# Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs

## Part 6. Comparison of terrestrial carbon mitigation options in the northeast United States

By
Walker, S.M., S. Grimland, N. Sampson, B. Sohngen, J. Winsten, J., and S. Brown

**Submitted 2007 by Sandra Brown, Co-Principal Investigator**

Winrock International

**1621 N. Kent St., Suite 1200**
**Arlington, VA 22209, USA**
**Telephone: 1-703-525-9430**

**Email: sbrown@winrock.org**

Report Collaborators:
Sarah Murdock, The Nature Conservancy
Sandra Brown, Winrock International
Neil Sampson, The Sampson Group
Bill Stanley, The Nature Conservancy

Report Submitted to US DOE-NETL
Cooperative Agreement DE-FC26-01NT41151

**Cite report as**:

Comparison of terrestrial carbon mitigation options in the northeast United States in. 2007. Walker, S.M., S. Grimland, N. Sampson, B. Sohngen, J. Winsten, J., and S. Brown. in: *Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs*. Winrock International, The Nature Conservancy, and The Sampson Group. Report to: US DOE-NETL Cooperative Agreement DE-FC26-01NT41151

## 6 Comparison of terrestrial carbon mitigation options in the northeast

by: Walker, S.M., S. Grimland, N. Sampson, B. Sohngen, J. Winsten, J., and S. Brown.
Winrock International

# Table of Contents



# List of Tables



# List of Figures

## 6.1 Executive Summary

Changing land management practices can result in increased carbon storage, however the potential magnitude of carbon benefits and marginal costs incurred vary spatially and are dependent on the management option that is implemented. The potential increase in carbons storage and associated marginal costs from a variety of management practices on agricultural and forest lands are compared here for the northeastern states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. This comparison allows for an unbiased presentation of the potential quantity and cost of carbon offsets only, other factors beyond the carbon sequestration potential of a particular land management use are outside the scope of this analysis. Many of the land management options discussed have additional benefits outside of carbon mitigation; however, these are not the focus of this analysis and are excluded from discussion. Consideration and analysis related to environmental co-benefits of afforestation activities was presented in Part 5 of this report.

Agricultural and forested lands dominate the landscape and provide large areas where current practices could be altered, resulting in increased carbon sequestration or reduced carbon emissions (Figure 6-1). The analysis was performed at a county level of resolution. Although forested lands contain higher carbon stocks than agricultural lands, the current land use practices on forest lands generally have goals besides maximizing carbon sequestration. However, opportunity still exists in forest lands to increase long term carbon stocks through changing practices.

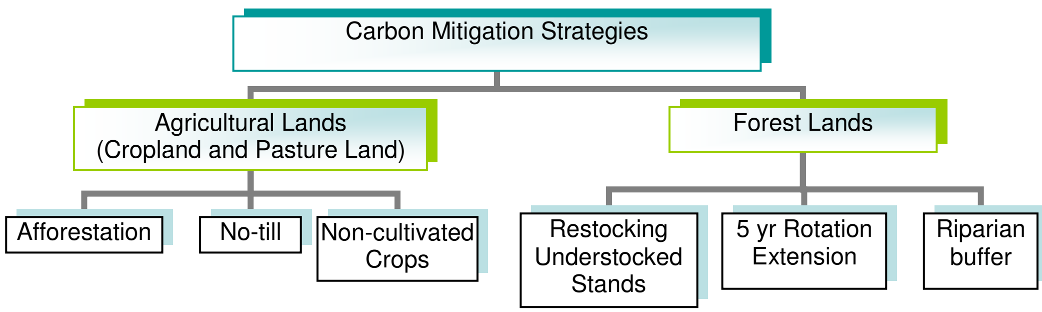



**Figure 6-1. Overview of land management options compared**

Afforestation of agricultural lands can potentially sequester the highest amount of $CO_2e$ per unit area (average 57 t $CO_2e$/acre after 20 years). Additionally, beyond 20 years, planted trees will continue to accumulate $CO_2e$ as compared to the conversion of agriculture lands to no-till and non-cultivated crops (such as hay, pasture or wildlife cover) which result in a new steady-state of carbon stocks in about 20 years (average of 11 and 14 t $CO_2e$/acre respectively). Although lower than agricultural land options, restocking of understocked forest stands can potentially sequester, over the long term, more carbon (9 t $CO_2e$/acre) than rotation extension (5 t $CO_2e$/acre) or riparian buffers (4 t $CO_2e$/acre). Because of the higher sequestration rates per area, afforestation requires the least area of land to sequester a given amount of $CO_2e$ and can potentially supply the greatest amount of sequestered carbon for the northeast region. The analysis considered the effects of afforesting all available agricultural lands; a scenario that is recognized as unilikely and not desireable. None-the-less this analysis was conducted to demonstrate the ultimate potential of carbon sequestration from this activity. Within 20 years, it is estimated that 1.2 billion tons $CO_2e$ could be sequestered from afforestation of agriculture lands. In contrast, forest management alteration could lead to a maximum carbon accumulation of 14.6 million tons $CO_2e$.

Marginal costs vary spatially for each land management option with most options spanning a large range of marginal costs (Table 6-1). Afforestation has higher marginal costs than other land management options because it requires cessation of agricultural production, and therefore has higher opportunity costs. Of the options on agricultural lands, no-till has the lowest marginal costs. Overall, restocking understocked stands has the lowest marginal costs with the majority of counties having negative marginal costs, indicating that switching to this land management practices would potentially create profits. The formation of riparian buffers has the highest marginal costs in the forested areas due to higher opportunity costs.

**Table 6-1. Area weighted average marginal costs, \$/t $CO_2$e, for all land management options (negative values indicate that the activity would potentially generate profits over the cycle).**

| | Agricultural Lands | | | | Forest Lands | | |
|---|---|---|---|---|---|---|---|
| | Afforestation of Cropland | Afforestation of Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| Average | 103 | 64 | 18 | 139 | -53 | 6 | 84 |
| Range | 36-254 | 13-265 | 10-29 | -137-348 | -1,434-693 | 3-21 | 0.11-240 |

The land management option that provides the greatest amount of $CO_2$e at a particular price varies across the region (Figure 6-2). Restocking of understocked forest stands and extending rotations in forest lands provide the lowest cost option with the greatest potential carbon mitigation for most counties in the region. Generally, land management on agricultural lands only is the least expensive option in counties where there is little forest land available for management alterations. Many counties in the region have no potential to provide $CO_2$e at a \$7/t $CO_2$e price point.

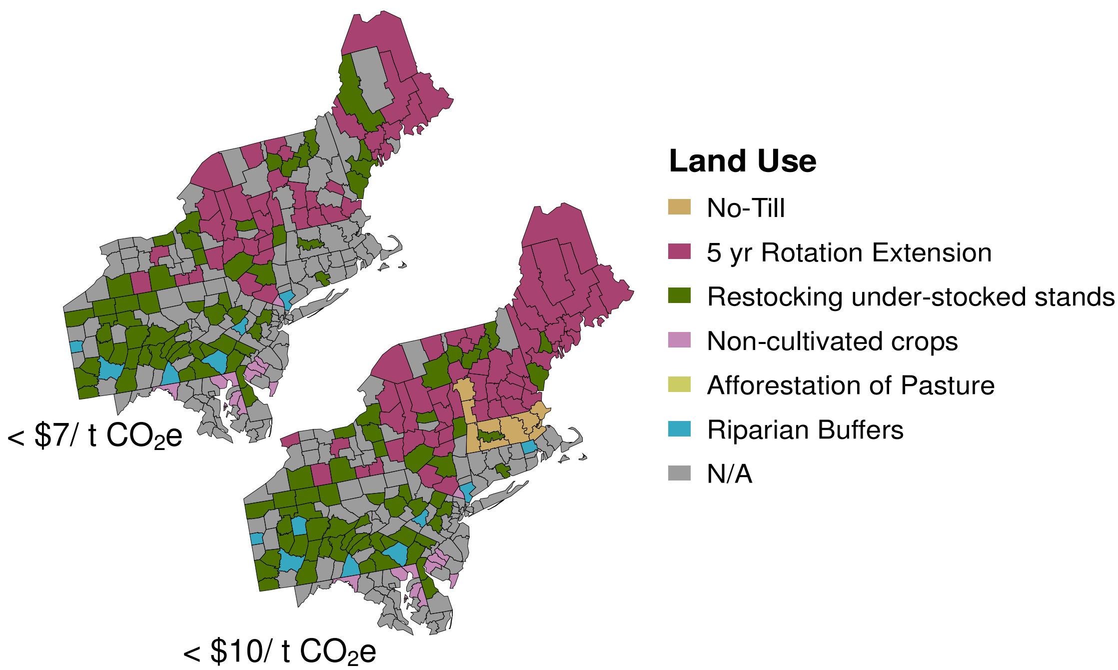



**Figure 6-2. Land management option on agricultural or forest land with largest potential t $CO_2$e at various price points (at 20 yrs for agricultural land and permanently for forest land).**

The state of Maine has a carbon mitigation potential of over 12.8 million tons $CO_2$e at marginal costs less than \$7/t $CO_2$e with a combination of afforestation of pasture land, restocking understocked stands, and increasing forest rotations (Table 6-3). Where as, in Maryland almost 475,000 acres of agricultural land could potentially be converted to non-cultivated crops at a price point of \$7/t $CO_2$e resulting in 5.6 million t $CO_2$e. Significant opportunities also exist in New York and Pennsylvania with the restocking of understocked stands at marginal costs below \$7/t $CO_2$e.

