7-30-2010

Integrating Forest Carbon Sequestration into a Cap-and-Trade Program to Reduce Net Carbon Emissions

Thomas L. Daniels
University of Pennsylvania, thomasld@design.upenn.edu

This is an electronic version of an article published in:
Daniels, Thomas L. (2010). "Integrating Forest Carbon Sequestration into a Cap-and-Trade Program to Reduce Net Carbon Emissions." Journal of the American Planning Association. Vol. 76(4).
The Journal of the American Planning Association is available online at: http://www.tandfonline.com/openurl?genre=article&issn=1939-0130&date=2010&volume=76&issue=4&spage=463

Integrating Forest Carbon Sequestration into a Cap-and-Trade Program to Reduce Net Carbon Emissions

Abstract

Problem: Most research on planning to mitigate climate change has focused on reducing CO2 emissions from coal-fired power plants or the transportation sector. The contribution of forests to lowering net CO2 emissions has largely been overlooked. U.S. forests already offset about one eighth of the nation's annual CO2 emissions and have the potential to offset more, all at a relatively low cost. It will not be easy to integrate forest carbon sequestration into a cap-and-trade program to reduce net CO2 emissions, however. Purpose: I explore what forest land use planning, forestry management practices, and land preservation strategies would be required to integrate forest carbon sequestration into a cap-and- trade program, and explain the role planning and planners can play in promoting forest carbon sequestration. Methods: The Regional Greenhouse Gas Initiative is a 10-state cap-and-trade program to reduce greenhouse gas emissions from coal-fired power plants in the northeastern United States. It provides a case study of how forest carbon sequestration can be included in a cap-and-trade program. Meanwhile, California has devised certifiable carbon credits from forestland. I analyze both approaches and generalize from them. Results and conclusions: To promote forest carbon sequestration through a cap-and-trade program will require ensuring the permanence of CO2 reductions, minimizing leakage from forestland conversion, and obtaining prices for carbon offsets that are high enough to induce forestland owners to participate in the program and offer them for sale. The capital needed to purchase and monitor permanent forest conservation easements as well as to provide a stream of annual income for timberland owners may require a national system of carbon credits. Ideally, the easements would be set up in advance through investments by government or non-profits, so that landowners will be ready to sell credits when they are demanded. Takeaway for practice: A cap-and-trade system could be a cost-effective way to lower net CO2 emissions if it included certifiable, trade-able credits from forestland preservation and management, and if the price of carbon credits were high enough to induce forest landowners to offer credits. To promote forest carbon sequestration, planners in rural areas should work with the local, state, and federal governments and non-profit land trusts to zone forestland at low densities, to preserve forest land through acquiring conservation easements, and to fashion forest management plans that ensure long cycles of timber harvesting. Planners in metropolitan areas should promote tree planting and tree retention ordinances to protect, expand, and manage urban forests to absorb greenhouse gases.

Comments

This is an electronic version of an article published in:

Daniels, Thomas L. (2010). "Integrating Forest Carbon Sequestration into a Cap-and-Trade Program to Reduce Net Carbon Emissions." Journal of the American Planning Association. Vol. 76(4).

The Journal of the American Planning Association is available online at: http://www.tandfonline.com/openurl?genre=article&issn=1939-0130&date=2010&volume=76&issue=4&spage=463

Integrating Forest Carbon Sequestration into a Cap-and-Trade Program to Reduce Net Carbon Emissions

Thomas L. Daniels

thomasld@design.upenn.edu

Department of City and Regional Planning

127 Meyerson Hall

University of Pennsylvania

210 S. 34th St.

Philadelphia, PA 19104-6311

Integrating Forest Carbon Sequestration into a Cap-and-Trade Program to Reduce Net Carbon Emissions

Problem: Most research on planning to mitigate climate change has focused on reducing carbon dioxide emissions from coal-fired power plants or the transportation sector. The contribution of forests in lowering net carbon emissions has largely been overlooked. U.S. forests offset about one-eighth of the nation's annual CO_2 emissions and have the potential to offset more emissions, and at a relatively low cost. A main challenge is how to integrate forest carbon sequestration into a cap-and-trade program to reduce net CO_2 emissions.

Purpose: To fill a gap in the research on planning to mitigate climate change that has focused heavily on lowering carbon emissions from coal-fired power plants and the transportation sector. To explore what forest land use planning, forestry management practices, and land preservation strategies would be required to integrate forest carbon sequestration into a cap-and- trade program. To explain the role of planning and planners in promoting forest carbon sequestration.

Methods: The Regional Greenhouse Gas Initiative is a 10-state cap-and-trade program to reduce greenhouse gas emissions from coal-fired power plants in the northeastern U.S. The Initiative provides a case study of how forest carbon sequestration is being included in a cap-and-trade program. Meanwhile, the State of California has devised certifiable carbon credits from forestland. Critical analyses of both the Initiative and carbon credit approach provide insight into the potential for cap-and-trade programs to promote forest carbon sequestration, and how land use planning, forest management plans, and forestland preservation could broaden the role of carbon credits in a cap-and-trade program.

Results and Conclusions: Promoting forest carbon sequestration through a cap-and-trade program is not easy. Ensuring the permanence of CO_2 reductions and minimizing leakage from forestland conversion are essential. The price of carbon credits must be sufficiently high to induce forestland owners to sell carbon credits, and, ideally, emitters who exceed their CO_2 allowances will be required to purchase carbon credits from forestland owners. But the participation of forest landowners will be voluntary whether to sell or donate a perpetual conservation easement, which is a pre-requisite for sales of carbon credits. A national system of carbon credits may be necessary to provide capital for permanent forest conservation easements as well as a stream of annual income for timberland owners.

Takeaway for practice: A cap-and-trade system can be a cost-effective way to lower net carbon emissions if it includes certifiable, tradable credits from forestland preservation and management, including tree planting. Also, the price of carbon must be sufficiently high to induce forest landowners to offer credits. To promote forest carbon sequestration, planners in rural areas can work with local, state, and federal governments, and non-profit land trusts to zone forestland at low densities, to preserve forestland through acquiring conservation easements, and to fashion forest management plans that ensure a long cycle of timber harvesting. Planners in metro areas can promote tree planting and tree retention ordinances to protect, expand, and manage urban forests to absorb greenhouse gases.

Keywords: cap-and-trade, carbon sequestration, carbon credits, climate change, conservation easement, forest management plans

Research support: None

About the author: Tom Daniels (thomasld@design.upenn.edu) is a professor in the Department of City and Regional Planning at the University of Pennsylvania.

Introduction

The United States is second only to China in the emission of carbon dioxide, the main greenhouse gas that contributes to climate change (Netherlands Environmental Assessment Agency, 2008). Carbon dioxide accounts for about 85 percent of total U.S. greenhouse gas emissions, and fossil fuels were the source of 94 percent of U.S. CO_2 emissions in 2007 (Perschel, Evans, & Summers, 2007). Consequently, much of the U.S. research for reducing CO_2 emissions has focused on decreasing the use of fossil fuels (Perschel, Evans, & Summers, 2007; Pew Center for Global Climate Change, 2007; U.S. Environmental Protection Agency (USEPA), 2005, 2007). By contrast, relatively little research has been conducted on the potential for increasing carbon sequestration (i.e. the capture and storage of carbon) in U.S. forests to offset CO_2 emissions.

