

Calculating Sequestration for County-Level Carbon Budgets: A Case Study in Chittenden County, Vermont

Erin E. Quigley, Jennifer C. Jenkins

Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, Vermont USA 05405

THE PROJECT

As concern grows over the effects of increased atmospheric carbon (C), there is substantial interest in understanding both natural and anthropogenic C dynamics. This project aims to quantify the sources and sinks of atmospheric carbon dioxide (CO₂) on a county scale. With support from the Hubbard Brook Research Foundation's (HBRF) Sciencelinks Carbon Group, a net C budget for Chittenden County, Vermont, was created, with key C sinks and emissions categorized in terms of land use. Land use history and its effect on C dynamics were also examined. The budget is part of a larger study by the HBRF, where five counties representing a variety of land uses are working together to both observe land-use-related trends in C flux and create consistent county-level C budgeting methodology. Here, the sequestration side of the Chittenden County budget is addressed in detail.

OBJECTIVES

This project has two primary objectives: 1) to provide up-to-date and accurate decision-making information to planners and policy-makers in the county, allowing them to get the most tangible benefits from their mitigation efforts, and 2) to create and refine a methodology that is easily replicable in any county in the United States, making county-level C data readily available beyond Chittenden's borders.

CHITTENDEN COUNTY

Chittenden County, Vermont is located in the northwestern corner of the state. Lake Champlain forms its western border. The county is home to the Burlington-South Burlington Metro Area, and has a population of over 150,000. It has a land area of 139,610 hectares and a population density of about 1 person per hectare (US Census). Chittenden County's land use has changed dramatically over time, as demonstrated in Figure 1 right. Over the past century, much of the county's agricultural land has returned to forest and, in some cases, both have succumbed to urban development.

METHODS

FOREST CARBON

Determining C Density and Accumulation in Live-Tree Biomass:

- Plot-level USDA Forest Service Forest Inventory and Analysis (FIA) data compiled and analyzed for biomass and net primary production was acquired from Jeff Hicke of the University of Idaho (personal communication). This dataset was prepared using methods described in Hicke et al. (2007).
- Plots in Chittenden County and the rest of the Northern Vermont region (Caledonia, Essex, Franklin, Grand Isle, Lamoille, Orange, Orleans, and Washington counties) were extracted from the larger dataset.
- For the Northern Vermont counties, average biomass and average wood net primary production were determined for each forest type present. All counties were used to create these averages, rather than just Chittenden, so that the data had a larger sample size.
- Average C density for each forest type was calculated by assuming that C is one-half biomass (Birdsey 1992), and average C accumulation for each forest type was calculated by assuming that C accumulation is one-half net primary production (Schlesinger 1997).
- Using the Forest Inventory Mapmaker version 3.0, available online at <http://www.ncrs2.fs.fed.us/4801/fiadb/fim30/wcfim30.asp>, the forest types in Chittenden County, and the land area of each, were determined.
- The amount of C (in Mg) stored in live tree biomass in Chittenden County was calculated by multiplying land area in each forest type in the county by average C density (in Mg/ha) for that type, then adding the results.
- The net annual C accumulation (Mg/ha/yr) in live tree biomass in Chittenden County was calculated by multiplying land area in each forest type in the county by average C accumulation for that type, then adding the results. Total county C accumulation (Mg/yr) was then determined by multiplying net annual C accumulation by total forest area.

Determining Carbon Density and Accumulation in Standing Dead Tree, Understory, Down Dead Wood, and Forest Floor Biomass:

- Average stand age for each of two broad forest type categories (maple-beech-birch and pine) in the county was determined from FIA plot-level data.
- C stock tables (B2 and B6) for those broad forest types were available in Smith et al. (2006). Carbon density values were found for the average stand age for each type.
- These values were added together and multiplied by the area of each forest type in the county to find the amount of C stored in standing dead tree, understory, down dead wood, and forest floor biomass. This value was added to the value calculated for live trees. C density in the county was then back-calculated by dividing county C storage by total forest area (as determined by Mapmaker).
- According to the tables in Smith et al. (2006), the addition to net annual C accumulation from standing dead tree, understory, down dead wood, and forest floor biomass was negligible, so the method for its calculation will not be described here.

FOREST SOIL

Area of forest soil was assumed to be the same as area of forest biomass, which was determined using Forest Inventory Mapmaker version 3.0. Forest soil C density was estimated from Table 5 of Ellert and Gregorich (1996). Annual forest soil C accumulation was considered negligible, as demonstrated in Smith et al. (2006).