**Table 6-2. Potential emission reductions (t CO2e) per state at marginal costs below $7/t CO2e for various land management options (at 20 yrs for agricultural land and permanently for forest land).**

| | Agricultural Lands | | | | Forest Lands | | |
|---|---|---|---|---|---|---|---|
| | Afforestation of Cropland | Afforestation of Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| Connecticut | | | | | 46,000 | | |
| Delaware | | | | | 227,000 | | |
| Maine | | 7,809,000 | | | 1,889,000 | 4,963,000 | |
| Maryland | | | | 5,657,000 | | | |
| Massachusetts | | | | | 128,000 | | |
| New Hampshire | | | | | 181,000 | 551,000 | |
| New Jersey | | | | 916,000 | 615,000 | | |
| New York | | 268,000 | | | 1,322,000 | 2,353,000 | 109,000 |
| Pennsylvania | | | | | 4,907,000 | | 28,000 |
| Rhode Island | | | | | | | |
| Vermont | | | | | 893,000 | 553,000 | |
| All States | | **8 million** | | **6.6 million** | **10 million** | **8.4 million** | **137,000** |

At higher marginal costs, afforestation can provide substantially greater amounts of carbon benefits than other land management options. However, there is only one county with marginal costs below $40/t $CO_2$e for the afforestation of cropland (Table 6-3). Afforestation of pastureland has lower marginal costs with several counties in New York and Maine having marginal costs below $20/t $CO_2$e. At $40/t $CO_2$e afforestation of pasture lands has the potential to sequester over 0.2 billion tons $CO_2$e. About half of the total carbon mitigation potential resulting from the conversion to non-cultivated crops on agricultural land is estimated to have marginal costs below $7/t $CO_2$e while about 70% of the total mitigation potential of restocking forest standing and extending rotations have marginal costs below $7/t $CO_2$e.

**Table 6-3. Summary of potential and amount of emission reductions area available at various price points for all land management options (at 20 yrs for agricultural land and permanently for forest land).**

| | Agricultural Lands | | | | Forest Lands | | |
|---|---|---|---|---|---|---|---|
| | Afforestation of Cropland | Afforestation of Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| t $CO_2$e | | | | | | | |
| < $7/t $CO_2$e | | 8 million | | 6.6 million | 10 million | 8.4 million | 137,000 |
| < $10/t $CO_2$e | | 8 million | 1.2 million | 6.6 million | 10.8 million | 11 million | 143,000 |
| < $20/t $CO_2$e | | 21 million | 32 million | 7.6 million | 12.9 million | 11.6 million | 201,000 |
| < $40/t $CO_2$e | 116,000 | 215 million | 33 million | 13 million | 14.3 million | 11.8 million | 490,000 |
| area (acres) | | | | | | | |
| < $7/t $CO_2$e | | 169,000 | | 550,000 | 1 million | 1.4 million | 79,000 |
| < $10/t $CO_2$e | | 169,000 | 110,000 | 550,000 | 1 million | 1.9 million | 87,000 |
| < $20/t $CO_2$e | | 351,000 | 5.7 million | 636,000 | 1.3 million | 2.1 million | 123,000 |
| < $40/t $CO_2$e | 2000 | 3.6 million | 5.7 million | 1 million | 1.5 million | 2.2 million | 193,000 |

In summary, several states have a large carbon mitigation potential through terrestrial land management alteration (Figure 6-3). Maine has multiple land management options with low marginal costs. In New

York, New Jersey, and Vermont large potential exists for restocking understocked stands while in Maryland conversion to non-cultivated crops provides a good opportunity.

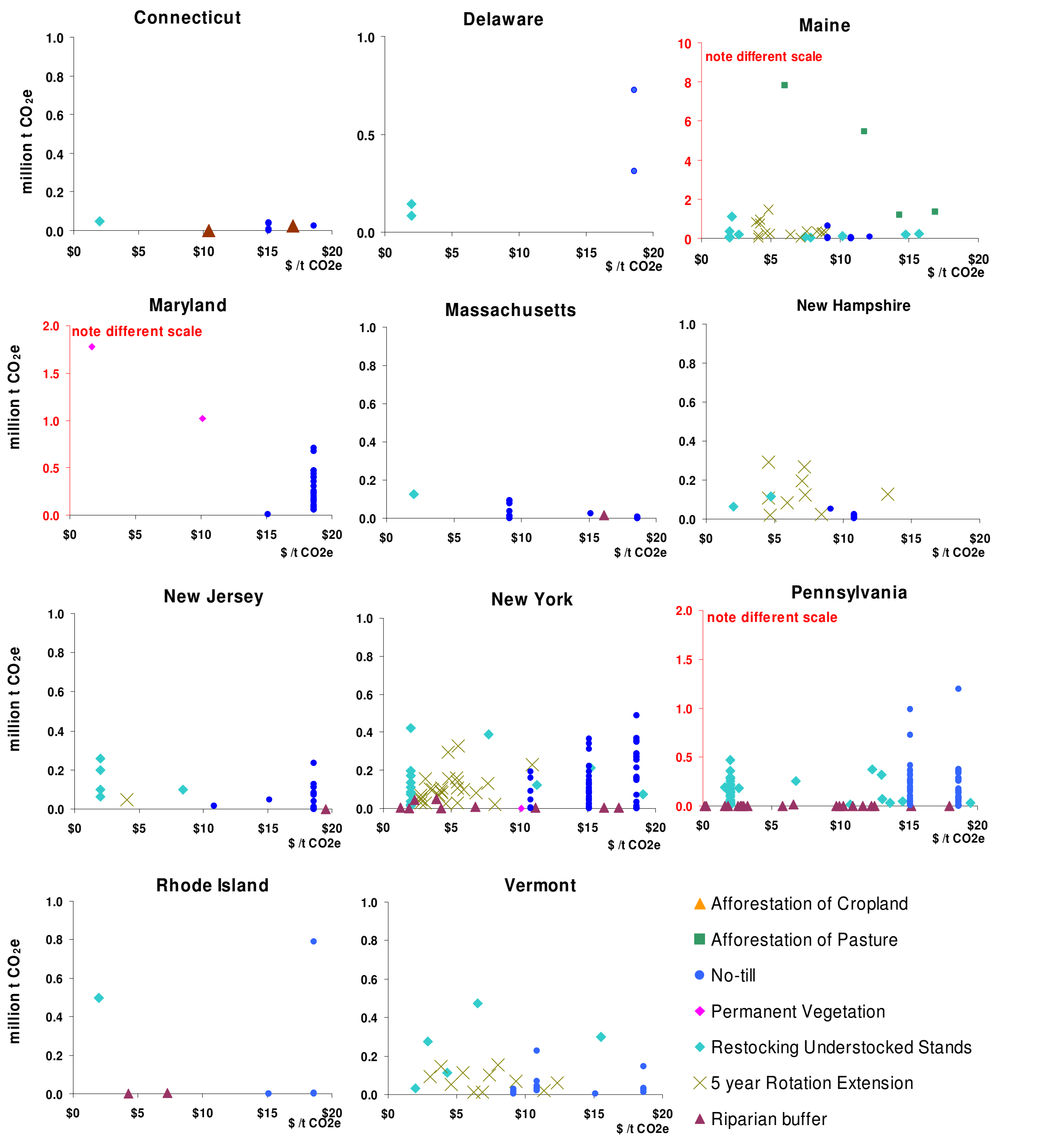



**Figure 6-3. The potential quantity of t $CO_2$e at each marginal cost below \$20/t $CO_2$e for each a county (at 20 yrs for agricultural land and permanently for forest land).**

## 6.2 Introduction

Before initiating a particular strategy of carbon sequestration/emissions reductions management options for agricultural and forest lands, the effectiveness of each option needs be evaluated in terms of the quantity of carbon potentially available and its marginal cost. In this section, the potential $CO_2$e gain, available land area, and marginal costs of each of the land management strategies are compared, providing the necessary information to inform the choice of any given strategy. This comparison allows for an unbiased presentation of the potential quantity and cost of carbon benefits only, other factors beyond the carbon sequestration potential of a particular land management use are outside the scope of this analysis.

