FORESTRY, AGRICULTURE, AND LAND USE CHANGE STRATEGIES FOR REDUCING GREENHOUSE GAS EMISSIONS IN RHODE ISLAND

A Report to the Forestry Working Group of the Rhode Island Greenhouse Gas Process

Prepared by:
Michael Lazarus, Tellus Institute
Gordon Smith, Ecofor

Under the direction of:
Janet Keller, Rhode Island Department of Environmental Management
Jonathan Raab, Raab and Associates

Final Report
July 23, 2004
# Table of Contents

Summary .......................................................................................................................................... i  
1. Introduction ........................................................................................................................................ 1  
  1.1 Role of land use and forestry in the GHG process ........................................................................... 1  
  1.2 Key concepts .................................................................................................................................. 1  
  1.3 Land use trends and forest conditions – Implications for GHG emissions .................................. 2  
  1.4 GHG reduction and sequestration opportunities: Analysis issues and approach ....................... 7  
2. Urban and community forestry (New tree plantings) ........................................................................ 10  
  2.1 Current status, issues, and options ................................................................................................. 11  
  2.2 Assessment of costs and potential ................................................................................................. 18  
  2.3 Implementation options .................................................................................................................. 19  
3. Forest protection .................................................................................................................................. 21  
  3.1 Current status, issues, and options ................................................................................................. 21  
  3.2 Assessment of costs and potential ................................................................................................. 22  
  3.3 Implementation options .................................................................................................................. 27  
4. Land restoration .................................................................................................................................. 29  
  4.1 Current status, issues, and options ................................................................................................. 29  
  4.2 Assessment of costs and potential ................................................................................................. 29  
  4.3 Implementation options .................................................................................................................. 31  
5. Enhanced forest management .............................................................................................................. 33  
  5.1 Current status, issues, and options ................................................................................................. 33  
  5.2 Assessment of costs and potential ................................................................................................. 35  
  5.3 Implementation options .................................................................................................................. 37  
6. Lower-potential options ....................................................................................................................... 40  
  6.1 No-till cropping ............................................................................................................................. 40  
  6.2 Farm fertilizer management ........................................................................................................... 40  
  6.3 Lawn fertilizer management ........................................................................................................... 41  
Glossary ............................................................................................................................................. 42  
Appendix A: Effect of Rotation Length on Carbon Sequestration ....................................................... 44  
Appendix B: Pine enhancement calculations ..................................................................................... 48

---

**Note on units:**

For consistency with the RI Greenhouse Gas Action Plan, we present greenhouse gas emissions in terms of metric tons of carbon (tC) or carbon equivalents (tCe). The latter term includes other greenhouse gases where relevant, such as nitrous oxide (N2O) from fertilizer applications or methane (CH4) from anaerobic decomposition of biomass, converted to carbon equivalents based on their Global Warming Potentials as published by the Intergovernmental Panel on Climate Change. Emissions can also be presented in terms of carbon dioxide (tCO2 and tCO2e).

For reference, 1 tC = 3.67 tCO2. Conversely, $3.67/tC$ is the same as $1/t CO2$. 

---
Summary

For the past three years, the Rhode Island Department of Environmental Management (DEM) and the State Energy Office have convened stakeholders from business, industry, citizen groups, environmental organizations, and other government agencies to address what the state and citizens can do to address the challenge of global climate change. The Rhode Island GHG Process stakeholders have initiated actions across a number of fronts including the development of renewable energy sources, the reduction of vehicle fuel use, and the improvement building and appliance energy efficiency. Stakeholders have also indicated high interest in forestry and land use activities, such as urban and community forestry and open space protection, which can provide key opportunities to reverse the rise in Rhode Island’s emissions of greenhouse gases.

This report examines a suite of potential forestry and land use actions that might help Rhode Island meet its goal of reducing GHG emissions goal (1990 levels by 2010, and 10% below that level by 2020) while providing an array of benefits to state residents and businesses. We find that:

- **The state’s forests, both urban and rural, appear to be important carbon sinks.** In other words, each year they grow and accumulate more carbon than is lost through harvest and conversion of forest to development and other uses.
  - Using more recent USDA studies than available at the time that the RI GHG Action Plan was prepared (2002) we conclude that the state’s net emissions are likely to be about 3% lower than previously calculated.
  - The future rate of carbon emissions/sequestration from RI forests is uncertain. The ongoing increase in pine component of Rhode Island forests will tend to increase carbon sequestration, since pine tends to hold more carbon per acre. On the other hand, forest maturation, land clearing, harvest, and disease could lead to decreases in the rate of carbon uptake or even net emission. If we assume that forests continue to sequester carbon at recent rates, meeting the state’s overall GHG emissions target for 2020 is likely to require about 10,000 metric tons carbon (tC) fewer emissions reductions than previously projected. This is a relatively small amount, subject to significantly larger uncertainties. Further research and analysis on the state’s carbon stocks and trends could provide useful insights for both foresters and GHG process stakeholders.

- **New forestry and land use initiatives, could, together, yield about 50,000 tC/year in carbon sequestration and emissions reductions by 2020.** For many of these measures, such as urban and community forestry and pine enhancement, the larger gains occur well after 2020, as tree mature and provide greater energy savings and carbon sequestration. As outlined in Table ES-1, individual strategies vary considerably in timing of emissions savings (or removals), costs, benefits, funding requirements, and implementation challenges. Specifically, we find that:
  - Urban and community forestry efforts could be expanded beyond current levels, especially with increased focus on yard trees, as well as vacant lots and other open spaces. Experience from other areas suggests a goal of planting 200,000 new trees in the next ten
years is achievable, and that new sources of funding could be tapped. For example, by locating trees where shading can reduce air conditioning costs and where windbreaks can lower heating bills, typically on private property, consumers could save nearly $1.3 million per year by 2020, and the state’s net carbon dioxide emissions could be reduced by about 3,000 metric tons carbon in 2020 and almost double that level in future years.

A 10-year, 200,000-tree program might cost $1.5 to $2 million annually. This is a significant sum. However a combination of funding sources and policy tools could be leveraged to achieve this goal. Support from traditional sources such as the State, USDA, and foundations could be expanded, and utilities, homeowners, and businesses could each contribute in return for the many benefits of an expanded urban forest.

For example, electric and gas utilities could invest in tree planting as a demand-side management activity, as they increasingly do in many California communities. Unlike in California, however, where higher cooling loads (and lower heating loads) make tree shading more clearly beneficial, the energy cost reductions are not sufficient in Rhode Island’s climate to render a tree planting program cost-effective on the basis of energy payback alone. Trees can provide some reduction of winter heating costs, but these are likely to be rather small overall. Nonetheless, municipalities may wish to leverage utility and consumer cost savings to expand urban forestry programs, and partnerships with utilities are worth exploring.

Policy mechanisms to increase canopy cover, such as ordinances and zoning laws in place in Providence and Warwick, could also enhance tree planting and maintenance at limited expense to individual towns. And with added support for effective outreach, more homeowners and businesses might be tapped to contribute to tree planting efforts, as they do in Newport. The DEM’s Forestry division has already helped to train over 400 tree stewards who are already contributing in similar efforts across the state.

The multitude of other benefits from urban and community forestry suggest that this option should be investigated further, perhaps by bringing the many individuals involved in RI urban forestry together with experts and program managers from other regions, and by better documenting the many economic and other benefits that urban forestry can provide.

Forest protection encompasses a variety of potential activities. We examine two of these: a) “conservation development” to promote more compact development patterns and b) voluntary development limits through current use taxation or public purchase of development rights.

The practice of conservation development involves retaining more forest area per dwelling (or commercial) unit created. RI DEM is seeking grant funding to support additional assistance to local planning officials. Our calculations suggest that enhanced conservation development, by avoiding forest loss, could save 16,000 metric tons per year of carbon emissions by 2020. Conservation development practices may also save building and infrastructure cost (e.g. by reducing land clearing and landscaping requirements, and by reducing the roads and utility service line lengths), and can reduce
travel costs and GHG emissions from travel. However, these cost savings are difficult to estimate, and are not reflected here. Costs of implementing the program are expected to be $200,000 per year for five years, for outreach materials and additional staff to work with municipalities. If 20% of clearing can be avoided, average cost will be $4/tC.

The Farm, Forest, and Open Space current use taxation program allows owners of forest land to pay property tax on land valuation that would be supported by potential revenues from forestry, rather than potential revenue from development. In exchange, the landowner commits to managing their land under the appropriate use for a period of 15 years. No quantitative analysis of avoided development was found; economic theory suggests that most development is displaced rather than avoided. Analysis does show that avoiding development of forest land can avoid greater costs of providing municipal services than the amount of property tax revenue forgone by current use taxation. It appears that the number of tons of mitigation resulting from current use taxation are small, but that the cost per ton of mitigation is likely to be negative.

State open space bond funds leverage federal and private foundation funds. These funds can be used to acquire development rights or acquire land at risk of clearing. The Governor’s proposed $35 million bond authorization, currently named the “environment and groundwater protection” bond, is a central element of this strategy. This strategy could avoid 7,000 metric tons of carbon emissions in 2020. If the entire cost of the program is assigned to GHG offsets, the price per ton would be high. The average price per ton as of 2020 would be $870, declining to $345/tC by 2050 as more carbon accumulates on lands acquired prior to 2020. However, it is misleading to view these as incremental costs needed to achieve GHG reductions. The state has a multi-decade history of using open space bonds to provide a variety of benefits including quality of life, water quality, and wildlife habitat, benefits that are not reflected in the $/tC.

- Land restoration sequesters carbon by rebuilding forests and soils. Two types of land restoration are analyzed here: restoration of riparian (river side) trees and restoration of meadows on former gravel mines.

Riparian restoration is included because of its large co-benefits in the form of improved water quality and visual amenities. Riparian restoration yields modest amounts of carbon sequestration because the areas restored tend to be narrow strips and small portions of urban lots. We estimate that achieving the 500 acre restoration goal of the RI DEM Sustainable Watersheds Office by 2015 can store 600 tC annually by 2020 at a cost of $570/tC.

Gravel mine restoration involves hauling topsoil or compost and establishing desired plant species. Creating grass meadow on 1100 acres by 2015 could store 1,000 tC annually by 2020. Sequestration would nearly stop about 30 years after restoration, as soil carbon levels reach equilibrium. 18,000 tC could be stored by 2050 with most of the gain occurring before 2040. Cost through 2020 would average $210/tC, declining to $100/tC by 2050.

Restoration of soil and grass meadow on unused gravel pits would provide early
successional meadow habitat, a goal of the state and federal wildlife management and soil conservation programs. The amount of meadow habitat in the state has decreased dramatically over recent decades as former pastures revert to forest and urban development spreads into formerly rural areas.

The bulk of funding for restoration projects is expected to come from federal conservation incentive programs. Federal funds would pay for land leases, conservation easements, and much of the cost of implementing restoration actions. Support for the RIDEM Sustainable Watersheds Office to do planning work would be required to access federal funds. Additional support may be needed to provide grants for landowner portions of cost shares required by federal programs.

- **Enhanced management of existing forests.** This measure represents a much larger long-term potential resource for carbon sequestration, and a much less expensive one from GHG mitigation cost perspective. Managing forest to promote forest health can sequester carbon as well as reducing chances of catastrophic loss of forest cover. This measure increases outreach to forest landowners, and encourages improvements in forest management. Three changes in management are expected to mitigate greenhouse gas emissions: Improving estate planning to decrease harvest and land conversion following estate transfer, encouraging private landowners to grow and hold more large trees, and encouraging landowners to favor white pine on appropriate sites. Of these changes, the one most likely to generate large amounts of emission mitigation is pine enhancement. In many locations pines can be established merely by timing harvests to occur during heavy pine seed years or scraping away plant litter and duff to expose mineral soil, making a suitable seedbed for pine, and allowing seeds from nearby trees to establish. For the most part, pines can be established in existing forest gaps. Facilitating establishment of white pines across the equivalent of 4000 acres each year for 10 years could ultimately store over 1.4 million tC by 2050, an amount equal to about 60% of a year of Rhode Island’s current total GHG emissions. Implementation involves additional expenditures for outreach to landowners, estimated be an average of $120/tC by 2020, declining to $13/tC by 2070 as trees grow. When interspersed with hardwoods, enhancement of the pine component of existing forests could improve forest diversity, increase winter resting cover for wildlife, and reduce the risk of future forest loss due to pathogens, such as sudden oak disease. Implementation would require dealing with at least several hundred landowners, which would require significant effort. This workload appears feasible because Rhode Island have had good success in communicating with forest land owners, as the recent surveys on the state forestry plan and on the wooly adelgid infestation both suggest.

- **No-till agriculture and fertilizer management options** offer very limited opportunities for GHG emissions reductions, likely amounting to less than 500 tC annually by 2020.

If viewed only through the lens of GHG cost-effectiveness or cost of saved carbon, many of these measures might appear rather expensive, with costs ranging from $10 to over $800 per metric ton of carbon sequestered, as shown in the right hand column of Table ES-1. In contrast, most of the higher-priority transportation, energy supply, and buildings and facilities options in the RI GHG Action Plan were estimated to have negative costs (i.e. net benefits). However,
there is an important distinction between forestry and energy projects. Energy-related GHG mitigation measures typically provide a stream of readily quantifiable fuel or electricity cost savings that quite often pay back the cost of measure. The major “paybacks” for forestry and land use options are typically more difficult to quantify: habitat restoration, stormwater management, community aesthetics, enhanced property values, and/or increased forest product revenue (where relevant), among others. The fact that many of the forestry and land use options discussed here, such as open space protection, are already being pursued, suggests that these paybacks are indeed very significant. Therefore, decisions regarding which options to pursue, and the extent to pursue them, should not focus too narrowly on the reported cost of saved carbon. Rather, they should consider on equal footing, these other key benefits, along with other factors such as ease of implementation, and the feasibility of obtaining funding from new and existing sources.