In 2007, U.S. forests offset more than 900 million tons or 12.7% of the nation's CO_2 emissions (Perschel, Evans, & Summers, 2007; USEPA, 2009). According to the U.S. EPA (2007), net CO_2 sequestration increased by 16 percent from 1990 to 2005, mainly from an increase in the rate of net carbon accumulation in forests. The potential exists for forests to offset more CO_2 emissions, with some forests able to increase their carbon storage by as much as 50 percent (Yardley, 2009). One government action recommended by Stern (2006) is to put a price on carbon through trading, such as in a cap-and-trade program, to encourage emitters to reduce CO_2 releases. Emitters would each be given a CO2 emissions allowance (a cap) and if they exceeded their allowance they would have to purchase allowances from emitters who released less CO_2 than their caps. Over time, the caps would be lowered to decrease CO_2 emissions. A cap-and-trade program could include payments from emitters to owners of forestland for carbon credits based on management practices that would increase carbon sequestration. And because forests take carbon out of the air and store it without the need for new technologies or major infrastructure investments, forest carbon sequestration holds promise as a cost-effective way to achieve net reductions in CO_2 emissions (Wayburn, 2009).

This paper asks three sets of questions about the potential for increasing carbon sequestration in U.S. forests:

1) What is the potential for better forest planning and management practices to contribute to carbon sequestration and climate change mitigation?

2) What can be learned from the experiences with a cap-and-trade program in the ten Northeast states that make up the Regional Greenhouse Gas Initiative (RGGI) and from California's emerging experience with certified forest carbon credits? Specifically, how might forest planning and management practices work in terms of incentives, regulations to change practices, private property rights, and institutional governance to ensure gains in carbon sequestration?

3) How do these changes in forest planning and management differ from the current forest management and land use planning programs? What are the current problems and future opportunities? What policies and programs will be required to make a forest carbon sequestration program work?

The Potential for Better Forest Planning and Management Practices to Contribute to Carbon Sequestration and Mitigate Climate Change

Planning for climate change features two approaches: 1) mitigating or reducing net carbon emissions; and 2) adapting to the effects of climate change. Planning efforts to promote forest carbon sequestration primarily address the mitigation of CO_2 emissions. Forests sequester carbon by absorbing carbon dioxide as part of the photosynthesis process. Trees store carbon in their wood and in the soil, and thus act as natural carbon sinks. An acre of trees can absorb about 10 tons of carbon dioxide a year (Little, 1997). But over time the amount of carbon a tree absorbs resembles a bell curve; thus older trees (roughly 20 to 100 years old) absorb more carbon dioxide than young trees (Gore, 2009). As a dead tree decays, it releases carbon into the atmosphere. Harvested trees that are turned into wood products release carbon more slowly than trees that die a natural death. Thus, forest management practices that lengthen the current timing of timber harvests and turn the trees into lumber can maximize the storage of carbon and minimize the rate of carbon release as the lumber decays.

Forests take a long time to produce a marketable crop of lumber. During that time, forests are vulnerable to rising property taxes, development pressures, changes in markets for wood products, forest fires, and diseases and pests. These events also threaten the ability of forests to store carbon over the long run. In addition, climate change may hinder the productivity of forests, and already warmer temperatures have led to infestations of the mountain pine beetle which have killed more than 1.5 million acres of pine trees in the Rocky Mountains (Millar, Stephenson, & Stephens, 2007).

Forests cover one-third of the United States or about 740 million acres and 68 percent of U.S. forests (520 million acres) are classified as timberland, capable of producing wood products on a sustained basis. About 60 percent of all U.S. forests are privately owned (Daniels and Daniels, 2003; Wayburn, et al., 2007). Since 1990, U.S. forestlands have increased by a net of 20 million acres, even though an estimated 1.5

million acres of forestland have been converted to residential and commercial development each year (Pacific Forest Trust, 2009; U.S. EPA, 2009). If 1.5 million acres of forestland a year continue to be converted, this deforestation would produce nearly 20 billion metric tons of carbon dioxide over the next 50 years (Wayburn, 2009). The conversion of forestland to other land uses not only releases stored carbon but also removes the long-term opportunity to sequester carbon in forests and wood products (ibid.). Therefore, minimizing the conversion of forestlands to residential or commercial development is important for maximizing forest carbon sequestration.

There are several forest management practices that can increase carbon sequestration (see Table 1). These management practices can increase carbon sequestration while still allowing the harvesting of wood products and protecting ecological values (Perschel, Evans, & Summers, 2007). Management practices can also make the forests more resilient to the effects of climate change and more resistant to forest fires, diseases, pests, and invasive species, thus improving the chances for achieving permanence in the sequestration of carbon in forests.

Table 1 about here

There is no clear agreement on the best forest management practices for maximizing carbon sequestration. The Congressional Budget Office reported that afforestation or planting trees on land previously used for other purposes raises annual sequestration by the equivalent of 2.2 to 9.5 metric tons of CO_2 per acre for 120 years (#1 and #3 in Table 1) (Birdsey, 1996; CBO, 2007). Reforestation (#2) or planting trees on land until recently devoted to forestry (such as severely burned land) would produce a slightly smaller increase in sequestration of 1.1 to 7.7 metric tons of CO_2 per acre (Birdsey, 1996). Selecting certain tree species, lengthening the timing between timber harvests, and managing pests and fires can also increase sequestration from an estimated 2.1 to 3.1 metric tons of CO_2 per acre per year (#4, #5, and #6) (Row, 1996). Sampson (2002) advocates planting or expanding riparian forest buffers (#3) and planting fast growing trees (#9) but offers no estimates of net carbon reduction. Other practices include processing trees into lumber and other woods products (#12), disposing of wood products in landfills rather than through incineration (#11), agroforestry (#8), urban forestry and tree planting (#10), and protecting forests through permanent conservation easements (#7) and forestland zoning (#13) to limit CO_2 releases that would result from the conversion of forestlands.

The two most expensive practices are lengthening the timber harvest rotation (#6 and purchasing permanent conservation easements (#7). Lengthening the rotation to increase a forest's natural carbon storage capacity means that it will take longer for the forest to generate revenue for the landowner. An actively managed forest with a harvest cycle of about 90 years rather than the typical commercial harvest cycles of 30 years for softwoods to 45 years for hardwoods is optimal for sequestering carbon (Perschel, Evans, & Summers, 2007; Wayburn, 2009).

The value of a conservation easement is the difference between the fair market value of a property and its value restricted to forestland and open space. The conservation easement value of forestland generally varies inversely with the size of the land parcel.

Also, the more remote the parcel, the lower the easement value is likely to be. For instance, in 2000 the Pingree Family sold a conservation easement on 762,192 acres in northern Maine to the New England Forestry Foundation for slightly more than $28 million, or just over $37 per acre (New England Forestry Foundation, 2009). Typically, the price per acre is low but the total price is large because of the size of the forestland parcel.

Incorporating better forest management, land use planning, and conservation easements on forest land to increase forest carbon sequestration may be accomplished through a cap-and-trade program. Ideally, owners of power plants, factories, and motor vehicles would be required to offset at least some of their CO_2 emissions through the purchase of carbon credits from forestland owners.

There are, however, several valid concerns about the reliability of carbon credits for forest carbon sequestration. The issues include: accuracy of measurement, additionality, double counting, leakage, permanence, and verifiability over time. Establishing protocols for forestry carbon sequestration is complicated because of the difficulty in identifying a beginning carbon baseline and measuring the amount of carbon sequestered over time, as well as measuring reductions in carbon linked to different forest management practices. The accuracy of measuring carbon sequestration will depend on developing a standardized life-cycle accounting for carbon gains and losses in forests and wood products (Pacific Forest Trust, 2009).