### Scope of comparison

Carbon mitigation strategies were analyzed for both existing agricultural and forest lands, and the potential supply of $CO_2$e benefits from these strategies are compared (Figure 6-4). The states within the analysis are: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The analysis was performed at a county level. On agricultural lands, the land management options compared include: afforesting existing agricultural lands, changing land management to no-till but continuing crop production, and altering crop production to non-cultivated crops (such as hay, pasture or wildlife cover). Although the mitigation potential for biomass energy was estimated (Section 3C), the approach and data are not as well developed and not comparable to the other options thus they will not be discussed further in this section. Restocking understocked stands, increasing rotations, and increasing the riparian buffer are the three forest practices compared here. The analysis for increasing rotations was only performed in the states Maine, New Hampshire, New York, and Vermont.

Each of the land management options is compared in total and spatially across the region, and the major trends and patterns highlighted (more details on each option are provided in the respective sections of the overall report). Potential sequestration/emissions reductions and associated costs vary spatially, and therefore by comparing each option on a county level, the most cost effective approach for a region can be elucidated. The detailed analyses for each management options on existing agricultural lands were examined at various points in time, however, for the purposes of this comparison, only data for a 20 year period are shown. Carbon continues to be sequestered in afforestation activities for longer time periods (for more than 100-200 yr), whereas for conversion of cropland to no-till cultivation or non-cultivated crops, carbon sequestration ceases. Thus a comparison over longer time frames would produce slightly different comparative results for activities on crop lands. For the forestry sector, data presented are based on the assumption of a “permanent contract’ meaning that once a land owner changed their management practice, it is assumed that the change would be permanent.

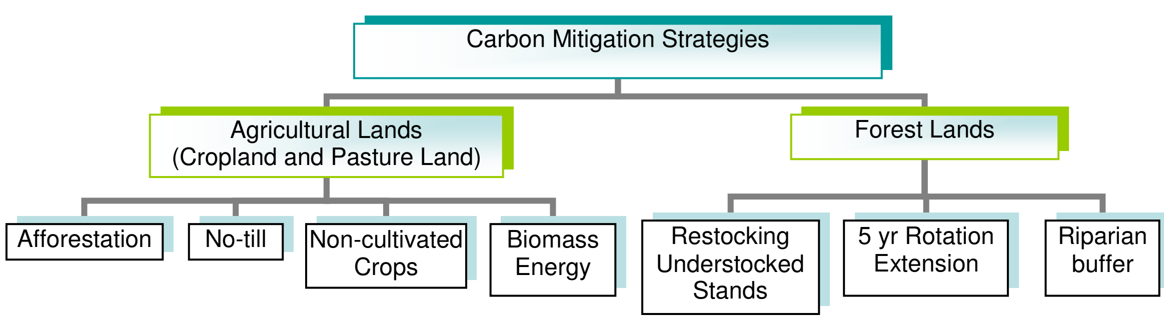



**Figure 6-4. Overview of land management options examined.**

## 6.3 Results of Comparison of all Land Management Options

All of the changes in land management examined here result in carbon dioxide sequestration and in some case reductions in carbon dioxide emissions. Converting agricultural lands to forests has the potential to accumulate the largest amount of carbon per unit land area (Table 6-4) and over longer time periods, greater quantities would be sequestered. Within the afforestation analysis, changes in other carbon pools such as soil, litter, and deadwood were not included in the analysis but are expected to increase or not decline significantly over time. Conversion to no-till or to non cultivated crops includes carbon sequestration mostly in the soil and fossil fuel emission reductions through altered farming practices. On a per unit area basis, carbon sequestration/emission reduction from conversion of cropland to no-till or to pasture is small, and about a quarter or less of that for afforestation, and the amount is unlikely to increase any further because the soil carbon pool will reach a new steady state at about 20 years. Carbon sequestration from restocking poorly stocked forest stands is also small, ranging from about 10-25% of that for afforestation of agricultural lands and up to half that of no-till or non-cultivated crops (Table 6-1). The analysis for extending rotation of softwood forests in Maine, New Hampshire, New York, and Vermont (see Section 4) resulted in an average increase in carbon stocks of 5.4 t $CO_2$/ac for a 5 year extension, 6.7 t $CO_2$/ac for a 10 year extension, and 9.7 t $CO_2$/ac for a 15 year extension. These amounts fell generally within the range of increased carbon stocks found for restocking poorly stocked stands. Permanently setting aside forests in riparian buffers would result in an average increase in carbon stocks on a permanent basis of about 5.5 t $CO_2$/ac across the region.

**Table 6-4. Area weighted average carbon dioxide sequestration/emissions reduction equivalence (t $CO_2e$/acre) for 20 year time period for each agricultural land management option and permanent conversion for forest lands.**

| | Agricultural Lands | | | Forest Lands | | |
|---|---|---|---|---|---|---|
| | Afforestation | No-till | Non-cultivated Crops | Restocking understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| Connecticut | 60 | 11 | 15 | 3 | | 4 |
| Delaware | 69 | 9 | 12 | 21 | | |
| Maine | 46 | 16 | 19 | 9 | 6 | 5 |
| Maryland | 52 | 9 | 12 | | | |
| Massachusetts | 65 | 15 | 18 | 10 | | 6 |
| New Hampshire | 58 | 16 | 22 | 5 | 5 | 6 |
| New Jersey | 53 | 9 | 9 | 7 | | 0 |
| New York | 56 | 11 | 13 | 8 | 4 | 4 |
| Pennsylvania | 60 | 10 | 14 | 9 | | 1 |
| Rhode Island | 52 | 10 | 14 | 5 | | 3 |
| Vermont | 53 | 14 | 20 | 17 | 5 | 7 |
| All States | 57 | 11 | 14 | 9 | 5 | 4 |
| Minimum | 23 | 7 | 0 | <1 | 1 | <1 |
| Maximum | 74 | 19 | 27 | 35 | 9 | 22 |

The potential carbon sequestration/emission reduction equivalence per unit area can then be used to estimate the amount of land needed to attain a given supply of $CO_2e$ (Table 6-5). Because the carbon sequestered per unit area for afforestation is high, the area of land needed to result in given quantity of $CO_2e$ is small compared to other land management activities. Changing management of forests requires the most land to reach a given supply of $CO_2e$ as expected because on a unit area basis these activities have the lowest potential increase in carbon stocks (Table 6-4).

**Table 6-5. Estimated area of land (in acres) required to attain different amounts of $CO_2$e benefits for each land management option (based on 20 year period on agricultural lands, and permanent land management change in forest lands).**

| ton $CO_2$e | Agricultural Lands | | | Forest Management |
|---|---|---|---|---|
| | Afforestation | No-till | Non-cultivated Crops | |
| 10,000 t | 177 | 1,103 | 749 | 12,300 |
| 50,000 t | 885 | 5,514 | 3,747 | 49,630 |
| 100,000 t | 1,770 | 11,028 | 7,495 | 66,220 |
| 1 million t | 17,695 | 110,281 | 74,946 | 359,520 |

The estimated maximum potential supply of $CO_2$e for the region through afforestation is substantial, due to both the high sequestration per unit area and the large area of agricultural land (Table 6-6). Because afforestation has the greatest per unit area potential, afforestation is the land management option with the largest potential within each county as well (Figure 6-5). If all the agricultural land in the region was afforested, the potential estimated $CO_2$e sequestered over 20 years would equal 17% of the 2005 greenhouse gas emissions of the United States (Energy Information Administration, USDOE 2006). The maximum potentials are considerably lower for other land management options. A scenario in which all agricultural land or forest land is converted to one land management strategy is highly unlikely, and so the total possible maximum is presented only to illustrate the management option's overall maximum capacity.