This report begins by providing an overview of key concepts in carbon accounting, current and projected carbon stocks in Rhode Island, and our overall analytical approach. The sections that follow provide detailed analysis of the strategies summarized here, along with more specific findings and recommendations.
Table ES-1. Forestry and land use change strategies for mitigating Rhode Island greenhouse gas emissions

<table>
<thead>
<tr>
<th>Option</th>
<th>Implementation Pathways</th>
<th>Annual GHG Savings</th>
<th>Cumulative GHG Savings</th>
<th>GHG Cost-Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Potential</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Urban and Community Forestry | - Consider a major statewide program to support enhanced capacity at the municipal level and ability to achieve a goal of 200,000 trees planted in 10 years  
                               - Focus on yard trees and lots to maximize energy and carbon benefits  
                               - Seek quantification and funding based on energy savings  
                               - Promote stronger ordinances and state enabling legislation | 3,000 tC (2020)  
                              |                                                                                         | 16,000 tC (through 2020)  
                              |                                                                                         | 190,000 tC (through 2050)  
                              |                                                                                         | $760/tC (through 2020)  
                              |                                                                                         | $38/tC (through 2050) |
| Forest Protection          | Conservation Development - Seek full implementation of Conservation Development efforts | 16,000 tC (2020)  
                              |                                                                                         | 260,000 tC (through 2020)  
                              |                                                                                         | $4/tC (through 2020) |
| Current Use Taxation       | - Support legislative authorization of a new open space and recreation bond (currently named “environment and groundwater protection” bond) | 7,000 tC (2020)  
                              |                                                                                         | 110,000 tC (through 2020)  
                              |                                                                                         | 304,000 tC (through 2050)  
                              |                                                                                         | $870/tC (through 2020)  
                              |                                                                                         | $340/tC (through 2050) |
| Open Space Bond            | Small                                                                                   | Small                    | Negative cost              |                              |
| Land Restoration           | Riparian Restoration - Increase target acreage for riparian restoration to 500 acres by 2015 and support to existing DEM Sustainable Watersheds program to achieve this target | 600 tC (2020)  
                              |                                                                                         | 7,000 tC (through 2020)  
                              |                                                                                         | 16,000 tC (through 2050)  
                              |                                                                                         | $570/tC (through 2020)  
                              |                                                                                         | $240/tC (through 2050) |
| Gravel Mine Restoration    | - Target restoration of 1100 acres of inactive gravel mines to grasslands by 2015, extending the on ongoing NRCS wildlife habitat program | 1,000 tC (2020)  
                              |                                                                                         | 9,000 tC (through 2020)  
                              |                                                                                         | 18,000 tC (through 2050)  
                              |                                                                                         | $210/tC (through 2020)  
                              |                                                                                         | $100/tC (through 2050) |
| Enhanced Forest Management | - Increase outreach to forest landowners by DEM Division of Forest Environment enhancing pine, encouraging growing larger trees, and estate planning | 23,000 tC (2020)  
                              |                                                                                         | 150,000 tC (through 2020)  
                              |                                                                                         | 1,400,000 tC (through 2070)  
                              |                                                                                         | $120/tC (through 2020)  
                              |                                                                                         | $13/tC (through 2070) |
| ALL OF THE ABOVE           |                                                                                         | 50,000 tC (2020)  
                              |                                                                                         | >550,000 tC (through 2020)  
                              |                                                                                         | >2 million tC (through 2050)  
<p>| | |
|                                                                                         |                              |</p>
<table>
<thead>
<tr>
<th>Option</th>
<th>Implementation Pathways</th>
<th>Annual GHG Savings</th>
<th>Cumulative GHG Savings</th>
<th>GHG Cost-Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Potential</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-till cropping</td>
<td>- Switch 4000 acres from conventional plowing</td>
<td>Negligible by 2020</td>
<td>6,000 tC (through 2020)</td>
<td>Not calculated</td>
</tr>
<tr>
<td>Farm fertilizer management</td>
<td>- Outreach to smaller farmers</td>
<td>&lt; 1000 tC (2020)</td>
<td>Not calculated</td>
<td>Not calculated</td>
</tr>
<tr>
<td>Lawn fertilizer management</td>
<td>- Outreach to homeowners</td>
<td>&lt; 1000 tC (2020)</td>
<td>Not calculated</td>
<td>Not calculated</td>
</tr>
</tbody>
</table>
1. Introduction

1.1 Role of land use and forestry in the GHG process

Global climate change presents a major challenge for Rhode Island. With its many coastal areas, the state faces major risks of flooding, contamination of drinking water supplies, and extreme weather events. Human-caused climate change also presents added threats to local agriculture and forest health. At the same time, Rhode Islanders have many opportunities to reduce their emissions of the heat-trapping or “greenhouse” gases (GHG), reductions that will ultimately be required to avoid dangerous interference with the global climate.

For the past three years, the Rhode Island Department of Environmental Management (DEM) and the State Energy Office have convened stakeholders from business, industry, citizen groups, environmental organizations, and other government agencies to address what the state and citizens can do to address this challenge. During Phase I, stakeholders developed a GHG Action Plan and prioritized a list of options for reducing the GHG emissions, most notably carbon dioxide (CO$_2$).

Forestry and land use activities present key opportunities for mitigating Rhode Island’s rising GHG emissions. Nationally, and in other regions, tree planting efforts and improved forest and agricultural management practices are recognized as significant opportunities to sequester CO$_2$ from the atmosphere, reduce fossil fuel use for heating and cooling, and limit emissions of other gases with potent heat-trapping effects (methane and nitrous oxide). Rhode Island municipalities, state agencies, foundations and others already pursue a variety of land conservation, forestry, and urban tree planting activities, with many notable accomplishments, as noted in this report. Further enhancing urban tree cover, conserving and restoring forests, and other strategies can enrich biological diversity, reduce air pollution, and provide jobs and other community benefits. In addition, forestry and land use strategies can also enlarge the number of participants in climate change mitigation and leverage new sources of revenue for forestry programs and landowners. Despite Rhode Island’s small land area and high land values, these strategies may nonetheless be quite significant and highly attractive, given their other environmental and social benefits.

1.2 Key concepts

Forestry, agriculture, and land use change affect greenhouse gas emissions in a variety of ways, leading to both emissions to, and removals of, greenhouse gases from the atmosphere. Land use affects three greenhouse gases: carbon dioxide, methane, and nitrous oxide. When plants grow they take carbon dioxide out of the atmosphere, return the oxygen to the atmosphere, and keep some of the carbon in their tissues. Roughly half of a tree’s dry weight is carbon. A small fraction of plant carbon enters the soil and becomes soil organic matter, which is stored for many centuries.

Depending on management strategies, harvesting forests (on existing forest lands) may increase or decrease total net sequestration. Extending rotation lengths can significantly increase the total amount of sequestered carbon, though by decreasing short-term wood supplies, it may shift harvest pressures to other lands. On lands where rotation lengths are largely unchanged, the total amount of carbon sequestered still increases over time, as a fraction of previously harvested wood remains stored in wood products. Substantially shortening rotations generally reduces
total sequestration because the total amount of carbon in products and live trees remains less than in the previous, older stand. See Appendix A for quantitative illustrations. If biomass is used for energy purposes, it can avoid the fossil fuel combustion and carbon dioxide emissions.

Methane and nitrous oxide are the two other principal greenhouse gases affected by forestry, agriculture, and land use change. They are emitted in much smaller amounts, but on per weight basis are from 23 (CH\textsubscript{4}) to over 300 (N\textsubscript{2}O) times more potent heat-trapping gases than carbon dioxide, and their dynamics are very complex. As a result, small changes in methane or nitrous oxide emissions can have significant impacts.

Nitrogen is an essential nutrient in ecosystems, and nitrogen cycles through many complex pathways in ecosystems. At some points in this cycling, nitrogen may leak from ecosystems in the form of nitrous oxide. This leakage generally increases when nitrogen fertilizer is applied, and N\textsubscript{2}O emissions are higher in warm, wet conditions. Nitrous oxide emissions can be reduced by reducing the total amount of fertilizer applied to lands, changing what form of nitrogen is applied, and changing when and how it is applied.

Soils that are saturated with water typically emit methane from anaerobic decomposition. Soil methane emissions can be reduced by reducing saturated soil conditions, reducing pathways for diffusion of methane produced deeper in the soil to the atmosphere, and encouraging growth of bacteria that break down methane in soils.

When considering strategies for mitigation of greenhouse gas emissions, decision makers should take into account their potential reversibility. For example, concerns have been raised that carbon sequestered in forests could be rapidly lost in the case of forest fires (RI has an exemplary plan for and record of containing forest fires to less than 200 acres per year) or disease, risks that may well be magnified by climate change itself. However, simply because a particular mitigation activity (like tree planting) present permanence risks does not mean that the activity is not worth implementing. Steps can be taken to minimize permanence risks (e.g. by diversification of strategies across sectors and locations). Furthermore, even if greenhouse gas savings are reversed (i.e. planted forests burn and do not regenerate), there is distinct climate value in removing emissions for many years.

Another concern commonly raised for GHG mitigation projects is emissions leakage. For instance, a land conservation strategy might seek to remove certain lands from development pressures, land clearing, and forest loss. However, in some cases, if proper steps are not taken, such a strategy might simply lead to land clearing, forest loss, and carbon emissions in another location. Like permanence, leakage concerns can be addressed through appropriate policy designs (e.g. by directing development to lower impact lands).

1.3 Land use trends and forest conditions – Implications for GHG emissions

From the mid 1600s through the late 1800s, land clearing, logging and crop tillage released a significant fraction of the carbon previously stored in Rhode Island’s forests and soils. Over the past century, forest re-growth has made lands a net sink. As of 1998 (the most recent date for
which data are compiled) about 59% of the land in Rhode Island is forest.\textsuperscript{1} Over the past four decades the area of forest in Rhode Island has generally been decreasing as forest land is converted to residential and urban use. Depending on the time period and definition of forest used in each study, the rate of loss has changed over time, ranging from rapid loss to slow and intermittent loss of forest. The general trend is movement of forest land out of large parcels into smaller parcels, and significant losses of area in timberland while there area in urban forest increases. From 1973 to 1993, the average size of forest ownerships in the state declined from 26 acres to 13 acres.\textsuperscript{2}

Future land management—including continued forest growth and land clearing for urban and suburban development—could cause the lands of Rhode Island to be either a net source or net sink of greenhouse gases. Even today, there is some uncertainty as to whether Rhode Island lands are a net source or sink of carbon dioxide emissions. The inventory prepared for the RI GHG Action Plan suggested that the state is currently a net source of 26,000 metric tons carbon per year, based on a draft USDA Forest Service assessment, which suggested that loss of forest to development (averaging 1450 acres per year from 1985-1997) outpaced forest growth.\textsuperscript{3}

However, more recent USDA Forest Service estimates (by the same authors) indicate that forests have actually been increasing carbon stored by about 53,000 metric tons carbon per year.\textsuperscript{4} This more recent analysis includes several key improvements.\textsuperscript{5} Though these changes provide a more accurate estimate of net forest carbon flux for the state, there are still many uncertainties. The most recent USDA carbon estimates are based on sampling of the forests through 1985, and may not adequately reflect the area of land converted to non-forest use. The Rhode Island Division of Forest Environment (DFE) estimates that, over the next 15 years, RI forests will grow at a rate that would store 76,000 tC/year, 44% more sequestration than USDA Forest Service historical figures would suggest.\textsuperscript{6} It should be noted that achieving these levels of carbon sequestration would require no major increases in rates of land clearing, harvest, and disease.


\textsuperscript{3} The draft USDA assessment uses simplifying assumptions that a) all soil carbon in areas going out of forest use is immediately emitted as carbon dioxide, and b) that forest floor and understory carbon pools do not change in density with tree carbon density. Despite a calculated gain in tree carbon of 51,000 metric tons carbon per year, the calculated losses in soil, forest floor, and understory pools were even larger, leading to a net emission.


\textsuperscript{5} When addressing land use change, the more recent assessment makes the more reasonable assumption that soil carbon remains stored at amounts that are typical for non-forest uses. It also uses non-linear regression analysis to develop ratios of non-tree forest carbon stocks as a function of tree carbon stock, and includes carbon stored in wood products but does not include carbon in mineral soil.

\textsuperscript{6} DFE anticipates that the existing standing stock of about 1.8 billion board feet will gain an additional half billion board feet in the next 15 years. (Tom Dupree, Chief, RI Division of Forest Environment, personal communication 13 April 2004.) This would mean an average annual gain of 33.3 million board feet per year. The Forest Service Forest Inventory Analysis program measured 494 million cubic feet of growing stock on Rhode Island timberland, which implies a ratio of 3.65 board feet per cubic foot. Dividing results in a gain of 9.1 million cubic feet per year. (USDA Forest Service, Northeast Forest Inventory and Analysis Program, Table 34, accessed at http://www.fs.fed.us/ne/fia/states/ri/tables/t34.8.l.htm). Multiplying by 18.43 pounds of carbon per cubic foot\textsuperscript{4}, and dividing to get metric tons, yields an estimated gain of 76,000 metric tons of carbon per year. This projected rate of
These annual changes are small compared with the total carbon stored in Rhode Island forests, 12.7 million metric tons carbon. The carbon stored in forests is equivalent to nearly four years of Rhode Island greenhouse gas emissions (3.43 million metric tons carbon equivalent in 2000). This ratio suggests that even modest changes in forest stock can have a significant effect on total state emissions.

Forest carbon estimates tell only part of the story. These USDA studies (Forest Inventory Analysis) consider only the carbon stored in “forests” as technically defined—undeveloped lands amounting to 393 thousand acres in 1997—which cover 59% of the state. Much of the rest of Rhode Island is in some sort of developed use. The use covering the largest proportion of area is residential. Other uses include roads, and various types of commercial and industrial uses. About 7% of the state land area remains in agricultural use.

Box 1. The dynamics of carbon in Rhode Island forests
Despite the general trend forest area loss, the total amount of carbon in Rhode Island forests and wood products has been increasing. The increase in total forest carbon stock results from an interaction of long-past land conditions and more recent usage patterns. Much of the current forest originated early in the 20th century. About 75% Rhode Island’s forests are dominated by trees 50 to 90 years old (as of 1998). In recent years, the rate of growth has exceeded logging rates; from 1984 through 1997, wood volume removed from forests by harvest was only 12% of wood growth of live trees, even after deducting for trees that died or decayed. In addition, a portion of this harvested wood remains sequestered in long-lived wood products, such as lumber and furniture. Conversion of forest land to other uses during this time period resulted in a loss of biomass and carbon equal to about 57% of net wood growth. The net effect was that Rhode Island forests accumulated about 2.5 million cubic feet of wood per year. This net gain of wood, plus gains in the amounts of carbon in forest soils, the forest floor, understory plants, and wood products resulted in average sequestration in forests at the rate of 53,000 metric tons carbon per year.\(^{10,11}\)

\(^{7}\) Biomass from USDA Forest Service Forest Inventory Analysis state summary tables, accessed at http://www.fs.fed.us/ne/fia/states/ri/tables/t57.6.1.htm, converted assuming that half of dry biomass weight is carbon. This estimate does not include soil carbon. Birdsey and Lewis (2003) estimate that and additional 1.3 million tons of carbon harvested from RI forests remain stored in forest products.


\(^{11}\) We have assumed these trends and calculations, conducted on data from the 1980s and 1990s are still relevant.
According to census definitions and as illustrated in Figure 1, 23% of Rhode Island is “urban”, among the highest percentages in the US. Of this urban land, only 9% is covered by trees, among the lowest urban tree cover rates in the US. Nonetheless, it has been estimated that Rhode Island’s urban trees store about 760,000 metric tons of carbon, and that this stock is increasing by 18,000 metric tons annually. 12 While the standing stock is only about 6% of rural forest biomass, carbon could be accumulating in urban lands at nearly half the rate of rural forests. This finding suggests that although urban forests store only a fraction of the carbon in the state’s traditional forests, they are of high relative importance in terms of the state’s carbon balance, and in terms of GHG mitigation strategies within the state.

Table 1 compares the overall contributions of urban areas and traditional forests to the state’s biomass carbon stocks. As noted earlier, these estimates differ from the analyses completed several years ago for the RI GHG Plan.

Table 1. Current (business-as-usual) contributions of rural and urban forests

<table>
<thead>
<tr>
<th></th>
<th>Fraction of RI land</th>
<th>Trees</th>
<th>Tree Cover</th>
<th>Carbon stored (tC)</th>
<th>Carbon sequestered (tC/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>59%</td>
<td></td>
<td></td>
<td>13,000,000</td>
<td>53,000 to 76,000</td>
</tr>
<tr>
<td>Urban areas</td>
<td>23%</td>
<td>4.1 million</td>
<td>9%</td>
<td>760,000</td>
<td>18,000*</td>
</tr>
</tbody>
</table>

Table 2 shows the effect of revising these estimates based on these updated numbers (a negative number indicates net removal of CO₂ from the atmosphere). We show the effects of using the more conservative (lower) USDA Forest Inventory Analysis historical estimates for rural forests described above. The net change is decrease in 2000 emissions by about 3%. Use of the higher estimates derived from the RI DFE analysis would decrease the state’s emissions by another 1%.

