Technical Progress Report on Application and Development of Appropriate Tools and Technologies for Cost-Effective Carbon Sequestration

Quarterly Report
July - September 2006

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Date Issued: October 2006

Cooperative Agreement No. DE-FC-26-01NT41151

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ABSTRACT

The Nature Conservancy is participating in a Cooperative Agreement with the Department of Energy (DOE) National Energy Technology Laboratory (NETL) to explore the compatibility of carbon sequestration in terrestrial ecosystems and the conservation of biodiversity. The title of the research project is “Application and Development of Appropriate Tools and Technologies for Cost-Effective Carbon Sequestration”.

The objectives of the project are to: 1) improve carbon offset estimates produced in both the planning and implementation phases of projects; 2) build valid and standardized approaches to estimate project carbon benefits at a reasonable cost; and 3) lay the groundwork for implementing cost-effective projects, providing new testing ground for biodiversity protection and restoration projects that store additional atmospheric carbon. This Technical Progress Report discusses preliminary results of the six specific tasks that The Nature Conservancy is undertaking to answer research needs while facilitating the development of real projects with measurable greenhouse gas reductions. The research described in this report occurred between April 1st and July 30th 2006. The specific tasks discussed include:

- Task 1: carbon inventory advancements
- Task 2: emerging technologies for remote sensing of terrestrial carbon
- Task 3: baseline method development
- Task 4: third-party technical advisory panel meetings
- Task 5: new project feasibility studies
- Task 6: development of new project software screening tool

Work is being carried out in Brazil, Belize, Chile, Peru and the USA. Partners include the Winrock International Institute for Agricultural Development, The Sampson Group, Programme for Belize, Society for Wildlife Conservation (SPVS), Universidad Austral de Chile, Michael Lefsky, Colorado State University, UC Berkeley, the Carnegie Institution of Washington, ProNaturaleza, Ohio State University, Stephen F. Austin University, Geographical Modeling Services, Inc., WestWater, Los Alamos National Laboratory, Century Ecosystem Services, Mirant Corporation, General Motors, American Electric Power, Salt River Project, Applied Energy Systems, KeySpan, NiSource, and PSEG.

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EXECUTIVE SUMMARY

The Nature Conservancy, partners and collaborators had a productive quarter conducting research under this cooperative agreement.

The California research team, including The Nature Conservancy, Carnegie Institution of Washington, Colorado State University, Stanford University, and the University of California, Berkeley, completed the analyses of forest inventory, LIDAR, and QuickBird data of the North Yuba carbon area, Tahoe National Forest, California (Task 2). The research provided a complete estimate of aboveground biomass and standard error in the 58 km^2 research area at a resolution of 25 m. Under this work, three milestone reports were completed:

Asner, G.P. and M. Palace. 2006. Regional analysis of crown diameter and aboveground biomass from Quickbird satellite data collected over extensive mountain terrain in California. Report to the U.S. Department of Energy. Carnegie Institution of Washington, Stanford, CA.

Lefsky, M.A. 2006. Lidar remote sensing of aboveground biomass at Tahoe National Forest and Garcia River forest, California. Report to the U.S. Department of Energy, Colorado State University, CO.

Waring, K.M., J.J. Battles, and P. Gonzalez. 2006. Forest carbon and climate change in the Sierra Nevada Mountains of California. Report to the U.S. Department of Energy. University of California, Berkeley, CA.

A report titled “Methods for Measuring the CO_2 Impacts of The Nature Conservancy’s Tropical Forest Conservation and Restoration Projects” based on the discussions from the 2002 Technical Advisory Panel meeting was completed and delivered (Task 4).

For the Northeast study (Task 5), this quarterly report contains the summary of work in Parts IIIA, IIIB, IIIC and IV of the report, “Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs." Part IIIA is titled, "Draft Part IIIA - Opportunities for Improving Carbon Storage and Management on Agricultural Lands," and reports the carbon storage potential and corresponding cost of afforestation opportunities on cropland and pasture lands. Part IIIB is titled, "Part IIIB, Opportunities for Improving Carbon Storage and Management on Agricultural Lands." This section of the report deals specifically with the carbon implications related to conservation tillage practices, conversion to non-cultivated crops, and the cultivation of organic soils. Part IIIC is titled, “Part IIIC Opportunities for Sequestering Carbon and Offsetting Emissions through Production of Biomass Energy.” This section looks at the wood biomass energy industry and its recent development in the Northeast, estimates the potential for producing biomass fuel as an outlet for the low-grade wood that can be removed in ordinary forest harvest operations, and suggests a price at which payments for carbon dioxide emission offsets could influence the supply of biomass fuels produced for the market. Finally, Part IV is titled, “Part IV. Opportunities for Improving Carbon Storage and Management on Forest Lands.” This section of the report examines management alterations for carbon sequestration in the northeast forests, including: (1) Improved stocking of under-stocked stands; (2) Extending Rotation Ages; (3) Expanded Streamside Management Zones and Forest Conservation; and (4) Thinning.

As planned, sections of the report are being issued in draft form for review by stakeholders. For easy access and availability, a web site has been set up and dedicated as a repository for all documents related to the project. Documents can be downloaded from this site. Stakeholders are encouraged to review the documents as they become available and to provide feedback. Besides the draft sections of the report, the web site contains presentations from our stakeholder outreach meetings, fact sheet on the project, and a list of project stakeholders. The web site address is: http://conserveonline.org/workspaces/necarbonproject

The following box contains the schedule of release for various portions of the report and a summary of level of feedback received.

Report Section	**Date Issued**	**Comments Received**
Part I	1/18/06	Several general comments re: the data used and how it was presented.
Part II	3/30/06	Several comments re: the data used and how it was presented.
Part IIIA	7/5/06	Many contacts re: general interest and inquiry on the study and requests for additional names to be added to the stakeholder list.
Part IIIB	10/5/06	One comment so far, but just released.
Part IIIC	10/17/06	Just released.

In addition, we have begun to plan for our final stakeholder meetings to be held on December 5th in Durham, NH and on December 6th in Newark, NJ. Sites for each meeting have been secured and invitations will be issued in the next week or so. The goal of these final stakeholder meetings will be to present the findings of the report and to allow time for questions, discussions and comment. The stakeholder meetings also present an opportunity to communicate the findings so that key stakeholders may be able to use the findings in their work going forward. If any major issues are raised, there will be time prior to the issuance of the final report to make final revisions. As with the previous stakeholder meetings, we will invite public agency representatives from each of the study states as well as other NGOs and business interests who have been tracking the progress of the study.

EXPERIMENTAL

Task 1 Carbon Inventory Advancements

Carbon Inventories can be enhanced and costs lowered through improved techniques. Forest Inventories have been carried out for a number of reasons; to use for M3DADI calibration (Task 2), for use in carbon baseline development (Task 3) and for development of new regression equations and improved estimates of biomass for different terrestrial systems.

Task 2 Emerging technologies for remote sensing of terrestrial carbon

Research in California: *Monitoring Forest Carbon and Impacts of Climate Change with Forest Inventories, High-Resolution Satellite Images, and LIDAR*

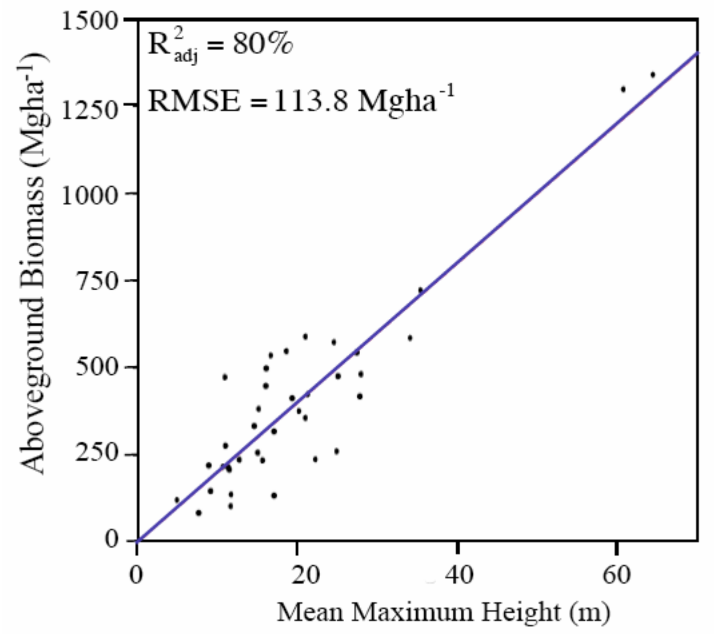
In an old-growth forest area of the Tahoe National Forest, on a 1.25 km geographic grid, the California team established thirty-six 0.4 ha and three 0.1 ha permanent forest inventory plots of a clustered four-circle U.S. Department of Agriculture Forest Service design. Global Positioning System (GPS) receivers recorded plot coordinates with an accuracy of < 1 m. The inventory included tagging and measurement of tree height (h) and trunk diameter at breast height (h = 1.37 m) (dbh) of 1526 live and dead trees of dbh ≤ 19.5 cm. The inventory also included measurement of 5590 other live and dead trees of all diameters, shrub biomass, coarse woody debris, litter, and duff, yielding estimates of aboveground biomass and carbon in all six live and dead aboveground pools in each plot.

The team applied 17 species-specific allometric equations to the inventory data to calculate aboveground tree biomass. The team also quantified measurement error and statistical uncertainty using a two-step Monte Carlo analysis. The team employed likelihood analysis and Akaike's Information Criterion to fit an allometric equation of biomass vs. crown diameter for the calculation of biomass from QuickBird data.

