Carbon Emissions and Sequestration from Fertilization of Pine in the Southeastern United States:

Timothy J. Albaugh, Eric D. Vance, Caroline Gaudreault, Thomas R. Fox, H. Lee Allen,

Jose L. Stape, and Rafael A. Rubilar

Forest Science, 58(5) 419-429, 2012

An analysis based on Critical Thinking: Concepts and Tools

Richard Venditti

Abstract: We estimated net carbon emission and sequestration directly attributable to common forest fertilization practices for pine plantations in the southeast United States. We used data from the literature to estimate the carbon emissions associated with the production, transportation, and application of fertilizers used for mid-rotation and early rotation applications as well as the stem wood growth response to these applications. These data were scaled to a regional basis with data from the literature and newly acquired fertilizer application information. Product disposition projections were completed through 125 years (five 25-year rotations). On average, application of nitrogen with 28 kg of elemental phosphorus ha^{-1} to mid-rotation stands sequestered 19.2 Mg ha^{-1} carbon dioxide (CO_2) equivalents as additional stem growth per CO_2 equivalent of emissions associated with the fertilizer application. Maximum combined emissions from forest fertilization were 0.34 Tg $year^{-1}$ CO_2 equivalents in 2002, whereas maximum sequestration was 8.70 Tg $year^{-1}$ CO_2 equivalents in 2007. Sequestration lagged emissions because of the long (up to rotation length) stem wood growth response period. After 100 years, approximately 38% of the CO_2 equivalent sequestration attributed to mid-rotation fertilization would still be in use or in a landfill, whereas 26% would have been emitted without capturing energy and 36% would have been used as an energy source. Carbon sequestration associated with forest fertilization was related to the area fertilized annually, which may have fluctuated with fertilizer material and wood product prices. Capturing economic value from the sequestered carbon would likely increase forest fertilization and consequently increase carbon sequestration. FOR. SCI. 58(5):419–429.

Keywords: nitrogen, phosphorus, nutrition

1. Purpose and Goal

- Determine whether fertilization of southern pines is beneficial wrt GHG mitigations.
- Consider
  - Fertilizer manufacturing, transport and application emissions
  - Carbon sequestration from plant growth

2. Fundamental Question:

- Does increased carbon sequestration overweigh GHG emissions from fertilizer production, transport and application?

- Related question: Does disposition of the products impact this discussion?

3. Information

- We used data from the literature (1) to estimate carbon emissions for fertilizer material production, transport, and application, (2) to estimate stem growth response to fertilization, (3) to calculate disposition of products made from stem growth fertilizer response, and (4) to scale stand data to a regional basis using fertilizer application survey data.

- We collected additional fertilizer application data to update those available in the literature. Forest Nutrition Cooperated member surveys from 1969-1999, 100% member participation. Covered entire Southeast.

- We used an expert system and growth-and-yield model to allocate the incremental growth response to product categories (sawlog or pulpwood).

- EcoInvent: GHG emissions of fertilizer, transport and synthesis
- NREL and DOT: transport from warehouse to forest
- Literature for aerial application of fertilizer

Information

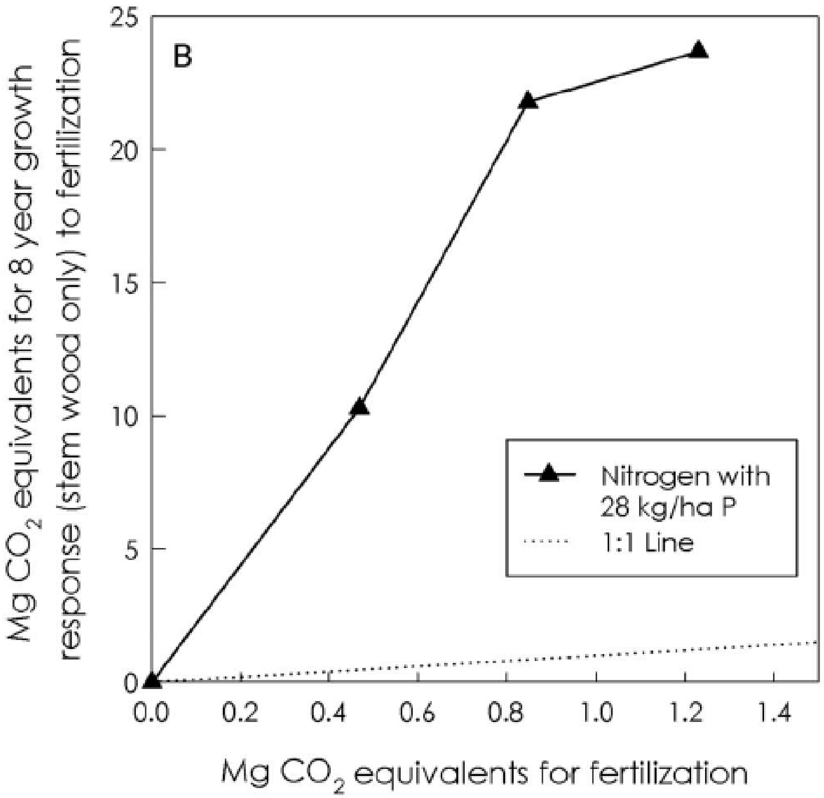
Table 1. Factors used to convert fertilizer manufacturing, transport and application and stem growth to common units.