The concept of additionality involves the question: "Would the carbon sequestration project have happened if the carbon credits could not have been sold?" In other words, the project has to provide *additional* carbon sequestration (Kollmuss, Zink,

& Polycarp, 2008). Double counting could happen from the sale of carbon credits to a company and then counting the credits both from the company and the forest in meeting a regional emissions reduction target. Leakage could occur if one forest landowner sold carbon credits from one forest and then *any* landowner accelerated timber harvesting in another forest. This way, the gains in carbon sequestration from the sale of credits are compromised by the loss of carbon sequestration somewhere else. Ultimately, net forest gain for a region will be the overall benchmark of the severity of leakage (Myers, 2007). So, if net forest gain is positive, then leakage is less of a problem than if it is negative.

The gains in carbon sequestration must be permanent to reduce CO_2 emissions over the long run. On the one hand, carbon gains can be lost through the destruction of trees from disease, insects, wild fires, and rapid timber harvesting. On the other, forestland can be restricted from commercial and residential development through the purchase or donation of conservation easements. But the sale or donation of conservation easements is a *voluntary* action by a landowner. There must be sufficient financial inducement for a landowner to sell or donate a conservation easement and the landowner must abide by the timber harvesting practices that promote carbon sequestration which are written into the deed of easement. In addition, the government agency or land trust that holds the conservation easement must monitor the forestland to verify that the landowner is abiding by the terms of the deed of easement and thus maintaining the permanence of the carbon credits (Gentry, 2009).

Cap-and-Trade Programs and the Sale of Forest Carbon Credits: Toward Workable Programs

The emerging U.S. experience with cap-and-trade programs to reduce net CO_2 emissions provides insight into the institutional governance, exercise of private property rights, forest management practices, land use planning, and forestland preservation techniques that are needed to create verifiable carbon credits and an active market in those credits..

The Kyoto Protocol of 1997 cited the importance of protecting and restoring forests to mitigate climate change and introduced the idea of an international cap-and-trade system for carbon credits (Wayburn, 2009). Companies, such as electrical utilities and manufacturers, would have a limit (cap) to how much carbon dioxide they could emit. If a company exceeded its limit, the company would have to purchase verifiable carbon credits, such as from forestland owners. A credit equals one ton of carbon dioxide equivalent, and each credit would offset one ton of a company's emissions of CO_2. By convention, the terms carbon credit and carbon offset are used interchangeably, and offsets can be thought of as tradable credits (California Air Resources Board (CARB), 2009a; Stockholm Environmental Institute, 2009). The funds from the sale of carbon credits could be used to pay for the planting of trees, the preservation of forestlands, or improved forest management to offset a company's carbon dioxide emissions. But the United States Senate has never ratified the Kyoto Protocol because of fears of heavy financial burdens on American companies.

In 2005, ten states consisting of the six New England states along with New York, New Jersey, Delaware, and Maryland felt they could not wait for Congress to enact a cap and trade program to reduce CO_2 emissions, and so they created the Regional Greenhouse Gas Initiative, known as RGGI or Reggie (see Figure 1). This is the nation's first mandatory regional cap-and-trade system aimed at reducing CO_2 emissions. The RGGI is similar to the cap-and-trade system to reduce greenhouse gases called for under the Kyoto Protocol, and the cap-and-trade approach successfully used in the U.S. to reduce sulfur dioxide emissions from power plants in the 1990s (Daniels & Daniels, 2003). The ten Northeastern states formed RGGI, Inc., a non-profit corporation, to create, implement, and manage the cap-and-trade program (RGGI, 2009).

Figure 1 about here

Fossil fuel burning power plants are the single largest source of greenhouse gas emissions both nationwide and in the Northeast where they account for one-quarter of the region's total emissions (RGGI, 2009; USEPA, 2009). The RGGI set a cap on annual CO_2 emissions from each of the region's 209 fossil fuel-based electric power generating plants. The operators of each power plant must purchase emission allowances equal to their annual cap. Each allowance permits a power plant operator to emit one ton of CO_2. If a power plant's emissions exceed the annual cap, then the operator can purchase emissions allowances from other power plant operators who have produced fewer emissions than their cap authorizes. Through RGGI, Inc., the ten states began to auction off emissions allowances to the operators of the power plants in 2008 (see Table 2). The lower prices in the latter part of 2009 and early 2010 suggest that power plant operators do not need to purchase as many allowances because they are reducing emissions below their caps and hence have less demand for allowances. The RGGI has raised more than half a billion dollars and established a price on carbon averaging slightly under $3 a ton (see Table 2). The states have already begun to use the revenues from the auctions to invest in energy efficiency, such as weatherizing homes, and alternative, clean energy technology (McCord, 2009).

Table 2 about here

The goals of the RGGI are modest: 1) to cap carbon dioxide emissions at 188 million tons per year from 2009 through 2014; 2) to lower the CO_2 cap by 2.5 percent each year from 2015 through 2018, or a total reduction of 10 percent to about 170 million tons a year; and 3) to reduce total regional CO_2 emissions by 2.5 percent below 2008 levels (RGGI, 2009). By comparison, the California Global Warming Solutions Act of 2006 (AB 32), requires the state to develop markets and regulations that will cut California's overall greenhouse gas emissions to 1990 levels by 2020, a reduction of about 30 percent, and then an 80 percent reduction below 1990 levels by 2050 (CARB, 2009b). The American Clean Energy and Security Act, (HR 2454), which passed the U.S. House in 2009 but has yet to become law, includes the goal of reducing the nation's greenhouse gas emissions by 17 percent below 2005 levels by 2020 (Mufson, Fahrenhold, & Kane, 2009).

Because the RGGI emissions cap will be lowered each year from 2015 through 2018, tradable emissions allowances are expected to become increasingly scarce and push carbon prices higher. It will probably become more difficult for power plant operators to purchase emissions allowances from each other. Therefore, power plant operators are expected to become very interested in purchasing carbon offsets (credits) from owners of forestland.[1] The RGGI has linked the anticipated rise in carbon dioxide prices to the expanded use of offsets. If the price of carbon dioxide stays below $7 a ton, then offsets can account for only 3.3 percent of an emitter's compliance obligation. But once the price of carbon dioxide reaches $7 per ton in 2005 dollars, an emitter can use offsets to satisfy up to five percent of the compliance obligation. And, if the price climbs to $10 per ton in 2005 dollars, offsets can be used to satisfy 10 percent of the emitter's obligation (RGGI, 2009).

So far, the RGGI has authorized tree planting, also known as afforestation, to qualify for the carbon offsets that power plants may purchase to reduce their overall carbon dioxide emissions. Afforested land must be subject to a permanent conservation easement, which mandates the afforested land: a) be maintained as a forest in perpetuity; b) sustain carbon sequestration levels reached by the end of the offset crediting period; and c) be managed according to sustainable forestry practices (ibid.).

One shortcoming of RGGI's afforestation policy is that it applies only to planting trees on land that has not had a forest for at least 10 years. Because forests store more carbon as they age, young trees add more carbon each year but overall store far less carbon than older trees (Birdsey, Pregitzer, & Lucier, 2006). Forests over 100 years old generally do not absorb much additional carbon, but they contain large stores of carbon (Gore, 2009). Also, the RGGI makes no distinction between afforestation projects in urban and non-urban areas, even though it is easier to plant large, thick stands in non-urban settings and non-urban stands on average store roughly twice as much carbon as urban forests (Nowak & Crane, 2002). Another challenge and expense with afforestation is the need for a state agency or contracted third party to monitor the afforestation site, usually on an annual basis.