**Table 6-6. Maximum potential estimated tons of $CO_2$e sequestered for each land management option (based on 20 year period on agricultural lands, and permanent land management change in forest lands).**

| | Agricultural Lands | | | | Forest Lands | | |
|---|---|---|---|---|---|---|---|
| | Afforestation of Cropland | Afforestation of Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| | million tons $CO_2$e | | | | | | |
| Connecticut | 6.62 | 16.19 | 0.19 | 0.47 | 0.08 | | 0.08 |
| Delaware | 34.73 | 0.26 | 2.08 | 5.32 | 0.23 | | 0 |
| Maine | 9.83 | 46.13 | 0.98 | 2.44 | 3.42 | 6.85 | 0.7 |
| Maryland | 92.2 | 12.35 | 6.07 | 15.78 | | | |
| Massachusetts | 14.55 | 5.95 | 0.4 | 0.99 | 0.19 | | 0.23 |
| New Hampshire | 0.9 | 12.02 | 0.13 | 0.33 | 0.25 | 1.3 | 0.42 |
| New Jersey | 4.46 | | 1.35 | 3.34 | 0.77 | | 0 |
| New York | 98.06 | 339.54 | 7.94 | 19.18 | 2.29 | 2.73 | 0.88 |
| Pennsylvania | 85.85 | 386.74 | 12.92 | 32.2 | 6.18 | | 0.17 |
| Rhode Island | 1.32 | 0.8 | 0.01 | 0.03 | 0.05 | | 0.02 |
| Vermont | 30.32 | 16.62 | 0.68 | 1.64 | 1.19 | 0.96 | 0.14 |
| All States | 378.85 | 836.6 | 32.73 | 81.72 | 14.64 | 11.83 | 2.64 |

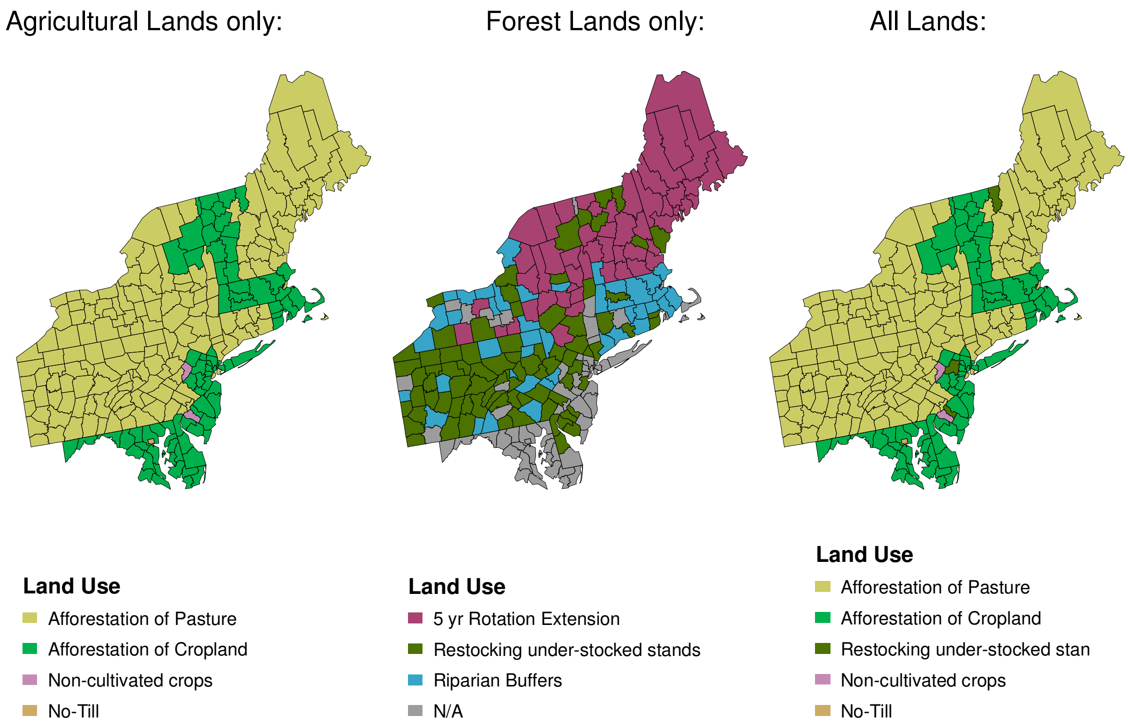



**Figure 6-5. Counties showing the management option with the largest potential t $CO_2$e for: agricultural lands only (left), forest lands only (middle) and all lands combined (right).**

Although afforestation produces the greatest quantity of t $CO_2$e, it is not the land management strategy with the lowest marginal costs (Table 6-7). Costs vary substantially by county, and restocking understocked forests and extending forest rotation both provide the option with the lowest overall marginal costs (Figure 6-6). Converting to no-till agriculture, on average, has the lowest marginal costs on agricultural lands because the existing practice does not need to change and thus there is little opportunity cost. For some counties in the more southerly states, conversion to perennial vegetation is the most cost effective management practice. For most of the counties where riparian buffers presents the best option, this is because either there is no other land management option, or because it is a more cost effective option than no-till.

**Table 6-7. Area weighted average marginal costs, \$/t $CO_2$e, for all land management options (negative values indicate that the activity would potentially generate profits over the cycle).**

| | Agricultural Lands | | | | Forest Lands | | |
|---|---|---|---|---|---|---|---|
| | Afforestation of Cropland | Afforestation of Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| Connecticut | 87 | 52 | 18 | 168 | 404 | | 26 |
| Delaware | 70 | 52 | 22 | 120 | -6 | | |
| Maine | 100 | 31 | 11 | 168 | 11 | 6 | 150 |
| Maryland | 121 | 97 | 22 | 53 | | | |
| Massachusetts | 87 | 51 | 14 | 130 | 65 | | 34 |
| New Hampshire | 98 | 50 | 12 | 138 | -3 | 8 | 103 |
| New Jersey | 100 | 82 | 23 | 85 | -1 | | 4 |
| New York | 99 | 48 | 19 | 178 | -214 | 5 | 101 |
| Pennsylvania | 107 | 84 | 19 | 140 | -58 | | 28 |

| | Agricultural Lands | | | | Forest Lands | | |
|---|---|---|---|---|---|---|---|
| | Afforestation of Cropland | Afforestation of Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 year Rotation Extension | Riparian Buffer |
| Rhode Island | 100 | 78 | 19 | 104 | 57 | | 28 |
| Vermont | 90 | 40 | 14 | 165 | -7 | 7 | 99 |
| All States | 103 | 64 | 18 | 139 | -53 | 6 | 84 |
| Minimum | 36 | 13 | 10 | -137 | -1,434 | 3 | 0.11 |
| Maximum | 254 | 265 | 29 | 348 | 693 | 21 | 240 |

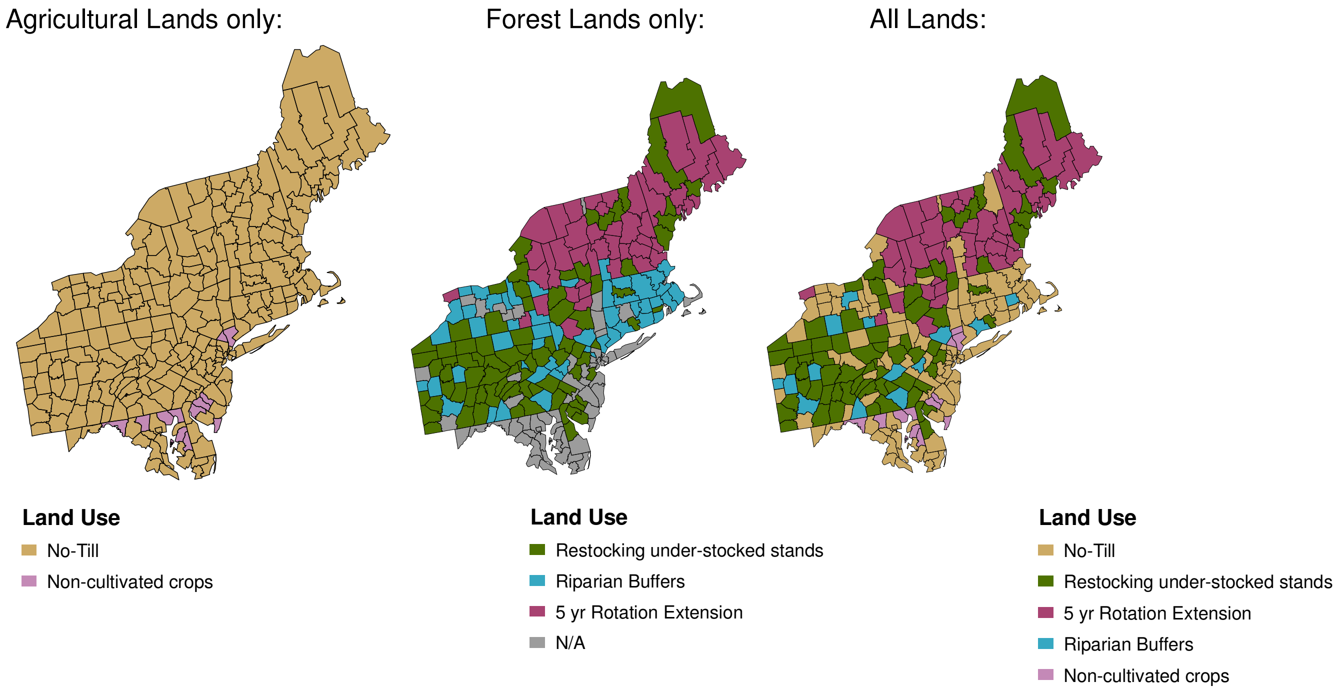



**Figure 6-6. Counties showing the management option with lowest marginal cost ($/ton $CO_2e$) for: agricultural lands only (left), forest lands only (middle), and all lands combined (right).**

At specified price points, the maximum amount of land economically available and the total maximum potential sequestered t $CO_2e$ for each land management option was calculated (Table 6-8). Conversion of pasture land to forests or cropland to non-cultivated crops and two forest management options appear to be economically attractive land management options at prices as low as $7/t $CO_2e$. Conversion of cropland to forests appears to be the least economic option as only a small quantity of $CO_2e$ would be available even if prices reached $40/ton.