In the period September 14-17, 2005, an airborne mission at 800 m altitude acquired LIDAR data at a posting of 1 m and an accuracy (root mean square error (RMSE)) of 15 cm vertical, and 50 cm horizontal. Application of a progressive morphological filter to the data produced a digital elevation model (DEM) of the ground surface at a resolution of 2 m. Analysis of first-return data produced a spatial data layer of canopy height at 25 m resolution, the approximate total width of the forest inventory plots.

Least squares multiple regression analysis generated a regression equation of biomass as a function of six LIDAR-derived height metrics: quadratic mean canopy height and height of the 10%, 20%, 30%, 40%, 50% percentile height measurements ($r2 = 0.8$, $n = 39$, $p \leq 0.075$, RMSE = 120 kg) (Figure 1). Application of this regression equation to the LIDAR-derived height indices produced an initial estimate of aboveground biomass at 25 m resolution. The team developed a two-step Monte Carlo error propagation analysis to accurately estimate confidence intervals of calculated biomass that account for field measurement error and statistical uncertainty in inventory sampling, species-specific allometric equations, the LIDAR biomass regression equation, and landscape variation. The team used estimates of standard error for each of the first four sources of uncertainty variables to generate 1000 sets of calculated biomass values for the 39 inventory plots and 1000 realizations of the LIDAR biomass regression equation. This simulated the potential results of 1000 field inventories.

Figure 1. Regression of aboveground tree biomass vs. LIDAR-derived mean maximum canopy height (Lefsky 2006).



The 1000 data realizations for the 39 plots provided data to calculate a regression equation of standard error as a function of mean aboveground biomass. A second Monte Carlo analysis for calculating total aboveground biomass of those parts of the research area of h > 2.8 m, the maximum measured height of shrubs, assigned each pixel an aboveground biomass equal to the sum of the mean aboveground biomass for that pixel and the product of the standard error for that pixel and a random normal variable.

The QuickBird satellite acquired an image of the research area on August 2, 2006 at a 0.6 m spatial resolution for the panchromatic (black-and-white) spectral band and 2.4 m spatial resolution for 4 multi-spectral (color) bands. Derivation of the Normalized Difference Vegetation Index (NDVI) delineated forest and non-forest areas. In forest areas, an automatic crown detection algorithm outlined tree crowns by local maximum filtering of the panchromatic band and ordinal transect determination of local minima.

Application of the inventory-derived allometric equation generated an estimate of aboveground biomass at a resolution of 25 m. Employment of a two-step Monte Carlo error propagation analysis method with 500 replications provided confidence intervals of calculated aboveground biomass that account for field measurement error and statistical uncertainty in inventory sampling, species-specific allometric equations, the crown detection algorithm, and landscape variation.

Task 3 Carbon Baseline Method Development

The task involves developing and refining spatially explicit methods for estimating the carbon sequestration baseline for proposed forest conservation and reforestation projects at three sites in the United States and five sites in Latin America. The methods project possible future deforestation and reforestation trends and permit the calculation of carbon offsets from project activities.

Task 4 Third-Party Technical Advisory Panel Meetings

Standardizing measurement procedures and methods for carbon monitoring is a major step in the demonstration that land use projects should be creditable under any future regulatory mechanism. The Technical Advisory Panel (TAP) gathers a group of experts to evaluate existing methods and to develop standardized carbon offset measurement guidelines for use in all land-use change and forestry projects.

Task 5 New Project Feasibility Study

While there seem to be a variety of project ideas that would lead to cost-effective sequestration and biodiversity projection, there has been little work accomplished to explore the feasibility of these ideas. Within the United States, we have yet to develop sound knowledge of the potential for implementing specific forestry and agricultural carbon sequestration projects. By assessing the cost and potential carbon benefits of different domestic projects we can learn more about how conservation and carbon sequestration projects may or may not be compatible.

Northeast Study

Part IIIA Opportunities for Improving Carbon Storage through Afforestation of Agricultural Lands

Information about current land use (based on state level land cover maps), potential changes in land use and the incremental carbon resulting from the change, opportunity costs, conversion costs, annual maintenance costs, and measurement and monitoring costs were obtained and used in the analyses. The analyses are performed in a geographic information system (GIS) to include the diversity of land uses, rates of carbon sequestration, and costs. As a result, not only are more realistic estimates of the potential supply of carbon produced, but the use of GIS shows where the least to most expensive carbon credits will most likely be found. The general approach was to identify and locate classes of land where there is potential to change the use to a higher carbon content, estimate the cost of changing land use practices, estimate rates of carbon accumulation of afforestation, and then estimate the cost per unit potential CO_2e sequestered at a county scale.

The analyses take the following steps to assess the quantity and cost of potential carbon sequestration through land use change:

1. Classify lands found in the region by harmonizing existing state-level land cover maps.
2. Identify the major land cover types with potential for carbon sequestration.
3. Estimate the area available for each potential land use change.
4. Estimate the total costs associated with land use conversion (opportunity, conversion, maintenance, and measuring and monitoring).
5. Estimate the quantities of carbon per unit area that could be sequestered for the change in land use over a given time period.
6. Combine the estimated sequestered carbon per unit area with corresponding land cover class to estimate the total quantity of carbon at the county scale that could be sequestered using each land use category for a given range of costs in \$/ton CO_2e[1].
7. Determine the geographic distribution of available carbon at various prices.

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[1] All values given in metric tons. To convert from metric tons to short tons, multiply by 1.102. (If tons in denominator, e.g. $/ton, divide value by 1.102)

The total cost associated with afforestation of agricultural land has three components: conversion and maintenance costs; monitoring costs, and opportunity cost. The conversion and maintenance costs are those associated with land preparation, planting, and land management. Data on ‘conversion cost’ was obtained state by state for the region through surveys of entities involved in afforestation activities. Costs differed within each state, with higher costs in Pennsylvania, Connecticut, and Maryland due mainly to measures needed to protect seedlings from deer herbivory. ‘Monitoring costs’ vary with size of the area being monitored, whether the total area is one large block or disaggregated into smaller parcels, the expected variation in the carbon stocks, the pools being monitored, and the frequency of monitoring. The third component is the ‘opportunity costs’ associated with loss of income from the current activity. For this section of the analysis, data were collected on the major crops grown in each state, and the respective areas planted over the past 5 years. The dominant agricultural land uses for the region as a whole are corn, hay/pasture, and soybeans. With corn and hay comprising about 3 and 4 million acres respectively; soybeans are a distant third with just over 1.3 million acres harvested annually. Wheat and oats each occupy less than 300,000 acres throughout the region. These data were collected from the USDA National Agricultural Statistics Service (NASS) via their website. In addition, data were compiled on the average (over recent years) prices, production costs, and yields for these dominant crops. Using this information, the average annual profitability per unit area for each crop was calculated. Yields are generally available at the county level and can provide spatial variation on the opportunity costs within each state. The average profitability per crop was weighted by the area that each crop represents within each county/state. This provides a representative opportunity costs for land within each county. Adding the conversion costs, monitoring costs, and opportunity costs together forms the total costs associated with converting agricultural land to forest land.

The carbon sequestration potential of lands found in the region was investigated using the USDA Forest Service’s FIA data sources. The FIA contains the largest database of forest biomass and growth and the database encompasses the entire region. County level data on the carbon stocks of FIA plots were downloaded for all forest types and site productivities. Based on these data, growth curves were developed for each forest type and site productivity class. These growth curves of above and belowground biomass were then used to estimate the carbon sequestration potential for each county. The productivity class dominant in the county within the FIA database was assigned to each county. Using an NRI-based database of the land which moved from non-forest in 1987 to a particular forest type in each county in 1997, a forest type was assigned to each county. The appropriate forest type and carbon growth curve was then used to estimate the potential carbon sequestered per area of land converted to forest land.

The final stage in the analysis is to combine the costs associated with ceasing agricultural activities and afforesting with the projected carbon to be sequestered from this land use action. Before doing this, carbon levels were discounted by 6% to present the net present value of the carbon stocks to be sequestered. Dividing the costs per acre by the discounted t CO_2e per acre, estimates the cost associated with each ton of CO_2e sequestered. Calculating the cost per CO_2e allows the various land management practices to be compared with other mitigation options. Prices per ton of CO_2e will vary dependent on both the costs associated with conversion and the potential carbon sequestration capacity.

Part IIIB. Opportunities for Improving Carbon Storage and Management on Agricultural Lands

Part 3B assesses the potential for increasing carbon sequestration on agricultural lands by changing management activities while remaining in agricultural production. Two management changes are involved: 1) conversion from conventional tillage or intermittent no-till (where the land is cultivated every few years) to continuous conservation tillage, where the land is never cultivated; and 2) conversion from cultivated crops to non-cultivated crops such as hay and pasture, or wildlife cover. The conversion of cultivated organic soils to forest was also evaluated and shows that the rate of carbon dioxide emissions from cultivated organic soils is very high, so they are considered to be of special interest as a carbon activity.

There are other agricultural management changes that can potentially affect carbon sequestration, such as improved crop rotations, irrigation water management, or nutrient management, but these were considered too minor in terms of potential impact to warrant analysis in this effort.

Soil carbon stocks change in response to tillage and vegetation changes, but there is a point at which sequestration and emission rates come into rough balance again under the new management regime. This is often referred to as “carbon saturation,” where the soil is maintaining a roughly uniform carbon stock, given the management, crop input, and climatic regime. In most agricultural soils, it is assumed that these saturation points will be achieved in about 20-40 years, so the following analyses are limited to a 20-year consideration of carbon supply opportunities.