As of 2008, RGGI reported no applications for afforestation projects (Smith, Lazarus, Lee, Todd, & Weitz, 2009). The main reason is the price of CO_2 is too low. According to Burgert (2008), afforestation is not attractive at prices of less than $5 a ton of carbon dioxide, and RGGI's allowance auctions have produced prices averaging less than $3 a ton (see Table 2). The US EPA (2005) has estimated that a CO_2 price of at least $7 a ton is needed to make it attractive for emitters to purchase forest carbon offsets and thus stimulate afforestation projects. The Congressional Budget Office has reported that if carbon dioxide prices in a cap-and-trade program began at $4.50 a ton in 2015, forest carbon sequestration would account for no more than five percent of annual CO_2 reductions nationwide by 2050; but if carbon prices began at $14 a ton in 2015, forest carbon sequestration could account for up to 20 percent of annual CO_2 reductions by 2050, second only to mitigation efforts in the energy sector (CBO, 2007).

Three other cap-and-trade programs to reduce greenhouse gas emissions are slated to start in 2012 (CARB, 2009a; Western Climate Initiative, 2009; Midwestern Greenhouse Gas Reduction Accord, 2009). These include: 1) the State of California; 2) the Western Climate Initiative, involving California, Montana, New Mexico, Oregon, Utah, Washington and four Canadian provinces; and 3) the Midwestern Greenhouse Gas Reduction Accord made up of Iowa, Illinois, Kansas, Manitoba, Michigan, Minnesota, and Wisconsin.

Each of the three proposed cap-and-trade systems allows emitters to purchase forest carbon sequestration credits to meet their emissions caps, but so far only California has actually certified forest carbon credits (Pacific Forest Trust, 2008). The two regional programs will accept sequestration credits from outside their regions. This policy could create opportunities for forestland owners in the northeastern states who have not been able to sell carbon credits through the RGGI. Also, the three proposed cap-and-trade programs call for carbon offset projects that are "real, additional, quantifiable, permanent, verifiable, and enforceable" (CARB, 2009a, p. 18).

California offers the leading example for generating credits from a forest carbon sequestration project. The passage of the California Global Warming Solutions Act of 2006 (AB 32) led to the creation of Climate Action Registry Forest Sector Protocols, administered by the California Air Resources Board. Forestland that is registered as part of a forestry carbon offset project must be permanently dedicated to forest use through a perpetual conservation easement (CARB, 2009b; California Climate Action Registry, 2009). Also, the forestland must promote and maintain native forests to avoid problems with invasive species. In addition, the forestland must be managed with natural forest management practices so water quality, biodiversity, and species habitat are not impaired. But California does allow clear-cutting of forests that participate in the carbon offsets program, which has not been well received by environmentalists (Bailey, 2009). A Forest Certification Protocol must be crafted to guide approved third party certifiers in conducting accurate, standardized assessments of CO_2 data to ensure verifiable carbon sequestration and net emissions reductions. To receive certification of a particular forest, a landowner must identify a baseline of current carbon sequestered in that forest, trends for future carbon sequestration under current management practices, and additional carbon sequestered because of changes in management practices.

In 2007-8, the California Climate Action Registry completed the registration of two forestland preservation projects with management practices to sequester carbon. The

2,200-acre Van Eck forest in Humboldt County, under a permanent conservation easement held by Pacific Forest Trust and sustainably managed, is expected to reduce 500,000 tons of carbon over 100 years. Already, carbon offset credits from the Van Eck forest have been sold for more than $2 million (Bourne, 2009; Pacific Forest Trust, 2008). And the company Green Mountain Energy through its BeGreen subsidiary is helping Pacific Forest Trust to market offsets from the Van Eck Forest for $19.95 per ton (Green Mountain Energy, 2009). This price for carbon is high enough to justify the carbon sequestration project, including the purchase of the conservation easement and forest management, and is well above the less than $3 a ton of carbon established in the RGGI allowance auctions.

The Conservation Fund/Nature Conservancy's 23,780-acre Garcia River forest in Mendocino County, California is a certified source of carbon credits and the sustainable forestry practices are expected to remove more than 77,000 tons of carbon emissions each year (The Conservation Fund, 2009).

In addition to these working forest projects, in 2008, the California Climate Action Registry adopted an Urban Forest Project Verification Protocol to guide the California Air Resources Board and approved third party verifiers for verifying carbon sequestration from urban tree planting and maintenance (California Climate Action Registry, 2009).

Lessons from RGGI and California

The experiences of the RGGI and California in creating cap-and-trade programs and the sale of forest carbon credits point to a number of strengths and shortcomings as well as land use planning implications. First, scientific studies must demonstrate that forests have the potential to sequester additional carbon. For instance, the forests in the Northeastern states sequester anywhere from 12 to 20 percent of the region's annual CO_2 emissions, based on forestland acres, age, and species composition as well as the implementation of specific forest management practices (Perschel, Evans, & Summers, 2007). But Northeastern forests have the potential to "substantially" increase carbon sequestration through best forest practices (ibid., p. 1).

Second, in the absence of a federal cap-and-trade program, either a state agency (as in California) or a state-supported regional organization (such as RGGI) is needed to manage a cap-and-trade program and certify carbon credits from forests. But as yet there is little connection between cap-and-trade programs and land use planning and zoning. A major challenge to sequestering carbon is the threat of leakage from the conversion of forestland to other uses. For instance, from 1987 to 2002, forestland in the RGGI states declined by a total of 343,000 acres (Smith, Miles, Vissage, & Pugh, 2002). Over the next 25 years, three million acres of forestland in the Northeast are projected to be converted to developed uses, and release about 150 tons of CO_2 per acre, or a total of 450 million tons of CO_2 (Ingerson, 2007). Without a link between land use planning and cap-and-trade programs, leakage will cut into and possibly overwhelm gains from forest carbon sequestration projects.

The local planning and zoning in the RGGI states (except for Maryland) is controlled by towns or townships of about 25,000 acres in size, rather than at the county level. As a result, planning and zoning are fragmented, and in general, the zoning on open land and forestland in the outer suburbs and rural parts of these states features one-acre and two-acre minimum lot sizes. This zoning is ideal for ex-urban and rural residential development, not the protection of active forestry operations from forest fragmentation and conflicting non-forestry land uses (Daniels, 2006).

In California, SB 375 of 2008 builds on AB 32 of 2006 by giving the California Air Resources Board the authority to set greenhouse gas reduction targets, by enabling the Air Resources Board to work with the state's 18 Metropolitan Planning Organizations to change their regional transportation, housing, and land use plans to reduce vehicle miles traveled, and by providing incentives to local governments to promote more compact development to reduce vehicle miles traveled and hence lower CO_2 emissions (CARB, 2010). California also has Timber Production Zones (TPZ) which exclude all other land uses and thus minimize the conversion of forestland to residential and commercial uses (Daniels & Daniels, 2003). To enroll in a TPZ, a landowner signs an agreement to maintain the land in forest use and receives a property tax break. If a landowner successfully petitions a county to remove the land from a TPZ, the land must be kept in forest use for another 10 years or else the landowner can pay the recaptured property taxes due and go through the environmental impact review process for immediate re-zoning (Cromwell, 1984). Forestlands in TPZs would be ideal candidates for permanent conservation easements and forest carbon sequestration practices.

Third, afforestation alone is not likely to produce significant increases in forest carbon sequestration. Afforestation projects are estimated to have a high rate of leakage (US EPA, 2005). Moreover, the RGGI has overlooked the considerable opportunity for the use of offsets from existing forestlands and especially from forestlands already under conservation easements (see Table 3) to reduce CO_2 emissions in the Northeastern states.

In northern New England, forest-related carbon offsets only for afforestation make little sense. Maine at 89 percent forest cover is the most heavily forested state in the nation; New Hampshire at 84 percent forested is the second most heavily forested state; and Vermont is 78 percent forested (Smith, Miles, Vissage, & Pugh, 2002). The State of Maine has asked RGGI, Inc. to add offsets from forest management to the list of acceptable offsets (Burgert, 2008). But so far, this has not happened.