**Table 6-8. Summary of potential and amount of emission reductions area available at various price points for all land management options**

| Price Points | Afforestation | | Crop Management | | Forest Management | | |
|---|---|---|---|---|---|---|---|
| | Cropland | Pasture | No-till | Non-cultivated Crops | Restocking Understocked Stands | 5 yr Rotation Extension | Riparian Buffers |
| | | | | t $CO_2$e | | | |
| < \$7/t $CO_2$e | | 8 million | | 6.6 million | 10 million | 8.4 million | 137,000 |
| < \$10/t $CO_2$e | | 8 million | 1.2 million | 6.6 million | 10.8 million | 11 million | 143,000 |
| < \$20/t $CO_2$e | | 21 million | 32 million | 7.6 million | 12.9 million | 11.6 million | 201,000 |
| < \$40/t $CO_2$e | 116,000 | 215 million | 33 million | 13 million | 14.3 million | 11.8 million | 490,000 |
| | | | | area (acres) | | | |
| < \$7/t $CO_2$e | | 169,000 | | 550,000 | 1 million | 1.4 million | 79,000 |
| < \$10/t $CO_2$e | | 169,000 | 110,000 | 550,000 | 1 million | 1.9 million | 87,000 |
| < \$20/t $CO_2$e | | 351,000 | 5.7 million | 636,000 | 1.3 million | 2.1 million | 123,000 |
| < \$40/t $CO_2$e | 2000 | 3.6 million | 5.7 million | 1 million | 1.5 million | 2.2 million | 193,000 |

The amount of carbon sequestered on existing lands by the various management options cannot be summed to arrive at a total potential because the land under consideration could be the same parcels. As the analysis was done at the county scale of resolution, it was not possible to separate the considered lands of each option. However, estimates for one land management option on agricultural land and one option on forest lands can be summed as these will be different land areas.

It is estimated that there is only one county (York, ME) with marginal costs below \$40/t $CO_2$e for afforestation of cropland (map not shown). Most of the sequestered $CO_2$ by afforesting pasture lands at marginal costs of less than \$40/t are located in counties in Maine, New Hampshire, New York and Vermont (Figure 6-7). The majority of these counties have the potential to sequester more than 1 million t $CO_2$ over a 20 yr period if prices reached \$40/t.

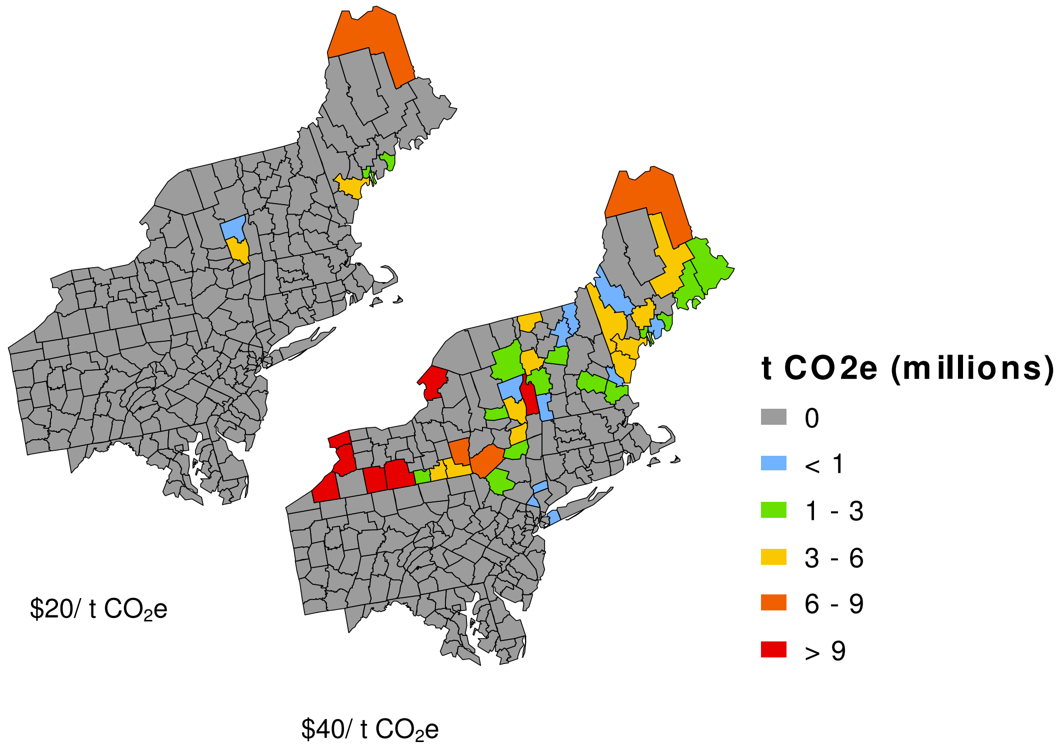



**Figure 6-7. Potential $CO_2$e sequestered per county by afforestation of pasture land at various price points.**

Conversion of cropland from conventional to no-till cultivation provides some potential carbon benefits if prices were <$10/t $CO_2$e in several counties in Maine, New Hampshire and Vermont (Figure 6-8). However, if prices were up to $40/t $CO_2$e, croplands in practically every county in the region could provide up to 150-300 thousand t $CO_2$e, with higher quantities in New York, Pennsylvania, Maryland, and Delaware.

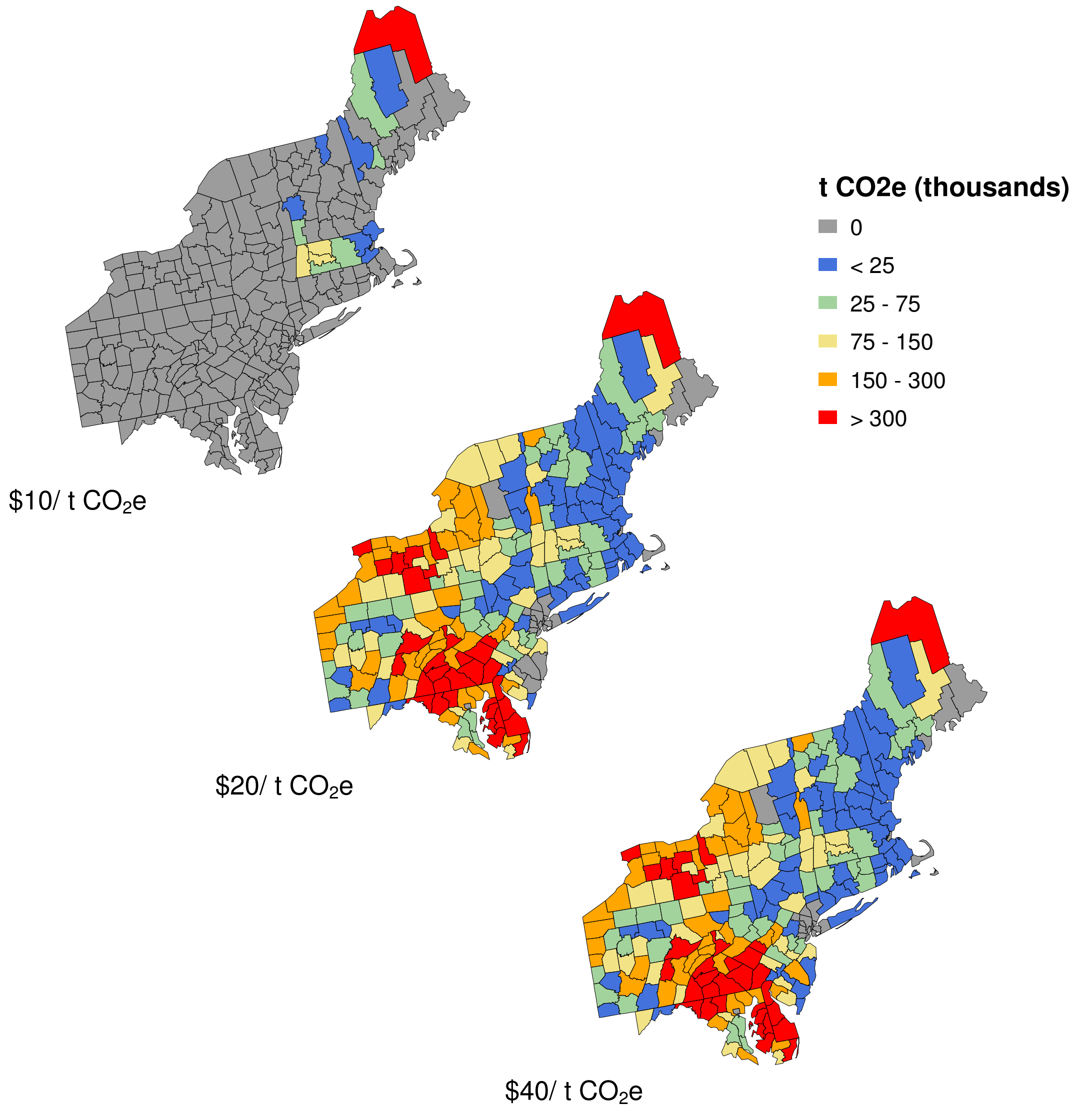



**Figure 6-8. Potential $CO_2$e sequestered/emission reduction per county by conversion of cropland to no-till agriculture at various price points**

Carbon benefits from conversion of agricultural lands to permanent vegetation are located mostly in 10-20 counties (fewer counties involved at lower prices) in the states of Maryland and New Jersey (no figure shown—see section 3B). The amount of $CO_2$e sequestered/emissions reduced ranges between 0.5-1.5 million t per county with higher quantities produced when prices reach $40/t $CO_2$e.