Emission reductions occur in both conversion to conservation tillage and conversion to permanent vegetation because there are significant reductions in the use of farm machinery with its associated fuel consumption, pesticides, and fertilization. As a first approximation, the machinery emissions from conventional tillage were eliminated when land was converted to pasture, but the agricultural inputs (primarily fertilizer) were estimated to be unchanged. The importance of emission reductions is that they will continue for as long as the practice is maintained, as opposed to the soil sequestration, which will slow and stop as the soils reach the carbon saturation limit.

The land available for converting to conservation tillage or permanent vegetation was assumed to be the cropland growing grain crops (corn, soybeans, wheat, barley, oats) in the region in 1997. This leaves out the specialty crops like tobacco, truck crops, orchards, etc. that were assumed to be too difficult or valuable to convert to other management types.

The cost of converting grain crops from conventional tillage to conservation tillage was estimated on the basis of an incentive program that would pay farmers $100 per acre over 10 years to carry out a 20-year program of continuous conservation tillage. No opportunity costs were involved, as it was assumed that farmers would continue to grow the same crops and that net profits would be similar.

A similar method was used for calculating total costs of converting from cultivated crops to permanent vegetation (pasture).

The carbon sequestration potential of these practices was estimated for “reference soil” data developed for each county on the basis of the most extensive soil type and the general climatic zone. The USDA indicates that a 20-year program of continuous conservation tillage will increase the soil carbon stock by an average of 13%, and that a 20-year program of conversion to permanent cover will result in a 20% increase (USDA 2004). These estimates were annualized, and applied to the soil carbon stock of each county’s “reference soil” to produce county maps and statewide potential estimates.

The final stage of the analysis was to look at the combination of opportunities and costs. The final step is to estimate the land available at different price levels, along with the amount of CO_2 that could be associated with projects of different length.

Part IIIC Opportunities for Sequestering Carbon and Offsetting Emissions through Production of Biomass Energy

Forest biomass chips can be produced in connection with timber harvesting operations by converting low-grade wood (small, deformed, limbs, etc.) into chips at the logging site. While the current prices barely cover the costs of logging, chipping, and transportation, the ability to remove low quality wood allows landowners to improve the health and vigor of their forests for the future. It is estimated that 3-3.5 million tons of forest biomass could be harvested in the Northeast by taking out low-grade wood during normal harvesting operations. The primary deterrent to expanding forest biomass production is the lack of markets within reasonable hauling distance of most Northeast forests. With current market conditions, it is estimated that a carbon payment of $5 to $10 per green ton would be needed to make forest biomass competitive with fossil fuels in producing electricity.

Part IV Opportunities for Improving Carbon Storage and Management on Forest Lands

The activities investigated include extending rotation ages of softwood forests beyond their economically optimal rotation age, harvesting and re-stocking currently under-stocked forests, conserving forests in riparian zones, and additional thinning. The first three of the analyses are conducted across the region, while the final analysis (the potential for increasing thinning to enhance carbon sequestration) is done as a case study.

Part VI. Co-Benefits of Carbon Sequestration Opportunities

This section of the report examines the environmental co-benefits of the carbon sequestration activities afforestation and restocking poorly stocked forests in the Northeastern United States. The analysis of potential afforestation activities is limited to land classes designated as pasture and croplands (agricultural lands) whereas restocking poorly stocked forests occurs on lands designated as forest. The analysis will present a quantification of the amount of agricultural and forestland contained within three different conservation landscapes.

1. Buffered areas surrounding all streams at a 1:100K scale
2. The Nature Conservancy (TNC) designated forest priority blocks and their buffer zones
3. Connecticut River floodplain forests (Case study)

To date, we have calculated a 100 meter stream buffer for all class two and above stream in the Northeast US and have ranked each buffer by its conservation value. Additionally, we have calculated a 10km buffer area around each forest matrix block of potential conservation value. The spatial extent of conservation enhancement through carbon sequestration activities will be quantified based on a forest block's core area plus its 10 km buffer. We will conduct an in-depth case study by quantifying the amount of agriculture land available for afforestation activities as well as the amount of FIA designated "poorly stocked" forest types available for restocking in modeled floodplain forests for the Connecticut River. Analysis is currently underway overlaying the previously mentioned datasets with the most current land cover information for the eleven states in the northeast US study region. We are developing a matrix describing the amount of land available for various carbon sequestration activities, the costs associated, and its resulting conservation value.

Task 6 Development of new project software screening tool

Carbon measurement and monitoring costs are unique transaction costs for forest-based carbon sequestration projects. Project developers need to weigh the costs of carbon measurement and monitoring against the potential benefits of the sale of carbon offsets (carbon revenue). Carbon benefit data from USDA Forest Service inventories will be combined with carbon measurement and monitoring variables in a spreadsheet-based tool to allow users to compare potential carbon costs and revenues on a project level.

RESULTS AND DISCUSSION

Task 2: Emerging technologies for remote sensing of terrestrial carbon

Research in California: *Monitoring Forest Carbon and Impacts of Climate Change with Forest Inventories, High-Resolution Satellite Images, and LIDAR*

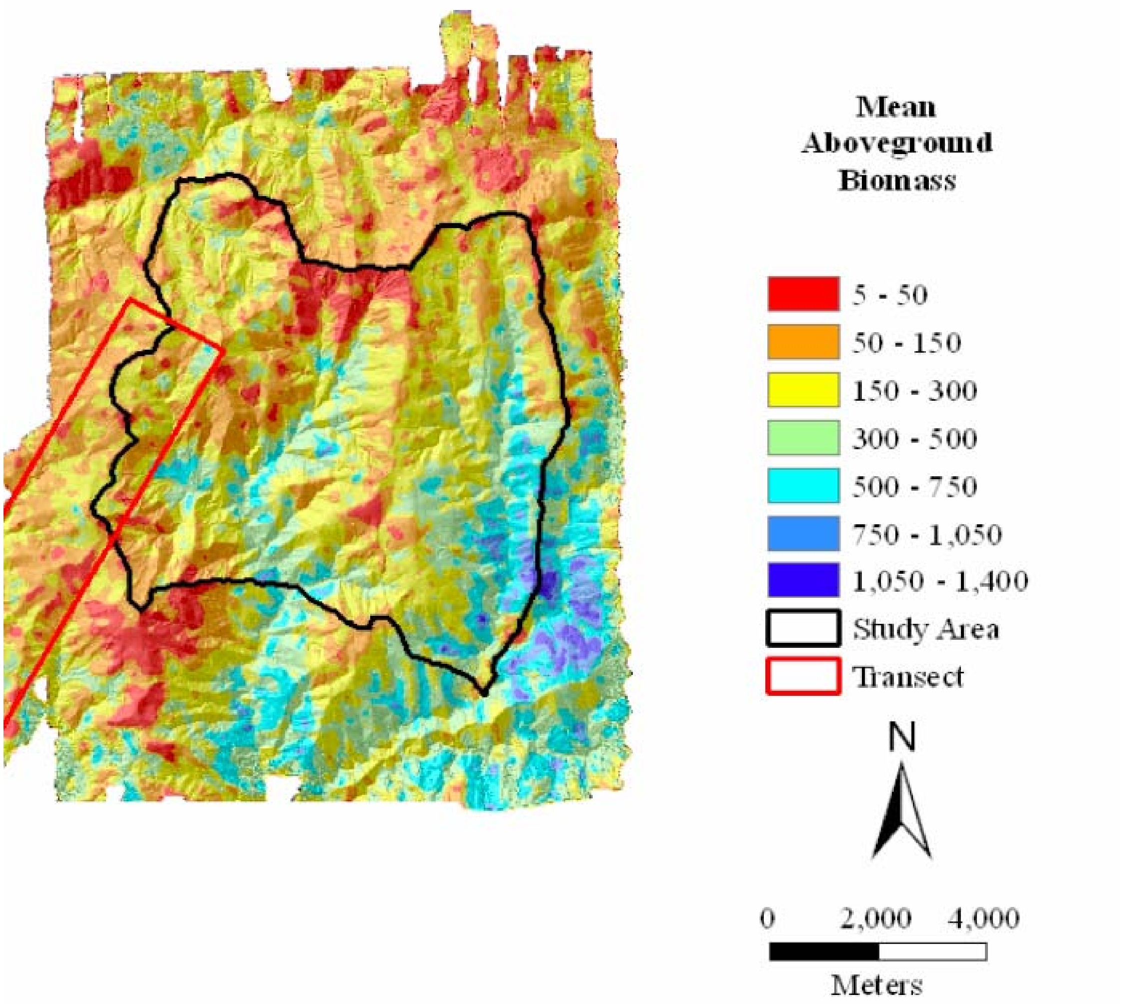
The forest inventories recorded eleven tree species, with *Abies concolor* (white fir) comprising 49% of stems, and *Abies magnifica* (red fir), *Pseudotsuga menziesii* (Douglas-fir), *Quercus kelloggii* (California black oak), *Quercus chrysolepis* (canyon live oak), and *Pinus lambertiana* (sugar pine) comprising the next most common species. Average d_{bh} was 37 cm. Aboveground tree biomass densities were 400 ± 340 t ha^{-1} in mid-altitude conifer forest, 440 ± 570 t ha^{-1} in hardwood and Douglas-fir forest, and 870 ± 400 t ha^{-1} in red fir forest (Table 1.)

Table 1. Aboveground tree biomass (t ha^{-1}) in the North Yuba carbon area by forest type and plot size (Waring et al. 2006).