Fourth, it is critical for forest carbon sequestration projects to occur on forestland that is subject to a permanent conservation easement. This will ensure as much as possible that the forest will not be converted to residential or commercial development at some future date. The conservation easement must also specify the timber harvesting and carbon sequestration management practices. Forest carbon credits must be certified by a state agency or regional authority and must be verifiable, either through the monitoring of the conservation easements or by an outside third party. And, the credits must be enforceable, with penalties and restitution required for forestland owners whose sequestration projects do not maintain the necessary standards and management practices.

Ideally, a cap-and-trade program would create a registry of forestlands under conservation easements that are potentially eligible for the sale of carbon credits. But because the sale or donation of conservation easements is voluntary, it uncertain how many forestland owners would be willing to sell or donate conservation easements and would then be willing to change their forest management practices to qualify for the sale of carbon credits.

A review of the easements held by the major national land trusts and state land trusts in the Northeast indicates that there are now more than 3 million acres of forestland under conservation easements, with at least 1.8 million preserved acres in Maine alone (see Table 3). This indicates that many forestland owners have been willing to sell permanent easements, a first step toward increasing forest carbon sequestration.

Table 3 about here

Fifth, carbon prices have to be sufficiently high to induce emitters to purchase carbon credits from forest carbon sequestration projects, and for forestland owners to sell carbon credits and adopt new forest management practices.

Sixth, the reality that no private timber company has voluntarily sold or donated a conservation easement and then sold a carbon offset is not encouraging. The California experience suggests that non-profit land trusts do not have the financial resources or personnel to be arranging carbon offsets with forest owners on a broad scale. Moreover, the primary purpose of land trusts is land preservation, not the generation of carbon credits.

Seventh, a major challenge is how to get thousands of small forestland owners to improve their management practices. For instance, about two-thirds of the forests in the Northeast are private, non-industrial forests, and there are 4.6 million acres with trees greater than 40 years of age that are poorly stocked or under-stocked (Smith, Miles, Vissage, & Pugh, 2002; Sohngen, Walker, Brown, & Grimland, 2007).

Eighth, protecting non-urban forests should have a higher priority in a forest carbon sequestration program because U.S. urban forests provide about half the carbon storage of non-urban forests (Nowak & Crane, 2002).

Ninth, the U.S. Forest Service could add forest management for carbon sequestration to its 155 national forest plans that cover more than 190 million acres (Daniels & Daniels, 2003). Under the Multiple Use-Sustained Yield Act of 1960 and the National Forest Management Act of 1976, individual national forest plans are required to reflect a management outcome of maximum sustainable yield for a variety of uses. But as yet, there is no requirement that national forest plans include carbon sequestration (The Wilderness Society, 2009).

Arguably, RGGI has laid the foundation for the pending federal cap-and-trade legislation, which includes a national market for carbon credits from farm and forest land and for a federal funding stream to purchase conservation easements on these resource lands. But California has demonstrated how the certification of forests for the sale of carbon credits can actually occur.

Comparing the Current Conditions and the Recommended Changes in Forest Planning, Preservation, and Management

To create a road map for effective cap-and-trade programs that promote carbon sequestration in forests, it is important to understand the gap between the current forest management practices, forest land use planning, and forestland preservation regimes and the recommended changes in these three areas. Currently, there is considerable variety among state forest practices acts, state planning legislation, local planning and zoning regulations, and state forestland preservation efforts. The major recommended changes for greater forest carbon sequestration feature: 1) a large increase in the preservation of forestland through conservation easements to avoid the conversion of forestland and to expand the area of forestland eligible for the sale of carbon credits; 2) greater use of forestland zoning to protect productive timberland, to discourage forestland conversion, and to encourage the sale of conservation easements; 3) new forest management practices that include lengthening timber harvest cycles and actively managing forests for a variety of tree ages and healthy forests; and 4) aggressive afforestation in both cities and the countryside.

Forestland preservation. A cap-and-trade program aimed at promoting significant increases in forest carbon sequestration would require millions of acres of forestland under permanent conservation easements. Conservation easements are a powerful tool against forest fragmentation and the conversion of forestland to other land uses, and they have proven to be far more durable than local zoning in protecting natural resource lands (Daniels & Daniels, 2003; RGGI, 2009). But there would have to be major sources of public and private funding to purchase permanent conservation easements on large areas of forestland over the next few decades.

In 1990, Congress created the Forest Legacy Program which enables the U.S. Forest Service to make matching grants to states to purchase forestland or, more commonly, conservation easements on forestlands. The Forest Service will pay up to 75 percent of the cost of the land or conservation easements. To date, the Forest Legacy Program has spent more than $406 million to preserve 1.85 million acres in 42 states (Trust for Public Land, 2009a). In the future, the Forest Legacy Program could be linked to funding forestland preservation projects that will involve the sale of carbon offsets.

State governments in Maine, Vermont, and New York have been leaders in purchasing conservation easements on forestland, and several land trusts—most notably the Trust for Public Land, the Nature Conservancy, New England Forestry Foundation, and Pacific Forest Trust—have preserved a total of more than two million acres of forestland (Trust for Public Land, 2009a; the Nature Conservancy, 2009; New England Forestry Foundation, 2009; Pacific Forest Trust, 2009). But given the weak state finances resulting from the recession of 2008-9, state funding for forest land preservation is likely to be sharply reduced, at least in the short run, and non-profit funds will probably not be able to fill the gap.

In 2009, the U.S. House of Representatives passed the American Clean Energy and Security Act of 2009 (HR 2454) which would create a cap-and-trade system for greenhouse gas emissions in which emitters would have to purchase carbon credits from each other or buy carbon credits from owners of farm or forest land (Mufson, Fahrenhold, & Kane, 2009). But, like the Kyoto Protocol, HR2454 has yet to pass the U.S. Senate.

The federal government is also debating senate bill S. 1733 that would create a national carbon offset market for farm and forest lands. The federal government would pay owners of farm and forest land for carbon reduction activities—including conservation easements—that might not qualify for a national offset market. The program would be funded through up to one percent of the carbon emission allowances sold each year, or up to an estimated $500 million a year, from 2012 to 2050 (The Trust for Public Land 2009b). Similarly, senate bill S. 2729 would pay for carbon reducing activities, including conservation easements, mostly on small farms and forests.

It is essential that forestland under a permanent conservation easement not have a heavy property tax burden or else few forestland owners will sell easements. Currently, most states offer use-value taxation for forestlands, taxing the land for property tax purposes based on its value as timberland not at its “highest and best use” as potential residential or commercial sites. Use–value taxation is meant to support the timber industry and to keep the property tax burden from forcing the sale of forestland for development. But use-value taxation in most states does not have any specific forest management requirements. Therefore, forestland under a permanent conservation easement must have a forest management plan that will require sustainable forestry practices that increase carbon sequestration.

Finally, there should be a central, publicly available data base of forestland under permanent conservation easements that would be eligible for the sale of carbon credits. For instance, there are more than 450 land trusts in the ten RGGI states and tracking down which land trusts hold easements on forest parcels and the size and location of those parcels is nearly impossible (Land Trust Alliance, 2009). A data base of conservation easements would be a first step in creating a registry of forests that could qualify for the sale of carbon offsets. For instance, starting in 2009, the State of Maine has required land trusts to register the conservation easements they hold with the State Planning Office (Maine State Planning Office, 2009).