12 Nowak, David J. and Daniel E. Crane. (2002) Carbon Storage and Sequestration by Urban Trees in the USA. Environmental Pollution; 116(3): 381-389. The lead USFS researcher in this analysis (David Nowak) acknowledges some large uncertainties with these data and is currently working to resolve their estimates with more recent, finer grained GIS data. He cautions that the current analyses for coastal city states is thrown off somewhat by the 1km grid resolution used in states like Rhode Island, where towns frequently border water bodies. The resulting numbers are likely to be low estimates, and should be improved with 30m grid resolution data now being processed. Nowak (2001) actually reports 25,000 tC/year of gross sequestration. We reduced this estimate by nearly 30% to reflect carbon released by tree death and decay.
Table 2. Effect of revised estimates on Rhode Island GHG emissions for the year 2000

<table>
<thead>
<tr>
<th>GHG Action Plan (2001)</th>
<th>Million tC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Emissions</td>
<td>3.53</td>
</tr>
<tr>
<td>of which Forests</td>
<td>0.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revised analysis (2004)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>-0.05</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>-0.02</td>
</tr>
<tr>
<td><strong>Revised Total Emissions</strong></td>
<td><strong>3.43</strong></td>
</tr>
</tbody>
</table>

How do these changes in baseline emissions affect meeting Rhode Island’s target?
First, they reduce estimated emissions for 1990, as these estimates were in fact derived from data from the 1980s and 1990s. Second, since 1990 is the index year of the Northeast Governors’ and Premiers’ GHG reduction target that Rhode Island has adopted, these revised estimates lower the emissions levels that the state must achieve in 2010 and 2020. As illustrated, in Figure 2 target drops by 3.2% in both 2010 and 2020.

If we assume that forests continue to sequester carbon at recent rates, meeting the state’s overall GHG emissions target for 2020 is likely to require about 10,000 metric tons carbon (tC) fewer emissions reductions than previously projected. As noted above, however, the future rate of carbon sequestration from RI forests however, is rather uncertain. The ongoing increase in pine component of Rhode Island forests, which would increase carbon sequestration, may not be adequately reflected in USDA inventory estimates. At the same time, forest maturation, land clearing, harvest, and disease could lead to decreases in the rate of carbon uptake.

Further review on the state’s carbon stocks and trends could provide useful insights for both foresters and GHG process stakeholders. The USDA is currently revising their estimates based on input by RI DFE staff and others. However, since the USDA analysis relies on historical sampling data, it must be complemented by the insights of RI foresters.

---

13 During Phase I, the Stakeholders accepted the New England Governors and Eastern Canadian Premiers’ regional Greenhouse Gas Reduction target of reducing GHG emissions to the 1990 level by 2010 and 10% below 1990 levels by 2020 as a reasonable goal for now, on which to base a Rhode Island GHG Action Plan.
1.4 GHG reduction and sequestration opportunities: Analysis issues and approach

In the RI GHG Action Plan, the stakeholders identified two high priority forestry and land use options: urban and suburban forestry and open space protection as well as several low priority options including conversion of marginal cropland to forest and wetlands, low-input agriculture, improved cropping systems, and forest management. Based on these decisions as well as more recent input from the RI DEM and ongoing Stakeholder deliberations, we prepared an initial list of more specific implementation options. This list was further refined by the Rhode Island Forest Working Group in October 2003, and during subsequent discussions with forestry and land use professionals in Rhode Island and nationally. The resulting list of options is shown in Table 3 below.

Based on our analysis, we consider four types of options as higher potential in terms of emissions removal/reduction potential and/or environmental or social co-benefits: urban and community forest, open space protection, land restoration, and pine enhancement in existing forest areas. The first two replicate the Phase I higher priority options, and our analysis of these options focuses on more detailed quantification of costs, emissions reductions, and possible implementation pathways. Land restoration emerged because it is already being pursued in Rhode Island for habitat, water quality and aesthetic reasons, and potential funding sources exist to further the work. Analysis of forest management options revealed enhancement of the pine component of existing forests to be ecologically desirable, tractable to implement, capable of generating a significant carbon sink.
Table 3. Forestry and land use strategies considered

<table>
<thead>
<tr>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Higher Potential</strong></td>
</tr>
<tr>
<td>Urban and Community Forestry</td>
</tr>
<tr>
<td>Forest Protection – Current Use Taxation and Farm and Forest Bond</td>
</tr>
<tr>
<td>Forest Protection – Conservation Development</td>
</tr>
<tr>
<td>Land Restoration – Riparian</td>
</tr>
<tr>
<td>Land Restoration – Gravel Mines</td>
</tr>
<tr>
<td>Enhanced Forest Management</td>
</tr>
<tr>
<td><strong>Lower Potential</strong></td>
</tr>
<tr>
<td>No-till Cropping</td>
</tr>
<tr>
<td>Farm Fertilizer Management</td>
</tr>
<tr>
<td>Lawn Fertilizer Management</td>
</tr>
</tbody>
</table>

We describe each of the higher potential options in detail in Sections 2-5 below. Analysis of each option faced a common challenge—limited experience and data upon which to estimate costs and benefits. While urban forestry, open space protection, and land restoration, are already being implemented in Rhode Island and elsewhere, they have rarely been pursued for their greenhouse gas benefits. Thus modeling of carbon sequestration and other benefits has required considerable research, and estimates of emissions reduction and cost-effectiveness ($/tC removed or reduced) retain considerable uncertainty. The principal metrics used to evaluate options are shown in Table 4 below. We provide a much briefer analysis of the lower potential options in Section 6.
<table>
<thead>
<tr>
<th>Metric</th>
<th>Unit (if quantified)</th>
<th>Definition/Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual GHG Impact (2020)</td>
<td>tC (metric tons carbon equivalent)</td>
<td>Total greenhouse gas emission removals (sequestration) or reductions in 2020, expressed in metric ton carbon equivalents. 2020 is the final target year of the RI and Governors’/Premier’s goal.</td>
</tr>
<tr>
<td>Cumulative GHG Impact (2004-2020 and 2004-2050)</td>
<td>tC (metric tons carbon equivalent)</td>
<td>Cumulative emissions reductions is a better indicator of climate impact than a single year’s emissions, since greenhouse gases accumulate in the atmosphere and many forestry and land use strategies yield savings that can change considerably from year to year.</td>
</tr>
<tr>
<td>Cost-Effectiveness (to 2020 and to 2050)</td>
<td>$/tC</td>
<td>Typically this is equal to the NPV divided by the cumulative GHG impact (discounted or undiscounted). It is the metric commonly used to compare among various options for mitigating emissions. These amounts include total program spending and do not attribute portions of the cost to other co-benefits.</td>
</tr>
<tr>
<td>Stakeholder Interest, Public and Political Support/Concern, Feasibility</td>
<td></td>
<td>Expected support and or concern from the general public and from policymakers. Ease of implementation and administration by implementing parties.</td>
</tr>
<tr>
<td>Ancillary Costs and Benefits</td>
<td></td>
<td>Environmental, job, community and other impacts other than GHG emissions reductions, including public health and ecosystem impacts. These are often difficult to quantify, though some estimates have been made for the many benefits of urban forestry.</td>
</tr>
</tbody>
</table>
2. Urban and community forestry (New tree plantings)

Given their many and varied benefits, urban and suburban tree planting and maintenance programs are pursued throughout the US, and Rhode Island is no exception. Urban and community trees reduce local air pollution, stormwater runoff, and urban heat island effects. They enhance community aesthetics, raise property values, and provide biological diversity. And with respect to carbon emissions, they can provide a dual benefit: carbon sequestration and lowered energy use for heating and cooling buildings, through shading and evapotranspiration in the summer, and windbreaks in the winter. One recent study estimates the full value of Rhode Island urban forests at $2.6 billion.\textsuperscript{14}

In developing the State’s GHG Action Plan, participating Stakeholders identified urban and community forestry as one of 30 highest priority options for removing GHG emissions. This determination was based on an initial assessment of the potential for reducing statewide emissions, of cost-effectiveness (calculated as the cost per ton of carbon saved or removed), and other factors that influence feasibility and attractiveness (such as the many co-benefits noted above).

In the case of urban and community forestry, the Action Plan suggested that as much as 30,000 to 120,000 metric tons carbon per year could be removed by increasing canopy cover by 5-20%. These estimates were based on the extrapolation of national figures to Rhode Island, figures that ascribed the majority of the carbon savings to reducing cooling and heating loads, rather than carbon sequestered by the trees themselves. However, recent studies suggest that combined cooling and heating benefits in the Northeast US may be far lower than in other parts of the US (see Boston case study below), especially given older urban landscapes and cooler-than-average climates. With this in mind, we have conducted a closer examination to get a better grasp of potential GHG emissions benefits.

To develop these estimates, identify implementation issues, and arrive at some concrete implementation strategies, we have consulted with numerous local, state, and national urban foresters and planners.\textsuperscript{15} We reviewed available literature and modeling studies on the energy (references), which are rather scant with respect to the Northeast specifically. Much of the activity aimed at capturing energy benefits of urban forestry has occurred in the West and South, given the clearer estimation of benefits from tree shading in warm, sunny climates.

A prime example is the Sacramento experience, where the municipal utility (SMUD) continues to invest $1.5 million annually in a shade tree program that has planted 350,000 trees since 1990.

\textsuperscript{15} Including, among others: Paul Dolan, Urban and Community Forestry, RI Department of Environmental Management; John Campanini, retired City Forester, Providence Parks Dept.; Scott Wheeler, Newport Parks Dept.; Margie Ryan, Warwick Planning Dept.; Michael Bartlett, City of East Providence; Tom Willett, Pawtucket Planning and Redevelopment; Jim Lucht, Community Planner/GIS Specialist, The Providence Plan; Jennifer Cole Steele, Providence Neighborhood Planting Program; David Nowak, USFS, Syracuse; James Simpson and Greg McPherson, USFS, Davis; Cheryl Kollin, Director, Urban Forestry, American Forests; Milton Marks, Friends of the Urban Forest; Misha Sarkovich, Project Manager, Sacramento Municipal Utility District; Baldeo Singh, Sacramento Tree Foundation.
Though their success is spreading throughout California and the Southwest, there have been no equivalent programs to date in the cooler, temperate climes of the Northern and Eastern US. While several Northeastern municipalities, such as Burlington, have adopted tree planting programs as elements of the climate change action plans, they have focused almost exclusively on the carbon sequestration benefits, which are typically rather small, especially for programs that focus on street and near-street trees. For example, Burlington’s expects a mere 45 metric tons carbon per year from its program. A CITY GREEN analysis for Buffalo found that an initiative to increase canopy cover to 50% in vacant parcels would sequester about 200 metric tons carbon per year. These indicative results confirm that street tree (and vacant lot) programs provide an important but most likely quite limited opportunity for carbon gains.

Therefore, for urban and community forestry to provide significant new CO$_2$ emissions reductions and removals, three elements are necessary:

- Targeting spaces where trees can grow to sizes where carbon sequestration can be significant, such as yards, parks, vacant lots, and open spaces. Street tree locations are inherently limited by size constraints, high mortality, relatively high costs, and frequently proximity of power lines.

- Locating trees and selecting species where energy benefits can be maximized. For instance, a large evergreen tree sited on the south side of a house in Rhode Island might actually increase overall CO$_2$ emissions through winter shading and increased home heating requirements.

- Developing implementation strategies, along with the institutional capacity and funding, that can achieve a large increase in tree planting and maintenance activity.

In addition, preserving and enhancing existing and urban forests is absolutely essential, especially in terms of achieve emission targets by 2020. With new planting activities, it will take many years before trees grow to a size where their carbon sequestration and energy saving benefits are substantial.

2.1 Current status, issues, and options

The Rhode Island DEM provides support to urban and community forestry activities across the state. It administers a grant program, which it has reoriented to support the development of municipal tree ordinances and help communities reach Tree City USA status, a designation of the National Arbor Day Foundation. Ten communities have achieved Tree City USA status, which requires a tree board or department, a tree care ordinance, and a community forestry program with an annual budget of at least $2 per capita. The DEM recognizes the widely varying capabilities among the state’s 39 cities and towns, and the importance of establishing the necessary foundations for successful urban forestry efforts (ordinances, tree wardens, city foresters and/or landscape architects that can review development plans, and provide effective guidance on planting strategies).

$^{16}$ [http://www.arborday.org/programs/TreeCityBenefits.html](http://www.arborday.org/programs/TreeCityBenefits.html)
Many Rhode Island communities have gone well beyond these minimum requirements, with well-established and successful tree planting and maintenance activities, ranging from Providence’s cutting edge tree ordinances and to Newport’s unique bareroot yard tree program. Examples include, but are not limited to:

- **Providence’s canopy cover requirements.** Building permits are issued only if plans are in place to achieve canopy coverage targets -- 25% for residential permits or 15% for commercial/industrial -- or if fees are paid (as offsets) to cover tree planting elsewhere.\(^{17}\) Similar initiatives are also possible at the statewide level, such as Maryland’s Forest Conservation Act, which provides guidelines for the canopy retained or planted after the completion of development projects.\(^{18}\) New Jersey has enacted similar requirements under the Whitman administration. The key to effective implementation of canopy cover ordinances or legislation is enforcement capability.

- **Newport’s bareroot program.** For several years, Newport has offered homeowners the option of ordering a bareroot shade tree for $55. These trees are planted by the city in front of the house, in the public right-of-way or up to 20 feet within the property line. This program is notable in a number of respects. It is one of the few, significant programs that can plant in private property, avoiding conflicts with utility lines, and often enabling trees to grow larger, thus providing greater shade tree benefits for the public (including more carbon sequestration and energy benefits). Second, the use of bareroot tree stock may lower tree purchase and planting costs, and may reduce tree mortality (due to less soil disturbance, subsidence, and crown burial), particularly in comparison with balled and burlapped trees.

- **Warwick’s zoning laws** that were rewritten to require 5% of commercial parking lots and 10% of commercial sites (overall) to have tree cover. With two checks in the process – an approved plan to commence construction and an inspection to get a certificate of occupancy – there is a high certainty of implementation.

- **Providence’s ambitious goals,** which include planting 40,000 new trees in 4 years to achieve its overall canopy cover target of 25%. Though funding and implementation plans are not yet established, the rough plan is to plant 10,000 street, 10,000 yard, 10,000 public space, and 10,000 vacant lot trees.

Ambitious urban forestry goals, like Providence’s, have also been articulated at the statewide level. The state’s Urban and Community Forest Plan, developed by the DEM’s Division of Forest Environment, RI Tree Council, and the Statewide Planning Program and adopted in May 1999, sets out an overall goal of enhancing tree canopy by 5-8% by 2020 in 24 communities (See Box 1). Taking the lower end of this range, and applying it to the full estimate of 4 million trees currently in Rhode Island urban areas as noted in Section 1, this would suggest the addition of at least 200,000 new trees. Given that young trees would provide only a fraction of the canopy cover of mature trees, this estimate is on the low end of the number of trees needed.

---

17 Present canopy coverage in Providence is 16% for residential and 4-5% for commercial/industrial sites.
18 [http://www.dnr.state.md.us/forests/healthreport/act.html#Forest_Conservation_Act](http://www.dnr.state.md.us/forests/healthreport/act.html#Forest_Conservation_Act)
Box 2: The Rhode Island urban and community forest plan  
(excerpted from the Appendix to the RI GHG Plan)

According to the Plan, “Rhode Island’s urban and community forests face a variety of challenges. Among the key issues are lack of knowledge of the value of trees, insufficient data on tree resources, little or no legal protection for tree resources, insufficient investment in tree resources, and lack of foresight and planning for protection of tree resources in concert with new development.”

To tackle these challenges, the Plan has laid out a set of targets and strategies, among them, strengthened legal protection for tree resources. For example, only one quarter of Rhode Island municipalities have tree ordinances, which require that significant tree resources be identified, maintained, and replaced if damaged or removed. Municipalities in some parts of the US are now extending these ordinances to include trees on private lands. The plan suggests several enhancements to ordinances, legislation, and zoning to enhance the urban and community tree resource.