Forest type	Plot type	plots	mean	std. dev.	minimum	maximum
Douglas-fir/hardwood	Annular	24	410	580	0	2600
	Subplot	24	28	27	0	100
	Total		440	570		
Mixed conifer	Annular	108	390	340	0	2000
	Subplot	108	11	11	0	50
	Total		410	338		
Red fir	Annular	12	870	400	360	1600
	Subplot	12	1	3	0	7
	Total		870	400		

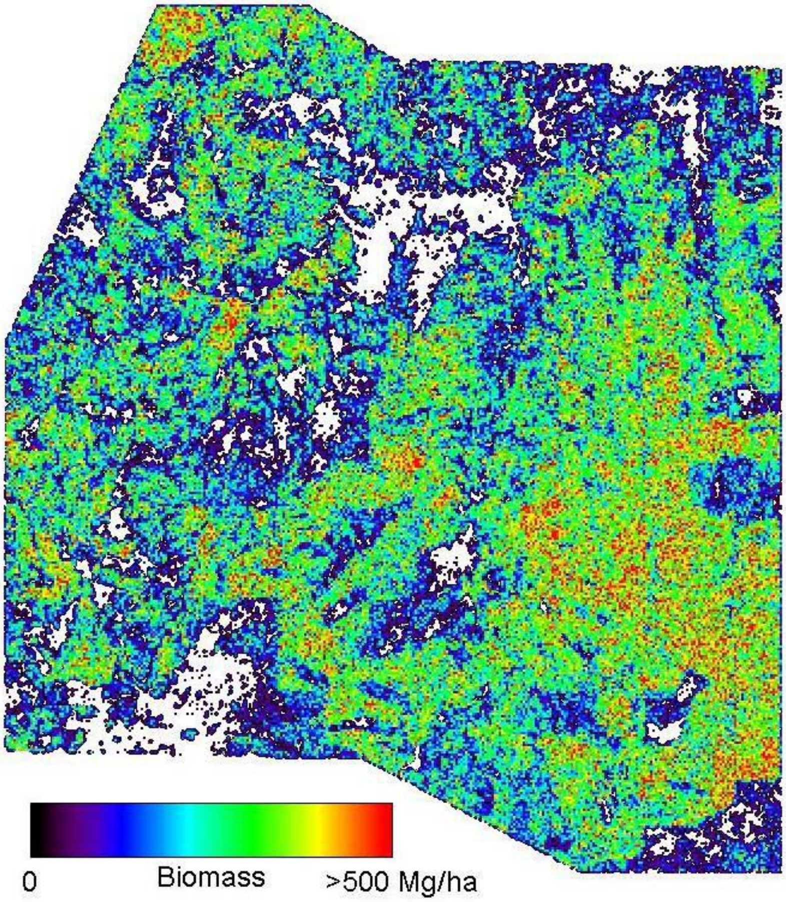
LIDAR data showed that the mean maximum canopy height was 34 ± 15 m; quadratic mean canopy height was 12 ± 7 m. Average aboveground tree biomass of forest areas was 280 t ha^{-1} ± 4 t ha^{-1} (confidence interval at $p = 0.05$) (Figure 2). Therefore, estimated error was ~1%.

Figure 2. LIDAR and forest inventory-derived aboveground tree biomass in the North Yuba carbon area, Tahoe National Forest, California.



Sensitivity analysis on a 1 km^2 sample identified optimal NDVI and reflectance values for the algorithm and showed an error of 0.7 m per crown (confidence interval at $p = 0.05$). Mean crown diameter of 421 900 trees was 8.2 ± 2.0 m. Due to inter-crown shading and steep topography, the algorithm could only detect tree crowns of diameter > 2.4 m. Nevertheless, comparison of field-measured and QuickBird-derived crown diameter showed a significant correlation ($p < 0.05$, $n = 40$). Average aboveground tree biomass of forest areas was 240 t ha^{-1} ± 100 t ha^{-1} (confidence interval at $p = 0.05$) (Figure 3). Therefore, estimated error was ~44%.

Figure 3. QuickBird and forest inventory-derived aboveground tree biomass in the North Yuba carbon area, Tahoe National Forest, California.



Task 4 Third-Party Technical Advisory Panel Meetings

"Methods for Measuring the CO_2 Impacts of The Nature Conservancy's Tropical Forest Conservation and Restoration Projects" – based on discussions at 2002 TAP meeting

Techniques for measuring the climate benefits of the projects have progressed to a point that estimates of their impacts on CO_2 concentrations are accurate and credible. For example, spatially-explicit regional baselines methods developed for these projects can be used in a reasonably cost-effective, transparent and portable manner, and are therefore well-suited for policy. Leakage methods continue to evolve and improve. An overview of leakage methods, and a more streamlined approach of how to proceed in future projects and policy regimes, based on standardized leakage deductions organized around project typologies and characteristics, is proposed. Additional research on leakage is still needed to complete this template and make it suitable for widespread use.

These projects and methods provide strong examples of how efforts in the land use sector can work. The learning suggests that a good future approach to providing incentives for changing land management may be through policies or programs that consider land use as a sector, where all emissions reductions and removals are monitored, rather than seeing land use change simply as a means of generating offsets to be used against fossil fuel emissions reduction targets. In this approach, baselines become a means for setting reasonable goals for improvements in land use and evaluating progress toward meeting those goals. This type of framework would reduce or eliminate the need for leakage monitoring, as the displacement of emissions from one location to another would be detected and accounted for through the system.

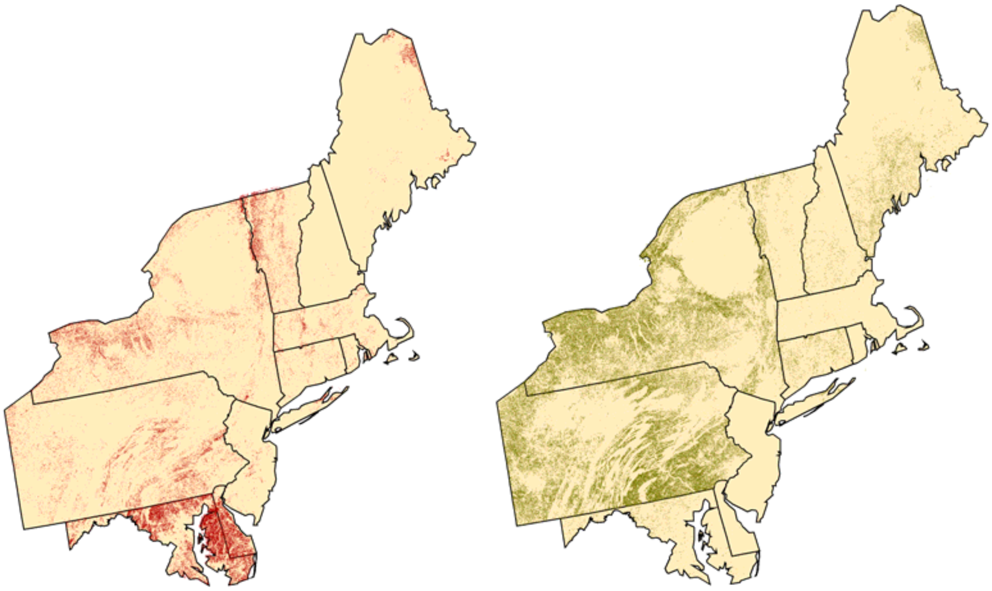
In the meantime, given the shape of current policies on climate change, or lack thereof, the project-by-project approach remains relevant. Application of ideas similar to the ones developed through these and other pilot projects and programs are critical to the validity of programs that allow offsets from the land use sector.

Task 5 New Project Feasibility Studies

Northeast Study

Part IIIA Opportunities for Improving Carbon Storage through Afforestation of Agricultural Lands

Lands are classified into four main groups for the analyses presented in this section: cropland, pasture land, forest, and other. Forests (~ 77 million acres) include mixed, deciduous, coniferous, clear cuts, and woody wetlands; croplands (6.7 million acres) include small grains, row crops, and fallow lands; and pasture (14.7 million acres) includes pasture, hay, & other non recreational grasses. This region is dominated by forest lands. Croplands and pasture lands make up only 6 and 13% of the total land area in the region, respectively (Figure 4). Delaware and Maryland have a greater percentage of cropland, with cropland covering 38 and 28% of the land respectively. Pasture land in Pennsylvania and New York are above the regional level at 22 and 19%, respectively. New Jersey does not provide a land cover dataset with pasture as a distinct category. The original New Jersey dataset consists of 55 of land use land cover categories of which pasture land and cropland were a single category. There wasn't a way to separate out pasturelands from croplands. As a result, for New Jersey, cropland was defined as the combination of two other categories, agricultural wetlands, and fallow fields. Pasture land in New Jersey was excluded from the analysis. The same situation occurred for Connecticut's 2002 dataset. As a result the 1995 Connecticut land cover data was used which had separate categories for pasture and cropland.



Cropland Pasture Land

Figure 4. Land cover of cropland and pasture in the northeast region

This analysis shows the costs to be variable across the region but averaged $1600/acre and $2300/acre for a ten year time period for pasture land and cropland respectively. Costs increase as the length of time increases, with opportunity costs making up a higher proportion of the costs. At ten years, opportunity costs account for an average of 62% of the costs, but by forty years they account for almost 80% of the costs.