Forestland zoning. Forestland zoning in large minimum lot sizes and with tight restrictions on non-forestry land uses is important for discouraging the conversion of forestland to residential and commercial uses and thus minimizing leakage that could cut into gains from forest carbon sequestration efforts. Forestland zoning is a mandatory regulation that can apply to large landscapes as well as individual parcels, and ideally is based on a public comprehensive plan. Forestland zoning can also encourage the sale of conservation easements as well as hold down the cost of purchasing conservation easements, as in the Pingree case in northern Maine. Currently, Oregon, California, and parts of New York, and Maine are known for their forestry zoning. Oregon zones timberland in 80-acre and 160-acre minimum lot sizes. California has Timber Protection Zones that forbid non-forestry uses. The Adirondack Park Agency in upstate New York zones most private forest land at a density of one house per 42 acres. And Maine designates an M-GN zone that regulates uses rather than lot sizes but allows some subdivisions in the Unincorporated Territory of northern Maine. However, because 26 states have enacted compensation laws that discourage downzoning (Jacobs, 1999), it is unlikely that forestland zoning will soon become widespread throughout the United States.

Forest management practices. The key changes in forest management practices include lengthening the timing of timber harvests, managing for a variety of tree ages and healthy forests, and implementing an overall forest management plan aimed at promoting carbon sequestration that is also sensitive to the impacts on water, wildlife, and soils. State forest practices acts have focused on timber harvesting methods, riparian buffers, and timber management plans to protect the environment. But these acts have yet to include requirements on how to manage forests for carbon sequestration. While third party certification organizations, such as the Forest Stewardship Council, have promoted sustainably managed forests for wood production, they have not yet rated forests according to carbon sequestration practices.

Forest management practices tend to differ according to who owns the forestland About one-third of America's privately-held forestland is owned by just one percent of all forestland owners (Wayburn, 2009). These forests tend to be industrial forests, which contain lumber mills or other wood processing facilities. Most owners of industrial forests are large timber companies, such as Weyerhaeuser and Plum Creek. These companies manage their land for a profit, and may look for real estate development opportunities on their forest holdings. A major challenge is how to encourage industrial forestland owners to lengthen current harvest cycles. But as of early 2010, no large timber company had sold carbon credits in a cap-and-trade program.

A majority of private forest land consists of non-industrial forests without any wood processing facilities on the property. The motivations for owning non-industrial forestland may include a rural lifestyle, aesthetics, recreation opportunities, wildlife habitat, a real estate investment, or harvesting timber or firewood. Many non-industrial forests are not well-managed or do not have a forest management plan (Perschel, Evans, & Summers, 2007). Some timber owners use harvesting practices such as high-grading (harvesting only the largest and most valuable trees) and simple overcutting, also known as liquidation cuts, that result in understocked forest stands with less ability to absorb carbon than well-managed forests (Sohngen, Walker, Brown, & Grimland, 2007). The challenge here is how to induce non-industrial forest owners to actively manage their woodlands for increased carbon sequestration.

Promoting tree planting. Tree planting on open land or to replace harvested timber can be an important part of increasing forest carbon sequestration. Tree planting in rural areas is likely to be more effective in sequestering carbon because thicker stands can be planted and there is usually less exposure to pollution and vandalism. In urban areas, subdivision regulations can require the retention of trees of a certain size, the replacement of trees removed during construction, and the planting of trees, either on environmentally-sensitive lands or to create buffers between properties. For instance, a number of counties in Maryland have effective forest conservation ordinances (Daniels & Daniels, 2003), and New York City in its PlaNYC (2008) established a goal to plant one million trees as part of its target to reduce carbon emissions by 30 percent between 2005 and 2030.

Considerable uncertainty exists about the likelihood of success of forest carbon sequestration efforts because of the gaps between current and recommended forest practices, land use planning, and forest preservation programs. Part of the reason is a lack of strong forestland zoning to minimize the conversion of forestland which may result in carbon leakage. Two big unknowns are the amount of future funding from state and federal agencies and private land trusts to purchase conservation easements, and the price emitters will be willing to pay for carbon credits. Also, it is uncertain how many forestland owners will want to voluntarily sell or donate permanent conservation easements, and then be willing to change their management practices, such as lengthening the timing of harvests, to maximize carbon storage in trees.

Conclusions

U.S. forests have the potential to sequester large amounts of carbon, and currently offset almost 13 percent of total U.S. carbon dioxide emissions (Perschel, Evans, & Summers, 2007; USEPA, 2009). So far, efforts to devise and implement effective forest management practices and forestland planning and preservation strategies for carbon sequestration are in their infancy. The Northeastern states have established a regional cap-and-trade program, RGGI, to reduce CO_2 emissions from power plants, but its afforestation offsets element has not worked at all. A key problem is the carbon price is too low to induce emitters to buy carbon credits for afforestation.

Carbon markets have begun to enable carbon dioxide emitters to pay forestland owners to store carbon in trees and soil, as demonstrated in California. But the price of carbon will probably have to exceed $7 or more a ton and ideally will need to reach $14 a ton in order to induce emitters to purchase a significant number of carbon credits and to compel forestland owners to offer to sell large amounts of credits. But to achieve a high level of credit sales, there will need to be major long-term funding sources to purchase conservation easements on millions of acres of forestland, along with more professional foresters to draft forest management plans, especially for non-industrial forests.

A major obstacle to ensuring net gains from forest carbon sequestration credits is the fact that forestland zoning is not widely used in the United States. Thus, even if some forestland is preserved and generates carbon credits, other forests will be converted to residential and commercial uses thus reducing the net storage of carbon. Another obstacle that has kept forestland owners from selling carbon credits is the lengthening of the timing of timber harvests that would be required to maximize carbon storage in trees. A national cap-and-trade system with carbon credits from forests is under debate in Congress and could provide capital for permanent forest conservation easements as well as a stream of annual income for timber companies and other forest landowners to compensate them for the longer harvesting cycles.

Planners can promote net forest carbon sequestration by working with cities and suburbs to adopt comprehensive plans that designate urban and suburban infill areas for new development along with afforestation projects and tree retention ordinances. In rural areas, planners can try to promote restrictive forestland zoning to minimize the conversion of forestlands to other uses and thus minimize leakage from forest carbon sequestration projects. Collaborative planning and funding for conservation easements between government agencies and private land trusts will be important for limiting forestland conversion, establishing eligible forestlands for generating carbon credits in cap-and-trade programs, and monitoring forestlands to verify that carbon sequestration gains are occurring.

References

Bailey, E. (2009, September 25). New california rules allow timber firms to sell carbon credits. *Los Angeles Times*. http://articles.latimes.com/2009/sep/25/local/me-logging25.

Birdsey, R. (1996). Regional estimates of timber volume and forest carbon for fully stocked timberland, average management after final clearcut harvest," in R. Sampson & D. Hair (Eds.), *Forests and global change,* vol. 2, *Forest management opportunities for mitigating carbon emissions* (pp. 309-334). Washington, D.C.: American Forests.

Birdsey, R., Pregitzer, K., & Lucier, A. (2006). Forest carbon management in the united states: 1600-2100. *Journal of Environmental Quality, 35*, 1461-1469.

Bourne, J., Jr. (2009). Redwoods: The super trees. *National Geographic*, *216* (4), 49.

Burgert, P. (2008) RGGI results due monday: Are regional initiatives ushering in the forestry age? Forest Carbon Portal, http://www.forestcarbonportal.com/article.php?item=30, Accessed, November 20, 2009.

California Air Resources Board. (2009a). Preliminary draft regulation for california cap-and-trade program. Sacramento, CA: California Air Resources Board.

California Air Resources Board. (2009b). Assembly bill 32: Global warming solutions act, http://www.arb.ca.gov/cc/ab32/ab32.htm, Accessed, October 26, 2009.

California Air Resources Board. (2010). Senate bill 375 implementation. http://www.arb.ca.gov/cc/sb375/sb375.htm, Accessed, April 16, 2010.

California Climate Action Registry. (2009). http://www.climateregistry.org, Accessed July 3, 2009.