Many counties in Maine and Pennsylvania provide opportunities for carbon sequestration by re-stocking poorly stocked forests, often at negative marginal costs (Figure 6-9). If prices were as high as $40/t $CO_2$e, practically every county in Maine and Pennsylvania and several counties in New York would be able to supply considerable quantities of $CO_2$e (200 to > 400 thousand tons).

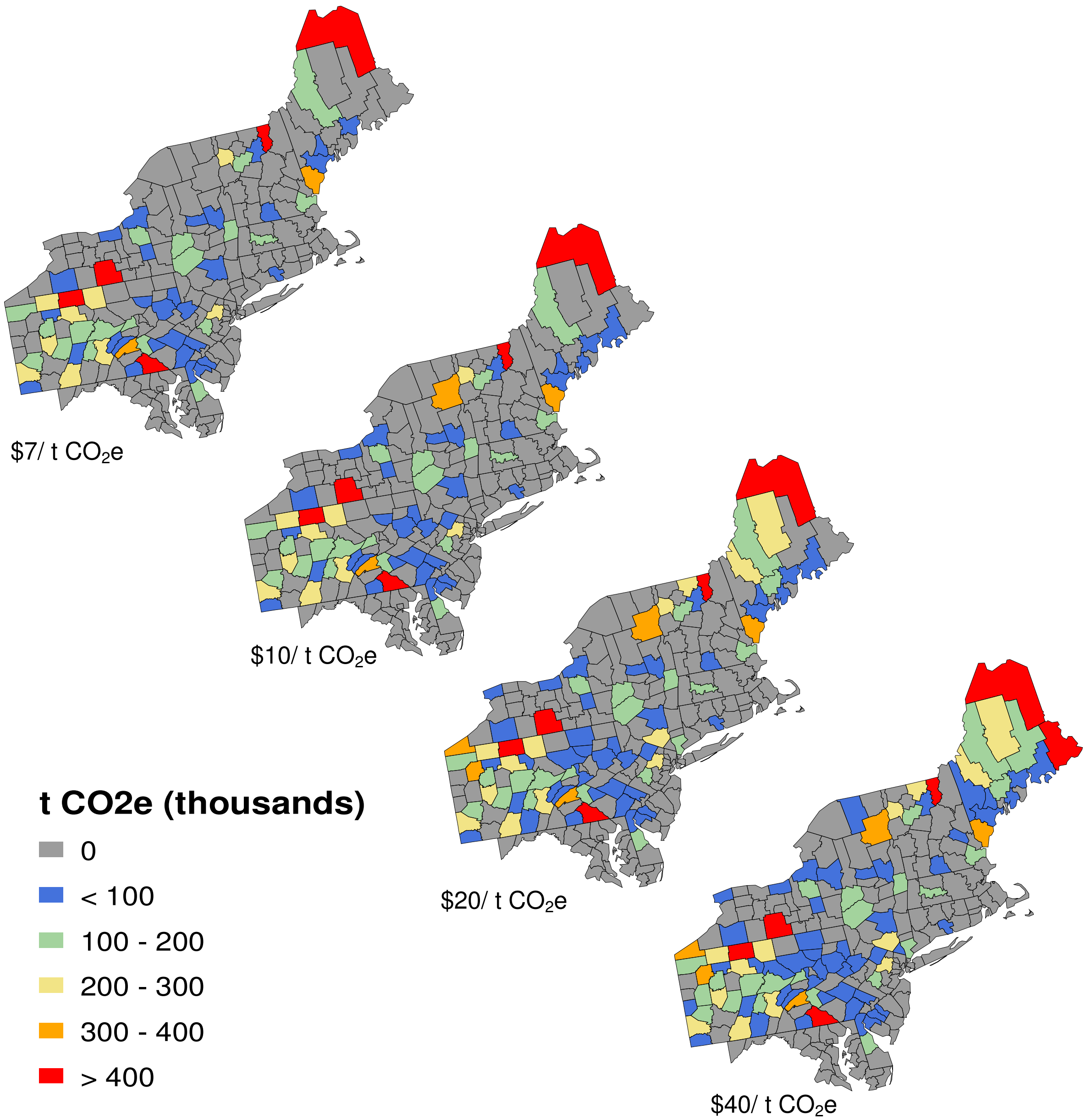



**Figure 6-9. Amount of potential $CO_2e$ sequestered per county by restocking understocked forests.**

Considerable opportunities exist in Maine for extending rotation of forest harvests by 5 year for additional carbon sequestration at all price points, with most counties providing up to 300 to >400 thousand t $CO_2e$ (Figure 6-10). This is not only due to the large size of the counties in Maine, but this state is dominated by softwood forests for which this management option is best suited. Additional quantities of $CO_2e$ are also potentially available in many counties in New Hampshire and Vermont at all price points. At the higher prices, several counties in New York have the potential so supply $CO_2e$, about 100-200 thousand t per county.

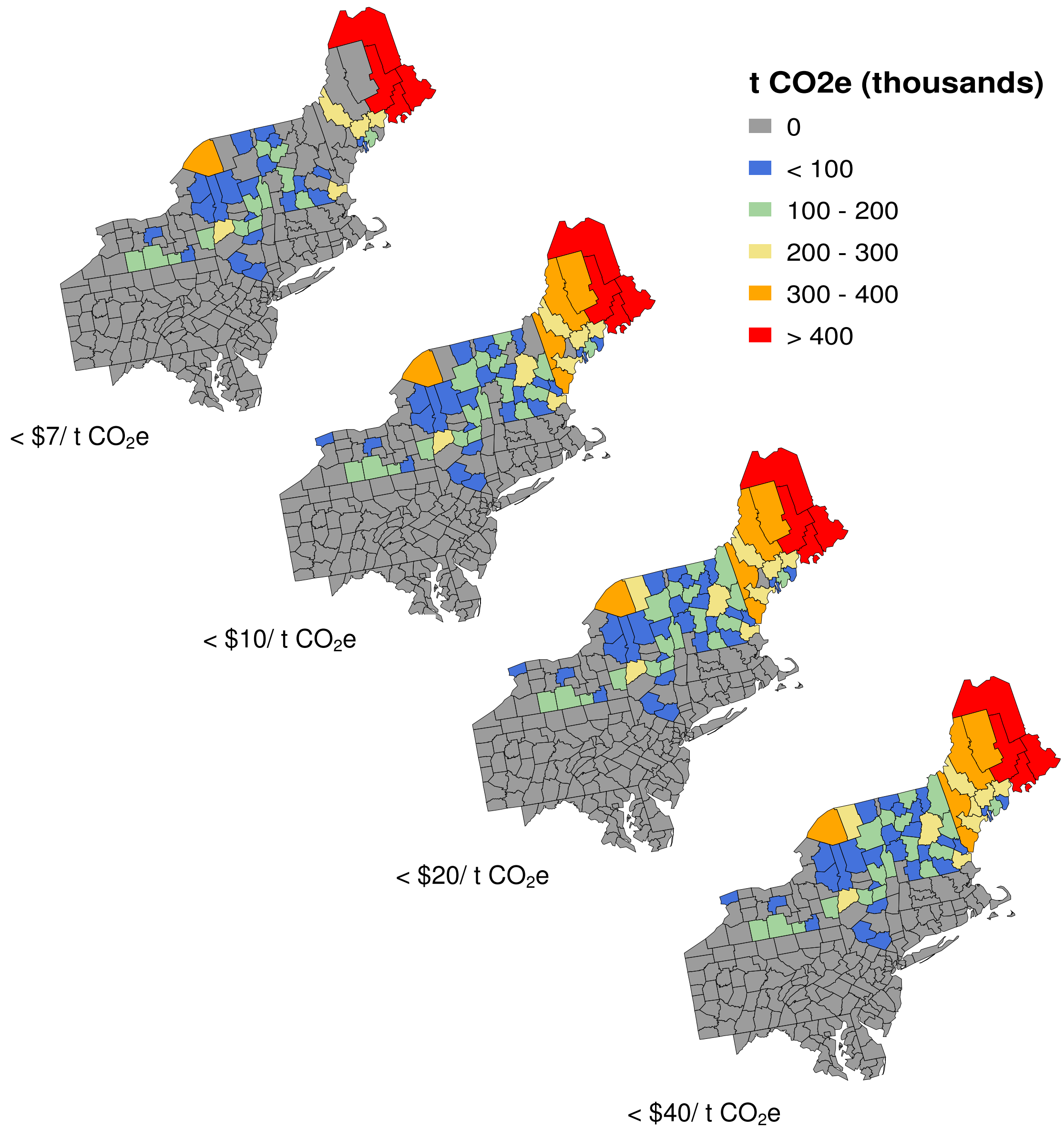



**Figure 6-10. Amount of potential $CO_2$e sequestered per county by extending the rotations of suitable forests.**

The creation of riparian buffers on suitable forest lands provide small quantities of $CO_2$e, about 10,000-20,000 t in general, mostly in Pennsylvania and Massachusetts and a couple of counties in New York (Figure 6-11).