WOOD PRODUCTS

Area with potential for wood product harvest was assumed to be the same as area of forestland. Net annual accumulation in wood products was calculated using the methods described in detail by Jenkins (personal communication), which utilize tables in Smith et al. (2006). C density in wood products was not determined, as the data were difficult to acquire and the result may not be relevant to the purposes of this report.

ACTIVE AGRICULTURAL VEGETATION

Area of active agricultural land was determined from the 2002 Census of Agriculture, as a summary of the land-use categories 'harvested cropland' and 'cropland in cultivated summer fallow'. As active agricultural land is harvested annually, no net C accumulation or C storage occurs.

ACTIVE AGRICULTURAL SOIL

Area of active agricultural soil was assumed to be the same as area of active agricultural land. The C density of active agricultural soil was estimated from Table 5 of Ellert and Gregorich (1996). Net annual C accumulation in active agricultural soil was estimated from Table 9 of West and Marland (2002).

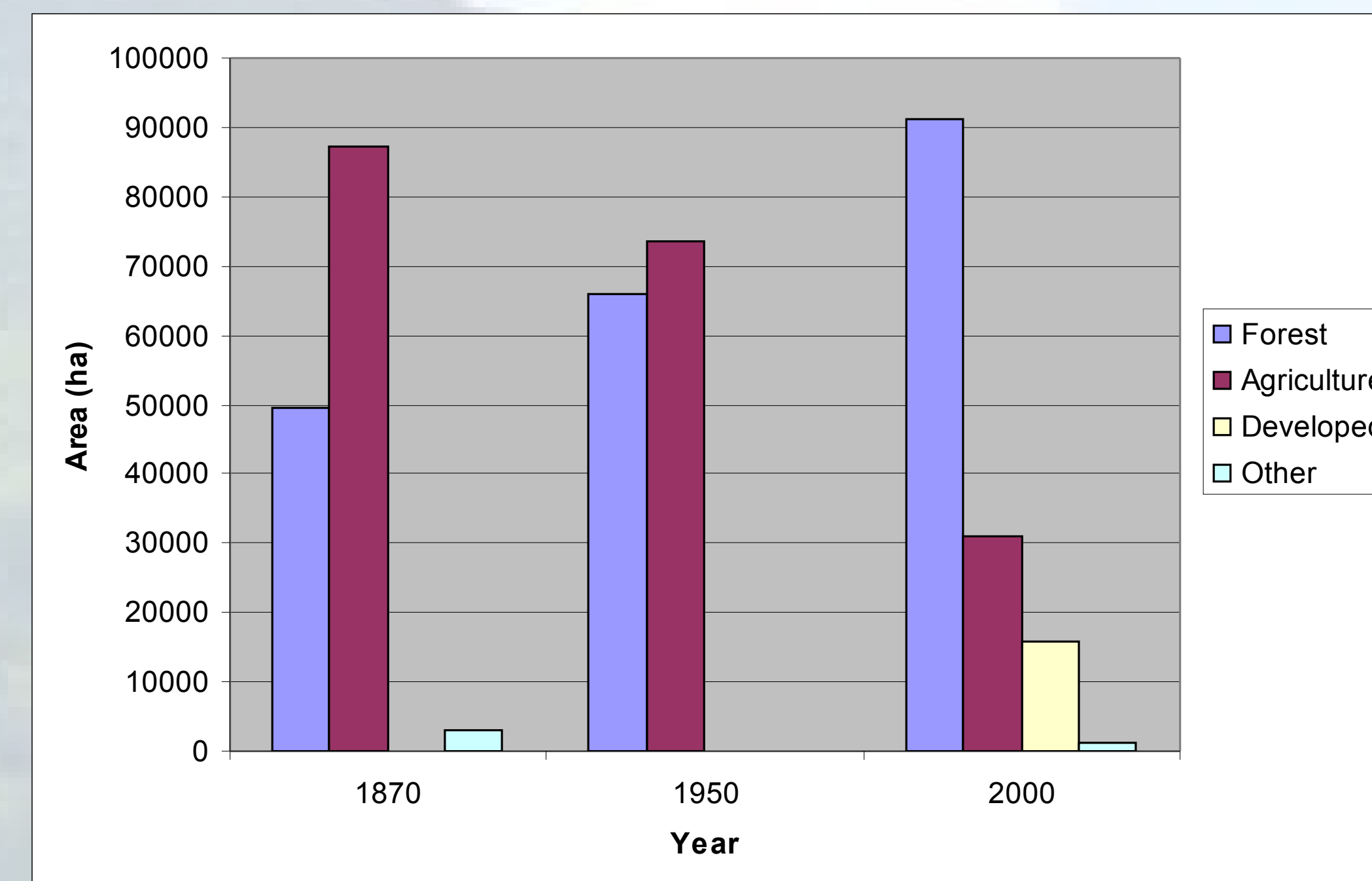


Figure 1. Land use change over time in Chittenden County, VT (Quigley 2007).