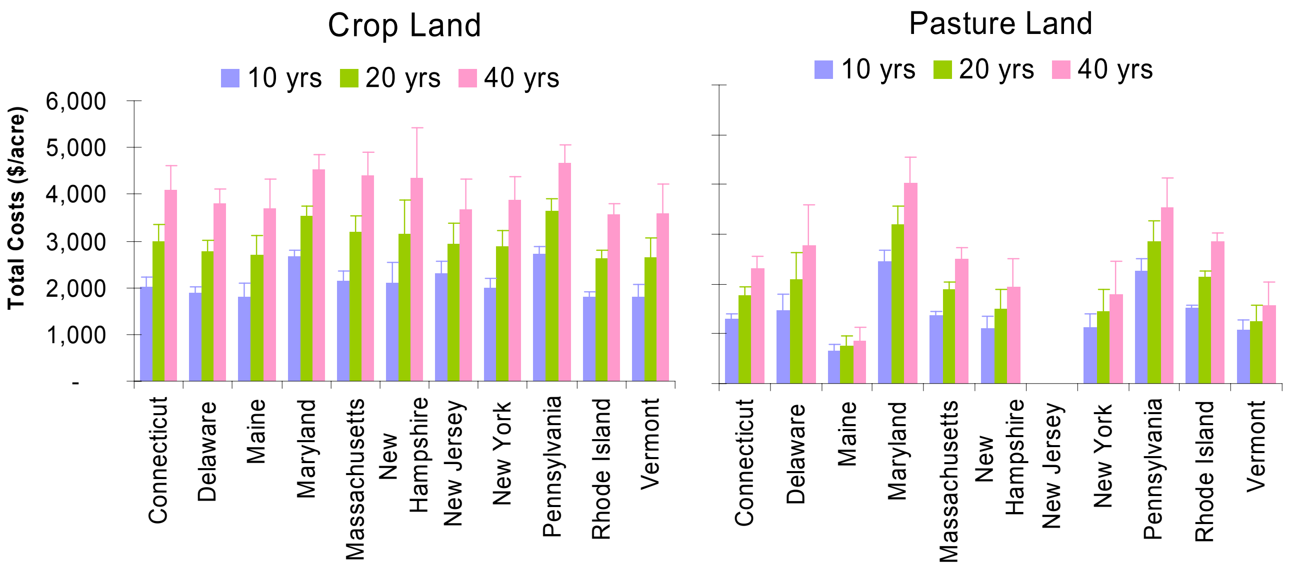


Figure 5. Total costs associated with land use change from agriculture to afforestation.

Estimated carbon sequestered averages 31 tons CO2e/acre after ten years up to 100 tons CO_2e/acre after 40 years (Table 2, Figure 5). Therefore, an area of 1,600 acres could be expected to accumulate an average of 50,000 tons of CO_2e in ten years (Table 3).

Table 2. Range of estimated potential carbon sequestered (in CO_2e) over different time periods per unit area.

	tons of CO_2e/acre		
	10 years	20 years	40 years
weighted mean	31	57	100
minimum	16	23	49
maximum	41	74	120

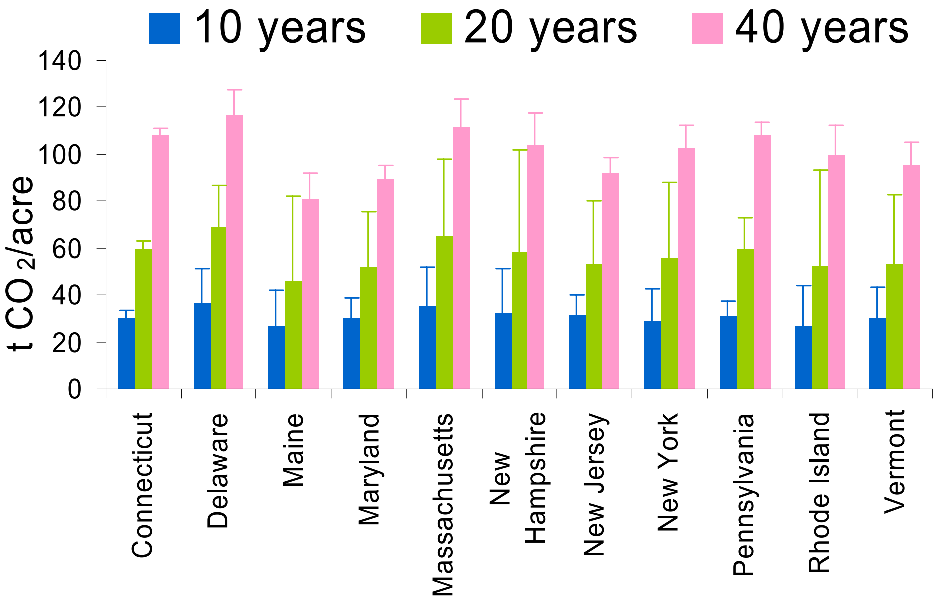


Figure 5. Mean estimated potential carbon sequestered per area in each state (in CO_2e).

Table 3. Potential estimated afforestation area needed to sequester given amounts of CO_2e.

	Estimated area needed (acres)		
ton CO_2e	10 years	20 years	40 years
10,000 t	327	177	100
50,000 t	1,635	885	498
100,000 t	3,270	1,770	996
1 million t	32,700	17,695	9,962

Prices per ton of CO_2e are lower in pasture land due to the lower opportunity costs (Table 3, Figure 6). Cropland only becomes available for afforestation when prices have reached $40/ton CO2e (Table 4). Some pasture land will be available at a price of $15/ton CO_2e, and the amount of land available increases dramatically as the time interval is extended (Table 4).

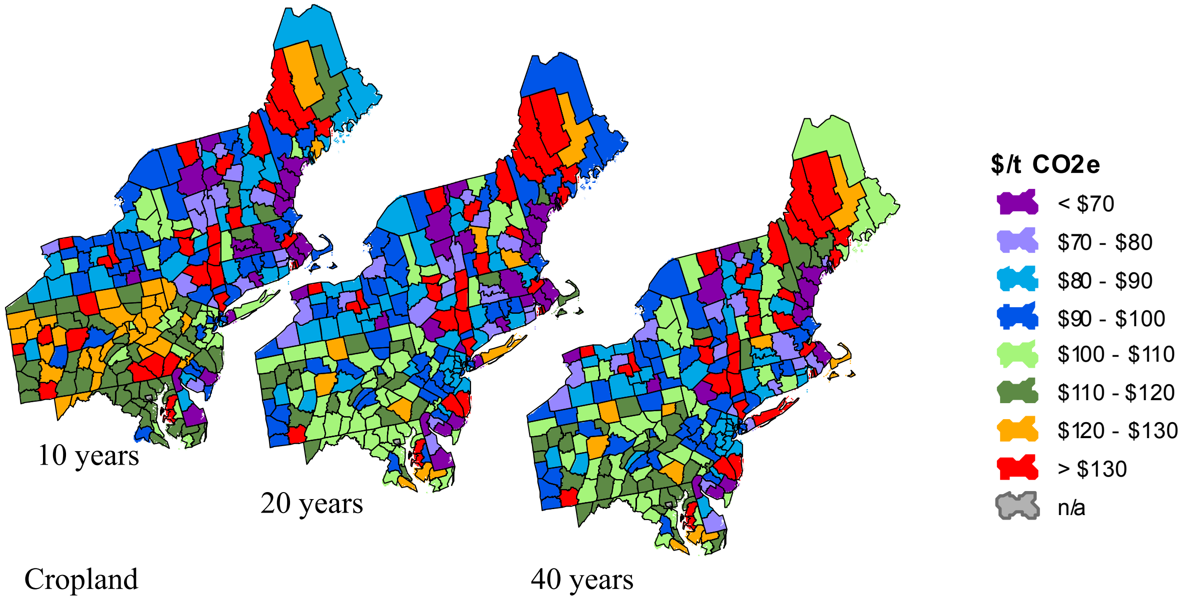
Table 3. Weighted mean estimated cost per ton of CO_2e sequestered in all Northeastern states on crop and pasture land.

	Cropland			Pasture Land		
	10 years	20 years	40 years	10 years	20 years	40 years
	estimated $/ton CO_2e					
Weighted mean	$107	$103	$107	$76	$64	$62
Minimum	$39	$36	$38	$18	$13	$10
Maximum	$235	$254	$233	$243	$265	$244

Table 4. Estimated potential tons of CO_2e that could be sequestered and area of land that would be available at various prices per ton of CO_2e.

Estimated total potential tons CO_2e

	Cropland			Pasture land		
	10 years	20 years	40 years	10 years	20 years	40 years
\$10/t $\mathrm{CO_2e}$	0	0	0	0	0	9 million
\$15/t $\mathrm{CO_2e}$	0	0	0	0	5.4 million	19 million
\$20/t $\mathrm{CO_2e}$	0	0	0	2.9 million	21.7 million	66 million
\$40/t $\mathrm{CO_2e}$	60,000	115,000	191,800	45.6 million	189 million	391 million
\$50/t $\mathrm{CO_2e}$	100,000	340,000	487,000	118 million	305 million	557 million
	Estimated potential available area (acres)					
	Cropland			Pasture land		
	10 years	20 years	40 years	10 years	20 years	40 years
\$10/t $\mathrm{CO_2e}$	0	0	0	0	0	75,000
\$15/t $\mathrm{CO_2e}$	0	0	0	0	75,000	160,000
\$20/t $\mathrm{CO_2e}$	0	0	0	75,000	350,000	645,000
\$40/t $\mathrm{CO_2e}$	1,600	1,600	1,600	1.26 million	3.2 million	3.7 million
\$50/t $\mathrm{CO_2e}$	2,800	5,000	4,700	3.5 million	5.2 million	5.3 million