Rhode Island and its communities should seek to manage the state’s urban and community forests as follows:

- the state as an entirety should seek to maintain forest land cover at approximately 55 percent of total land area through the year 2020.
- communities having 50 percent or higher forest land cover in the 1995 land use survey, should seek to avoid a more than 2 percent decrease below their 1995 baseline of forest land cover through the year 2020.
- communities having 20-49 percent forest land cover in the 1995 land use survey should seek to increase their forest land cover by 4 percent over the 1995 baseline by the year 2010 and by 8 percent over the 1995 baseline by 2020.
- communities having less than 20 percent forest land cover in the 1995 land use survey should seek to increase their forest land cover by 2 percent over the 1995 baseline by 2010 and by 5 percent over the 1995 baseline by 2020.

Overall, the plan is to enhance tree canopy by 5-8% by 2020 in 24 urban/suburban communities. The Urban and Community Forestry Plan targets limiting canopy loss to 2% in 15 rural communities.

In keeping with these types of goals, it is possible to envision an overall statewide effort that might deliver the substantial carbon gains that the RI GHG Process is targeting, building upon the existing foundation of activity and innovation spread across the state, while yielding many of the urban forestry benefit long sought by municipalities and other institutions (RI DEM, Tree Council and others) in Rhode Island.

Along these lines, students at Brown University have prepared an interesting analysis and highly informative website that examines the potential carbon and other benefits of initiatives to plant
250,000 new trees throughout the state in the coming 5-10 years. Many of their comments and insights are also reflected here.

**Bigger trees, yard trees.** Encouraging homeowners to grow large yard trees can sequester significant amounts of carbon.\(^\text{19}\) Newport and Warwick will plant near-street trees within 20-25 feet of a right-of-way. Other towns have considered, but not pursued planting on private property (e.g. Pawtucket), as it can entail additional concerns and communication efforts. However, Sacramento’s program provides an example of how tree programs can succeed in getting large numbers (350,000) of trees planted in front, back, and side yards (See Box 3 below).\(^\text{20}\)

---

**Box 3: Key features of the Sacramento shade tree program**

- Now in its 14\(^{\text{th}}\) year, the program has reached 130,000 SMUD customers, and planted over 350,000 trees.
- The utility now spends $1.5 million, and sponsors 21,000 trees annually.
- The program is marketed through electricity billing inserts. It provides an introductory free video, followed by a home visit with tree selection and location recommendations.
- Residents plant their own trees.
- The value of electricity savings (30 year present value) roughly matches the cost of tree planting. Thus, program is considered an effective utility Demand-Side Management (DSM) program.
- Los Angeles and other California communities are emulating the program, at a larger scale.
- Most utility sponsors are publicly-owned; the exception thus far is San Diego Gas and Electric. (Note that there are far more public than private utilities in California).
- SMUD has conducted numerous evaluations, and has refocused its program to maximize benefits (limiting number trees/household, prioritizing locations). Tree planting teams carry lookup tables that indicate the energy savings associated with 30 different combinations of species, location, and other factors.

---

**Location, Location, Location.** While the carbon a tree sequesters depends largely on its size, energy benefits are another story. A tree’s azimuth, or cardinal direction from houses, will dictate the extent it will provide shade in summer, winter, spring, and fall, and the extent to it

---

\(^\text{19}\) Growing a single six-inch diameter tree to a foot in diameter can sequester approximately one ton of carbon dioxide. According to Nowak, D. and Crane, D, *Environmental Pollution*. 2001. 116(3): 381-389: “Total carbon storage and sequestration within cities generally increases with increased urban tree cover (city area multiplied by % tree cover) and increased proportion of large and/or healthy trees in the population. Large healthy trees greater than 77 cm in diameter sequester approximately 90 times more carbon than small healthy trees less than 8 cm in diameter (Nowak, 1994). Large trees also store approximately 1,000 times more carbon than small trees (Nowak, 1994). Moreover, large trees with relatively long life spans will generally have the greatest overall positive effect on carbon dioxide as fossil fuel carbon emissions resulting from tree planting and removal will happen less frequently.”

will lessen prevailing winds. Figure 3 illustrates that in the Eastern US climate, the overall carbon benefits of an urban tree depend critically on size, tree species, and azimuth, and distance from a house. This figure also serves to illustrate the complexity of calculating urban tree carbon benefits.

---

Figure 3. Effects of location and tree type on carbon uptake, release, and avoided fossil fuel emissions (based on reference data for mid-Atlantic region, McPherson and Simpson, 1999)

- Shade cooling - lowers electricity use. Trees sited to the W of a house provide the greatest benefit, by shading during the warmest hours of summer days.
- Climate cooling - decrease in ambient temperature across communities, due to shading and evapotranspiration effects (urban heat island). It is a function of tree size and type.
- Shade heating - increases heating fuel use in winter, spring, and fall. It is significant for trees sites to the south, esp. for evergreens.
- Climate heating - is the general windbreak effect affecting other homes across a community.
- Windbreak - reduces heating fuel use needed to heat in cooler months; typically maximized by trees that shield northern winds.
- CO2 uptake - is the gross carbon sequestered by a tree.
- CO2 release - results from dead and decaying tree matter.
- NET - is the sum of all of the preceding seven effects.
This analysis of factors influencing urban forestry energy benefits – developed largely by USDA Forest Service researchers in California and New York – has been practically applied by planners and outreach agents in Sacramento to select tree planting locations and species that maximize energy saving benefits.

This type of information could also be used in Rhode Island to maximize the overall carbon benefits of urban forestry strategies. For instance, to maximize energy bill reductions and carbon savings, urban planting programs can maximize wind protection and solar control by:

- Locating trees close enough to buildings to provide shade without creating root or limb problems.
- Favoring large, fast-growing, solar-friendly tree species, especially on the South and East of building. McPherson and Simpson (1999) provide a useful listing of solar-friendly trees. See also the Brown students’ urban forestry website.  
- Planting windbreak trees to the north and northwest, using evergreens where possible.
- Selecting locations and species that enabling larger, mature trees.

These factors are not always well-integrated into tree selection and planting decisions (of course in part because few programs have focused on yard trees and energy benefits). A recent modeling study of existing tree cover in Boston demonstrates this clearly. This USFS study suggests that, given the rather haphazard locations of existing trees, their net energy benefits are limited. Aggregated across the entire city, the cooling effect of Boston’s tree cover appears to save residents about $3 million annually in avoided air conditioning bills. However, these trees also provide considerable shading in the cooler months, adding to heating bills, negating the cool season windbreak benefits. These results suggest that if tree locations and species were better optimized, the net energy benefits could be far greater.

$\S, \S, \S$. The final issue, and the key one raised by nearly every urban forester and planner contacted, should be no surprise. Funding available for tree planting is hard to come by, even more so given the recent local and state budget crunches. Therefore, to achieve the types of goals embodied in the state and providence’s urban forestry plans, new sources of funding along with innovative planting and outreach strategies are needed, to both increase available resources (both staff and budgets) and lower the effective cost of planting trees. Traditional street tree plantings can cost upwards of $200 per tree. Recent experience suggests that various strategies including possibly the greater use of bareroot tree stock, greater resident participation, and enhanced outreach efforts (e.g. use of electricity bill inserts) might be able to lower costs per tree.

Yard trees, in particular, present an interesting challenge. Though public benefits may be less obvious, experience in some communities (such as Newport or Sacramento) suggest that residents are willing to devote money or time to tree planting. As noted by those active in tree planting efforts, Rhode Islands larger and older communities can present particular challenges,

\[\text{Sources:}\]

\[\text{22} \quad \text{http://envstudies.brown.edu/classes/es201/2003/Forestry/intro.htm.}\]
\[\text{23} \quad \text{http://www.fs.fed.us/ne/syracuse/Data/State/data_MA_bos_ufore.htm.}\]
\[\text{24} \quad \text{Winter/spring/fall shading costs residents about $3 million, while the general windbreak effect saves about $3 million.}\]
where prevailing attitudes are not always favorable to larger trees (as evidenced by pollarding) or trees in general.

2.2 Assessment of costs and potential

Based on data and relationships drawn from US Forest Service research\(^{25}\), we constructed a spreadsheet model to estimate the costs and benefits of a planting program. We assumed a planting target of 200,000 trees in 10 years, roughly consistent with the state urban and community forest plan as noted above, also equivalent to a scale-up of Providence’s 40,000 in 4 goal to other Rhode Island communities. The rate of planting is similar to Sacramento’s, where 21,000 trees are being installed annually. We also assumed a similar cost per tree planted, $75, on the notion that this level of activity could yield significant economies of scale compared with activities in Rhode Island today. Although these estimates are drawn from a program that focused on residential yard trees, we assumed this was a reasonable proxy for an expanded program that also would seek to plant trees along streets, and in parks and vacant lots.

Model results are shown in Table 5 below. It is assumed that 23,000 trees would need to be planted annually for 10 years to achieve 200,000 trees, given mortality rates for young trees, even where carefully planted.\(^{26}\) The annual costs for such an effort are considerable, over $1.7 million; however, cost sharing among homeowners, businesses, state and local government and other sources could mitigate the cost burden for municipalities and tree planting programs.

Table 5. Summary results for urban forestry effort (200,000 trees in 10 years)

<table>
<thead>
<tr>
<th></th>
<th>2005-2014 avg.</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees Planted Annually</td>
<td>23,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual costs</td>
<td>$1,725,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Carbon removal/savings (tC)</td>
<td>582</td>
<td>2,910</td>
<td>5,291</td>
</tr>
<tr>
<td>Annual energy bill savings</td>
<td>$145,420</td>
<td>$727,100</td>
<td>$1,322,000</td>
</tr>
<tr>
<td>Cumulative Carbon removal/savings (tC)</td>
<td>$16,402</td>
<td>189,679</td>
<td></td>
</tr>
<tr>
<td>Cost-effectiveness ($/tC)</td>
<td>$762</td>
<td>$38</td>
<td></td>
</tr>
</tbody>
</table>

Assumes 15% early mortality for trees planted, 75 kWh/tree in reduced cooling load, 0.1MBtu/tree in reduced heating loads and 13 kgC net sequestration for mature trees, and 20 years from planting to reach mature tree benefits.

In early years, CO\(_2\) benefits are very modest, averaging less than 600 metric tons carbon over the first 10 years. With tree planting, it takes many years to achieve significant savings as trees get established and grow to heights where they an effective shade and provides wind and other climate benefits. A ten-year effort starting in 2005 would yield its maximum carbon benefits, 1400 metric tC/year starting in 2029, with over half this level achieved by 2020.

Rhode Island consumers could see energy cost reductions of over $700,000 per year by 2020, rising to $1.3 million by 2035, mostly in lower electricity bills.\(^{27}\) From a utility and fuel supplier

---


\(^{26}\) Note that later tree mortality and CO\(_2\) release is captured in a simple factor reflecting the average percent of gross sequestration (27%) that is released due to loss and decay (based on Boston case study). This assumption tends to understate sequestration in early years and overstate in later years.

\(^{27}\) Assuming retail prices of 11c/kWh for electricity, and $10/MBtu for heating fuels.
perspective, the 30 years NPV of avoided supply costs adds up to $4.5 million. Unlike in California and other warmer climates, these savings, however, would fall short of levels needed to pay back tree planting costs ($14 million, NPV). Nonetheless, they represent a major economic benefit, and suggest that energy supplier savings might be leveraged to cover up to one-third of a major tree planting program. Note that from a consumer perspective, the present value of energy bill savings is roughly considered equal to planting costs, when considered over a 45 year horizon.

Carbon sequestration remains the largest contributor to net carbon gains. The ratio of carbon benefits due to net sequestration vs. avoided energy use is 60:40, similar to that found for Boston. With a tree planting program, improved location and species selection can yield significantly greater per tree energy savings, while at the same time, new trees sequester more carbon per tree than an existing stand that is more mature.

2.3 Implementation options

The indicative analysis and experience for major tree planting programs (e.g. Sacramento) suggests that a major urban and community forestry effort on the order of 200,000 trees in 10 years can be successful, yield modest but important carbon savings, and significant energy benefits even in a Rhode Island context. Yet it also poses some major questions given the challenges noted by those involved in tree planting efforts across Rhode Island:

*How can tree planting activities be scaled up to levels that are over 10 times higher than current levels?*

- **Shift focus beyond street trees.** The traditional focus on street and near street locations makes sense, given the obvious public benefits. However, overall urban forest benefits, and particularly in this context, energy and CO$_2$ savings, can be greatly enhanced by considering yards, as well as vacant lots and parks.

- **Consider new program models,** such as the Sacramento approach, which uses utility funding, foundation implementation (similar to Providence), and homeowner labor for tree planting.

- **Incent and compel new construction and renovation to maximize tree planting,** with good species selection for climate benefits, through ordinances, zoning laws, and other leverage points. Warwick’s zoning laws and Providence’s canopy cover ordinances are good examples. In other cases, tree planting can be included as a negotiating point in major construction and development activities (e.g. airport expansion or new subdivisions).

- **Support funding for town foresters in all larger communities.** General Law 2-14 requires towns to have tree wardens to enforce protection of trees on public lands. However, only a few currently have planners or foresters able to track and maintain tree cover, especially with respect to new developments. One possible funding mechanism would be for developers who fall short of meeting tree canopy cover or other zoning requirements to pay into a fund supporting town foresters and tree wardens.

---

28 Assuming utility and fuel supplier avoided costs of $50/MWh and $5/MBtu, delivered.

29 John Campanini, Rhode Island Tree Council, personal communication.
• **Provide an educational component** that encourage proper care and siting.

*How can communities afford these efforts?*

• **Investigate cost sharing with electric utilities and fuel suppliers.** In many California communities, tree planting programs are now considered as utility demand side management programs, with major funding and marketing provided by utilities. As indicated above, a major tree planting effort could yield nearly $4 million in avoided utility power acquisition costs (30 year net present value).

• **Reduce cost per tree planted.** Consider greater use of bareroot stock to lower purchase costs and mortality rates, and developing stronger markets for container trees of regionally-appropriate and maximum benefit species (instead of solar-unfriendly, small, and often regionally inappropriate species often carried by big box retailers). Container trees are also easier for programs that encourage homeowner planting.

• **Seek greater contributions in time and effort by home owners and businesses.**

• **Use ordinances and planning processes** to leverage tree planting as part of routine residential and commercial development and renovation.

• **Explore foundation and other new sources of support.** A truly innovative and ambitious program might draw the attention and support from funders across the region.

• **Establish a state-funded seed program** to get this overall effort moving. Communities are currently at very different levels of awareness, capacity, and action.

*How can residents and business owners be motivated?*

• **Better quantification of energy cost savings.** This analysis suggests that a consumer that a typical yard tree can yield $25 or more in energy savings over 20 years, and over 5 times more for trees planted in optimal locations.

• **Outreach efforts,** possibly extending to new media, such as electricity billing inserts.

We recommend, as a next step, that tree program representatives from communities across the state – possibly along with regional urban forestry experts (Nowak) and staff from other large scale programs (Sacramento) – be gathered to refine goals, to define good practices for future activities, and discuss implementation strategies.
3. Forest protection

3.1 Current status, issues, and options

Forest protection and conservation development are distinct land protection strategies, with different GHG emission mitigation benefits. Forest protection includes a variety of strategies that keep land in forest or agricultural use, in either private or public ownership. Tax reduction programs give private landowners an incentive to keep lands in forest use. Conservation development is an approach to private land development where ecological and cultural values of properties are evaluated, and development is arranged and concentrated to preserve much of these values. Acquisition of development rights can keep private land in forest or agricultural use when development pressure would otherwise result in hardening of surfaces or clearing of forest. Acquisition of title to land by a conservation minded owner or public entity can maintain forest or agricultural use on land that otherwise would be developed.

Clearing of forest and conversion of pasture to buildings or roads results in the loss of carbon stored in wood and soils. Comprehensive surveys of land cover in Rhode Island show increasing area in developed uses. From 1988 through 1995, Rhode Island gained an average of 1476 acres of developed land each year. Most of this land, about 1404 acres per year, came from forest, with the remainder from agriculture, unvegetated areas (sand, rock outcrops) wetlands, and brush areas. Most of the increase in area of developed use, about 1376 acres, went to residential use.