INACTIVE CROPLAND AND CRP SOILS

The Conservation Reserve Program (CRP) reimburses farmers for taking agricultural land temporarily out of production. Area of inactive cropland and CRP soils was determined from the 2002 Census of Agriculture, as a summary of the land-use categories 'cropland used only for pasture and grazing,' 'cropland idle,' 'pastureland and rangeland,' and 'land enrolled in Conservation Reserve or Wetland Reserve programs.' C density of inactive cropland and CRP soils was estimated from Paul et al. (2003) as an average of all afforested plot pools. C accumulation was estimated from Gebhart et al. (1994).

ABANDONED AGRICULTURAL VEGETATION

Area of abandoned agricultural land was determined from the 2002 Census of Agriculture, as the land-use category 'cropland on which all crops failed or were abandoned.' C density on abandoned agricultural lands was estimated from Table 1 in Hooker and Compton (2003). Net annual C accumulation was estimated from Table 3 in Hooker and Compton (2003) as the sum of values for plant biomass, woody debris, and the forest floor.

ABANDONED AGRICULTURAL SOIL

Area of abandoned agricultural soil was assumed to be the same as area of abandoned agricultural land. The C density of abandoned agricultural soil was assumed to be the same as that of inactive cropland and CRP soils. Net annual C accumulation was estimated from Post and Kwon (2000), using an average of values in Table 1 for succession from old field/agriculture to cool temperate moist forest.

URBAN VEGETATION

Urban vegetation area was determined using the National Land Cover Database (2001), available online for download at <http://www.mrlc.gov>. Land use classifications considered urban included: developed open space (less than 20% of total cover impervious), developed low intensity (20-49% of total cover impervious), developed medium intensity (50-79% of total cover impervious), and developed high intensity (80-100% of total cover impervious). An estimate of impervious area was determined using the category definitions, and was subtracted from the total urban land area to find area of urban vegetation. C density of urban vegetation was estimated from Figure 5 of Jo and McPherson (1995), using an average of the two plots. Net annual C accumulation was also estimated from Jo and McPherson (1995).

URBAN SOIL

Urban soil area was determined using the National Land Cover Database (2001) and, following the procedure described above, was divided into two categories: pervious soil and soil under impervious surfaces. C density of urban soil in both categories was estimated from Table 5 in Pouyat et al. (2006) using the values for impervious/commercial-industrial-transportation and residential areas. Net annual C accumulation in urban soils was estimated from Jo and McPherson (1995), using an average of the two plots.