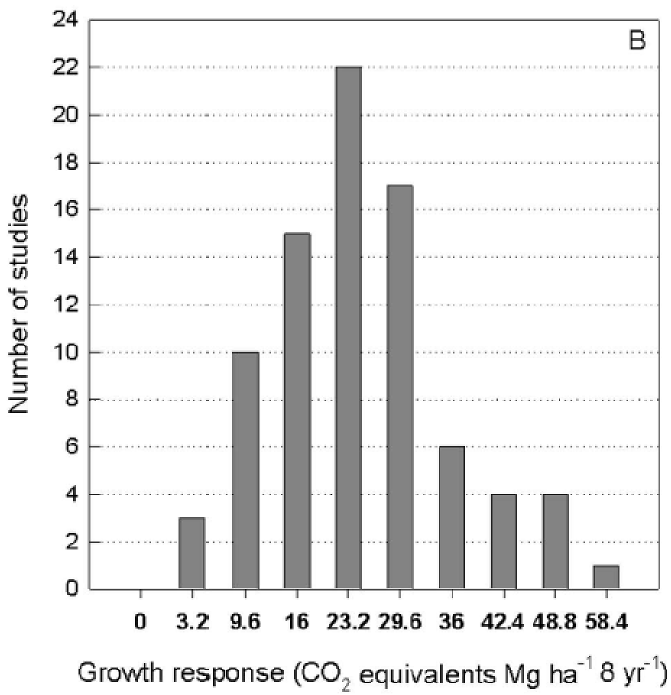
Factor	Units	Amount	Citation
Production of DAP (phosphorus)	kg CO_2 Eq dry kg $P_2O_5^{-1}$	1.433	Modified from Nemecek and Kägi 2007
Production of DAP (nitrogen)	kg CO_2 Eq dry kg N^{-1}	2.527	Modified from Nemecek and Kägi 2007
Production of TSP (phosphorus)	kg CO_2 Eq dry kg $P_2O_5^{-1}$	1.855	Modified from Nemecek and Kägi 2007
Production of urea (nitrogen)	kg CO_2 Eq dry kg N^{-1}	3.127	Modified from Nemecek and Kägi 2007
Transportation (for all materials)	kg CO_2 Eq dry kg material^{-1}	0.0208	National Renewable Energy Laboratory 2011, US Departments of Transportation and Commerce 2010
Aerial application (for all materials)	kg CO_2 Eq dry kg material^{-1}	0.104	US Department of Energy 2006, Payne's Flying Service, Brandon, MS, pers. comm., Oct. 17, 2007
Carbon in biomass	kg C kg dry mass^{-1}	0.5	Intergovernmental Panel on Climate Change 2006
Carbon conversion to CO_2 equivalents	kg CO_2 Eq kg carbon^{-1}	3.667	US Environmental Protection Agency 2005
Elemental phosphorus in DAP	kg elemental P kg DAP^{-1}	0.2	
Elemental nitrogen in DAP	kg elemental N kg DAP^{-1}	0.18	
Elemental phosphorus in TSP	kg elemental P kg TSP^{-1}	0.2	
Elemental nitrogen in urea	kg elemental N kg urea^{-1}	0.46	

420 *Forest Science* 58(5) 2012

Information

- Fertilizer emissions 92-96% of the fertilization emissions: key step in the emissions

