United States
Environmental Protection
Agency
Research and Development

Air and Energy Engineering
Research Laboratory
Research Triangle Park, NC 27711
EPA/600/S7/91/003 Apr. 1991

EPA

Project Summary

Global Warming Mitigation Potential of Three Tree Plantation Scenarios

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Increasing concentrations of carbon dioxide (CO_2) and other radiatively-important trace gases (RITGs) are of concern due to their potential to alter the Earth's climate. Some scientists, after reviewing the results of general circulation models, predict rising average temperatures and alterations in the Earth's hydrologic cycle. While the debate continues over the actual magnitude of global warming, most scientists agree that some change will occur over the next century. This places a burden on policymakers to address global warming and to develop mitigation measures. To support the decision-making process, the U.S. EPA's Air and Energy Engineering Research Laboratory (AEERL) is providing technical analyses of a variety of global warming mitigation measures. This study analyzed alternative uses of forests in the U.S. to reduce atmospheric CO_2 concentrations.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project report ordering information at back.)

Introduction

Since forests provide a sink for carbon by fixing carbon dioxide (CO_2) to produce biomass, halting deforestation and creating new forests have been proposed as means of slowing the buildup of carbon in the atmosphere. However, using trees to scrub CO_2 from the atmosphere is a near-term solution. During the early, high-growth phase of life, a forest serves as a carbon sink. Eventually, the rate of growth slows, and the death and decay of branches and leaves begins to offset the carbon sink effect. Finally, as trees die and decompose, much of the sequestered carbon returns to the atmosphere. An alternative is to harvest the trees periodically and replant. This maintains the forest in its active growth phase, maximizing the carbon uptake. In order for this to be effective, the harvested wood must be used in a way that conserves RITGs. If the wood is used for fuel (replacing fossil fuels) then, although CO_2 is released, no "new" CO_2 is added to the atmosphere. On the other hand, if it is used to make disposable paper products, the carbon will again be released into the atmosphere without offsetting other CO_2 sources. If the wood is used in a form that delays its eventual decay and release to the atmosphere, then some mitigative effect will be realized.

The purpose of this project was to analyze three reforestation scenarios that are potential global warming mitigation methods: (1) planting trees with no harvesting (NH), (2) traditional forestry (TF), and (3) short-rotation intensive culture (SRIC) of trees for biomass. In addition to the cycling of CO_2 through the trees, all other sources of CO_2 and other RITGs associated with site preparation, tree planting, harvesting, and other activities specific to each scenario also were estimated. The costs associated with each scenario were estimated, and the cost of using wood biomass as an alternative to fossil fuel was evaluated.

In this study, a common land base was used to evaluate the three scenarios. In both the NH and TF scenarios, trees are planted in plantations at densities that average 1,000 trees/ha. The SRIC scenario assumes an average density of 2100 trees/ha. The NH scenario assumes the tree plantations are never harvested, but are left to follow a natural successional pattern. Trees are harvested every 6-8 years under the SRIC scenario, compared to 35-80 year rotations under the TF scenario. Existing forest land was not included in the land base. The land base included only crop and pasture land in need of erosion control in the U. S. A total of 40.4 million hectares in 10 geographical regions was used for this study.

In the NH scenario, global warming is mitigated by sequestering carbon in growing trees. In an actively growing forest, carbon (as CO_2) is removed from the atmosphere at a much higher rate than it is released (as CO_2 or methane) by decomposition. After some period of time, the growth rate slows, dead biomass accumulates, and decomposition processes become more predominant. For this study, it was assumed that a steady-state carbon balance (i.e., no net flux) is reached at maturity. The length of one rotation in traditional forestry was assumed to represent the period of active growth. Therefore, in the NH scenario, carbon is sequestered for a period of time equal to the length of one TF rotation for the region.

The TF scenario, in effect, extends the carbon sink indefinitely by maintaining the forest in the active growth phase. It is assumed that the wood is used in such a way that carbon is not immediately returned to the atmosphere. Yields were derived from published data and were assumed constant over time. These same yields were used for the NH scenario, but were assumed to apply only to the young, rapidly growing forest.

The Short Rotation Intensive Culture (SRIC) scenario assumes that trees are grown solely for the production of biomass. The biomass will be burned to produce electricity, replacing coal as a fuel. In this scenario, mitigation is achieved by the displacement of coal emissions. Although combustion of wood releases CO_2, it is fixed in new plantations, resulting in no net increase of CO_2 in the atmosphere. If it is assumed that coal would have been used to produce the same amount of electricity, then wood combustion actually results in negative CO_2 emissions. Yields were estimated for the next 20 years (near-term) and, assuming continued research, for 20 years and beyond (mid-term).