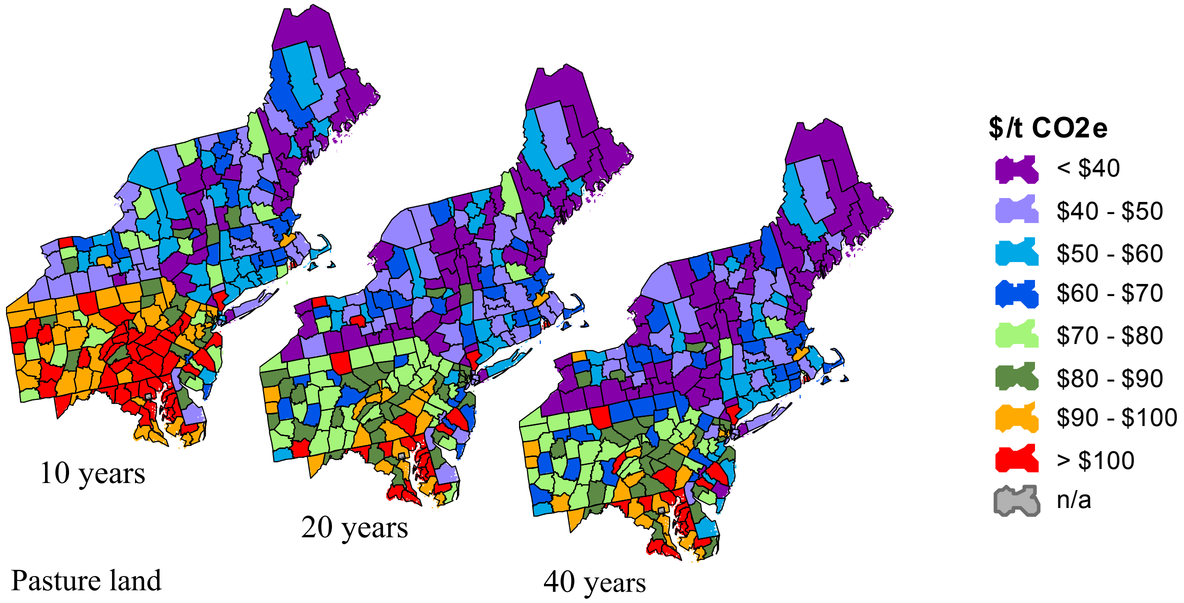


Figure 6. Estimated price point ($/t CO_2e) at which land would become available for afforestation of both cropland and pasture land.

Part IIIB. Opportunities for Improving Carbon Storage and Management on Agricultural Lands

Assuming payments were made at $10 per acre per year for 10 years, the discounted cost (at 4% net discount), plus the discounted cost of measuring and monitoring soil carbon, was calculated for each county and averaged for statewide estimates (Table 5). These costs ranged from about $5/t$CO_2e$ for 20-year projects to almost $26/t$CO_2e$ for 10-year projects (Figure 7).

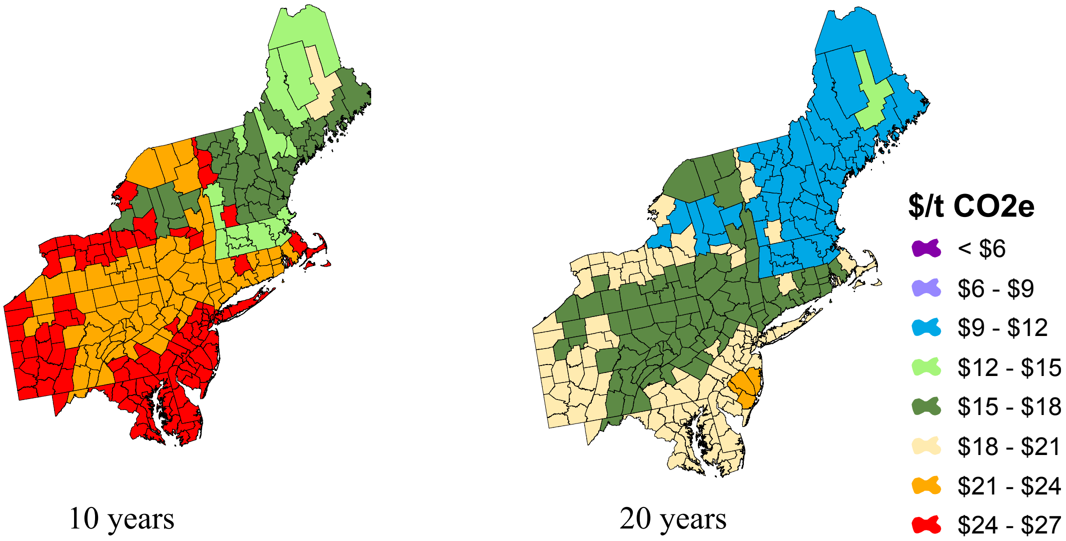


Figure 7. Estimated cost per ton of carbon dioxide sequestered with continuous conservation tillage.

A similar method was used for calculating total costs of converting from cultivated crops to permanent vegetation (pasture). In this case, the costs were significantly higher, due to the opportunity costs incurred by eliminating the production of profitable crops (Table 5). They were also significantly more variable, because in some counties, the shift to pasture would be profitable, creating negative opportunity costs.

Table 5. Average statewide costs of changing agricultural management on cultivated cropland.

State	Conservation Tillage $/tCO2e 10 yr	Conservation Tillage $/tCO2e 20 yr	Permanent Vegetation $/tCO2e 10 yr	Permanent Vegetation $/tCO2e 20 yr
Connecticut	26.73	17.77	174.34	167.52
Delaware	32.88	21.86	136.28	119.91
Maine	17.02	11.32	168.73	168.08
Maryland	32.59	21.66	92.25	53.24
Massachusetts	20.75	13.79	136.16	129.77
New Hampshire	17.81	11.84	142.55	138.34
New Jersey	34.33	22.82	106.22	84.73
New York	27.91	18.55	183.97	177.63
Pennsylvania	29.11	19.35	151.13	139.60
Rhode Island	28.67	19.05	119.43	104.08
Vermont	21.47	14.27	168.60	165.31
Minimum	14.80	9.84	-96.71	-137.21
Maximum	44.02	29.26	336.61	347.95

Table 6. Range of carbon dioxide sequestered and emission reductions per acre over different time periods.

	Convert to Continuous Conservation Tillage		Convert to pasture or other permanent vegetation		Convert organic soils from cultivation to forest		
	10 years	20 years	10 years	20 years	10 years	20 years	40 years
				tCO_2e/acre			
Weighted Mean	4.53	9.07	6.71	13.34	208	425	815
Minimum	3.22	6.44	4.44	8.87	73	154	284
Maximum	9.31	18.62	13.20	26.40	250	508	979
				percent from emission reduction			
Percent	9.3	9.3	10	10	80	79	82

The final stage of the analysis was to look at the combination of opportunities and costs. It is one thing to say that there is a low-cost opportunity to sequester carbon or reduce emissions, but if there is little or no opportunity in terms of land availability, the option may not be worth pursuing. To provide a general sense of this, we can compare each state's total opportunity with the average cost per ton of CO_2e achieved in 10-year projects (Table 7.). It is important to recognize, however, that these are mutually exclusive opportunities. Every acre converted to pasture is an acre of opportunity lost for conversion to conservation tillage. What the table suggests, however, are some areas that states may consider encouraging agricultural management changes, based on the amount available and the price per ton of carbon that can be anticipated.

Table 3.B.3. Opportunity extent compared to cost (assuming 10-year projects)

Action	Convert to Continuous Conservation Tillage		Convert to pasture or other permanent vegetation		Convert organic soils from cultivation to forest	
State	tCO_2e/yr	$/$tCO_2e$	tCO_2e/yr	$/$tCO_2e$	tCO_2e/yr	$/$tCO_2e$
Connecticut	16,800	26.73	23,500	174.34		
Delaware	181,300	32.88	267,900	136.28		
Maine	84,900	17.02	122,100	168.73	27,100	132.00
Maryland	528,800	32.59	794,500	92.25	17,500	42.00
Massachusetts	34,700	20.75	49,800	136.16	8,100	116.00
New Hampshire	11,400	17.81	16,400	142.55		
New Jersey	117,600	34.33	167,900	106.22	20,000	38.00
New York	691,800	27.91	964,300	183.97	687,200	35.00
Pennsylvania	1,126,300	29.11	1,618,800	151.13		
Rhode Island	1,000	28.67	1,300	119.43		
Vermont	58,900	21.47	82,600	168.60		

The final step is to estimate the land available at different price levels, along with the amount of CO_2 that could be associated with projects of different length (Table 8).

Table 8. Estimated potential tons of CO_2 that could be removed from the atmosphere and area of land that would be available at various prices per ton of CO_2.

Action	Convert to Continuous Conservation Tillage		Convert to pasture or other permanent vegetation		Convert organic soils from cultivation to forest		
	10 years	20 years	10 years	20 years	10 years	20 years	40 years
$/tCO$_2$e	*estimated potential tons of CO_2*						
10	-	22 million	160,000	7.6 million	1.3 million	2.7 million	5.2 million
15	2.1 million	54.5 million	160,000	7.8 million	1.3 million	2.7 million	5.2 million
20	11 million	54.5 million	160,000	10.4 million	1.3 million	2.7 million	5.2 million
40	27.3 million	54.5 million	3.3 million	16.4 million	7.1 million	14.5 million	27.9 million
	estimated acres available						
10	-	1,907,000	27,000	635,000	6,100	6,100	6,100
15	252,000	5,723,000	27,000	652,000	6,100	6,100	6,100
20	1,907,000	5,723,000	27,000	868,000	6,100	6,100	6,100
40	5,723,000	5,723,000	550,000	1,353,000	30,200	30,200	30,200

Part IIIC Opportunities for Sequestering Carbon and Offsetting Emissions through Production of Biomass Energy

To evaluate the potential impact of converting some of the existing coal-fired plants in the region to 10% biomass co-firing, we selected 4 sample plants from the eGRID data base maintained by EPA (Figure 8). The estimated forest areas and biomass yields (10 green tons per acre per harvest), combined with the fuel consumption data on these sample plants, provides some insight into the potential impact each plant might have on the land within its 50-mile radius (Table 9). From this general analysis, it would appear that Cornell and Mount Tom would have minimal impact, Schiller may be near a sustainable level (harvest every 50 years), and Bruner Island would have insufficient forest biomass nearby without supplements from other sources such as mill waste and urban tree removals.