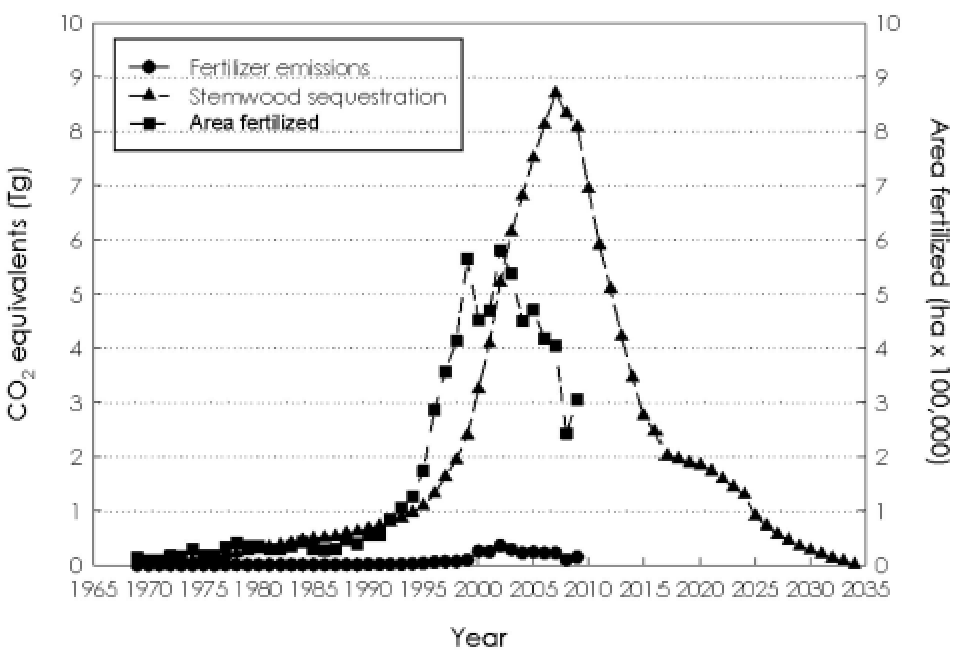




the fertilizer application of 224 and 28 kg elemental nitrogen and phosphorus ha-1 applied as urea and diammonium phosphate, respectively, emitted 0.85 Mg CO2 equivalents ha-1. Mg=tonne

4. Inference:

- On average, carbon sequestration in stem wood growth response to fertilization far exceeded (8.70 versus 0.36 Tg year-1 CO2 equivalents for sequestration and emission, respectively) the emissions associated with fertilizer production, transport, and application for typical forest fertilization practices in the southeastern United States (Figure 5).



5. Point of view:

- Authors were interested in GHG emissions of wood growth and fertilizer
  - Foresters
  - Land owners
  - Forestry Industry
  - Researchers in forestry management

Manuscript received April 28, 2011; accepted November 22, 2011; published online February 23, 2012; http://dx.doi.org/10.5849/forsci.11-050.

Timothy J. Albaugh, North Carolina State University, Forest Nutrition Cooperative, Raleigh, NC 27695-8008—Phone: (919) 513-4048; Fax: (919) 515-6193; tim_albaugh@ncsu.edu. Eric D. Vance, National Council for Air and Stream Improvement, Inc. (NCASI)—EVance@NCASI.org. Caroline Gaudreault, NCASI—cgaudreault@NCASI.org. Thomas R. Fox, Virginia Polytechnic Institute and State University—trfox@vt.edu, H. Lee Allen, North Carolina State University—Lee_allen@ncsu.edu. Jose L. Stape, North Carolina State University—jlstape@ncsu.edu. Rafael A. Rubilar, Universidad de Concepción—mail: rrubilar@ncsfnc.cfr.ncsu.edu.

Acknowledgments: We gratefully acknowledge the support provided by the National Council for Air and Stream Improvement, the National Aeronautics and Space Administration Project, "Decision Support for Loblolly Pine Carbon Management," (grant NNS06AA576), the Department of Forestry and Environmental Resources at North Carolina State University, and members of the Forest Productivity Cooperative. The use of trade names in this article does not imply endorsement by the associated agencies of the products named or criticism of similar ones not mentioned.

