

# **Carbon Sequestration in Massachusetts Forests as an Offset for Energy Sector Carbon Dioxide Emissions**

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## **Abstract**

Greenhouse gases are both a regulatory and scientific challenge. Policymakers are developing new legislation to utilize forests to mitigate the greenhouse gas, carbon dioxide. The Regional Greenhouse Gas Initiative (RGGI) uses afforestation, the planting of new forests, for this purpose. Using afforestation alone, however, ignores current sequestration due to growth, which is already happening within the Northeastern United States. In addition, it does not take into account carbon that is preserved due to avoided deforestation. In this paper, we look at carbon dioxide sequestration due to growth and land-use change within Massachusetts between 1998 and 2005, and compare it to state-wide energy-sector emissions. We then looked at the amount of the state's forest that is at risk for deforestation. We estimate that over 10% of the state's energy-sector carbon dioxide emissions were sequestered within the state's forest. In addition, using the Maine Forest Service's guidelines for identifying forests at risk for deforestation, 52% of the state's forest is categorized as having a high likelihood of conversion to development, which would substantially reduce the state's carbon sequestration abilities. This suggests that only including afforestation in emission-mitigation policy ignores an additional and current pool of carbon that is being sequestered naturally and should be protected for future use.

## 1. Introduction

Regulating greenhouse gases is both a political and scientific challenge. Policymakers and researchers alike are examining ways to control these pollutants. One method that is gaining popularity through regional policy initiatives is the sequestration (the fixation and storage) of carbon dioxide in forests. The northeastern states, well known sinks for carbon (Barnes *et al.*, 1998), have developed a policy that uses forests to help offset emissions. The Regional Greenhouse Gas Initiative (RGGI) requires states to minimize their emissions by 10% by the year 2018. To help achieve this goal, carbon sequestered in forests can be calculated and then sold to greenhouse gas polluters in order to meet 3.3% of their compliance obligation. Currently, the plan is to use afforestation, the planting of new forests, alone as a carbon offset. Massachusetts and some other states, however, do not have significant amounts of open land that could be converted to forest, and some of this forested land is under constant threat from developers. In these states young and productive forests sequester significant amounts of carbon and we suggest that these forests should be protected and included in regional policies.

Extensive research has already been completed calculating biomass and carbon storage of forests within specific regional parameters. The difference between fixation and loss over an established period of time is used to estimate biomass and carbon stocks among and within large regions (Schroeder *et al.*, 1997; Brown & Schroeder, 1999; Mickler *et al.*, 2002; Jenkins *et al.*, 2001). The primary goal of such studies has been to quantify changes in carbon stocks in different regions under different management practices. Southern New England forests in particular are important sinks for carbon dioxide, as

forests are where the majority of terrestrial carbon is sequestered (Uriarte & Papaik, 2007). This type of information can be utilized for larger models looking at carbon inputs and outputs with the goal of eventually informing policy. These studies, however, do not address these carbon stores in practical terms in relation to offsetting actual energy emissions in the local region.

In July 2009, the Maine Forest Service and others released a series of recommendations to RGGI regarding forestry offsets. These recommendations suggested including other types of forest offsets in the RGGI policy. These were avoided deforestation, forest management and urban forestry. Though each of these has great potential for carbon storage and sequestration, we chose to focus on avoided deforestation due to the vast forest coverage in Massachusetts. In this paper we calculate carbon storage in Massachusetts forests over an 8-year period and compare it to statewide energy-sector emissions. From this we estimate the degree to which these forests are currently offsetting carbon emissions, and calculate the amount that would be lost through deforestation. We argue that avoided deforestation should be included in future RGGI policy due to the ability of Massachusetts' forests to offset a substantial proportion of its own energy sector emissions.

## 2. Methods

### 2.1 Study Area

The history of Massachusetts and other New England forests is directly linked to their carbon sequestration capacity today. In general, these forests experienced severe

deforestation followed by remarkable preservation and regeneration. From the colonial era up until the turn of the 20<sup>th</sup> century, most Massachusetts forests were converted to pasture, timberland and farmland. With the movement of agriculture further west and the push towards other fuel sources aside from wood, forests began to regenerate in the state. Today 64% of the state is forested again (Foster *et al.*, 2006), with the majority of the forest found in the western counties (McDonald *et al.*, 2006). Of the 3.2 million acres of forest in the state, 99% are regenerating secondary growth forests with only 3,000 acres of old-growth (Foster *et al.*, 2006).

