U.S. Tree Planting for Carbon Sequestration

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Climate change is a growing concern for Congress. "Cap-and-trade" and carbon tax proposals have been suggested to limit and reduce domestic emissions of greenhouse gases, especially carbon dioxide (CO_2).[1] Most cap-and-trade proposals would establish limits on emissions from many economic sectors, while allowing "offsets"—reduced emissions or enhanced carbon sequestration—from uncapped sectors, such as forestry and agriculture.[2] Alternatively, carbon tax proposals might include tax expenditures or credits for such "offsets." In the 111th Congress, a discussion draft of possible legislation from Representatives Markey and Waxman would allow offsets for up to 2 billion metric tons of CO_2 emissions (or the equivalent thereof in other greenhouse gases), divided equally between domestic and international programs.[3] In addition, the draft includes discounting for offsets—1.25 offset tons are required for each ton of emission allowance. Thus, under the proposal, domestic CO_2 offsets would be about 1.25 billion tons.

Tree Planting

One of the widely discussed options for domestic CO_2 offsets is tree planting. Tree planting aims to establish stands of trees that can grow for anywhere from 20 to 2,000 years, depending on the species, location, and intent of the planting. Two terms are generally used for tree planting:

- reforestation, for planting trees or other activities to establish tree stands (such as assisting natural tree regeneration or preparing sites and sowing tree seeds) on areas recently cleared of forest through timber harvesting or natural disaster; and
- afforestation, for planting trees on sites that have long been cleared of forests, such as crop, pasture, and brush lands.[4]

As shown in **Table 1**, tree planting has greater carbon sequestration potential than other land use practices. Afforestation of crop or pasture land is estimated to have the potential to sequester between 2.2 and 9.5 metric tons of CO_2 per acre per year. Reforestation is estimated at 1.1 to 7.7 metric tons of CO_2 per acre per year. These estimates have a very wide range of possibilities because tree growth and forest soil carbon accumulation varies widely among species and locations.[5]

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[1] For information on such legislation in the 111th Congress, see CRS Report R40556, *Market-Based Greenhouse Gas Control: Selected Proposals in the 111th Congress*, by (name redacted), (name redacted), and (name redacted).

[2] For information on offsets generally, see CRS Report RL34436, *The Role of Offsets in a Greenhouse Gas Emissions Cap-and-Trade Program: Potential Benefits and Concerns*, by (name redacted).

[3] See Discussion Draft Summary, The American Clean Energy and Security Act of 2009, http://energycommerce.house.gov/Press_111/20090331/acesa_summary.pdf.

[4] There is no explicit time span to distinguish reforestation from afforestation, although tree planting within a decade of forest clearing is generally considered to be reforestation, and tree planting on sites clear of trees for at least a decade is generally considered to be afforestation.

[5] See CRS Report R40236, *Estimates of Carbon Mitigation Potential from Agricultural and Forestry Activities*, by (name redacted) et al.

Table 1. Estimated Sequestration Potential for Selected U.S. Land Use Practices

(in metric tons of CO_2 per acre per year)

Activity	EPA (2005)	USDA (2004)
Afforestation (previously cropland/pasture)	2.2 - 9.5	2.7 – 7.7
Reforestation	1.1 - 7.7	—
Riparian or conservation buffers (non-forest)	0.4 - 1.0	0.5 - 0.9
Reduced/conservation tillage	0.6 - 1.1	0.3 - 0.7
Grazing management	0.1 - 1.9	1.1 - 4.8

Sources: EPA: U.S. Environmental Protection Agency, Office of Atmospheric Programs, *Greenhouse Gas Mitigation Potential in U.S. forestry and Agriculture*, EPA 430-R-05-006, Washington, DC, November 2005, Table 2-1, http://www.epa.gov/sequestration/pdf/greenhousegas2005.pdf. **USDA:** Jan Lewandrowski, Mark Peters, and Carol Jones et al., *Economics of Sequestering Carbon in the U.S. Agricultural Sector*, USDA Economic Research Service, Technical Bulletin TB-1909, Washington, DC, April 2004, Table 2.2, http://www.ers.usda.gov/Publications/TB1909/.

Land Requirements

Because of its greater sequestration potential and various aspects of measuring and monitoring performance, afforestation is a widely discussed option for providing domestic CO_2 offsets. Based on the estimates in **Table 1**, achieving annual carbon sequestration offsets of a hypothetical 1 billion metric tons of CO_2 (near the target identified in the Markey-Waxman draft) through tree planting would likely require between 105 and 455 million acres of afforestation. It should be recognized, however, that within this very broad range of estimates, there is substantial uncertainty over potential carbon sequestration from forestry activities.[6] In addition, other activities, including forest management and various agricultural practices (see **Table 1**), likely could be used for domestic CO_2 offsets.