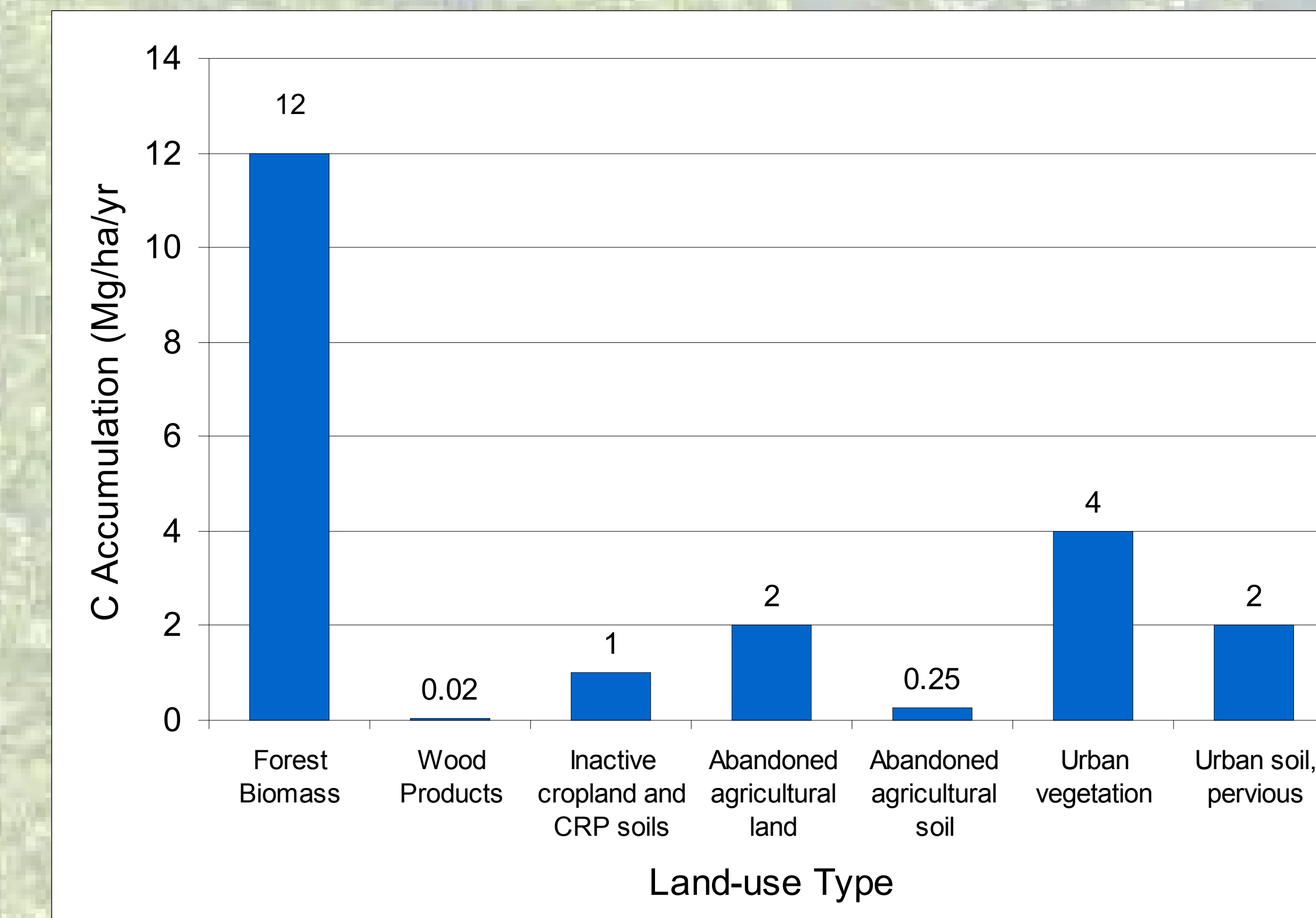


Figure 3. Net annual C accumulation by land-use type in Chittenden County, VT.

RESULTS

Table 1. Terrestrial C stocks and accumulation in Chittenden County, VT.

Land-use type	Area (ha)	C density (Mg/ha)	C pool (Mg)	Net accumulation (Mg/ha/year)	County accumulation (Mg/year)
Forest	85891	136	11,652,741	12	1,042,727
Forest Soil	85891	107	9,190,294	negligible	negligible
Wood Products	85891	not calculated	not calculated	0.02	1,524
Active agricultural vegetation	11301	negligible	negligible	negligible	negligible
Active agricultural soil	11301	70	791,088	negligible	negligible
Inactive cropland and CRP soils	4826	82	393,502	1	5,308
Abandoned agricultural vegetation	141	4	627	2	275
Abandoned agricultural soil	141	82	11,483	0.24	34
Urban vegetation	15886	41	650,672	4	68,308
Urban soil, pervious	10772	144	1,551,102	2	20,466
Urban soil, under impervious surface	5114	33	168,762	negligible	negligible
TOTAL:					1,138,642