Table 9. Estimated annual biomass consumption and approximate area of forest harvest required for four sample power plants in the Northeast.

Power Plant	Annual Coal Net Generation (MWh)[a]	Co-firing or conversion target (MWh)	Estimated annual biomass needs (green tons)[b]	Approximate area of forest harvest (ac-yr)	Percent of available forest
Cornell University	26,969	2,697	5,400	540	0.02%
Bruner Island	9,015,240	901,524	1,803,000	180,300	12.22%
Mount Tom	1,094,848	109,485	219,000	21,900	0.53%
Schiller	856,261	282,566	423,800	42,380	1.90%

[a] Source: EPA 2006

[b] Estimated at 2 green tons per MWh for co-firing; 1.5 green tons per MWh for Schiller

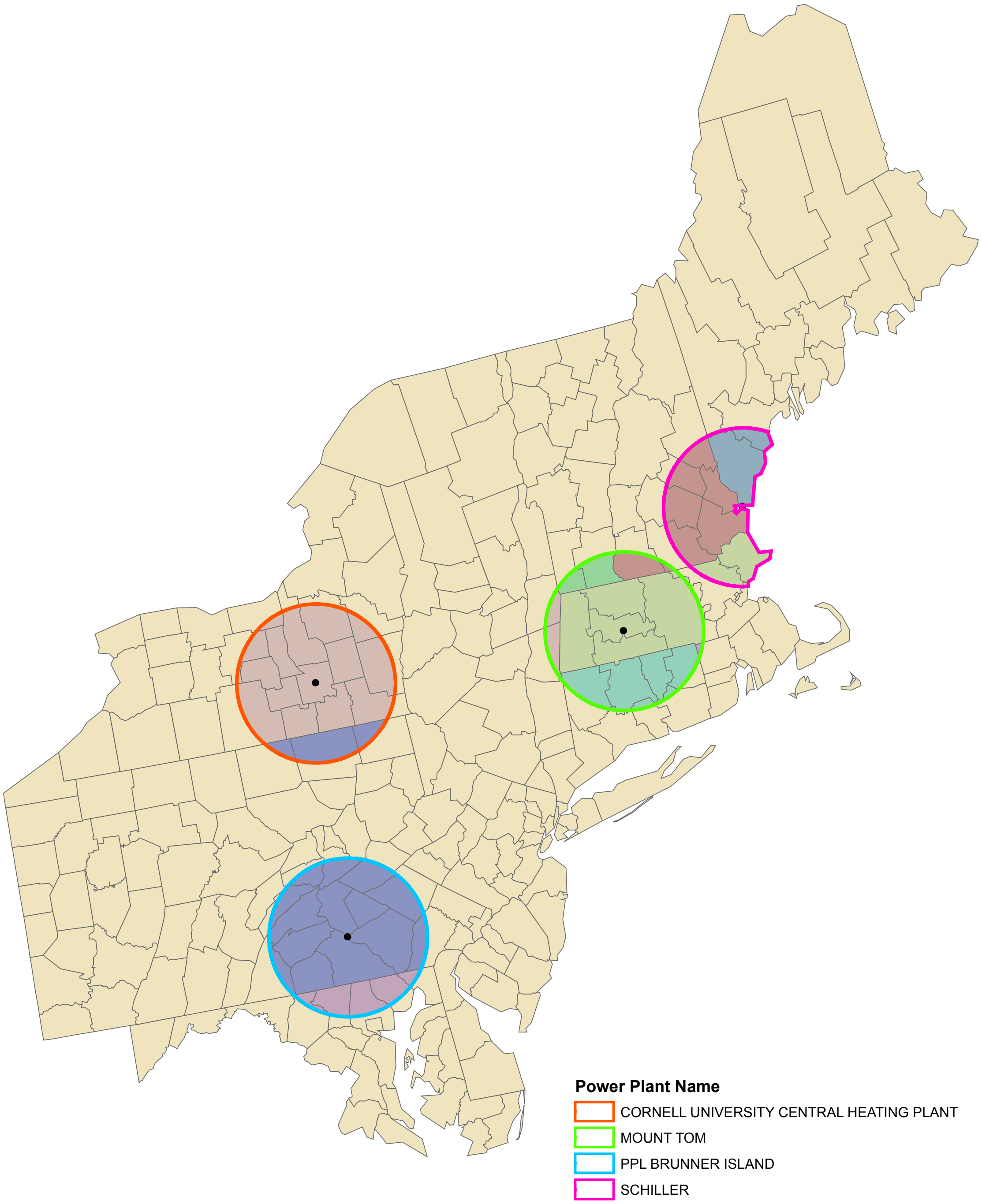


Figure 8. Location of 4 selected coal-fired power plants in the Northeast.

Growing field crops such as switchgrass or hybrid willow specifically for energy has been limited largely to research institutions in the past. In the Northeast, the leading research programs have been in New York, located at Cornell University and the SUNY College of Environmental Science and Forestry at Syracuse.

The Northeast appears to have plentiful land and production opportunity. In addition to some 59 million acres of privately-owned forestland in the region, this analysis identifies over 7 million acres of existing crop and pasture land that are of medium to marginal productivity for field crops such as corn and soybeans, but which could be well adapted for producing willow biomass. At the current time, about half of that land produces field crops; the other half produces hay and pasture.

With average yields of around 4 bone dry tons (BDT) of biomass per acre per year, it would take about 45,000 acres in a willow production system to sustainably support a 20 MW electrical generating plant, or about 65,000 acres to provide the biomass needed to replace 10% of the coal in a 300 MW coal-fired facility. That amount of production would amount to somewhere between 3 and 5 percent of the land in a 25-mile radius around the power plant, assuming the willow was the only feedstock available to the plant, leaving 95 to 97 percent of the land available for other uses.

The impact on regional carbon supply from willow biomass would average about 8.3 metric tons of carbon dioxide removed from the atmosphere per acre per year over a 20-year time. Of that amount, over 7 tons would result from offsetting the fossil carbon emissions that would otherwise be needed in the energy production system, and about 1 ton would be the additional sequestration on the land in terms of accumulated soil carbon and large roots in the willow crop. The total costs of producing those offsets would range from \$10.29 to \$37.95 per ton of CO_2 over 10- or 20-year project lifetimes (Table 10).

Table 10. Estimated average cost of emission reductions and increased carbon sequestration associated with production of willow biomass.

	$/tCO$_2$e	
State	10 yr	20 yr
Connecticut	27.56	29.35
Delaware	26.00	27.76
Maine	29.69	31.50
Maryland	24.31	24.86
Massachusetts	25.66	27.41
New Hampshire	27.96	29.75
New Jersey	19.85	21.43
New York	24.85	26.49
Pennsylvania	26.22	27.99
Rhode Island	25.12	26.87
Vermont	26.45	28.22
Minimum	10.29	11.83
Maximum	36.05	37.95

Part IV Opportunities for Improving Carbon Storage and Management on Forest Lands

The results indicate that up to 8.4 million t C of present value carbon may be sequestered in the region for \$10/t CO2e, and up to 11.6 million t C present value carbon may be sequestered for \$20/t CO2e. Around 60% of the sequestration available at these prices is due to harvesting and re-stocking of under-stocked stands, with most of the remaining carbon due to extending rotation ages beyond optimal rotation periods in softwood forests. Setting aside riparian zones along streams appears to have little carbon benefit in the region.

Potentially large quantities of carbon are available in relatively short time periods from these actions. For instance, up to 273 thousand t C could be sequestered within the next 10 years on around 157 thousand acres of land by harvesting and re-stocking forests. Similar amounts of carbon would be available in 10 years through extending the rotation age of softwood stands on only about 116 thousand acres. The riparian analysis indicates that it would take around 162 thousand acres for this much carbon in 10 years.

With all of these analyses, it is important to distinguish between short-run and permanent sequestration. All of the actions investigated in this study can provide short-term carbon gains, but because the baseline and the scenarios include forest rotations, the actual sequestration in any particular future year can be positive or negative. Simply summing sequestration over a particular number of years provides estimates of positive or negative sequestration depending on the number of years considered. The relatively large quantities of near term carbon, particularly in the analysis of extending rotation ages, tends to drive down the overall cost estimates when considered in present value terms (i.e., present value carbon and present value tons).

Regionally, the largest potential for extending rotation ages was found in the northern and eastern counties of Maine. In general, Maine appears to have the greatest potential with extending rotation ages. Moving further west, the potential declines. Similarly, Maine appears to have the greatest potential with options to re-stock poorly stocked stands, although there are no discernible spatial trends when mapped. There do appear to be fairly large areas with little potential at less than \$10/t CO2e.

A number of sensitivities were investigated in the analysis. When extending rotation ages, the inclusion of credits for biomass energy produced from milling residues reduces the potential carbon sequestered and raises the costs of carbon sequestration relative to the case where no credits are provided for biomass energy produced. Similar effects are inferred for the harvesting and re-stocking of under-stocked stands. Reducing the interest rate of the analysis increases the costs for extending rotation ages. All of the studies assume that timber prices remain constant, although widespread extending of rotation ages or widespread harvesting of under-stocked stands in initial periods would both be expected to alter prices in the near-term and raise costs.