Massachusetts' success in reforesting the landscape is impressive in the face of it being the 3<sup>rd</sup> most densely populated state in the nation (Foster, 1998). Due to preservation it has become the 8<sup>th</sup> nationwide in percent forest cover (Foster *et al.*, 2006). Because the forests are young, growing rapidly, diverse and plentiful they have the potential to sequester significant carbon.

## 2.2 Inventory Data

Data for this study was taken from the Forest Inventory and Analysis (FIA) dataset provided by the US Forest Service using the Forest Inventory Database Online (FIDO) (available at <http://fiatools.fs.fed.us/fido/index.html>). This dataset includes information on tree counts in forestland by both tree species and size (diameter at breast height) in plots randomly distributed across the states. In Massachusetts, one plot per 5,933 acres of land was sampled repeatedly and data are available for all mainland and island counties, except for Suffolk County. For more information regarding the sampling protocol see

Bechtold & Patterson (2005). The FIDO program allows the user to estimate changes in tree cover over time. We used data collected in 1998 and 2005 to estimate forest gain and loss for each county. A change in forest biomass within these forestlands primarily is due to the growth of existing trees or to tree mortality. Tree mortality could be due to both natural sources, such as storms, or human activities, such as harvesting.

### 2.3 Analysis of Forest Carbon

To estimate carbon, we first determined biomass. General biometric equations for hardwood and softwood tree biomass were combined with tree diameter (DBH) and species information from the FIA database (Tritton & Hornbeck, 1982). This was then multiplied by 50%, the estimated carbon content of tree biomass (Pettersen, 1984) to estimate the change in carbon content of above-ground woody biomass in forestland within each county from 1998 to 2005.

### 2.4 Analysis of Carbon Emissions

Carbon dioxide (CO<sub>2</sub>) emissions data was collected from the Environmental Information Administration for the years 1998-2005 for the energy sector in Massachusetts (Energy Information Administration, 2006). This dataset quantifies the carbon dioxide emissions in metric tons from coal, natural gas, petroleum and minority power sources, including biomass and wood burning. CO<sub>2</sub> emissions were then converted to metric tons of carbon in order to compare to the forest sequestration using the following equation based on the atomic weights of carbon (12) and oxygen (16):

$$\text{Carbon} = \text{Carbon Dioxide} / (44/12)$$

(Energy Information Administration, 2000)

## 2.5 Risk of Carbon Loss from Deforestation

We based our deforestation risk analysis on the recent release of a policy framework recommendation from the Maine Forest Service and others (Maine Forest Service *et al.*, 2009). Outlined in this paper were factors that indicated the likelihood of forests to be converted to development. These factors included distance to population centers, major and local roads, and already developed parcels, as well as the slope of the land (Table 1). We chose to omit distance to population centers, as the majority of Massachusetts is within 3 hours of Boston, a population center with over 500,000 people. This was the cut off for high likelihood of conversion. Because over 90% of the land in Massachusetts fell into this category, it may be an unreliable indicator of development. We also omitted forests that are currently being protected or are considered conservation land. GIS layers for roads were taken from the MassGIS website. The road map layer was published in 2007. The GIS layer for elevation from which slope was calculated was taken from the MassGIS website. The elevation map layer had a cell size of 5 x 5 meter and was published in 2005. The layers for development and forest cover were taken from the National Land Cover Database 2001 with a 30 x 30 meter cell size. Layers were analyzed and reclassified according to the Maine Forest Services recommendations with associated point values, in order to decipher the areas with high, medium and low risk of deforestation. We assigned high risk to the areas of forest with the highest values in each category.

## 3. Results

Carbon storage for the entire state of Massachusetts in 1998 and 2005 was 76,877,134 and 84,517,647 metric tons of carbon respectively, resulting in an increase in carbon storage of 7,640,513 metric tons. This represents an average of 955,064 per year.

Though there was an increase in carbon storage overall for the state, carbon storage in some counties actually decreased during this time period (Figure 1). Overall, there was more carbon stored in the western part of Massachusetts than the east. The low storage in the eastern part of the state was in large part due to poor soil quality and development that reduced forest productivity and cover.

Between 1998 and 2005, the state's energy sector released 57,319,484 metric tons of carbon, with an average of 7,164,935 metric tons of carbon per year (Figure 2). As a result, the state's forests are estimated to sequester 13.33% of the state's emissions in above-ground woody biomass.