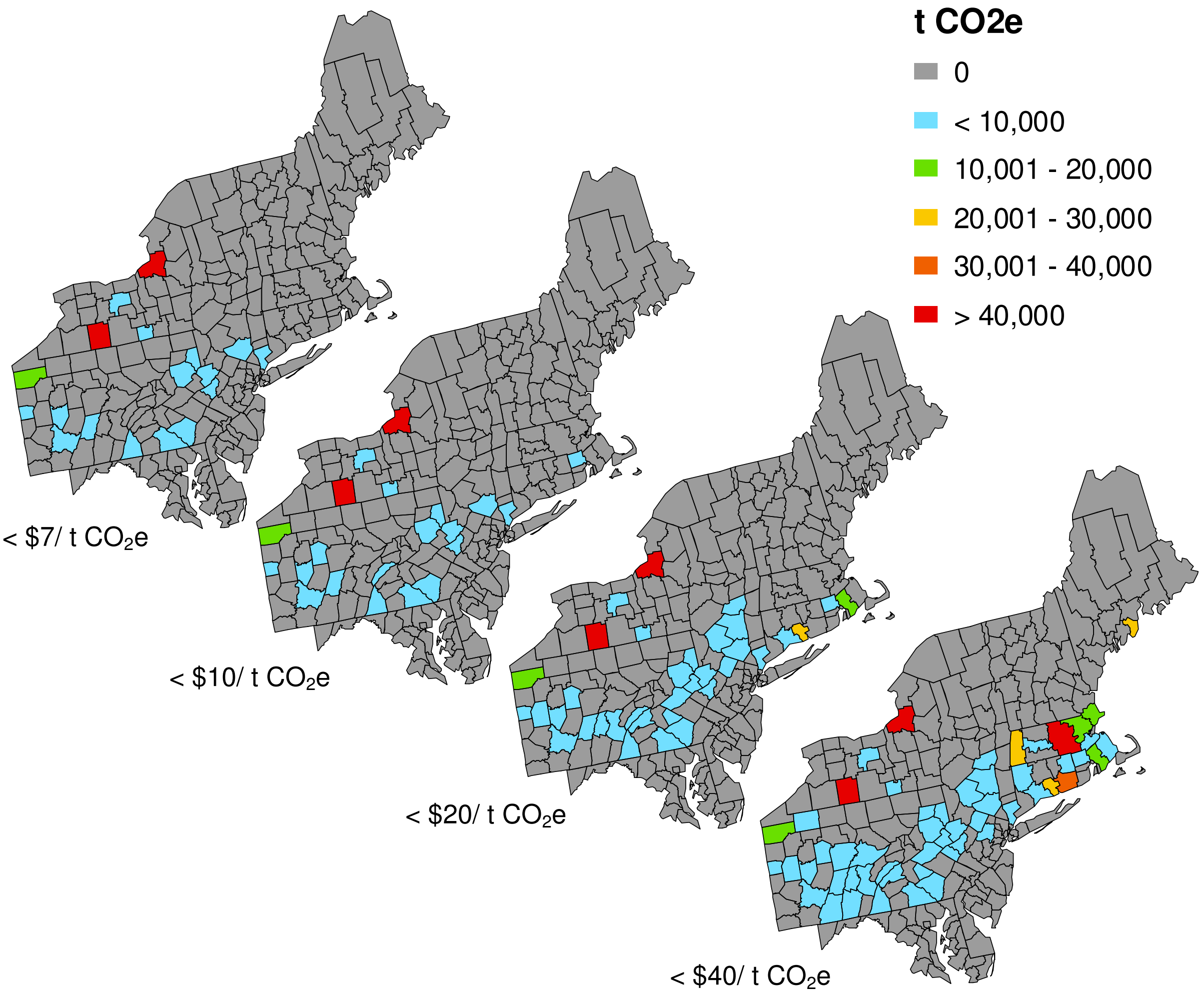



**Figure 6-11. Amount of potential $CO_2$e sequestered by county by creating a riparian buffer on suitable forest lands.**

At the $7/t $CO_2$e price point, extending forest rotation and restocking poorly stocked stands are the two options that provide a substantial quantity of $CO_2$e in the majority of counties in the region (Figures 6-12 and 6-13). Many counties in the region have no potential to provide $CO_2$e at the $7/t $CO_2$e price point. If the price increased to $20/t $CO_2$e, conversion to no-till agriculture can provide larger quantities than forest for many counties, although extending forest rotation by 5 yr still dominates in several counties. At $40//t $CO_2$e, afforestation of pasture lands starts to dominate, and at this price point all management options are represented.