In order to compare the SRIC and TF scenarios better, the use of wood produced under TF conditions as a fuel was also analyzed. This is referred to as "TF burn." Again, it is assumed that the wood would be used in place of coal to produce electricity.

Air pollutants are emitted from forest management activities due to machine use, production and use of fertilizers and herbicides, and the end-use of forest products. Activities varied by scenario; for example, harvesting occurred more often in the SRIC scenario than in the TF scenario, and did not occur at all in the NH scenario.

Table 1 lists the forest management activities included in this analysis, and the pollutants emitted from these activities that were included in the analysis. A few emissions were not included because the data were inadequate to calculate a reliable emission factor.

Emissions Analysis Results

The annual emissions for each scenario are shown in Table 2. The cumulative emissions are also shown for the years 2050 and 2100. The cumulative numbers were derived as follows:

- for SRIC, the near-term yields were assumed for the first 20 years, the mid-term yields thereafter;
- for TF and TF (burn), yields were assumed constant over time; and,
- for NH, TF yields were assumed through 2050, when carbon cycling was assumed to reach a steady-state. VOCs continue to be produced, however.

In Table 2, a negative number indicates a sink, a positive number indicates a source. Choosing the best mitigation scenario depends on the criteria used. If CO_2 reduction alone is considered, the SRIC scenario is clearly the most effective. This result is driven entirely by the high yields assumed for SRIC. Using TF-produced wood for combustion is not nearly as effective, but only because yields are lower.

The TF scenario does appear to be a good long-term solution if only CO_2 reduction is considered. However, the periodic harvesting and planting emissions result in greater emissions of CO, CH_4, NO_x, N_2O, and SO_2 for the TF scenario than for the NH. Since the first four are greenhouse gases with radiative forcing values higher than CO_2, the relative contribution of these emissions should not be ignored. Furthermore, SO_2 is a contributor to acid precipitation. Overall, the NH scenario may be a better choice for RITG reduction than the TF.

The SRIC and TF (burn) scenarios result in decreased CH_4, NO_x and SO_2 emissions. The last two are reduced because wood combustion releases somewhat less NO_x and significantly less SO_2 than coal combustion. The CH_4 reduction occurs because less coal has to be mined (methane is released when coal is mined).

All scenarios result in increased CO, VOC and N_2O. The increase in VOC comes almost entirely from the trees in the form of terpenes and isoprenes. The increase in CO is partly due to the combustion of diesel fuel in the machinery used for planting and harvesting, but is mostly attributable to wood combustion. In the two cases where wood replaces coal, a net increase in CO occurs because wood combustion produces relatively high amounts of CO. Also, prescribed burning in the TF scenario contributes some CO. N_2O is released due to the application and degradation of nitrogenous fertilizers.

Cost Analysis Results

To adjust for differences in the rotation length and annual yields between the investment scenarios, present net costs for each investment scenario were found and annualized over the investment's length. The method used to annualize the investments converted cash streams, which were variable over time, into even flow cash streams. The annualized values were then divided by the annual biomass yields to give the annualized cost of producing one Mg of biomass. These costs are reported in Table 3.

Management costs, including planting and harvest costs, for traditional forestry and no harvest scenarios were lower than for the SRIC scenario. This is countered by higher yields and shorter rotations for the SRIC scenario. Biomass can be grown more cheaply under the traditional forestry option in all Southeast regions, the North Central Lake States, and the Pacific Northwest. Growing biomass using SRIC technologies is competitive in the Pacific Northwest, the Northeast, and North Central Non-lake States. In the South Florida region, high land costs also favor SRIC forestry (although high land costs could lead to the elimination of forestry altogether). Higher annual expenditures in general tend to favor shorter rotations.

Additional CO_2 emissions savings can be obtained by using biomass instead of fossil fuels. Both electricity and ethanol can be produced using wood as the feedstock. These fuel costs are reported as a function of feedstock price. Given the unit costs of producing biomass under the scenarios, the viability of producing electricity and ethanol from wood was determined.

The costs of producing electricity from wood biomass are reported in Table 4. In order for biomass to be competitive with coal for producing electricity, the biomass must be available for less than $25.78/Mg. This occurs only in the Pacific Northwest.