We found that 52 % of the state's forests are at high risk for deforestation. These high risk forests have a slope less than 25%, are less than 1 mile from a local road, are less than 5 miles from a major road and are less than 1 mile from an already developed parcel of land. In addition, forests in this high risk category are not currently protected or considered conservation land, meaning that if the owner chose, these forests could be open to development. The region with the highest carbon sequestration, Worcester County, had the most forest at the highest risk for deforestation (Figure 3).

#### 4. Discussion

Overall, Massachusetts forests were able to sequester over 10% of the state's energy-sector emissions in above-ground woody biomass. This is an impressive amount, considering that these forests are not currently being managed for carbon stores. The increase in sequestration over this time period is mostly due to the young age of the forests in this state, allowing them to be a carbon sink. Deforestation resulting from development could, in the future, reduce this sequestration by as much as 52% given that so much of the state's forests fall into the "high risk for deforestation" category.

It should be noted that this paper only looked at above-ground woody biomass. Carbon soil stores below-ground are more than twice that of vegetative stores in some mid-latitude forests (Dixon *et al.*, 1994). While we can not be sure that all forest types within the state would have sequestered 50% or more belowground, this research suggests that Massachusetts forests may have offset significantly more than our calculations show during this time period.

Massachusetts forests offset substantial amounts of energy-sector emissions but are at high risk for deforestation and land conversion due to development. We feel that our research shows a clear argument for the inclusion of avoided deforestation in RGGI policy. Preserving Massachusetts forests will preserve the carbon sequestration within the state and continue to offset over 10% of the state's energy-sector emissions provided that emissions do not increase. RGGI's current plan of using solely afforestation is insufficient, as it is missing an opportunity to protect forests and carbon stores as well as continue carbon sequestration to offset energy-sector emissions. An expanded RGGI

initiative should include sequestration by existing forests and give credits to landowners to protect their forests from deforestation.

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Figure 1. Change in Carbon Storage in Massachusetts Forestland by County for the Time Period 1998-2005. Carbon content was calculated by integrating FIA data for the state with general allometric equations for above-ground woody biomass and multiplying by 50%. Note that not all counties increase in carbon content over this time period.

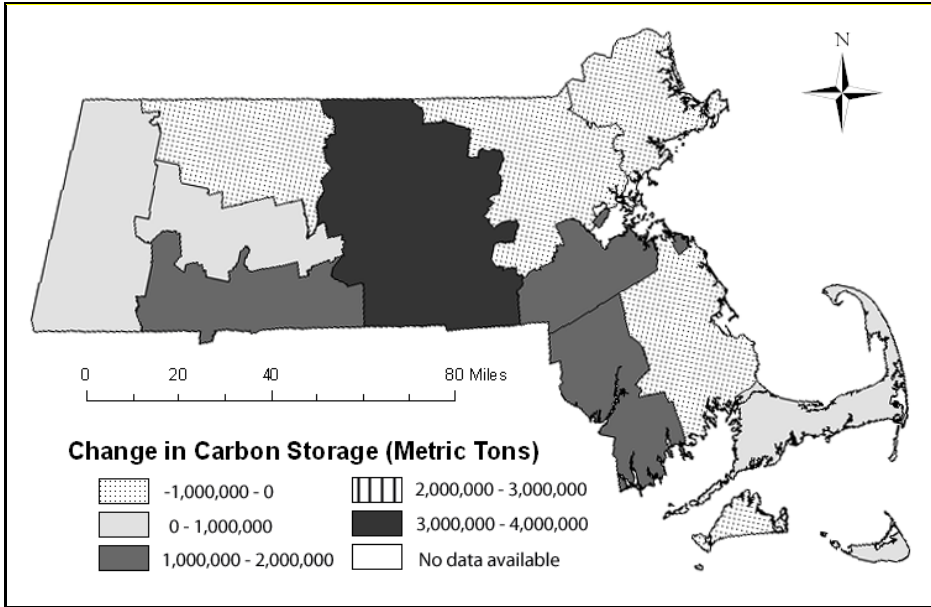


Figure 2. Carbon Dioxide Emissions Converted to Carbon from the Energy Sector for the State of Massachusetts, 1998-2005. The majority of the energy-sector emissions are from the burning of coal, natural gas and petroleum. Carbon dioxide emissions data was obtained from the Energy Information Administration and then converted to carbon using the formula: Carbon = CO<sub>2</sub>/(44/12).