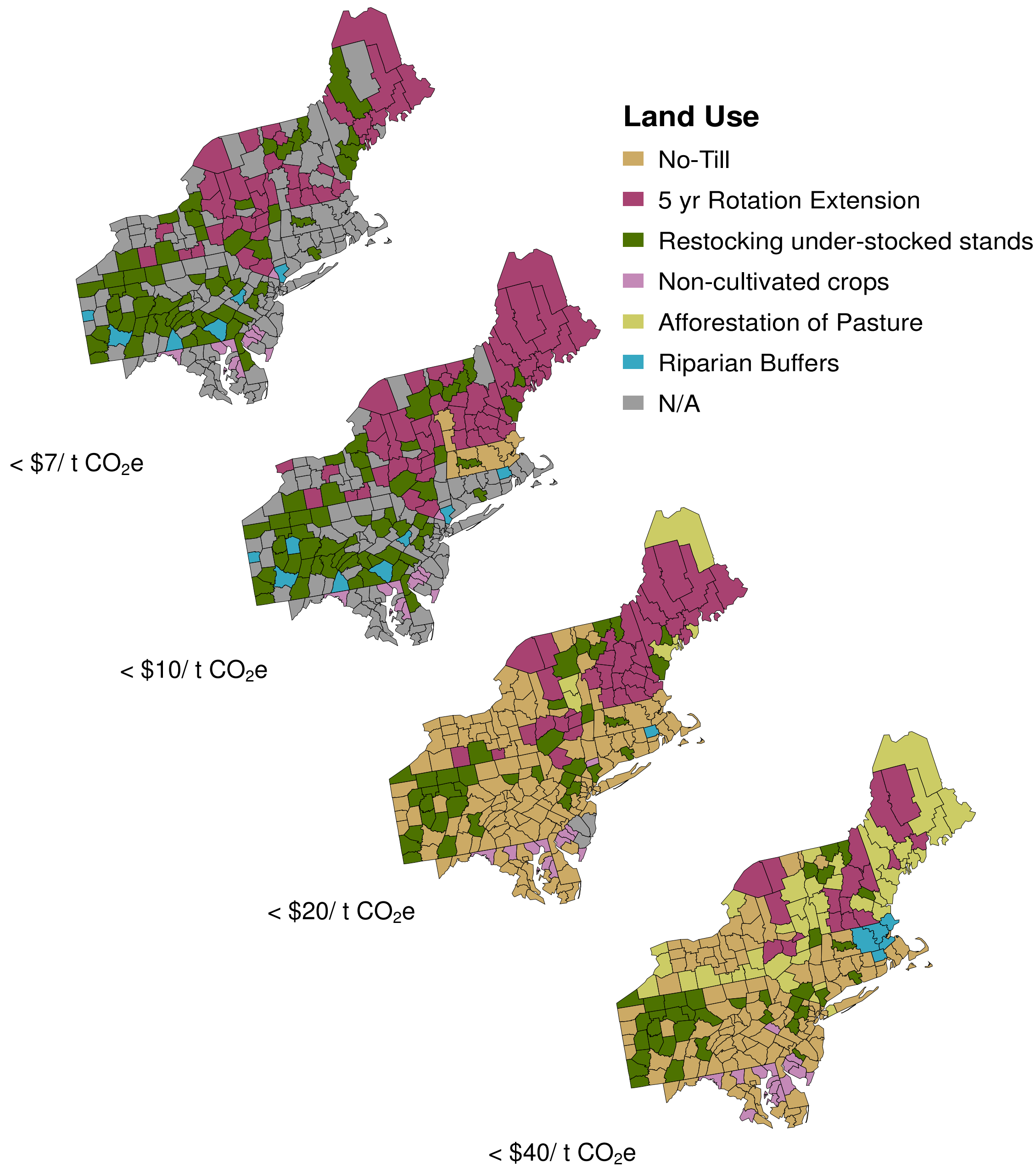
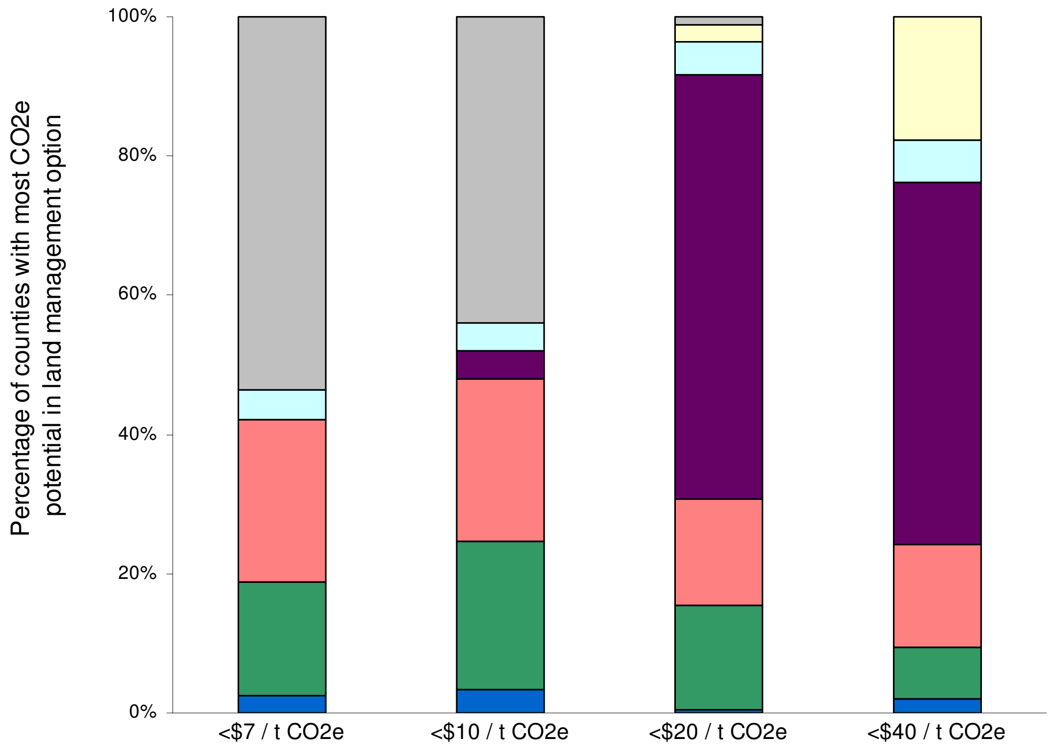



**Figure 6-12. Land management option on agricultural or forest land with largest potential t CO2e at various price points (at 20 yrs for agricultural land and permanently for forest land).**




| | <$7 / t CO2e | <$10 / t CO2e | <$20 / t CO2e | <$40 / t CO2e |
|---|---|---|---|---|
| None | 131 | 107 | 3 | 0 |
| Afforestation of Pasture | 0 | 0 | 6 | 43 |
| Non-cultivated crops | 10 | 10 | 11 | 15 |
| No-Till | 0 | 10 | 149 | 127 |
| Restocking under-stocked stands | 57 | 57 | 37 | 36 |
| 5 yr Rotation Extension | 40 | 52 | 37 | 18 |
| Riparian Buffers | 6 | 8 | 1 | 5 |

**Figure 6-13. Percentage of counties with greatest $CO_2e$ potential for all land management options at specific price points. Table indicates number of counties that each land management options provides greatest $CO_2e$ at each price point**

It is clear from the scatterplots of quantity of $CO_2e$ potentially available versus the marginal cost that New York and Maine can provide the most carbon across all management options at some of the lowest costs (Figure 6-14). Pennsylvania and Maryland have the potential to provide substantial quantities of $CO_2e$, but at high costs (greater than about $75/t $CO_2e$). As expected, the smaller states (Delaware and Rhode Island) or the highly developed states (New Jersey) have few opportunities to provide carbon sequestration benefits at any reasonable price.

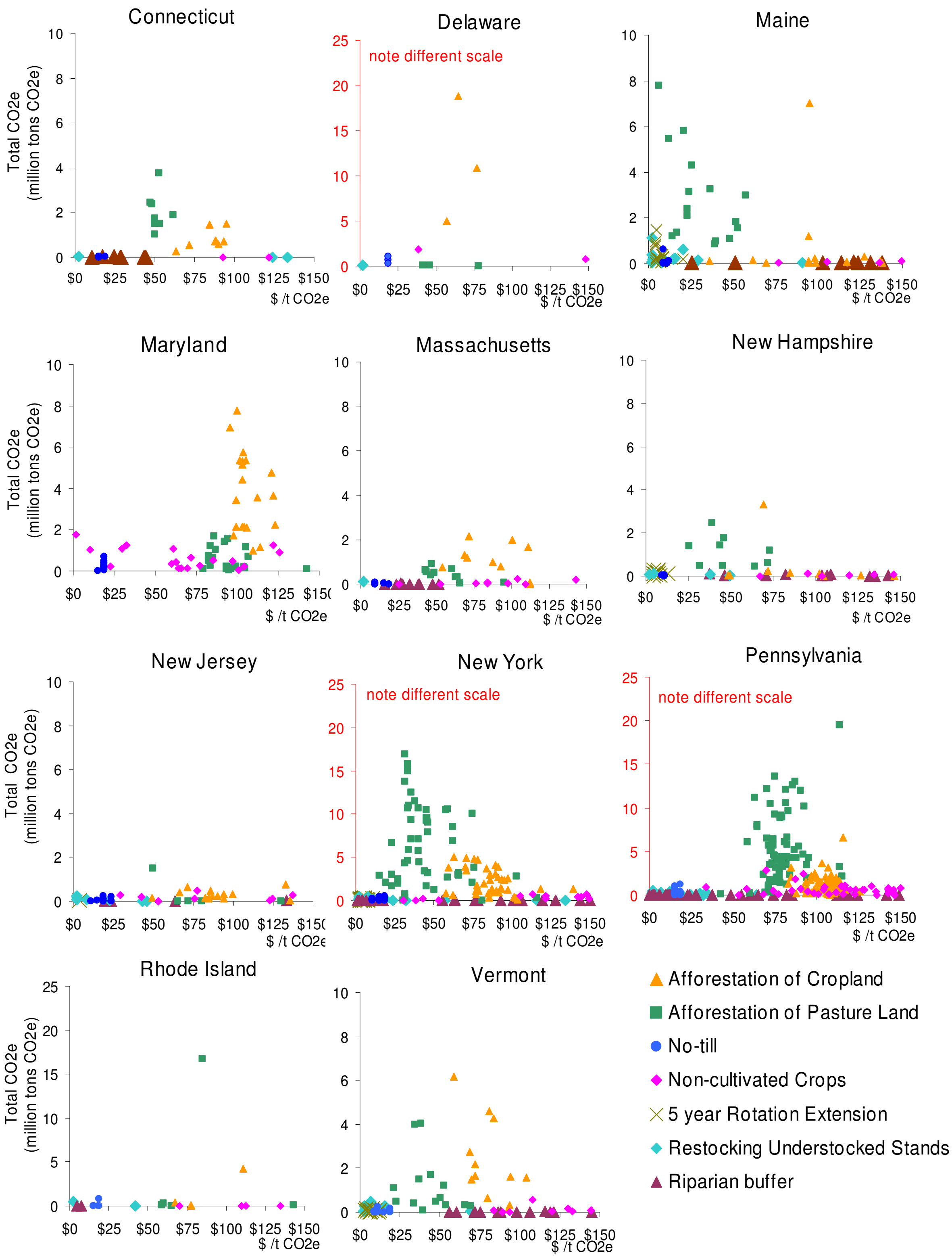



**Figure 6-14. Scatter plots of the quantity of $CO_2e$ potentially available after 20 yr for agricultural land and permanently for forest land versus the marginal cost ($/ton $CO_2e$) for each management option for all counties in the 11-state region.**

## 6.4 References:

2006. *Emissions of Greenhouse Gases in the United States 2005.* Energy Information Administration, Office of Integrated Analysis and Forecasting, U.S. Department of Energy.
Washington, DC