The land needed to fulfill forest carbon sequestration of 1 billion metric tons of CO_2—more than 100 million acres (as a low estimate)—would represent a substantial shift in land use in the United States. The USDA Natural Resources Conservation Service reported that there were about 1.8 billion acres of undeveloped land in the continental United States in 2003, including 368 million acres of cropland, 117 million acres of pastureland, 405 million acres of private rangeland, 406 million acres of private forestland, and 402 million acres of federal land.[7] It should be recognized that some of these undeveloped lands, particularly rangelands, are arid (desert) and may be incapable of sustaining forest cover, and thus impractical if not impossible for afforestation. While some afforestation could occur on federal lands, the low-end estimate of 100 million acres would be a 25% increase in total private forest land in the United States, with very significant decreases in cropland, pastureland, and private rangeland (11% in aggregate) through afforestation of these lands. At the high-end estimate, about a quarter of all undeveloped land would need to be afforested to sequester a billion tons of CO_2. The increasing interest in growing biofuels for energy production will only exacerbate the competition for land.

[6] See CRS Report RL31432, *Carbon Sequestration in Forests*, by (name redacted), and CRS Report RS22964, *Measuring and Monitoring Carbon in the Agricultural and Forestry Sectors*, by (name redacted) and (name redacted).

[7] USDA Natural Resources Conservation Service, *National Resources Inventory: 2003 Annual NRI*, http://www.nrcs.usda.gov/technical/NRI/2003/national_landuse.html.

Establishing forest stands on the scale needed to achieve a billion tons of CO_2 offsets would be a dramatic increase compared to recent activity. Forest Service reforestation efforts in 2007 totaled 73,921 acres. Two programs that provided and reported on assistance for private forest stand establishment were the Forestry Incentives Program (FIP) and the Stewardship Incentives Program (SIP), replaced by the now-defunct Federal Land Enhancement Program.[8] In 1994 (the last published report), FIP accomplishments included 188,017 acres of tree planting; the 2003 SIP accomplishments (the last published report) included 3,144 acres of tree planting. The last report on tree planting on all lands in the United States (1997) showed 2.6 million acres planted in 1997.[9] The peak in tree planting—nearly 3.4 million acres—occurred in 1988. This was partly due to tree planting under the Conservation Reserve Program (CRP), the largest federal tree planting program in U.S. history, with 2.2 million acres of trees on the 33.7 million CRP acres under contract.[10] It is unclear whether the reported planting is reforestation or afforestation (i.e., whether it represents a net increase in forest area). Even if tree planting has increased significantly in the past 12 years, afforestation of 100 million acres even spread over a decade would be a huge increase in tree planting. Thus, it is unclear whether the historic costs of treatments would be applicable; the unit (per acre) costs for such an increase in effort could also increase substantially as the more desirable areas are afforested.

Potential Cost

The potential costs—and benefits—of such an afforestation program are both large and highly uncertain. Afforestation costs are not widely available. One study estimated *reforestation* costs following a severe fire in western Oregon in 2002 as ranging from $250 to $2,000 per acre, depending on the aspect of the terrain and the time lag between the fire and the reforestation efforts (with delays increasing reforestation costs).[11] These data are consistent with the average cost of establishing forest vegetation—$523 per acre—for the national forests in FY2007.[12] Afforestation costs are likely to be significantly lower on private lands, in part because of their location. (National forests are located predominately in the West and on more rugged terrain than private forests.) Still, at perhaps $200 per acre for afforestation, the low-end estimate of 100 million acres of forest stand establishment would cost about $20 billion. The other extreme—the high-end estimate of 450 million acres at $2,000 per acre—would cost about $900 billion.

It is also possible to examine costs from a carbon price perspective. If afforestation costs $200 per acre and yields 9.5 metric tons per acre per year, carbon offsets through afforestation would be profitable if carbon prices were $21 per ton. Alternatively, if the yield were only 2.2 tons per acre per year, carbon prices would need to exceed $91 per ton for carbon offsets through afforestation

[8] FIP was created in the Cooperative Forestry Assistance Act of 1978 (P.L. 95-313, 16 U.S.C. §2101, et seq.). SIP was added to that act in the 1990 farm bill (P.L. 101-624). Both were replaced by the Federal Land Enhancement Program (FLEP), created in the 2002 farm bill (P.L. 107-171), but no reports were published on FLEP accomplishments. About half of the FLEP funding was directed to other purposes, and the program expired and was not renewed in the 2008 farm bill.

[9] Robert J. Moulton, "Tree Planting in the United States-1997," *Tree Planters' Notes*, USDA Forest Service, vol. 49, no. 1 (1999), pp. 5-11.

[10] USDA Farm Service Agency, *Conservation Reserve Program: Monthly Summary—March 2009*, Washington, DC, http://www.fsa.usda.gov/Internet/FSA_File/mar2009.pdf.

[11] John Sessions, Pete Bettinger, and Robert Buckman et al., "Hastening the Return of Complex Forests Following Fire: The Consequences of Delay," *Journal of Forestry*, vol. 102, no. 3 (Apr/May 2004), pp. 38-45.