Table 1. *Forest Management Activities and Pollutants Emitted*[a]

Activity	CO_2	CO	VOC	NO_x	CH_4	SO_x	N_2O
Planting	X	X	X	X		X	
Fertilizer Production	X			X			
Pesticide Production	X	X		X		X	
Fertilizer Use							X
Hydrocarbons Emitted from Trees			X				
Prescribed Burning	X	X	X	X	X		
Harvesting	X	X	X	X		X	
Wood Transportation	X	X	X	X			
Wood Combustion	X	X		X			
Coal Mining (Displacement)					X		
Coal Transportation (Displacement)	X	X	X	X			
Coal Combustion (Displacement)	X	X		X		X	

[a] Only those pollutants and activities quantified in this study are shown.

Table 2. *Summary of Reforestation Scenarios: Emissions*

Scenario	CO_2	CO	VOC	CH_4	NO_x	N_2O	SO_2
			Total Annual Emissions (1000 Mg/Yr)				
SRIC							
Near-term	-980000	2006.4	8037.9	-2867.0	-1004.1	0.7	-4865.5
Mid-term	-1700000	3045.7	8005.3	-5038.4	-1720.3	0.7	-8275.5
TF	-210000	2376.9	7884.5	104.0	63.1	0.3	1.4
TF(burn)	-90000	2597.8	7873.8	-240.7	-81.2	0.3	-566.9
NH	-260000	0.2	7740.1	--	1.5	0.3	1.0
			Total Emissions by Year 2050 (1000 Mg)				
SRIC	-8.8E+07	176356	480990	-258876	-8894	42	-428330
TF	-1.3E+07	142614	473070	6240	3786	18	84
TF (burn)	-5400000	155868	472428	-14442	-4872	18	-34014
NH	-1.6E+07	12	464406	0	90	18	60
			Total Emissions by Year 2100 (1000 Mg)				
SRIC	-1.7E+08	346641	881255	-510796	-174909	77	-842105
TF	-2.3E+07	271459	867295	11440	6941	33	154
TF (burn)	-990000	285758	866118	-26477	-8932	33	-62359
NH	-1.6E+07	12	851411	0	90	18	60

Table 3. Anthropogenic Emissions from Tree Plantation Scenarios Expressed as Percentage of 1985 NAPAP Anthropogenic Emissions

Scenario	*CO*	*NO_x*	*SO_2*	*VOC*
SRIC				
Near-term	*3.62*	*-5.38*	*-23.21*	*-.23*
Mid-term	*6.14*	*-9.21*	*-39.47*	*-.39*
TF	*4.29*	*0.34*	*0.01*	*.72*
TF (burn)	*4.68*	*-0.43*	*-2.70*	*.67*
NH	*0.00*	*0.01*	*0.00*	*0*
*1985 NAPAP Annual Anthropogenic Emissions (1000 Mg/year)**	*55,460*	*18,670*	*20,960*	*20,084*

Table 4. Cost of Electricity Production from Wood Biomass (per MWh)

Region	*Near-term SRIC*	*Mid-term SRIC*	*Traditional Forestry*
South Florida	*$73.69*	*$61.45*	*$73.71*
Southeast Coast	*75.25*	*63.06*	*57.78*
Southeast Piedmont	*79.40*	*65.37*	*57.14*
Southeast Mountains	*82.18*	*66.97*	*58.65*
Northeast	*79.08*	*68.62*	*84.45*
North Central Lake States	*76.44*	*66.78*	*59.53*
North Central Non-Lake States	*71.58*	*64.14*	*72.88*
South Central Plains	*85.57*	*71.73*	___*
Pacific Northwest-West	*71.70*	*62.32*	*37.77*
Pacific Northwest-East	*80.87*	*71.70*	*106.56*

**Yields projected to be obtainable in 20 years.*

However, as the technology of wood fired power plants improves, the economics of producing electricity from wood biomass are likely to improve as well. If credits are given to utilities for using wood instead of coal, the economics could improve further.

Two methods of producing ethanol from wood biomass were examined. The costs of these methods were compared to those for producing ethanol from corn. For both of the wood based systems, the capital costs and non-feedstock operating costs were too high to make them competitive with ethanol produced from corn.

On a per acre basis, growing biomass using traditional forestry methods appears to be cheaper than SRIC methods. However, the total potential productivity of the land is much higher for SRIC. Because of this high productivity, SRIC appears to be the best choice for mitigating emissions of greenhouse gases. However, if a variety of other factors are considered, the "best" mitigation method is likely to be a composite scenario with different methods implemented in different regions.

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Christopher D. Geroni *is the EPA Project Officer (see below).*

The complete report, entitled "Global Warming Mitigation Potential of Three Tree Plantation Scenarios," (Order No. PB91-159 608/AS; Cost: $17.00, subject to change) will be available only from:

National Technical Information Service
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