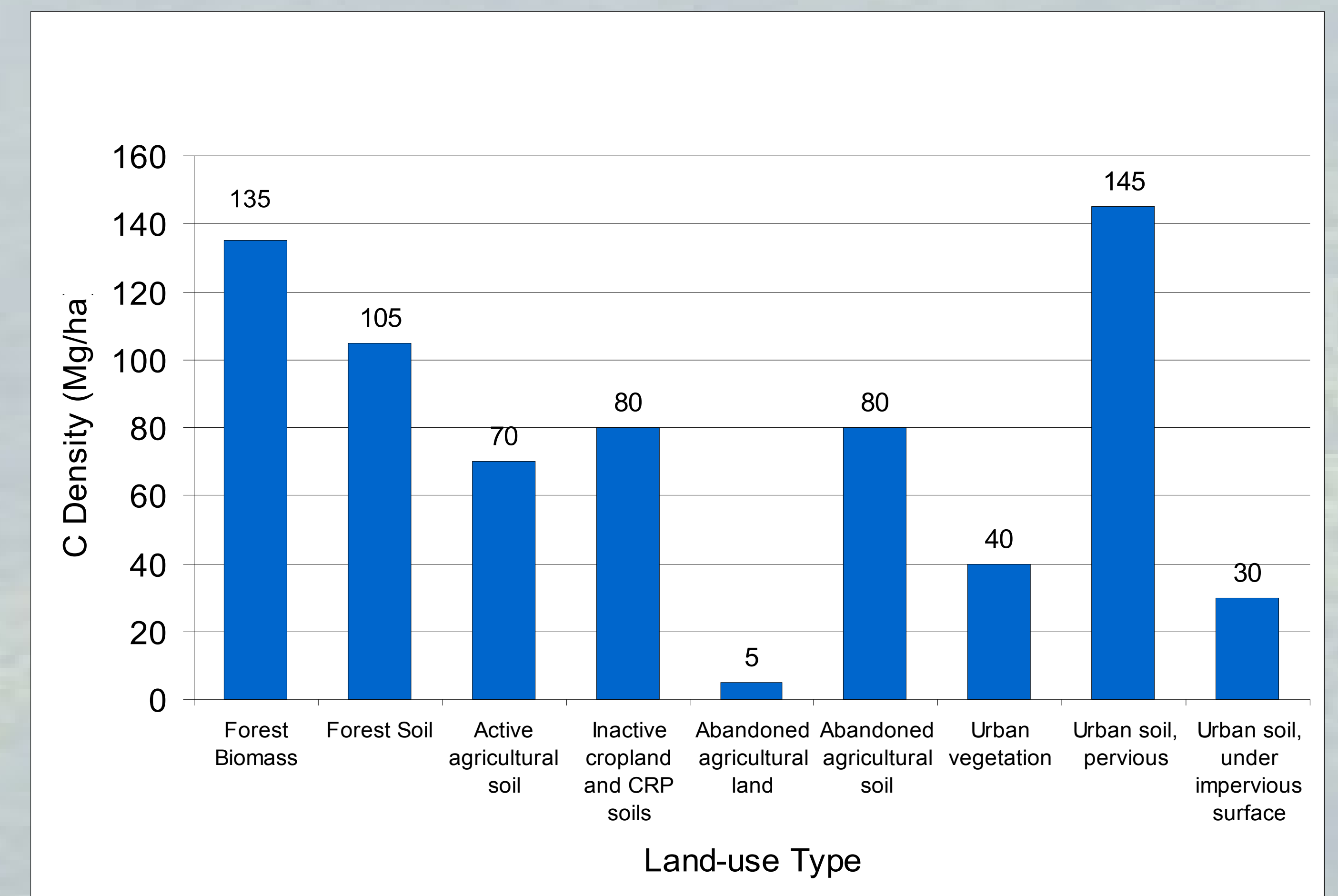


Figure 2. C density by land-use type in Chittenden County, VT.

CONCLUSIONS

Chittenden County stores the majority of its sequestered C in forest biomass and soils. Urban soils and vegetation are also important C sinks. C density is highest in forest biomass and soils, as well as urban soils. Agricultural soils also have relatively high C density. Net annual C accumulation is largest in forest biomass, by a wide margin. Urban vegetation also has a high level of net annual accumulation. Wood products, surprisingly, only accumulate very small yearly amounts. Total annual county C accumulation is dominated by forest biomass. Urban soil and vegetation also contribute. The total amount of C sequestered in the county annually is about 1,140,000 Mg C/year.

ACKNOWLEDGEMENTS

Special thanks to the Hubbard Brook Research Foundation and the University of Vermont Transportation Center for funding this research. Thanks also to my advisor, Jennifer Jenkins, and the rest of my committee: Lesley-Ann Dupigny-Giroux, Austin Troy, and Timothy Fahey (Cornell University). Additionally, this project could not have occurred without the guidance of the primary authors of a similar report for Tompkins County, NY (Vadas et al. 2007): Timothy Vadas, Timothy Fahey, and Ruth Sherman. A special thanks, as well, to the Carbon Dynamics Lab and, of course, the Carbonators for camaraderie and academic fellowship.