[12] USDA Forest Service, *Fiscal Year 2009 Budget Justification*, pp. 8-28 to 8-30.

to be profitable. Thus, the profitability of afforestation for carbon offsets depends greatly on how efficient the particular lands are at sequestering carbon, as well as on carbon prices.[13]

The *federal* cost for afforestation could be substantially less. Most private lands are reforested or afforested with little or no federal assistance, because of the expected returns to the landowner from future timber sales and/or other often non-financial benefits, such as scenery, wildlife, and recreational opportunities. Nonetheless, federal funds have been used to assist forest stand establishment, in part because of the public benefits of forests, such as clean water and wildlife habitat. Two programs identified above, FIP and SIP, provided some relevant information. The last published report on FIP accomplishments (1994) showed average federal assistance for tree planting of $57.77 per acre (nearly $84 per acre in 2008 dollars, adjusted for inflation).[14] The last published report on SIP accomplishments (2003) showed average federal assistance for tree planting of $87.15 per acre ($102 per acre in 2008 dollars, adjusted for inflation).[15] Thus, federal cost-share assistance for private efforts might be only half of the total cost of afforestation—$100 per acre, or about $10 billion for the low-end estimate of 100 million acres of private forest stand establishment or about $450 billion for the high-end estimate. The acres reforested under these programs, however, may have been the relatively easy, low-cost acres for treatment, and thus unit costs for a larger scale program might be higher.

Additional Considerations for Congress

The scale and cost of an afforestation program to provide a billion tons of carbon offsets are substantial. Several additional factors should also be recognized, including natural hazards to forests, the timing of forest carbon sequestration, the impacts of significant shifts in land use, and the capacity to achieve an afforestation program of this magnitude.

Forests face various natural risks—wildfires, insects, diseases, severe storms, etc.—that kill trees, releasing significant amounts of carbon. This is a concern for the permanence of forest carbon offsets.[16] An unknown, but probably significant, amount of current reforestation is to establish forests on lands cleared by such natural catastrophes. It is unknown how much additional reforestation or afforestation might be needed to offset the additional carbon releases from natural disasters affecting existing and newly established forests, as well as from the effects of climate change on forests.

In addition, for carbon offsets, credit is only earned when the carbon is sequestered. Carbon accumulation in forests probably parallels woody biomass growth. Tree growth curves are generally S-shaped, with slow accumulation in the early years, increasing as the trees get well established, and reaching a peak (termed culmination of mean annual increment by foresters), with growth then slowing. A typical growth pattern is shown in **Figure 1**. There are substantial

[13] See CRS Report RL34560, *Forest Carbon Markets: Potential and Drawbacks*, by (name redacted) and (name redact ed).

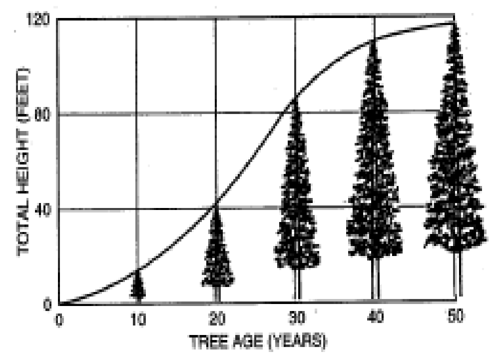
[14] USDA Consolidated Farm Service Agency, *Forestry Incentives Program: From Inception of the Program Through 1994 Fiscal Year*, January 1995, 44 p.

[15] USDA Farm Service Agency, *Stewardship Incentives Program: 2003 Fiscal Year Statistical Summary*, March 2004, 18 p.

[16] See CRS Report RS22964, *Measuring and Monitoring Carbon in the Agricultural and Forestry Sectors*, by (name re dacted) and (name redacted).

variations and uncertainties in the exact shape of the curve. Carbon accumulation in the early years is slow and increases during the strong growth period; whether carbon accumulation continues or peaks when net additional wood growth is minimal (in "old-growth" forests) is disputed. The shape of the curve undoubtedly varies among tree species and locations; for example, the culmination of mean annual increment occurs at about 20 years on many Southern pine sites (about 28 years in **Figure 1**), but may be at 60 years or more for many Douglas fir sites on the Pacific Coast.

Figure 1. Tree Growth Patterns



Source: Thomas Eugene Avery and Harold E. Burkhart, *Forest Measurements*, 5th ed. (Boston: McGraw-Hill, 2002), p. 338.

Another consideration is that a shift of more than 10% of cropland, pastureland, and rangeland into forests could also have a significant impact on the agricultural production from these lands. It is unclear which lands would most likely be afforested, but significant changes in land use would almost certainly lead to significant changes in outputs, and declines in traditional crop and livestock production could lead to higher consumer costs for these commodities as producers compete for the remaining lands. How much land might actually be shifted into forests, and the impacts of such shifts on agricultural commodity prices, are beyond the scope of this brief analysis. Nonetheless, these and other opportunity costs of a significant change in land use could have substantial impacts on landowners, consumers, and taxpayers.

Finally, it is unclear that the nursery capacity exists to produce enough seedlings to reforest or afforest 100 million acres. Spread over 10 years, such a program would still be roughly triple the highest level of reforestation reported in the United States. This capacity limitation, combined with the time delay in carbon sequestration by forests, may prevent afforestation/reforestation programs from providing significant carbon offsets in the near term. Nonetheless, forest carbon offsets through reforestation and afforestation could contribute to a domestic CO_2 control and reduction program.

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