One driver of this conversion is the increase in residential land area per Rhode Island inhabitant. In recent years, the amount of land in residential use has grown over twice as fast as population. These trends clearly place greater pressures on existing open space and forests.

Rhode Island is currently encouraging conservation development practices that conserve rural land while allowing the number of housing units to increase. Conservation development should not be confused with cluster development. Conservation development concentrates development onto a small portion of the lot while the remainder (at least 50% of the parcel) is left in a natural state. A deed restriction is placed on the parcel so the open space remains undeveloped in perpetuity. This open space land is subject to a community approved

---


32 The Growth Centers Executive Order is a separate project from Conservation Development (although it was linked in the draft Land Use Strategy Plan). This concept could protect open space and reduce greenhouse gas emissions by concentrating growth in urban areas; greenhouse benefits of this program would be calculated within the transportation portion of this stakeholder process. Visit the Growth Centers project website at: http://www.state.ri.us/DEM/programs/bpoladm/suswshed/gpc.htm.
management plan. In rural areas, during subdivision of land, individual houses can be located along a few roads while leaving much of the land in forest. Conservation development promotes location new housing units on smaller footprints of developed land, and blocking conserved portions of lots.\textsuperscript{33} In Rhode Island, conservation development attempts to reduce development at two acre minimum lot size and instead promote placing new homes on lots one acre or smaller, with preservation as open space, the remaining land that would have been included in two-plus acre lots. Three communities have adopted this concept, four more are in the planning stage and DEM is soliciting a consultant to provide technical assistance to five more communities. The Manual and companion brochure are available for download from the project website: \url{http://www.state.ri.us/DEM/programs/bpoladm/suswshed/ConDev.htm}.

Land enrolled in the Farm, Forest, and Open Space program is assessed and taxed according to its current use, and development is restricted for the duration of the 15 year long enrollment. This program conserves forest because landowners are not forced to sell for development due to high property taxes. A publication describing this program is available for download at \url{http://www.state.ri.us/DEM/programs/bnatres/forest/pdf/citgui03.pdf}.

Several land preservation programs are now operating in Rhode Island. Counting state, federal, and private efforts, at least 6,537 acres were put into conservation status in 2002 and 3,938 acres in 2003.\textsuperscript{34} In each of the past two years, somewhat less that half of the acreage put into preservation status was accomplished by the state DEM, with smaller amounts preserved by a variety of other organizations. The four main preservation programs operated by the DEM’s Division of Planning and Development are a general state land acquisition program (using funds from a variety of state, federal, and foundation sources), the Forest Legacy Program (using federal funds), the agricultural Land Preservation Program (which acquires development rights), and acquisitions under the North American Wetland Conservation Act.

Many funders of land preservation require state matching funding. The bulk of state matching funds for land preservation have been generated by sale of bonds for funding open space acquisition. The amounts authorized under the current bond authorization have largely been spent. The Governor has proposed an environmental bond issue that includes $35 million for land protection.

\subsection*{3.2 Assessment of costs and potential}

Conservation development and land preservation mitigate greenhouse gas emissions in different ways. By reducing the land area cleared for a given number of dwelling units, conservation development can lower the carbon emissions by leaving more trees standing and less soil disturbed. Similarly, land preservation can protect the carbon in trees and soil. But unlike conservation development, there is the risk that land preservation might simply displace


development to other locations, thereby creating emissions “leakage”. Thus our assessment addresses the two approaches separately.

**Conservation Development.** Conservation development uses planning to fit a given amount of development into a smaller footprint on the ground. By clearing less land to meet a given need for new housing (or other developed uses) conservation development can keep some land in forest that would have been cleared under traditional development. Reducing land clearing reduces greenhouse gas emissions from cleared forest. The final amount of avoided clearing depends on parcel sizes, developer preferences, and how rules are applied by local planning authorities. We estimate that full implementation of conservation development policies could maintain in forest from 10% to 50% of the land typically converted to development each year.

Because the amount of clearing that can be avoided is uncertain, we analyze high, low, and midrange rates of avoided clearing. Summary tables in this report give the midrange option, which assumes that 20% of clearing will be avoided. This range translates to 140 to nearly 700 additional acres of retained in forest annually, with a median estimate of 280 acres per year of avoided clearing. These forests, in turn, represent from 10,000 to 40,000 metric tons carbon retained annually, with a median estimated savings of 16,000 tons carbon annually. These retained forest acres will also continue to grow, sequestering additional carbon. However, because we analyze sequestration from business-as-usual forest growth, and propose achieving additional sequestration through pine enhancement we to not include tree growth on conserved acres, in order to avoid any double counting of tons or counting sites as used for two different programs.

At the annual rates presented here, through 2020 the low rate of conservation would avoid 129,000 metric tons carbon emissions. The median estimated conservation rate would avoid 258,000 tC of emissions and reducing clearing by 50% would avoid 645,000 tC.

Avoided emissions were calculated as follows. On average, from 1988 through 1995, 1404 acres per year went out of forest use.\(^{35}\) 1376 acres per year were added to residential use, and additional acres were added to commercial and industrial uses. This estimate assumes continued conversion of 1376 acres per year. Interviews with practitioners and searches for documents revealed no studies showing what area is actually cleared under conservation vs. conventional development. The Rhode Island Conservation Development Manual states that half the conventional lot size is a starting point for choosing lot sizes under conservation development. We took this estimate to be the high end of the range of possible accomplishment because, under conventional development, new development typically leaves a portion of the lot in forest cover.

On a per-acre basis, avoided emissions are the difference between the stock of carbon in the standing forest, minus the amount of carbon remaining if the land is cleared. The difference in carbon stock between a typical stand of northeastern U.S. hardwood forest at age zero and age 65 was taken as the average amount of carbon not emitted from each acre saved from clearing by

---

conservation development. This difference is 32 metric tons carbon per acre.\(^{36}\)\(^{37}\) Multiplying yields annual avoided emission estimates.

Because Rhode Island has been working on implementing conservation development for several years, and because we are assuming what we think is a moderate rate of implementation, this analysis assumes implementation beginning in 2004. A constant rate of avoided clearing is assumed through the analysis period.

The estimated avoided emission was checked by calculating the avoided emission from information on timber removed from Rhode Island forests by change of land use out of forestry. Estimates of avoided emissions made from Forest Service data about wood volumes removed during land use change yielded savings sufficiently greater than the amounts reported here. We believe the method used here is more robust than calculating potential emission reductions from wood removed from land use change because of the small sample size in the Forest Service study and because expansion from the Forest Service data requires use of expansion factors that are not well fitted to Rhode Island forests. Also, using a lower estimate of savings is more conservative.

The estimated financial costs of conservation development should be refined. The DEM Sustainable Watersheds Office is expending staff time to provide technical assistance to town planners and planning boards, to promote use of conservation development practices. Further funding would be needed to continue or expand these efforts. It is not clear whether using conservation development approaches changes the workload of town planners. Costs could be increased for developers in that they might have to hire a landscape architect or other expert to do planning, instead of simply dividing land parcels into rectangular lots. However, conservation development can reduce costs borne by developers by reducing costs of land clearing, running utility lines, road building and possibly construction. The costs included in this analysis are $200,000 per year for five years, for additional outreach materials and staff to work with municipalities. It is assumed that after the five year period municipalities would have adopted conservation development as standard practice, and no further costs would be incurred.

Over time, conservation development should reduce costs borne by homeowners, by reducing maintenance costs. Reducing net construction costs allows builders to sell homes for less. Costs of providing public services that require travel should also be reduced. For example, less travel will be required for school transportation, mail delivery, and snow plowing. If conserved areas can be located around streams, many of the ecological benefits of forest can be retained, including maintaining water quality and a significant proportion of wildlife habitat functioning.

**Land Preservation.** This analysis applies to both preservation of forest on private lands through the Farm, Forest, and Open Space current use tax program and various land acquisition programs including authorization of a new open space bond. Land preservation can store carbon and offset greenhouse gas emissions. However, land preservation does not mitigate emissions in the way that many people think. Many people believe that the avoided emission is equal to the amount of


\(^{37}\) Note: This carbon stock change estimate assumes no change in soil carbon amounts.
carbon in preserved forest. However, unless a project address the demands for land or products satisfied by land clearing, merely putting some land in conservation status does not substantially reduce total emissions. Economic analysis shows that, instead, clearing is displaced to other locations and almost as much clearing occurs as would have occurred in absence of land preservation. Emissions are mitigated by land preservation when trees on the preserved land continue to grow, and store more carbon per acre than unpreserved acres. The emission mitigation is the carbon stock on the preserved lands, minus the average stock on the same area of typical unpreserved lands.

**Open space potential.** A primary mechanism for open space preservation in Rhode Island is issuance of bonds to provide funding for open space acquisition. Rhode Island voters have approved seven bond issuances since 1985. Currently approved funding is running out. The governor has proposed a referendum on $35 million of new bonding authority for land preservation. Conservation groups are advocating various larger amounts. The amount put before voters will be selected by the General Assembly. For this analysis, we consider the potential benefits of passing a new $35 million state open space bond that would enroll new lands starting in 2005. This analysis also assumes that for every state dollar three other dollars are matched from federal, foundation, private, and municipal sources. Land is assumed to be acquired for an average of $8,000 per acre. 75% of the preserved land that is assumed to be forest, so only 75% of total preservation costs and 75% of preserved acres are counted in this analysis. All lands are enrolled over four years, which as a rate of enrollment about 80% of the average 2002-2003 rate in the state.

**Current Use Taxation Potential.** Continuing the Farm, Forest, and Open Space current use taxation program can provide a greenhouse benefit. A survey of landowners with more than ten acres in Rhode Island’s rural communities found 51% of eligible landowners who responded to the survey are enrolled in the program. Twenty-nine percent of this property is enrolled under the forestland classification, which requires a (DEM approved) written forest management plan and active management. The main reason non-participating landowners gave for not participating in the program (89%) was that they didn’t know enough about the law. 5% said they are not interested in active management and 4% said they did not think they could fulfill the

---

38 In the U.S., for forest land preservation, the amount of timber harvest that occurs elsewhere through displacement is 85% of the amount that would have occurred on the preserved lands. See: Murray, Brian C, Bruce A McCarl, and Heng-Chi Lee. 2004. Estimating leakage from Forest Carbon sequestration programs. *Land Economics*. 80(1):109-124.

39 This land cost is based on costs of recent land preservation projects, as calculated by Rhode Island's Quality of Place Coalition for a 2004 Open Space & Recreation Bond.

40 Much of the land put into conservation status in Rhode Island is forest. Detailed information about exactly how much preserved land is forest is not readily available. However, a reasonable estimate can be made. In recent years, 3-6% of the total area conserved has been agricultural. In recent years, in Rhode Island, the NRCS Wetland Reserve program reports preserving only a few dozen acres. Land cover analyses of Rhode Island have shown that 60% of the total state land area is forest. Dividing the amount of area of forest as calculated by the Forest Service (excluding urban forest) but the area of land counted by the state as undeveloped land, suggests that 75% of the undeveloped land area is forest. Because the information about types of lands preserved appears to correspond to this ratio, this analysis assumes that 75% of acres preserved are forest.

requirements of the law. These survey results indicate that additional outreach effort could bring more lands into the program.

Even if the total amount of development is not decreased, land preservation can result in net carbon sequestration. This occurs if forests on reserved lands grow to ages older than the typical age on unreserved lands, because older forests store more carbon than younger forests (for a given forest type and site productivity). Mitigation is calculated as the amount of carbon on preserved forest minus the amount found on an equal area of average, non-preserved forest.

The total mitigation resulting from the current use taxation program depends on the proportion of lands re-enrolled in the program, and the amount of development that is avoided because lands remain in the program. Landowners enrolling in the program commit to maintaining forest for 15 years. After that time they may develop the land without penalty. We know of no quantitative studies that have a robust methodology that measure the amount of development avoided by current use taxation. Analysis showing that there is less development in jurisdictions where there is more enrollment in current use tax programs do not show that the programs cause the lower rate of development. It is possible that landowners would not have developed for other reasons, and merely enroll in the land to decrease their taxes. In the absence of quantitative data we assume that there is some avoidance of opportunistic development resulting from the current use taxation program, but that the number of tons of mitigation is small.

**Open Space Costs.** Detailed data on the age classes and stocking levels of reserved forests is not available. Consequently, this analysis assumes that reserved forests have the same age and density as the average forest in the state. This analysis assumes that unreserved forests would remain at their current mass. With these assumptions, open space protection through purchase of development rights or land is projected to store 110,000 metric tons carbon through 2020. The average cost per ton is high, at roughly $870 per ton, discounted. Because all costs occur in the first four years of the program, yet tons continue to accrue for decades, the average cost per ton declines as time goes on. Considering sequestration and costs through 2050, 304,000 tons are expected to be sequestered, while the average cost drops to $340 per ton carbon.

**Current Use Taxation Costs.** Current use taxation may have a net financial benefit for municipalities. Analysis of the costs of providing community services to developed and undeveloped lands in Rhode Island showed that it cost more to provide services to developed lands than those lands provided in property tax revenue while the cost of providing services to undeveloped lands was less than tax revenues, even at reduced tax rates. This analysis did not consider other tax revenues that may accrue as a result of development. Assuming that current

---

42 Forests would remain at current mass if cumulative removals from harvest, disease, and fire equaled growth. The forests of Rhode Island are increasing in mass because recent harvests and other removals have been less than growth. However, total increases in carbon stock in Rhode Island forests, plus wood products appear to be at a rate less than 0.3% per year. Over the analysis period, baseline growth should be less than the amount of clearing that is not displaced. Consequently, the combination of the very conservative assumption of total displacement of development and constant baseline stock yields a relatively conservative combination of assumptions.


use taxation displaces some development from open land to developed lands (increasing the density of developed lands), and accepting the analysis that it costs municipalities less to provide services to existing development (that tends to be located in developed areas) that to new development in forested areas, then it is reasonable to conclude that current use taxation programs have a negative cost. That is, the public is financially better off from displacing development from forest land to existing developed lands, and the cost per ton of mitigating emissions is negative.

3.3 Implementation options

Rhode Island has done considerable work on conservation development. In addition to providing a design manual, the state offers model ordinances that towns can enact to encourage conservation development during land subdivision and permitting of development.\textsuperscript{44} The Rhode Island Department of Environmental Management Sustainable Watersheds Office provides training to town planners and planning commissions on how to do conservation development.

The Sustainable Watersheds Office has already conducted a cooperative project to explore creative ways to guide commercial and residential growth in a more environmentally sensitive manner in southern Rhode Island. Products helpful to protecting open space, including an environmental design manual, transfer of development rights report, and farming and forestry strategies, were developed as part of this project.\textsuperscript{45} The Sustainable Watersheds Office is seeking additional funding to enhance outreach efforts to local planners and planning boards. If this funding is not obtained, the state might assist in seeking funding, or allocate state funds for this work. Outreach to developers, land surveyors, architects, and landscape architects could increase the use of conservation development practices. The DEM Office of Strategic Planning and Policy could advise or facilitate identification of an appropriate institutional home for this work.

One of the challenges to conservation development is managing conserved lands. In subdivisions, it is possible to make the conserved lands a condominium owned by property owners in the subdivision. Alternatively, a local land trust may accept the land and hold it as open space. There are 46 land trusts operating in Rhode Island.\textsuperscript{46} The local municipality or the state may be willing to accept the land as a park or conservation land, if it offers exceptional recreational value, or important water protection or habitat qualities.

As with all programs, it is highly desirable to measure the efficacy of the program. Most simply, the achievements of the program could be indicated by using building permit information to tally the average lot size of parcels with new residential construction for some five to ten year period in the recent past, and measure the same information in the future. If resources are available for more discriminating assessment, building inspectors could assess the area cleared for


\textsuperscript{45} These products are available at the project web site: http://www.state.ri.us/DEM/programs/bpoladm/suswshed/scpap.htm.