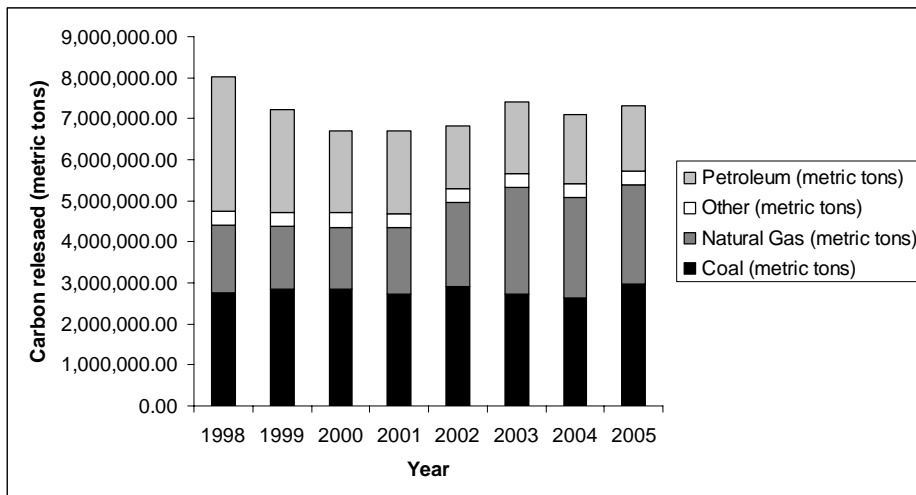


Figure 3. Risk of Deforestation by County. This analysis is based on the Project Score for Likelihood of Conversion from recommended policy framework by the Main Forest Service and others released July, 2009.

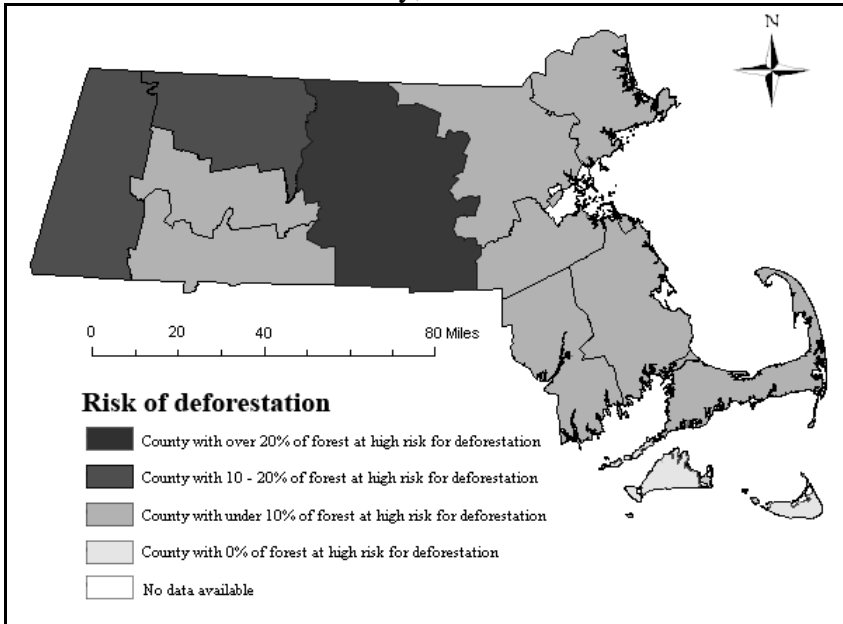


Table 1. Project Score Likelihood of Conversion from Forest to Development. This is taken from “A Policy Framework for Including Avoided Deforestation and Forest Management Practices as Forest Offset Types in the Regional Greenhouse Gas Initiative” released by the Main Forest Service and others in July 2009. Distance to population center was omitted from our analysis, as the majority of Massachusetts is within 3 hours of Boston which has a population of over 500,000.

Likelihood of conversion	Slope	Distance to population centers	Distance to local road	Distance to major road	Distance to already developed parcel
High (2 points)	<25%	< 3 hours to a population >500,000	<1 mile	<5 miles	<1 mile
Moderate (1 point)	25-40%	< 3 hours to a population > 50,000	1-5 miles	5-15 miles	1-5 miles
Low (0 points)	>40%	> 3 hours to a population > 50,000	> 5 miles	> 15 miles	> 5 miles

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