Congressional Budget Office. (2007). The potential for carbon sequestration in the united states. Washington, D.C: The Congress of the United States, Congressional Budget Office.

Daniels, T. (2006). Land preservation in new york, new jersey, and pennsylvania: Strategy, funding, and cooperation are key," in K. Goldfeld (Ed.), *The race for space: The politics and economics of state open space programs* (pp. 9-24). Princeton, N.J.: Princeton University, Woodrow Wilson School.

Daniels, T., & Daniels, K. (2003). *The environmental planning handbook for sustainable communities and regions*. Chicago: APA Planners Press.

Gentry, B. (2009). Stormy seas: Land trusts navigate the uncertainties surrounding climate change. *Saving Land, 28* (2), 14-17.

Gore, A. (2009). *Our choice: A plan to solve the climate crisis*. Emmaus, PA: Rodale Press.

Green Mountain Energy. (2009). http://www.begreennow.com/store/home.php?cat=265, Accessed July 15, 2009.

Ingerson, A. (2007). U.S. forest carbon and climate change. Washington, D.C.: The Wilderness Society.

Jacobs, H. (1999). State property rights laws. Cambridge: MA: Lincoln Institute of Land Policy.

Kollmuss, A., Zink, H., & Polycarp, C. (2008). Making sense of the voluntary carbon market: A comparison of carbon offset standards. Frankfurt, Germany: WWF Germany.

Land Trust Alliance. (2009). Land trust directory. http://www.ltanet.org/landtrustdirectory/, Accessed, July 14, 2009.

Linder, M. (2000). Developing adaptive forest management strategies to cope with climate change. *Tree Physiology 20*(5-6):299-307.

Little, C. (1997). *The dying of the trees*. New York: Penguin Books.

Maine State Planning Office. (2009). New state registry for all conservation easements held in the state of maine. Augusta, ME: Maine State Planning Office, http://www.maine.gov/spo/lmf/docs/easementregistryintroductionforLMFwebsite.pdf, Accessed April 16, 2010.

McCord, M. (2009, September 20). RGGI: Quietly setting a standard: 10-state alliance promotes energy efficiency. news@seacoastonline.com, Accessed December 7, 2009.

Midwestern Greenhouse Gas Reduction Accord. (2009). Advisory group draft recommendations. Washington, D.C.: Midwestern Greenhouse Gas Reduction Accord.

Millar, C., Stephenson, N., & Stephens, S. (2007). Climate change and forests of the future. *Ecological Applications, 17*(8), 2145–2151

Mufson, S., Fahrenhold, D., & Kane, P. (2009, June 27). In close vote, house passes climate bill. *The Washington Post*, pp. A1, A 4.

Myers, E. (2007). Policies to reduce emissions from deforestation (redd) in tropical forests: An examination of the issues facing the incorporation of redd into market-based climate policies. Washington, D.C.: Resources for the Future.

New England Forestry Foundation. (2009). The pingree forest partnership. http://www.newenglandforestry.org/projects/pingree.asp, Accessed, July 8, 2009.

Netherlands Environmental Assessment Agency. (2008). China contributing two thirds to increase in CO2 emissions. Press release, June 13, 2008. Bilthoven, Netherlands: Netherlands Environmental Assessment Agency.

New York City. (2008). PlaNYC: A greater, greener new york. New York, NY: The City of New York.

Nowak, D. & Crane, D. (2002). Carbon storage and sequestration by urban trees in the usa. *Environmental Pollution, 116*, 381–389.

Pacific Forest Trust. (2008). Van eck forest project co_2 emissions reductions– questions and answers. San Francisco: Pacific Forest Trust.

Pacific Forest Trust. (2009). No net loss. *Forest Life*. Summer 2009, p. 4.

Perschel, R., Evans, A., & Summers, M. (2007) Climate change, carbon, and the forests of the northeast. Santa Fe: Forest Guild.

Pew Center for Global Climate Change. (2007) Coal and climate change facts. http://pewclimate.org/global-warming-basics/coalfacts.cfm, Accessed, November 17, 2009.

Regional Greenhouse Gas Initiative. (2009). www.rggi.org, Accessed December, 13 2009.

Row, C. (1996). Effects of select forest management options on carbon storage," in R. Sampson & D. Hair (Eds.), *Forests and global change,* vol. 2, *Forest management opportunities for mitigating carbon emissions* (pp. 59-90). Washington, D.C.: American Forests.

Sampson, R. (2002). Forestry and carbon sequestration. Paper presented at the Annual Meeting of the Association of Consulting Foresters, San Antonio, TX, July 1, 2002.

Skog, K. & Nicholson, G. (1998). Carbon cycling through wood products: The role of wood and paper products in carbon sequestration. *Forest Products Journal, 48*(7/8), 75-83.

Smith, G., Lazarus, M., Lee, C., Todd, K., & Weitz, M. (2009) EPA road-testing of afforestation project methodologies, epri ghg emissions offset policy dialogue: Workshop 6 July 30, 2009. Stockholm: Stockholm Environment Institute.

Smith, W., Miles, P., Vissage, J., & Pugh, S., (2002) Forest resources of the united states, 2002. A technical document supporting the usda forest service 2005 update of the rpa assessment. St. Paul, MN: U.S. Forest Service North Central Research Station.

Sohngen. B., Walker, S. Brown, S. & Grimland, S. (2007). Terrestrial carbon sequestration in the northeast quantities and costs: Part 4 opportunities for improving carbon storage and management on forest lands. Arlington, VA: The Nature Conservancy Conservation Partnership Agreement.

Stern, N. (2006). *The economics of climate change: The stern report*. Cambridge, UK: Cambridge University Press.

Stavins, R. & Richards, K. (2005). The cost of us forest-based carbon sequestration. Arlington, VA: Pew Center on Global Climate Change.

Stockholm Environment Institute. (2009). Carbon credit in glossary. http://www.co2offsetresearch.org/policy/CapAndTrade.html, accessed February 9, 2010.

The Conservation Fund. (2009). Garcia river forest: A new future in carbon. http://www.conservationfund.org/west/california/garcia, Accessed July 14, 2009.

The Wilderness Society. (2009). National forests. http://wilderness.org/files/national-forests-CBB-09.pdf, Accessed, February 18, 2010.

Trust for Public Land. (2009a). TPL joins obama administration and senator leahy at forest legacy program announcement. Washington Watch, June 15, 2009. http://www.tpl.org/tier3_cd.cfm?content_item_id=23003&folder_id=2205#flp. Accessed, June 18, 2009.

Trust for Public Land. (2009b). Senate takes action on climate change legislation. Washington Watch, November 19, 2009. http://www.tpl.org/tier3_cd.cfm?content_item_id=23233&folder_id=2205#climate Accessed, November 25, 2009.

U.S. Environmental Protection Agency. (2005). Greenhouse gas mitigation potential in u.s. forestry and agriculture. Washington, D.C.: US EPA.

U.S. Environmental Protection Agency. (2007). Inventory of u.s. greenhouse gas emissions and sinks: 1990 – 2005. US EPA 430-R-07-002. Washington, DC: US EPA.

U.S. Environmental Protection Agency. (2009). Inventory of u.s. greenhouse gas emissions and sinks: 1990-2007. US EPA 430-R-09-004. Washington, DC: US EPA.

U.S. Forest Service. (2007). Northeastern area yearbook of the forest legacy program. Newtown Square, PA: U.S. Forest Service. http://na.fs.fed.us/pubs/legacy/yearbook/flp_yearbook_07.pdf, Accessed July 15, 2009.

Wayburn, L., (2009). The role of forests in u.s. climate policy. *Land Lines*, *21* (4): 2-7.