\textsuperscript{46} Rupert Friday, Director, Rhode Island Land Trust Council, personal communication February 20, 2004.
development (including buildings, yards, driveways and roads, and road rights of way), and this information could be tallied annually and watched to see if the average area decreases over time.

Rhode Island has a strong history of open space protection. Renewing the open space bond would provide funding to continue operation of existing land conservation programs. Foundation support for open space protection continues, and federal farm bill support for land conservation programs has increased over recent years. State open space bond renewal provides funding for matching, to bring federal and foundation dollars to the state.

Activities of The Nature Conservancy may provide greenhouse gas emission mitigation substantially greater than the amounts estimated here. In particular, The Nature Conservancy’s “Borderlands” program seeks to conserve a large block of forest land in western Rhode Island and eastern Connecticut. The core area would be 20,000 acres that would be restored to older forest.\(^{47}\) This forest could store substantially more carbon that “business as usual” forest that is not preserved. The amount of carbon greater than unpreserved forest represent removals of carbon dioxide from the atmosphere.

---

4. Land restoration

4.1 Current status, issues, and options

In general, land restoration increases carbon stocks in vegetation and soil, and thus it offers a potential greenhouse gas mitigation option. However, because most lands in Rhode Island are in relatively good condition, opportunities for restoration are limited. Most lands with impaired ecological functioning are already in high value use, such as commercial development or transportation infrastructure, where restoration is not a viable option. Nonetheless, several opportunities for land restoration still exist, particularly among riparian areas and inactive gravel pits.

Rivers and associated floodplains provide a wide variety of ecological services, including moderating floods, removing pollutants, and providing habitat for a wide variety of aquatic and terrestrial species. Because of Rhode Island’s history of water-powered industrial development prior to the 20th century, many urban stream banks and floodplains were lined with buildings, hardened banks, or other constructed features that reduce the ecological functioning of the river system. Many riparian developments have since been abandoned, or are in low value uses such as parking lots, especially in light of flood risks.

As redevelopment of these areas occurs, the state actively encourages restoration of stream functioning and riparian vegetation. This, in turn, yields the incidental benefit of increased carbon storage. However, capacity and funding for riparian restoration are limited, and opportunities are going untapped. Efforts to increase restoration could meet both the state’s objectives for riparian function and reducing overall greenhouse gas emissions.

Similarly, restoration of soil and grass meadow on unused gravel pits can achieve a dual purpose: providing early successional meadow habitat, a goal of the state’s wildlife habitat and wetland reserve program, and increasing carbon storage in soil. In the uplands of Rhode Island, as pastures have been abandoned and developed or returned to forest, the amount of meadow habitat has decreased dramatically. Maintaining meadow and other early successional habitats is a new state priority. Of the approximately 5,500 acres of gravel pits and quarries exist in the state, many are no longer in use and could be restored to meadow habitat.

4.2 Assessment of costs and potential

Riparian restoration. Riparian restoration in Rhode Island offers the potential to mitigate a modest number of tons of greenhouse gas emissions. However, because of the tremendous ecological and aesthetic benefits resulting from riparian restoration, the Forestry Working Group has indicated that restoration programs should be a high priority.

---

48 Personal communication, Fred Presley, Supervising Environmental Planner, Rhode Island Department of Environmental Management, Sustainable Watersheds Office.
The Sustainable Watersheds Office has a target of restoring 300 acres of riparian area by year 2015, which averages about 27 acres per year. The Governor has established a goal of restoring 200 acres of riparian buffers in the Narragansett Bay Watershed by 2015. This is an ambitious goal considering most of these riparian areas are small and in private ownership. DEM has initiated planning studies in the Woonasquatucket Watershed that have resulted in identification of potential restoration sites and implementation of some restoration activities.\textsuperscript{50}

Several issues, including the small size of the parcels, cost of restoration, and limited availability of technical assistance make restoration difficult. The nature of riparian buffers lead most restoration projects to be long and linear. Coordinating restoration on multiple ownerships is difficult so the acreage of most projects is small. Restoration efforts in the Chesapeake Bay Area have found that their most successful (large acreage) restoration projects are in rural areas. Typically a farmer will plant a 100-foot wide buffer for hundreds of feet along a stream. In Rhode Island buffer widths may be 35 feet or less.

Degraded riparian areas typically contain little soil carbon, thus restoration could sequester carbon in both soil and growing vegetation. The only readily available analysis of restoring Northeastern forest on formerly degraded soil predicts sequestration at a rate of 1.2 metric tons carbon per acre per year for the first 50 years.\textsuperscript{51} At this rate, achieving the Watersheds Office target would remove 7,000 metric tons carbon cumulatively through 2020, and 16,000 tons through 2050.\textsuperscript{52}

The cost of restoring riparian areas is likely to be significant. This analysis uses a cost of $9,300 per acre restored. This amount is provided by the Sustainable Watersheds Office as the cost of a project in the Smithfield area. This is a substantial cost, but not unreasonable given that the sites that provide carbon sequestration benefits are sites where woody vegetation is restored, and restoration typically includes substantial plant costs, and may include substantial costs for removal of invasive or competing vegetation. Based on this estimate, the cost-effectiveness of mitigation achieved by 2020 would be $570 per metric ton carbon, dropping to $240/tC, if the time horizon is extended to 2050.

\textbf{Gravel pits.} For gravel mine restoration, we consider a target of restoring 110 acres per year to grasslands for 10 years. This rate is similar to the rate implied in the Natural Resources Conservation Service plan, under its Wildlife Habitat Incentives Program, which set a target of restoring 1000 acres of Rhode Island grassland from 2002 to 2005.\textsuperscript{53} The Conservation Service

\textsuperscript{50} For information see \url{http://www.state.ri.us/DEM/programs/bpoladm/suswshed/RBDP.htm} and \url{http://www.state.ri.us/DEM/programs/benviron/water/wetlands/wetplan.htm}.


\textsuperscript{52} Because the restored areas are typically narrow – generally about 25 feet wide and very rarely more than 70 feet wide – this analysis assumes planting only tree species that do not grow large. Consequently, this analysis assumes that from years 2020 through 2050 that the lands store carbon only at the rate of a typical upland hardwood stand regenerating after clearcutting, not at the faster rate predicted for the first 15 years of growth.

is actively pursuing gravel mine restoration, but only an unspecified portion of the 1000 acre target would be implemented on former gravel mines. We assume that this program is continued for an additional 10 years, and consider what this might yield if 1100 acres of gravel mines – about 20% the state total – were converted to grassland.

Restoring 1100 acres per year at a cost of $2000 per acre (NRCS estimate) would require annual spending of $220,000 per year. The cost per ton of carbon stored is substantial, but not as high as one might think. Meadow grasses store significant amounts of carbon during the first 30 years after establishment, roughly 16 metric tons of carbon per acre in the top 30 centimeters (11.8 inches) of soil. This large gain is possible because the initial soil carbon content is extremely low. After 30 years, the rate of sequestration declines to a very low rate. Restoring 1100 acres would sequester 9,000 tC by 2020, with annual sequestration in 2020 of 1,000 tC. By 2050 cumulative sequestration would be 18,000 tC.

As with the riparian restoration project, costs are incurred during the first years of the project, and the benefits accumulate over a relatively long time horizon. The cost-effectiveness of gravel mine restoration, from a GHG perspective alone, is $210/tC through 2020 and drops to $100/tC by 2035. Because the rate of sequestration is very low after the 30th year of the project, the average cost would only decline a small amount after this time, and the 2035 price is a reasonable approximation of the average cost of all tons achieved through 2050.

4.3 Implementation options

Both the riparian restoration and gravel mine restoration programs analyzed here are extensions of existing programs operating in Rhode Island, both in time span (to 2015 for gravel mine restoration) and extent (riparian acres). In terms of riparian restoration, the Governor’s Narragansett Bay and Watershed Planning Commission proposes a goal of restoring 200 acres by 2015. No statewide assessment of need has been conducted but watershed staff estimate statewide need greater than 1000 acres, and believe the Watershed Planning Commission goal can be exceeded. We have analyzed the GHG benefits of achieving a target of 500 riparian acres by 2015, a rate that is considerably faster than what resource constraints currently allow. To expand riparian restoration programs would likely require additional staff to manage additional project workloads, and increasing matching funding from federal conservation programs.

The rate of grassland restoration analyzed here appears to be about 10% of the rate currently being achieved by all NRCS habitat restoration activities in the state, and the Rhode Island NRCS has a goal of restoring 1000 acres of grassland by 2005. However, only a small portion of the current grassland restoration is occurring on abandoned gravel mines or other sites currently lacking topsoil. The program level analyzed here both continues the grassland restoration program an additional ten years, and focuses grassland restoration activities on gravel mines. The total annual number of acres restored is similar to the existing target rate, but this analysis would require that restoration occur on sites denuded of topsoil. NRCS programs require cost sharing by landowners and achieving the target area of restoration may require grants to owners to offset owner cost share expenses. Although NRCS supports and is doing gravel mine

restoration, dropping other types of restoration would be incompatible with continuing to make progress on the agency’s full range of goals. Also, the per-acre costs of riparian restoration work are high and it is not clear how competitive these projects will be in federal program funding decisions. Accessing federal funds requires cost sharing. It may be more difficult to obtain cost share funding than it is to obtain federal conservation incentive program funding. Possibly one of the existing land conservation programs could support cost sharing payments, because of the habitat value of meadows created by the restoration.
5. Enhanced forest management

5.1 Current status, issues, and options

Prior to the 20th century, most of the state’s land area was cleared of forest for farming. Over the past century, much of the cleared land has returned to forest. The peak extent of forest cover in the 20th century was in the 1950s and 1960s when about two thirds of the state area was in forest cover. With land conversion to developed uses, the proportion of forest had declined to about 59% in 1998 (the latest year for which statistics have been compiled). Calculated either area or by wood volume, the forests of Rhode Island are dominated by hardwood species, with about 57% of the hardwood volume in oaks and about 25% in maple. About 23% of the total forest volume is in conifers, with about 80% of the conifer wood volume composed of white pine (Pinus strobus L.). Existing surveys of change in forest land over time show differing results but agree on some trends. The most comprehensive survey available, by the RI Department of Planning, shows declining area of forest, increasing area of developed land cover, and relatively constant area of other uses. Despite the decline in acres, studies show an increase in standing timber volume and total forest carbon stock.

The existing age class structure of Rhode Island forests, and typical management activities, provide opportunity for enhanced management to increase forest carbon stocks by increasing the number of large trees, increasing the pine component of forests, and reduce cutting and land development resulting from estate transfers. White pine enhancement could be achieved largely by favoring pine during thinning and ingrowth into existing forest gaps. Conventional “stand type conversion” where the existing stand is clearcut and a new species planted, is NOT envisioned.

Although enhancing forest management offers opportunities to provide multiple greenhouse benefits, this analysis only estimates benefit that may result from white pine enhancement. We do have reliable studies of the effect of education on reducing land clearing or conversion following estate transfers. As a result, we do not estimate any greenhouse benefits that might accrue from improved estate planning. Also, this program is expected to increase the amount of carbon stored in trees in Rhode Island forests, by increasing the number of large trees. At this time we do not have data on the effect of education on landowners growing more large trees.

57 As of 1998 (the most recent year for which data are available) 63% of the forest area in Rhode Island was oak/hickory type. Only about 8% of the forest area is dominated by pine although 18% of the total wood volume is pine. USDA Forest Service. 2002. The Forests of Rhode Island. Report NE-INF-155-02. Newtown Square, PA: Northeastern Research Station, USDA Forest Service. Also see http://www.fs.fed.us/ne/fia/states/ri/ri_view.html.
We have data showing that growing fully-stocked stands with uneven age management, including large trees, can yield more timber over time than short rotation clear cutting or “high grading” that removes only the largest trees. Also, we have studies showing that a major motivation of owners of forested parcels smaller than 20 acres is the aesthetic value of the forest. However, growing and holding more large trees involves deferring some harvest income. Given this financial incentive, we are reluctant to predict further sequestration from extending rotations and only project sequestration and that would result from white pine enhancement.

Prior to European settlement, white pine was a major component of the forest. Forest surveys from that time do not exist, so we do not have quantitative information about the extent of pine. Currently, with little management effort the pine component is increasing, although it is still only about 18% of the total forest, by volume.

Increasing the white pine component of Rhode Island forests can, over several decades, store several million tons CO₂ more than would be stored by continuing present trends. Rhode Island forests are predominantly hardwood and, over time, pine can store much more carbon per acre than hardwoods. On all but poor sites, pine grows more slowly than hardwoods for about the first five years after establishment. After about age five, pine generally grows much more quickly than hardwoods, and grows to much larger sizes. Pine wood is significantly less dense than hardwood, and stores less carbon per cubic foot of wood. However, because pine stands several decades old hold much more wood volume than hardwood stands of the same age, on the same quality site, total white pine sequestration is greater.

The white pine component of Rhode Island forests could be increased by enhancing existing DEM Division of Forestry landowner education programs. This effort would include educating landowners about forest management options that have (among other things) the potential to encourage the sequestration of carbon including: estate planning to conserve open space and avoid the need to harvest to pay estate taxes, promoting white pine regeneration on appropriate soils, and or encouraging trees to grow to large sizes. It is likely a high percentage of forest landowners would choose a management strategy that will meet the goal of increased sequestration.

In many existing stands, pine could be enhanced during forest management operations planned for other purposes. Also, Forest Service Forest Inventory and Analysis field surveys find that approximately 53% of the timber land in the state is poorly or moderately stocked.\textsuperscript{61} Stocking is the degree to which trees occupy land, measured by basal area and/or number of trees in a stand compared with the basal area and/or number of trees required to fully use the growth potential of the land (or the stocking standard). In the Eastern United States this standard is 75 square feet of basal area per acre for trees 5.0 inches d.b.h. and larger, or its equivalent in numbers of trees per acre for seedlings and saplings. The Forest Service defines its stocking class categories to be: nonstocked (0 to 9% of the standard); poorly stocked (10 to 59% of the standard); moderately stocked (60 to 99% of the standard); fully stocked (100 to 129% of the standard); and overstocked (130 to 160% of the standard).

In contrast to the Forest Service inventory, the Rhode Island Division of Forest Environment staff suggest that most of the forest land in the state is fully stocked or overstocked. Our analysis used the Forest Service stocking rates. However, if most of RI forest land is already fully stocked, then adding pine to the area proposed in this analysis would displace some existing hardwoods, reducing the net sequestration achieved. Assuming a linear relationship between stocking and area and assuming that under stocked acres are have a stocking rate that is in the middle of the class definition, the Forest Service inventory numbers suggest that trees could be added within existing stands to generate an increase in basal area equivalent to afforesting 43,400 acres. Site specific analysis would be necessary to determine what of this area is suitable for white pine; some locations will be better suited to species other than white pine.

### 5.2 Assessment of costs and potential

Expanding DFE’s landowner education activities does not represent a departure from current strategies since DFE already provides technical assistance to forest landowners. A recent survey of forest landowners done as part of updating the forest resource plan found over 30 percent of forest landowners receive forest management information from DFE Foresters. Consultants, books, neighbors/friends and brochures/fact sheets were other means landowners obtained forestry information. Almost 38 percent of landowners who replied to the survey have received no forestry information, indicating a significant opportunity to increase communication.

Growing white pine on one acre, to age 60, starting from bare land, would store 255 metric tons carbon dioxide. This amount is in live trees only, and does not include dead trees, underbrush, down wood and leaf litter, or any increases in soil carbon. These other components could store additional carbon, but one would need to know the initial amounts of these other components to be able to predict whether they would remain constant or increase. If starting from previously tilled crop land, the sequestration in these other components could be more than the sequestration in live trees.

