO).
- In this project simulations of land use are run under different policy scenarios. Results can be compared in terms of this sprawl index.
- We also hope to work with our collaborator on this project, the Vermont Forum on Sprawl, to help publicize this approach as an easy way for towns and regions to assess their land use patterns.
- In the future it may also be possible to develop a desktop application that automates the spatial analysis done manually in this project, allowing planners to easily replicate this approach

List of products

- Master's thesis: "Developing and Applying Ecological Indicators of Suburban Sprawl: A Case Study for Chittenden County Vermont"
 - By Katrin Moffroid, approved October 2006
 - Included three papers, currently in revisions for submission to journals
- A new Geographic Information Systems methodology, which can be replicated by local and regional planning agencies
- A digital dataset and map layers of sprawl indicators for Chittenden County, VT, for use by town and county planners