Wayburn, L., Franklin, J., Gordon, J., Binkley, C. Mladenoff, D., & Christensen Jr., N. (2007). Forest carbon in the united states: Opportunities and options for private lands. Santa Rosa, CA: Pacific Forest Trust.

Western Climate Initiative. (2009). www.westernclimateinitiative.org, Accessed, Feb. 15, 2010.

Yardley, **W.** (2009, November 29). Protecting the forests, and hoping for payback. *The New York Times*, p. 22.

Table 1. Forest Practices to Increase Carbon Sequestration

1. Planting trees on agricultural land.
2. Replanting trees on harvested or burned forestland.
3. Planting or expanding riparian forest buffers.
4. Modifying forest management practices to emphasize carbon storage, such as selective cutting and thinning of trees, maintaining stands of uneven aged trees, maintaining stocking of trees per acre, and maintaining species diversity in forests because the effects of climate change on any one species are uncertain (Linder, 2000).
5. Low-impact harvesting methods to decrease damage to soils and trees, and minimize carbon release, such as avoiding clear-cutting.
6. Lengthening the timber harvest rotation by more than five years and up to 40 years.
7. Preserving forestland from conversion to other land uses through permanent conservation easements.
8. Agro-forestry practices that combine the production of trees along with the production of crops and/or livestock.
9. Establishing of short-rotation woody biomass plantations, such as fast growing poplar.
10. Urban forestry: growth of trees and planting trees.
11. Disposing of wood products in landfills rather than through incineration; landfills significantly retard the decay of wood and release of carbon.
12. Producing structural lumber and furniture woods, which release carbon much more slowly than rather than paper or cardboard (Skog & Nicholson, 1998).
13. Protecting forestlands through forestland zoning.

Source: see, Stavins & Richards, 2005.

Table 2. Auctions of Carbon Dioxide Emission Allowances by RGGI, 2008-2010.

Year of Sale	Number of Allowances	Price Per Ton of Carbon Dioxide	Total Revenue
2008	12,565,387	$3.07	$38,575,738
2008	31,505,898	$3.38	$106,489,930
2009	31,513,765	$3.51	$110,613,310
2009	2,175,513 (for 2012)	$3.05	$6,635,315
2009	30,800,000	$3.23	$99,484,000
2009	2,170,000 (for 2012)	$2.06	$4,470,200
2009	28,408,945	$2.19	$62,215,589
2009	2,172,540 (for 2012)	$1.87	$4,062,650
2009	28,591,698	$2.05	$58,612,980
2009	1,599,000 (for 2012)	$1.86	$2,974,140
2010	40,612,408	$2.07	$84,067,684
2010	2,137,992 (for 2012)	$1.86	$3,976,665
TOTAL	214,153,146	$2.72	$582,178,201

Note: An allowance is the right to emit one ton of carbon dioxide.

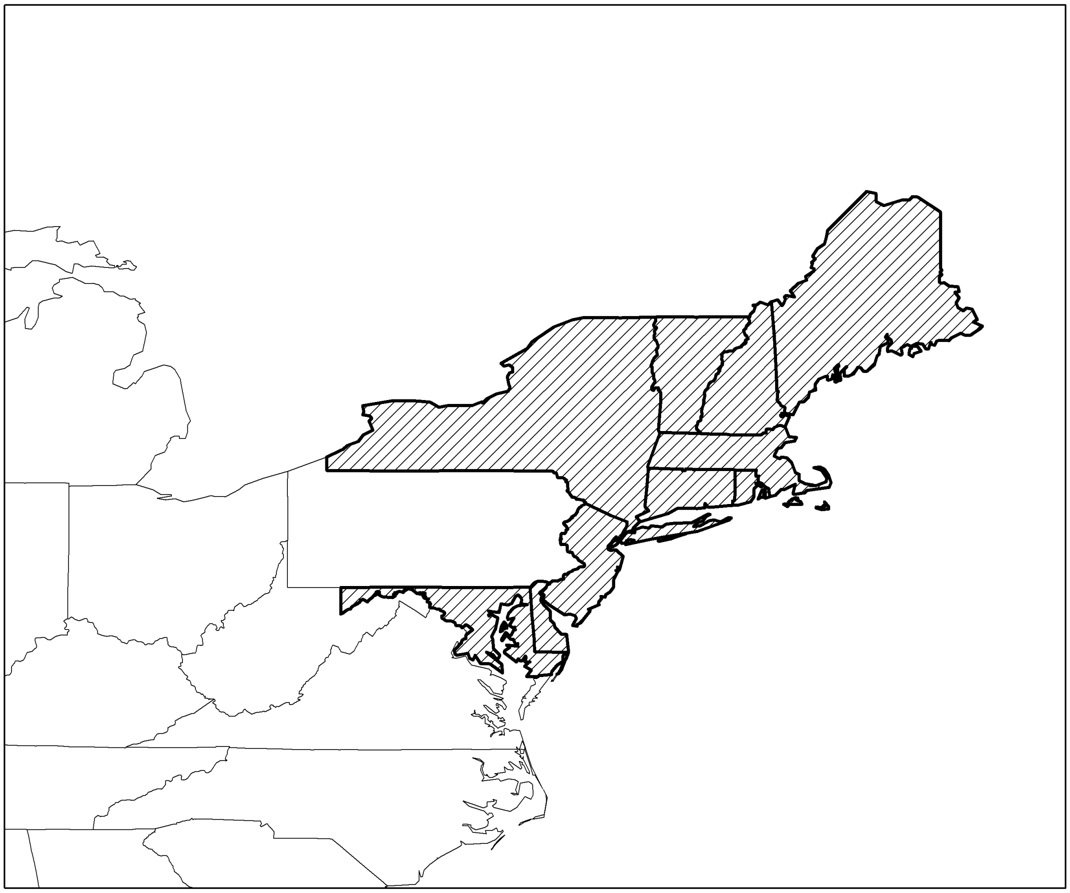
Source: Regional Greenhouse Gas Initiative http://www.rggi.org/co2-auctions/results

Table 3. Total Land Area, Forested Acreage, Public Forest Acreage, and Forest Acreage under a Conservation Easement in the Ten States in the Northeastern United States.

State	Total Land Area	Total Forested Acreage	Forest Acreage in Public Ownership	Forest Acreage Under a Conservation Easement
Connecticut	3,101,000	1,859,000	315,000	8,347
Delaware	1,251,000	383,000	32,000	1,684
Maine	19,753,000	17,699,000	970,000	1,829,300
Maryland	6,295,000	2,566,000	609,000	1,247
Massachusetts	5,016,000	3,126,000	743,000	9,200
New Hampshire	5,740,000	4,818,000	1,088,000	416,000
New Jersey	4,748,000	2,132,000	810,000	5,413
New York	30,223,000	18,432,000	3,977,000	842,000
Rhode Island	668,000	385,000	95,000	1,690
Vermont	5,920,000	4,618,000	754,000	199,938
TOTAL	82,715,000	56,018,000	9,392,000	3,314,819

Sources: Smith et al., 2002; Forest Society of Maine, New England Forestry Foundation, Society for the Protection of New Hampshire Forests, The Nature Conservancy, U.S. Forest Service Forest Legacy Program, Vermont Land Trust.

Figure 1. States Participating in the Regional Greenhouse Gas Initiative.



Notes:

[1] RGGI allows four types of carbon offsets in addition to afforestation. These include: Landfill methane capture and destruction; reduction in emissions of sulfur hexafluoride (SF6) in the electric power sector; reduction or avoidance of CO_2 emissions from natural gas, oil, or propane end-use combustion due to end-use energy efficiency in the building sector; and avoided methane emissions from agricultural manure management operations, (see, www.rggi.org).