Adding the equivalent of 45,400 acres of new pine forests would sequester 3.2 million tC in 60 years. However, under business-as-usual conditions, it is likely that existing trees would continue to spread, and within 60 years, much of the currently under-stocked area would become fully stocked. Therefore, the effect of greater white pine stocking of forests must be measured relatively to a fully stocked, typical stand of similar age. Expansion of trees in existing stands could be expansion of hardwoods or pine. There is some gain from converting expansion from hardwood to white pine. An oak/hickory stand contains slightly more than half of the carbon of a white pine stand of site index 60 (37 tC/acre vs. 70 tC/acre). Thus the net effect of white pine stocking is to ultimately increase carbon storage by 23 tC/acre. If the stand would have regenerated to white pine anyway, there is no additional carbon benefit to actions facilitating

---

62 Tom Dupree, Chief, RI Division of Forest Environment, personal communication 12 April 2004.
64 Also, this calculation assumes Site Index 60. Site index is a measure of the productivity of a site. Site Index 60 means that an average tree will be 60 feet tall at age 50 years. Site Index 60 is a moderate quality site. On a site that has a site index of 60 for pine, the site index for hardwood would be about 58 or 59.
pine establishment. This analysis makes the more conservative assumption that the areas that would have regenerated anyway would have regenerated to pine, not hardwood.

We evaluate a potential program that would stock pines over the next ten years, at a rate of 4,000 acres per year. This analysis assumes that only half the existing space could be utilized because not all forest sites are suitable for pine, and not all landowners would accept pine enhancement on their lands, leaving half of 45,000 acres, which is 22,500 acres. Spread over a ten year program, this would be the equivalent of 2,250 acres per year. Additionally, Forest Service inventory and harvest reports suggest that the equivalent of about 3500 acres per year are harvested across the state (in practice more acres will be harvested with partial cutting and almost no acres are clearcut). Assuming half of this area can be harvested in a way that favors white pine, it is the equivalent of adding 1,750 acres per year. Adding the areas from increasing stocking and favoring white pine during harvest results in the equivalent of 4,000 acres per year.

Based on a series of assumptions, by the end of year 2020 the program would store an additional 150,000 tC, compared to business-as-usual. (See also Appendix B.) Over 60 years, the total additional sequestration would be 1.4 million tons of carbon. Additional sequestration would continue to occur for at least another 60 years, but would occur at a slower rate.

Costs of this program would occur during the first years of the program. Costs are involved in identifying sites, communicating with landowners, and providing technical assistance to help landowners plan and implement forest management activities. No costs are allocated to implementation of forest management activities as landowners would bear any of these costs.

This analysis assumes that the program is initiated in 2004, and continues for 10 years at a constant rate. Costs for developing educational materials and conducting outreach activities are assumed to be $300,000 per year for two additional service foresters (salary, benefits, office, and vehicle costs) and funding for outreach material development and distribution. Rhode Island forests are owned in small parcels, and the average size is decreasing. If the program addresses parcels down to 20 acres in size, the program would address 77% of the forest area and 3,700 owners. Beyond this amount, a large increase in the number of owners involved would only yield a modest increase in the proportion of total forest acres addressed. Implementing activities on 86% of the land would require addressing all parcels of 10 acres and larger, and would encompass 5,800 owners.

---

65 Of the lands that are enrolled, these calculations assume that half the enrolled area would have regenerated to hardwood. On clay soils and very productive sites, hardwood can out-compete pine. On sandier soils and less productive soils hardwoods are slow to establish and, if pines are established on bare mineral soil, the pines can out-compete the hardwoods and form a pine-dominated stand. Because of the different competitive strengths of the different species, pine sites would not necessarily regenerate to hardwood. This analysis assumes that half of the pine sites would have regenerated to hardwood in absence of this project. Furthermore, the calculations make the very conservative assumption that all of this natural hardwood regeneration would occur within the next ten years. These calculations do not count any changes in carbon stock that may occur on lands that are already stocked.

With costs accruing during the first ten years of the project, and sequestration benefits stretching over several decades, the cost per ton is high if one considers only the first few years of the project. Average cost per ton sequestered declines spectacularly if one considers the benefits accruing over several decades. The present value of spending, averaged over the total number of metric ton of carbon sequestered, is expected to be $120 through year 2020, falling to $13 per ton if calculated over a 60 year time span. The average price per ton sequestered would continue to decline for many more decades.

This program would provide other environmental benefits, which depending on circumstances, these benefits could be moderate or quite large. Increasing the degree to which forest stands are mixed white pine and hardwood, and increasing the frequency of small patches of white pine could increase forest diversity and increase winter resting cover for wildlife. Establishing white pine in open—largely upland—spots in existing forest that is largely hardwood would create a fine-scale mosaic of forest types, and provide both horizontal and vertical forest diversity. This type diversity could become very important to maintaining Rhode Island’s forests. A newly-identified disease, called sudden oak death, is killing tens of thousands of oak trees in infection sites in California and Oregon. The dynamics of the disease are not well understood, but red oaks and intermediate oaks are susceptible while white oaks often are not infected. Deaths occur in clumps, and correlate to periods of warm, wet conditions. In laboratory tests, eastern tree species northern red oak (Quercus rubra) and pin oak (Quercus palustris) have been shown to be susceptible to the pathogen. The pathogen has not been identified in pines. If this pathogen becomes widespread in Rhode Island, like Dutch Elm Disease and Chestnut Blight, the effect on Rhode Island forests would be devastating. Mechanisms of spreading of the Sudden Oak Death pathogen are not well understood, but wind blown spores are suspected. It is possible that clumping oaks between pines might decrease spreading of infection. Having a large white pine component well distributed through Rhode Island forests provides insurance against broad-scale loss of forest cover caused by sudden oak death.

This program could also provide financial benefits to the citizens of Rhode Island that are not quantified in this analysis. Water quality could be enhanced, reducing water treatment costs or reducing medical costs of health problems caused by polluted water. Cleaner water could enhance sport and commercial fisheries. Assuming an average annual cost of $100,000 per forestry job, eight jobs would be supported by this project, for a period of ten years. In future decades, thinning or other harvest of pines established by this project could provide revenue to landowners, jobs for forest workers, and raw materials for wood products manufacturing.

5.3 Implementation options

DEM Division of Forest Environment has service forestry as a key part of its activities. Implementing this program would require restoring some of the capacity that has been cut over the past several years but would not require development of a new program. Implementation would require educating service foresters about the carbon implications of various forest management activities, and development of new communication materials for landowners.

---

67 Costs are discounted at an annual rate of 4%. Sequestration is not discounted.
Biologically, expansion of the white pine component of Rhode Island forests is relatively easy. The major challenge to implementation would be coordination with landowners.

Fragmentation of properties is occurring in Rhode Island. The general trend is movement of forest land out of large parcels into smaller parcels, and significant losses of area in timberland while there area in urban forest increases. From 1973 to 1993, the average size of forest ownerships in the state declined from 26 acres to 13 acres.\(^{69}\) One consequence of the decrease in the size of ownerships is that few owners pay attention to actively managing their lands, and even fewer have expertise to predict the effects of alternative management practices. As a result, carrying out a program that implements forest management activities on many small ownerships will require a great deal of time to do outreach to many owners of modest parcels. As noted in the cost section above, if the program addresses parcels down to 20 acres in size, the program would address 77% of the forest area and 3,700 owners. Increasing the coverage to 86% of the land would require addressing all parcels of 10 acres and larger, and would encompass 5,800 owners.\(^{70}\)

Using several different methods to reach landowners is likely to have greater effect than using a single mechanism of communication. The two organizations with the largest capacity for reaching forest owners are the DEM Division of Forest Environment (DFE) and the Southern New England Forest Consortium. These organizations could send informational mailings about the program to forest landowners, and in their contacts with landowners could supply information about forest management.

Existing programs promote development of forest management plans and provide cost sharing of plan implementation that could include pine enhancement. Service foresters who assist in preparation of plans and filing cost share paperwork would have to be made aware of the issue, and encouraged to include pine enhancement in management plans. Federal cost share programs already in use by DFE include the NRCS Forestry Incentives Program and the Forest Service Stewardship Incentives Program.

DFE has tracked the number of landowners who have written management plans. This is an inexpensive way to get an indication of the effectiveness of forestry outreach activities. However, there is no data about the extent to which landowners carry out actions necessary to achieve goals stated in their plans. It would be desirable to have data about rates of implementation of management activities. Ongoing Forest Inventory Analysis surveys are not sufficiently intensive to provide a reliable indicator of rates of implementation of management activities, and it would take many years for the results of management actions to manifest in timber volumes measured by FIA.

Not all management activities will sequester carbon during the time period addressed by this report. When trees are harvested for wood products, through thinning, clear cutting, or uneven aged management, not all the carbon in those trees goes into wood products. Part remains in the

---


forest as decomposing slash. Typically, part of the tree carbon is emitted within a year of harvest, from burning bark and sawdust as hog fuel, burning of fuel wood, or from decay of post-consumer product waste. Until growth exceeds these emissions, harvest is a net emission. With thinning to reduce competition in a vigorously growing stand, it can take only a few years for net sequestration to become positive again. See Appendix A for more detailed discussion of this matter.

Some elements of a large white pine enhancement program would require increased funding of DFE, either from state budgets or grants. These additional costs include preparation of outreach and educational materials, mailing costs, adding service forester capacity. University of Rhode Island Cooperative Extension has not focused on forestry issues. With sufficient state interest, it may be possible to increase Extension capacity to address forest issues.
6. Lower-potential options

6.1 No-till cropping.

Some traditional agricultural practices can be modified to reduce greenhouse gas emissions or sequester carbon. In general, these practice changes also have other environmental benefits such as reducing erosion, improving soil quality, improving water quality, and decreasing air pollution. However, only limited opportunities exist for changing agricultural practices in Rhode Island in ways that mitigate greenhouse gas emissions. Relatively few acres in Rhode Island are farmed using practices amenable to changes that reduce greenhouse gas emissions. Throughout the U.S., the two main agricultural practice changes for mitigation of greenhouse gas emissions are switching from conventional plowing to no-till direct seeding, and more efficiently managing nitrogen fertilizer.

A rough rule of thumb is that a moderate amount of sequestration resulting from switching from plowing to no-till is 1-2 metric tons carbon per acre, achieved over ten to fifteen years. Some crops that are prominent in Rhode Island, such as sod and potatoes, are not amenable to no-till systems. Only about 4,000 acres appear to be in crops amenable to no-till management. Even if all suitable acres are converted to no-till, the cumulative mitigation over 15 years or more would be 4,000 to 8,000 metric tons of carbon sequestration. Nationally, after years of encouragement and equipment development, the rate of use of no-till and strip tillage practices is still less than 20%. If Rhode Island could double this rate, the greenhouse gas mitigation would be a few hundred tons per year, tapering to almost near zero after about ten years of sequestration. Switching from conventional tillage to no-till also reduces fuel usage. However, the rate of emission reduction is small, possibly totaling a couple dozen tons of carbon per year for the entire state.

6.2 Farm fertilizer management

Reducing nitrogen fertilizer use can reduce greenhouse gas emissions because a portion of nitrogen fertilizer applied to fields is emitted to the atmosphere as nitrous oxide (N\textsubscript{2}O) and N\textsubscript{2}O is a potent greenhouse gas. The combination of strong competitive pressure on commodity prices and increasing regulation of fertilizer for water quality reasons means that larger farmers are generally knowledgeable about the current state-of-the-art of nutrient management and do a reasonable job of limiting excess fertilizer application. Smaller farmers, particularly those who make the bulk of their income from some occupation other than farming, are often less efficient at managing nutrients, but also typically the hardest to reach and convince to change.

Pound for pound, nitrous oxide has a much greater warming effect than carbon dioxide. However, only a small percentage of nitrogen applied as fertilizer ends up as nitrous oxide, and—as noted above—only a modest number of acres in Rhode Island are in agriculture. Assuming any plausible rate of convincing farmers to reduce nitrogen use, the net reduction in greenhouse emissions would be no more than a few hundred metric tons carbon equivalent per year, at most.

---

6.3 Lawn fertilizer management

Just as nitrogen fertilizer applied to fields release nitrous oxide, so does fertilizer applied to lawns. Agricultural extension agents and lawn management experts often assert that homeowners often apply fertilizer at rates that are much higher than needed. However, after substantial searching, we could find no measurements of actual rates of fertilizer application by homeowners. As a result, we are unable to provide any authoritative estimate of the potential greenhouse gas reductions that could be achieved by getting homeowners to apply fertilizer at proper rates. Guessing at the potential scope of the problem indicates that potential mitigation amounts are modest. If 10% of lawns and gardens are fertilized at rates several times what is needed, and somewhere between 10% and 30% of those who are over fertilizing can be convinced to fertilizer at the proper rate, then the annual reduction in state greenhouse gas emissions would be a few hundred metric tons carbon equivalent.\footnote{This calculation assumes that one quarter of the state land in residential use is in lawn or garden, that 10% is over fertilized by 175 pounds of nitrogen per acre per year. If 10% of the over fertilized area is switched to a proper fertilization rate, emission reduction would be about 70 metric tons carbon equivalent per year; getting 30% of the over fertilized area to the proper application rate would avoid 210 metric tons carbon equivalent each year.}

Appropriate fertilization could be encouraged by providing a brochure with every retail fertilization sale. The brochure could provide recommended rates of fertilization in easy-to-understand terms, and describe negative effects of over-fertilization. Negative effects include wasted money, possible plant damage, water quality impairment, possible human health impairment, and greenhouse gas emissions. An existing water quality programs might implement a fertilizer use education program, to help achieve water quality targets.
Glossary

Key issues, concepts, and definitions
Analyses of mitigation of greenhouse gas emissions use a variety of terms having specific meanings. Major concepts are outlined here.

**Emission reductions.** Claiming a greenhouse benefit from reducing emissions is based on reducing an ongoing stream of emissions. For example, an electricity company may serve its load by generating electricity by burning coal, and may switch to generating power by burning natural gas. With natural gas, the same number of megawatt hours of electricity can be produced with less emission of greenhouse gases. Common types of emission reductions from land management include slowing deforestation, increasing fuel efficiency of farm equipment or farming practices, and reducing methane emissions from growing rice by switching to cultivars that require less flooding or that are less efficient at transporting methane from below the soil surface to the atmosphere.

**Global warming potential (GWP).** A variety of gases allow solar radiation to enter the atmosphere, but trap energy emitted from the earth. These gases are called greenhouse gases. Three gases are emitted from land: carbon dioxide (CO\textsubscript{2}), methane (CH\textsubscript{4}), and nitrous oxide (N\textsubscript{2}O). Each greenhouse gas has a different half life in the atmosphere, and a pound of one gas free in the atmosphere will cause a different amount of radiative forcing than the other gases. The relative effects of different gases are compared calculating their cumulative radiative forcing for a period of 100 years following release into the atmosphere, relative to carbon dioxide. Current GWP values are given in Table 1.\textsuperscript{73} For example, one ton of methane has the warming effect of 23 tons of carbon dioxide.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Global Warming Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>1</td>
</tr>
<tr>
<td>Methane</td>
<td>23</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>296</td>
</tr>
</tbody>
</table>

**Leakage.** Leakage refers to effects caused by a project that occur outside the boundary of the project. The classic example of leakage is where a project preserves a parcel of forest that would have been logged to produce wood products. If the project does nothing to serve the continuing demand for wood, the economics of supply and demand show that most of the protected amount of wood will be replaced by increased cutting somewhere else.