5. Point of view:

Global Carbon Cycle

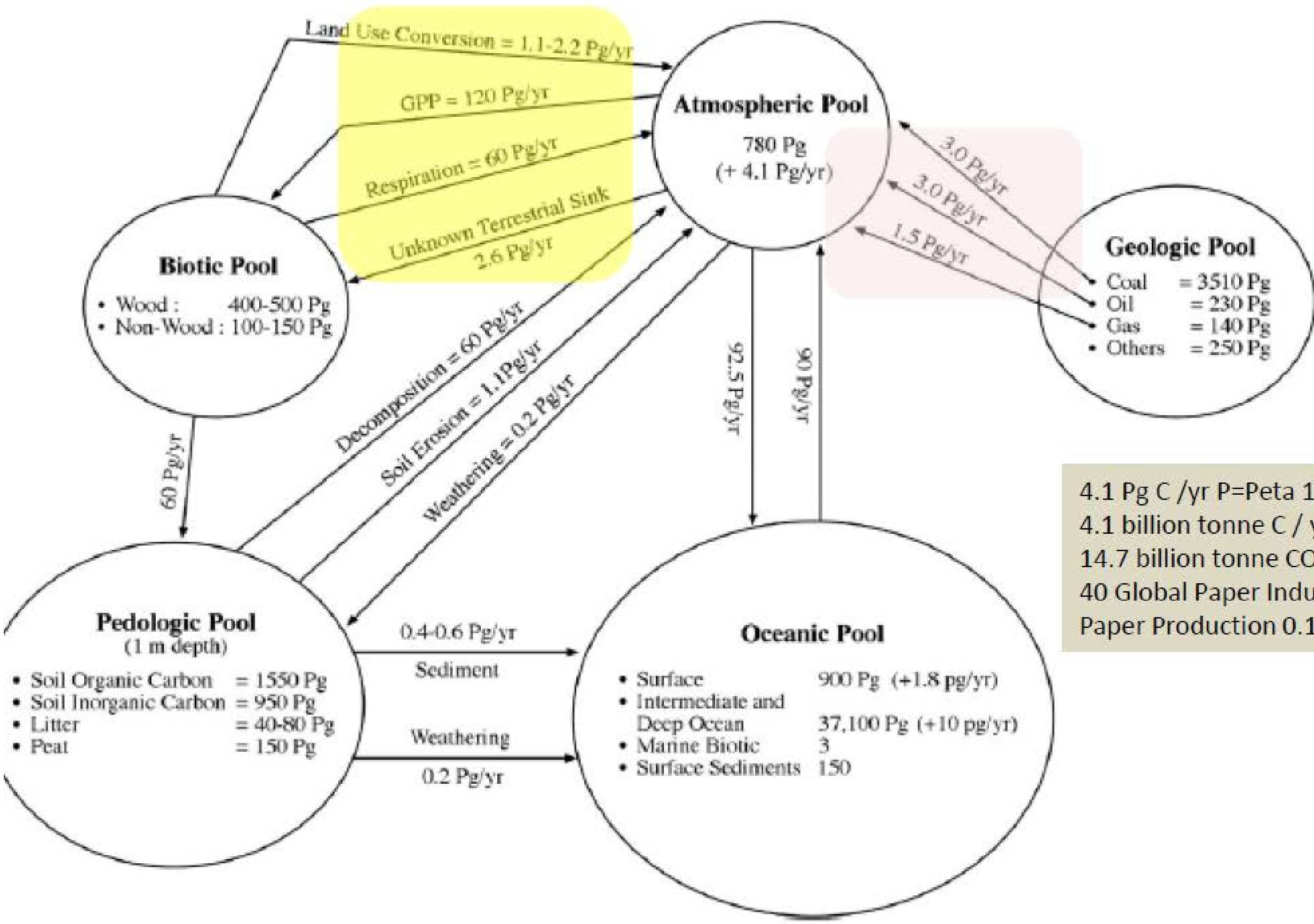


Fig. 1 Estimates of the global pools and fluxes between them.[1,4,5,7,152]

4.1 Pg C /yr P=Peta 10^15
4.1 billion tonne C / yr
14.7 billion tonne CO2 / yr
40 Global Paper Industries
Paper Production 0.15 billion tonne C/yr

M=10^6, G= 10^9, P=10^15, T=10^12, Energy Environment Science, 2008. go.ncsu.edu/venditti

5. Point of view:

- SOUTHEASTERN FORESTS IN THE UNITED STATES account for 16 and 60% of world and US timber production, respectively (Wear and Greis 2002).
- The portion of US timber production from Southern pine plantations has increased steadily in recent decades, at least in part due to increasingly intensive management and greater productivity (Prestemon and Abt 2002).
- In addition to their fiber production, estimated **net sequestration** from managed southern pine forests is **up to 210 Tg of carbon annually**, equivalent to 12% of annual US fossil fuel emissions (Johnsen et al. 2001b).
- Estimated productivity of today's intensively managed southern pine plantations is 12–18 Mg ha1 year1, compared with 2–7 Mg ha1 year1 for the naturally regenerated forests that preceded them (Stanturf et al. 2003; Cubbage et al. 2007).
- Eighteen percent of this increase in productivity is attributed to improved nutrition management.