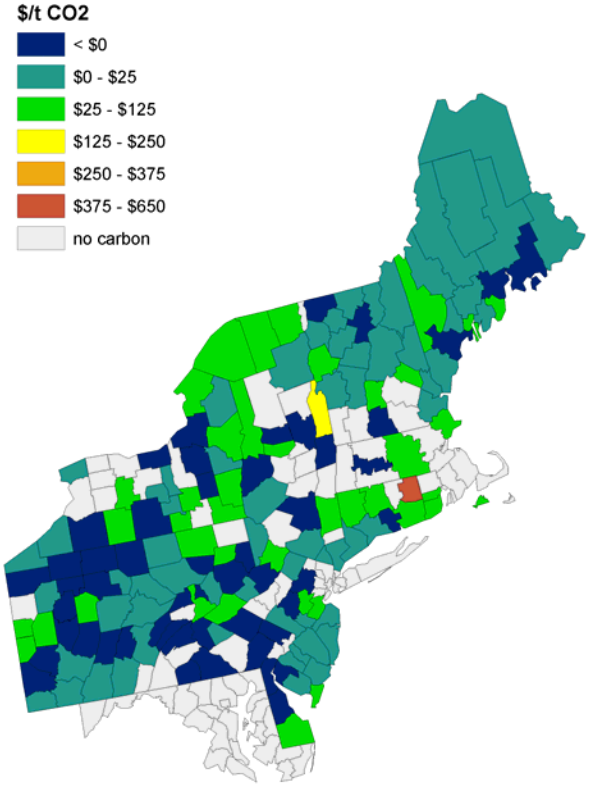


Figure 9: Average cost of carbon sequestration in each county from improving stocking conditions in poorly stocked forests.

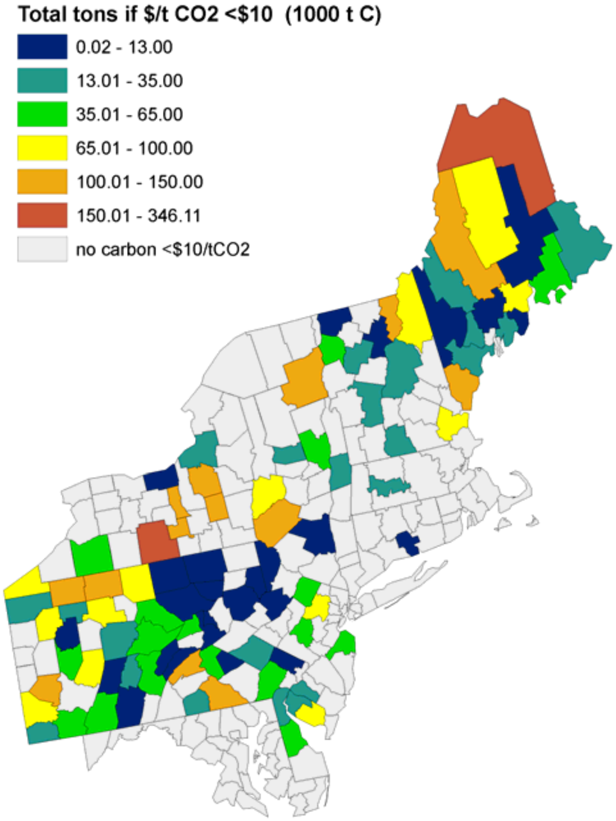


Figure 10: Total carbon potential by county for projects that cost less than $10/t CO_2e.

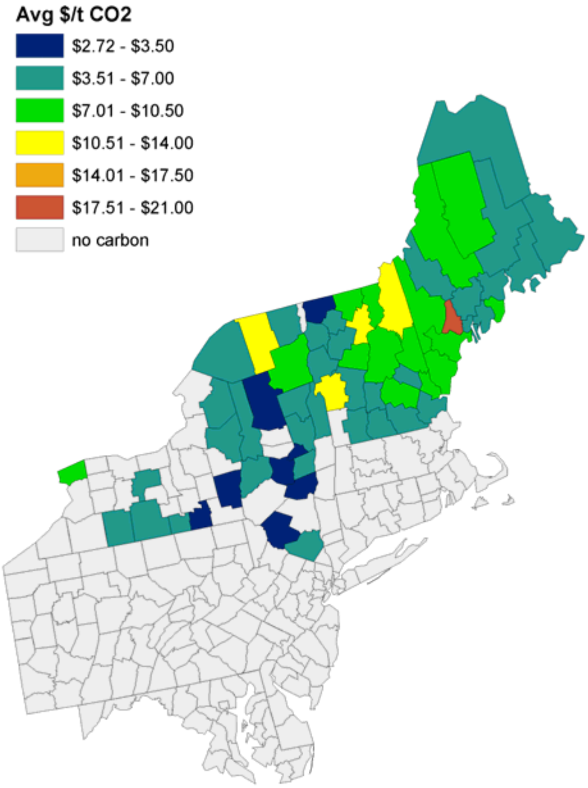


Figure 11: Average cost per t CO_2e for sequestering carbon in 5 year rotation extensions in softwoods of four NE states (Maine, New Hampshire, New York, and Vermont).

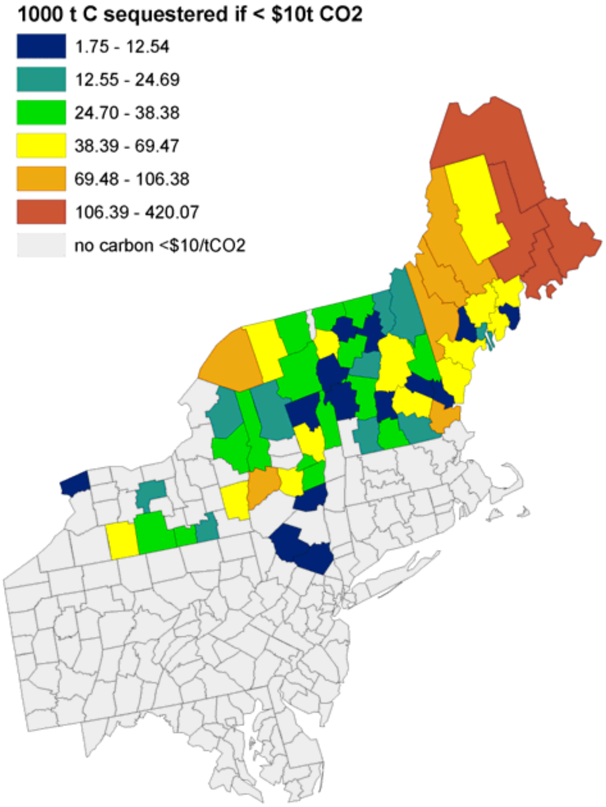


Figure 12: Total carbon potentially sequestered by county for aging forests 5 years where marginal costs are <$5/t CO_2e. Four NE states only (Maine, New Hampshire, New York, Vermont).

CONCLUSIONS

Interesting and practical findings have resulted from the work accomplished in the July to September 2006 quarter.

Under task 2 work in California, overall, this large-scale operational test showed that LIDAR is suitable for spatial estimation of forest carbon, although QuickBird is unsuitable under conditions of high shadows and steep topography. This research has provided data on forest species, tree density, biomass, and fuels to assist in the management of a priority natural resource conservation area. The network of permanent forest inventory plots will allow long-term studies of old-growth forest. The allometric relationships derived can be applied to the estimation of forest carbon in other California forests of similar species composition and structure. The research results also contribute to the Department of Energy National Energy Technology Laboratory goal to "develop instrumentation and protocols to accurately measure, monitor, and verify both carbon storage and the protection of human and ecosystem health."

Under task 4, a report titled "Methods for Measuring the CO_2 Impacts of The Nature Conservancy's Tropical Forest Conservation and Restoration Projects" was completed. This report details baseline methods for deforestation, reforestation, and afforestation projects that are well-developed and provide credibility, accuracy, and reduced transaction costs. Regional approaches for various different project types are proving to be credible, are useful for keeping costs down and are suitable for integration into policy. While leakage methods are less well-developed, a great deal of progress has been made, and the typology approach seems to offer the most promise. Third-party evaluations are likely to be needed to determine or verify where a particular project will fall within the range of potential leakage for projects of its type. Even with existing methods and ongoing progress, the project-by-project approach remains a challenge. Rigor can be ensured, but only through careful application of the best methods and verification of approaches by third-parties. Uncertainties regarding whether or not projects would have happened even in the absence of carbon funding remain.

Under task 5, a draft of Part III examining the potential of afforestation on cropland and pasture lands in the Northeast was completed. Preliminary results indicate that the Northeast region has variable amounts of available land for afforestation, with agricultural land covering 20% of the land area. The nature of forest growth causes carbon dioxide accumulation to be minimal in the first 10 years. Over longer time periods, carbon accumulation through afforestation is substantial. The costs associated with changing land use management to afforestation are large in the region due to the high opportunity costs, high estimated conversion costs, and slower carbon accumulation. However, a large amount of pasture land in many states could be available at relatively lower prices and provides the best opportunity for economically attractive afforestation.

Also under task 5, a draft of Part IV examining the opportunities for improving carbon storage and management on forest lands in the Northeast was completed. Improved stocking of under-stocked stands and extending the rotation age in softwood forests were explored in detail. Preliminary results indicate that there is a large range of very low cost carbon potential in under-stocked stands and there are potentially substantial opportunities for increasing carbon sequestration through aging in softwood forest, with lower cost opportunities existing with 5-year rotation extensions.

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