**Sequestration.** Sequestration refers to removing a greenhouse gas from the atmosphere. The gas may be converted to other substances that do not cause greenhouse warming, or may be stored outside the atmosphere. The most common form of sequestration is plants removing carbon

\textsuperscript{73} Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: The Scientific Basis*. Cambridge University Press. Note that these GWP values have not yet been adopted by the Conference of Parties to the Kyoto Protocol of the United Nations Framework Convention on Climate Change and as a result calculations made under the Kyoto Protocol rules still use GWP values published by the Intergovernmental Panel on Climate Change in 1995.
dioxide from the atmosphere through photosynthesis, returning the oxygen to the atmosphere, and retaining carbon in plant tissue. Restoring previously cleared land to forest generally sequesters carbon. Reducing tillage disturbance of soil or increasing carbon inputs to soil by increasing plant productivity can sequester carbon by causing soil carbon levels to rise.

**Baseline.** The emissions baseline for an activity is used to calculate net emissions reductions. For an emissions reduction activity, achieved emissions are subtracted from baseline emissions. Any remaining positive amount is mitigation. Baselines may be a stock, such as a carbon stock in a forest. Baselines may be an amount during a specified period of time. For example, the baseline emissions against which project achievements might be the emissions from the project facility (or lands or process) the year prior to the project. The baseline for a forest carbon sequestration project might the carbon stock present immediately before the start of the sequestration project. Baselines may change over time. For example, a reforestation project might assume that some amount of natural regeneration of forest would have occurred in the absence of the project, and the baseline could change over time as the expected natural regeneration would have stored carbon. Baselines are net of any adjustments for additionality within the project, and adjustments for leakage outside the project boundary.

**Reversibility and Permanence.** Emission mitigation may be reversible or permanent. In general, sequestration is reversible. Forests that store carbon as they grow can continue to hold that carbon indefinitely, as individual trees die and are replaced by other individual trees. But the forest can be logged, or burn, which would emit the stored carbon. If emission mitigation is reversible, accounting must address this reversibility. One way to address reversibility is to continue to monitor the mitigation, and if it reverses to count that emission. Alternatively, one can monitor for a specified length of time and then assume that the mitigation is reversed after that time. The only way mitigation can be totally irreversible is for the mitigation to be generated by having emissions lower than a baseline emission amount or emission allowance. For example, if a coal fired power plant had been emitting one million tons of carbon dioxide to serve its load for the year 2003, and it switches fuel to natural gas and serves the same load while emitting only 900,000 tons in 2004, if all other things are equal, it has mitigated 100,000 tons in 2004. In later years its emissions may rise or fall, but it can not go back in time to 2004 and increases 2004 emissions. Therefore, the 2004 emission mitigation is irreversible.
Appendix A: Effect of Rotation Length on Carbon Sequestration

In general, establishing on previously non-forested land sequesters carbon, with the total amount of sequestered carbon growing over time until some disturbance causes some loss of carbon. When trees are harvested, a portion of the carbon in those trees is converted to wood products and remains sequestered for many decades. As the forest regrows, eventually, the total amount of sequestration could be greater than the amount stored prior to harvest. Depending on initial conditions, durability of wood products, rate of regrowth, and number of rotations counted, the total amount of carbon stored after harvesting an existing stand may be more or less than the initial amount of carbon present before harvest. Except over very long periods or situations with very fast rates of reaching maximum live carbon stock, reducing rotation lengths will reduce the total amount of carbon stored.

We constructed a model to illustrate these outcomes for Rhode Island forests. The modeled scenarios are intended to show the range of potential management regimes, from no cutting to intensive clear cutting. The idea is to bracket the range of management intensities that might occur on Rhode Island forests to show how different management regimes lead to opposite net greenhouse effects. In practice, most forests are selectively harvested or not harvested. Further work could be done examining commonly used management regimes, to identify variations that lead to net carbon sequestration.

In the model, tree carbon accrues at the average rate for Northeastern U.S. pine and hardwood forests. Of the tree volume harvested, 50% is used for fuel wood and assumed to be burned within one year, 32% is removed as logs for wood products, and 18% is assumed to remain in the forest as residue. Of sawlogs harvested, 60% is assumed to go into products. This proportion varies by log size and quality and type of product produced. 60% is a relatively high proportion, and would be appropriate for a sound log 15” diameter inside bark at the small end of the log. A portion of wood products is landfilled and is anaerobically decayed and emitted as methane. Methane has 23 times the warming effect as an equal mass of carbon dioxide. This model does not account for the additional warming effect of converting some carbon to methane. The proportion of total tree biomass relative to merchantable stock (in cubic feet) is 2.1665. Cubic feet of merchantable timber is converted to pounds of carbon at a rate of 18.43, which is the

---

average of rates given for pine, oak-hickory, and maple-beech-birch in the Northeast. The number of pounds in a metric ton is rounded to 2205. Wood products are assumed to decay at an annual rate of 0.0085. Logging debris, stumps, roots, and other woody residue is assumed to decay at a rate of 0.125 per year, which is midrange in the distribution of decay rates for these components.

Figure 4.

The model was run for three different forest management scenarios that illustrate situations in Rhode Island. The simplest scenario is establishing forest on bare ground, such as a previously tilled field, is presented in Figure 4. In this scenario, there is no carbon in products or debris because there is no prior forest stand to serve as a source for this carbon. Eventually, the carbon

---


stock will reach an equilibrium and remain there until some sort of disturbance reduces the stock and provides an opportunity for new growth.

The next scenario assumes a constant rotation length of 60 years, also starting from bare ground (Figure 5). In this scenario, at any year in the rotation, the second rotation stores more carbon than the first. This is because live tree growth is assumed to be the same in all rotations, and carbon stock in the second rotation includes carbon in debris and products retained from the prior rotation. Over time, on average, this scenario continues to gain carbon, until the product pool reaches equilibrium. Because of the very slow decay rate of products, this equilibrium would not be reached until several centuries have passed. However, even with products, after the first harvest, the carbon stock would still remain less than in the no-cut scenario illustrated in Figure 4.

Figure 5.

![Rhode Island Forest Carbon Constant Rotation Length](image)

The third scenario modeled is an intensification of management. This scenario assumes starting with a 75 year old stand that regenerated from a farm field early in the 20th century. This existing stand is harvested and regenerated using 50 year rotations (Figure 6). Note that as rotations pass, the amount of carbon in the product pool increases. However, because the rotation is shortened, the peak and average carbon stocks in live biomass is reduced relative to
stocks in the original stand that grew to age 75. Because only a small proportion of carbon harvested from live trees enters the long-term product pool, the total amount of carbon stored remains less than the amount stored by the original stand. It is possible that after several rotations, the accumulated carbon in products could bring the total amount sequestered up to the amount present immediately before the initial harvest. However, this amount would be less than the amount that would be stored without any harvest, as shown in Figure 4.

**Figure 6.**

![Rhode Island Forest Carbon Reducing Rotation Length](image)

There may be conditions where it is possible to have greater total carbon sequestration with harvest than without harvest. If the proportion of live tree carbon that goes into the long-term product pool can be made large, and if the forest type would rapidly reach maximum biomass without harvest, it is possible that the total amount of carbon stored with harvest would be greater than without harvest. Forest management actions that increase the rate of forest growth or maximum carbon stock will increase carbon storage with or without harvest, relative to the amount stored without the management action. Pine enhancement of hardwood stands is one example of such an action. Thinning that retains rapid stand volume growth might also increase total carbon storage.
Appendix B: White pine enhancement calculations

Projecting sequestration likely to result from establishing pine in gaps in Rhode Island forest involves a number of calculations. First, typical yields for white pine\textsuperscript{82} and northern hardwoods,\textsuperscript{83} as a function of stand age, were obtained from Forest Service publications. These volumes were in cubic foot measure, per acre. Amounts were converted to cubic meters per hectare using direct linear conversion. Stand volumes were converted to total tree biomass using equations developed from Forest Service Forest Inventory Analysis plot data using non-linear regression.\textsuperscript{84} Equations used in these calculations were for the northeastern U.S. region, for the oak-hickory forest type and the white-red-jack pine forest type. The equation form is:

\[
\text{Live-tree mass density} = F \times (G + (1 - e^{(-\text{volume}/H}))
\]

Where mass is in metric tons per hectare, volume is in cubic meters per hectare, F, G, and H are regression coefficients, and e is a constant that is the base of the natural logarithm and is approximately equal to 2.71828182845904. The values of regression coefficients are in the table below.

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak-Hickory</td>
<td>488.2</td>
<td>0.0509</td>
<td>312.8</td>
</tr>
<tr>
<td>White-Red-Jack Pine</td>
<td>415.6</td>
<td>0.0349</td>
<td>276.1</td>
</tr>
</tbody>
</table>

Biomass was converted to carbon at the proportion of 0.521 for pines and 0.498 for hardwoods.\textsuperscript{85} Carbon mass per hectare was converted to carbon dioxide equivalent per acre. Generally, annual sequestration between ages where stand volumes were given was interpolated linearly. The exception to this general extrapolation is the first five years after establishment of pine. Pine grows slowly for the first five years, so no carbon was assumed to be stored during those years. This is a conservative assumption that somewhat understates actual achievement of sequestration. Relative sequestration by the two forest types is shown in Figure 7 below. Over time, adding a pine component to existing hardwood forests can substantially increase total sequestration.


There is conflicting information about how much area is available for establishing pine in gaps in existing hardwood stands. Forest Service Forest Inventory Analysis survey plot measurements find that 53% of the total timberland area in the state is moderately stocked or poorly stocked. However, the Rhode Island Division of Forest Environment suggests that most acres in the state are fully stocked or overstocked, and thus less area of canopy gaps would be available for adding new trees without displacing existing trees. If existing hardwood trees are displaced with white pine, over time the total carbon stock would increase, but in the short term net sequestration would be decreased by emissions from decay of logging residue and emission of carbon from a portion of any trees harvested to make room for pine.

The calculations presented here use Forest Service stocking measurements. Area eligible for additional stocking was calculated from Forest Service Forest Inventory Analysis report summaries for 1998, the most recent year available. Forest Service Forest Inventory and Analysis field surveys find that approximately 53% of the timber land in the state is poorly or moderately stocked.

---

87 Tom Dupree, Chief, RI Division of Forest Environment, personal communication 12 April 2004.
Stocking is the degree to which trees occupy land, measured by basal area and/or number of trees in a stand compared with the basal area and/or number of trees required to fully use the growth potential of the land (or the stocking standard). In the Eastern United States this standard is 75 square feet of basal area per acre for trees 5.0 inches d.b.h. and larger, or its equivalent in numbers of trees per acre for seedlings and saplings. The Forest Service defines its stocking class categories to be: nonstocked (0 to 9% of the standard); poorly stocked (10 to 59% of the standard); moderately stocked (60 to 99% of the standard); fully stocked (100 to 129% of the standard); and overstocked (130 to 160% of the standard).

Under business-as-usual conditions, it is likely that existing trees would continue to spread, and within 60 years, much of the currently under-stocked area would become fully stocked. Therefore, the effect of greater white pine stocking of forests must be measured relatively to a fully stocked, typical stand of similar age. Expansion of trees in existing stands could be expansion of hardwoods or pine. There is some gain from converting expansion from hardwood to white pine. An oak/hickory stand contains slightly more than half of the carbon of a white pine stand of site index 60 (37 tC/acre vs. 70 tC/acre). Thus the net effect of white pine stocking is to ultimately increase carbon storage by 23 tC/acre. If the stand would have regenerated to white pine anyway, there is no additional carbon benefit to actions facilitating pine establishment. This analysis makes the more conservative assumption that the areas that would have regenerated anyway would have regenerated to pine, not hardwood.

We evaluate a potential program that would stock pines over the next ten years, at a rate of 4,000 acres per year. This analysis assumes that only half the existing space could be utilized because not all forest sites are suitable for pine, and not all landowners would accept pine enhancement on their lands, leaving half of 45,000 acres, which is 22,500 acres. Spread over a ten year program, this would be the equivalent of 2,250 acres per year. Additionally, Forest Service inventory and harvest reports suggest that the equivalent of about 3500 acres per year are harvested across the state (in practice more acres will be harvested with partial cutting and almost no acres are clearcut). Assuming half of this area can be harvested in a way that favors white pine, it is the equivalent of adding 1,750 acres per year. Adding the areas from increasing stocking and favoring white pine during harvest results in the equivalent of 4,000 acres per year. White pine enhancement could be achieved largely by favoring pine during thinning and ingrowth into existing forest gaps. Conventional “stand type conversion” where the existing stand is clearcut and a new species planted, is NOT envisioned.

In contrast to the Forest Service inventory, the Rhode Island Division of Forest Environment staff suggest that most of the forest land in the state is fully stocked or overstocked. Our analysis used the Forest Service stocking rates. However, if most of RI forest land is already fully stocked, then adding pine to the area proposed in this analysis would displace some existing hardwoods, reducing the net sequestration achieved. Assuming a linear relationship between stocking and area and assuming that under stocked acres are have a stocking rate that is in the middle of the class definition, the Forest Service inventory numbers suggest that trees could be added within existing stands to generate an increase in basal area equivalent to afforesting

---


89 Tom Dupree, Chief, RI Division of Forest Environment, personal communication 12 April 2004.
43,400 acres. Site specific analysis would be necessary to determine what of this area is suitable for white pine; some locations will be better suited to species other than white pine.

It would be unrealistic to assume that pines could be established in all canopy openings. Even though pine can be established on sites where it would not naturally out-compete other species, by using silvicultural interventions, it cannot be established on all sites. On some sites soils or moisture conditions are not appropriate. Also, even if Rhode Island offered to establish pines at no cost to landowners, not all landowners would accept the management intervention. Funding available for this analysis did not permit site specific investigations to evaluate rates of owner acceptance or actual proportions of unstocked timberland that will support white pine. In the absence of this detailed data, only half unstocked area was assumed to become established with pines as a result of the program. These inputs result in a calculation of 40,000 acres being established in pine by the program.

The active establishment program was assumed to start in 2004, and continue for 10 years. The area treated and established was assumed to be constant each year at 4,000 acres.

Only carbon that is stored as a result of the program is counted as mitigation of greenhouse gas emissions. Carbon that would have been stored anyway, without the program, should be counted in the state emissions inventory and counted as the baseline condition. The forests of Rhode Island have been accumulating carbon at the rate of 53,000 metric tons carbon per year. Some of this increase in carbon stock comes from growth of existing trees and some comes from expansion of trees into previously unstocked areas. Forest Inventory Analysis plots show that 91% of the net increase in stocking is white pine, because much of the growth of hardwoods is removed by harvesting for wood products or land clearing for development. Because the lands of Rhode Island are generally suitable for trees, and trees naturally regenerate on suitable soils near other trees, one should assume that this trend of increasing stocking rates will continue. On much of the forest land of Rhode Island, either white pine or hardwoods can grow. On much of the land, the environment allows hardwoods to out-compete pine under unmanaged conditions. Pine does relatively better than hardwoods on sandier, less productive sites.

Because of the existing substantial rate of natural pine regeneration, this analysis assumes that half of the area established in pine would have been colonized anyway, without the program. This assumption is used because a pine enhancement program would focus on sites that are suitable for pine and it is not possible to predict exactly which of these sites would have been colonized by pine in the absence the enhancement program. As a result, this “business as usual” sequestration is assumed to be already counted in the expected “business as usual” carbon gains of Rhode Island forests. This analysis assumes that half of the areas where enhancement is performed would have regenerated to pine without the enhancement actions. If the program were implemented in 2004, the cumulative sequestration achieved through year 2020 is shown in Figure 8. These amounts are only the additional sequestration attributed to enhancement actions, and do not include amounts expected to have occurred anyway, in absence of the program.

---


91 These numbers may not be correct because they show no pine harvesting in the state.
Sequestration would continue to increase for several decades as a result of expenditures made in the first few years of the program.

Figure 8.

Costs are presented in present value terms. The annual discount rate used in the analysis is 4% using standard methods. Costs are not discounted for the year in which they are incurred, but only for years after project initiation but before the year of expenditure. Costs per ton represent the present value of all program investments, divided by the number of additional tons expected to be sequestered in the period reported.