6. Assumptions:

- Did not consider fully
  - Other parts of the plants other than stem
  - other types of plants,
  - soil quality,
  - ecosystem carbon storage,
  - water quality,
  - Biodiversity
  - Soil emissions from Nox
  - Product mix from the generated wood
- The main assumption is that these are small or secondary to the main issue involved at hand, fertilizer emissions vs wood stem growth

6. Assumptions:

- Did not consider fully what happens to the wood after conversion to products
- However, did explore with some macro-data

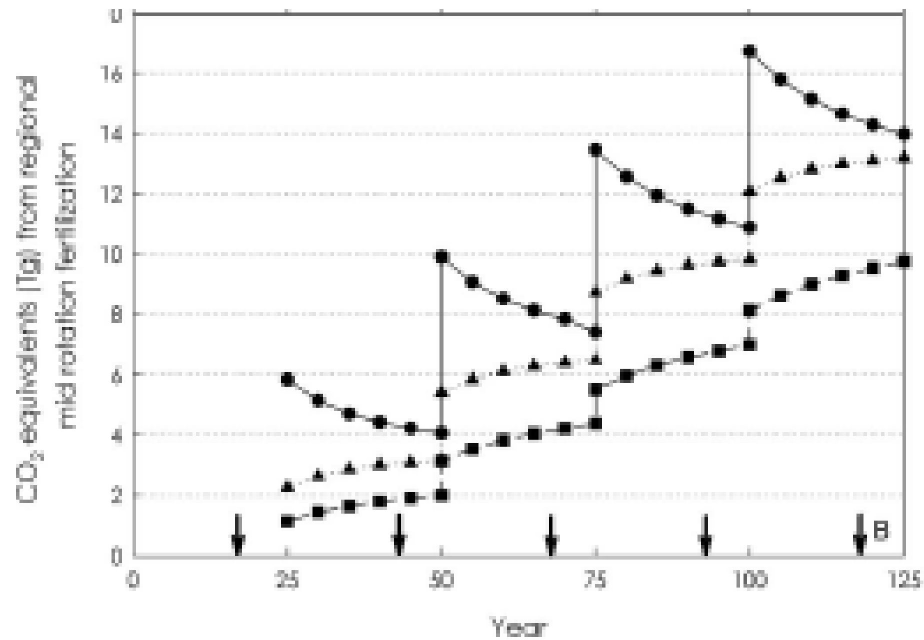


Figure 7. A. Disposition of products (% CO_2 equivalents) resulting from the stem wood response to one mid-rotation application of 224 and 28 kg elemental nitrogen and phosphorus ha^{-1} applied as urea and diammonium phosphate, respectively, to a loblolly pine stand for each of five 25-year rotations. Fertilization occurred in years 17, 42, 67, 92, and 117 (see arrows) but emissions from fertilization are not included in this analysis. B. Disposition of products (Tg CO_2 equivalents) resulting from one mid-rotation application of 224 and 28 kg elemental nitrogen and phosphorus ha^{-1} applied as urea and diammonium phosphate, respectively, to 400,000 ha of loblolly pine for each of five 25-year rotations. Disposition data are from Smith et al. (2006); in use and landfill data are combined because both were considered recalcitrant. Energy indicates that energy was captured when carbon in the product was emitted, whereas Emitted is product carbon emission without capture of energy. For each line there are two points for years 50, 75, and 100 corresponding to the harvest years where one point is before harvest and one point is after harvest.

7. Key concepts:

- Life cycle analysis approach must be taken to understand the true benefits of fertilization of pines
- Macro data and great simplifications are used to develop one main point

8. Implications:

- Fertilization increases in practice in the SE United States occurred when better knowledge of what the benefits of fertilization were found.

- Fertilization goes up and down as a result of
  - Fertilizer prices
  - Wood product prices

- **If the carbon sequestered with forest fertilization were valued in the market and forest owners could capture that value it would likely increase the area fertilized on an annual basis.**

- Providing some economic incentive to fertilize will help forest owners and will help the environment