Sequestration Offsets versus Direct Emission Reductions: Consideration of Environmental Externalities

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Abstract

Atmospheric greenhouse gas accumulation, and consequential temperature increase, can be remedied by emission reductions or agricultural sequestration. Both have direct and external environmental effects. Externality considerations affect the socially optimal portfolio mix of these strategies. This paper examines the magnitudes of the existing estimates of the external benefits and the role that these benefits play in formulating optimal GHG mitigation policy. We discuss some of the options for correcting market failures, caused by external benefits from sequestration and emission reduction strategies, and question whether government intervention is justified considering relative magnitudes of implementation costs and potential benefits that could be derived from such intervention. We conclude that at this time the existing estimates of external benefits from sequestration and emission reduction do not provide enough support for allocating resources to alter the market mix of carbon sequestration and direct emission reduction strategies. We would like to express our gratitude to Robert Stavins for the discussion that led to this work.

Introduction

Over the last few years the issue of global climate change has become a major environmental research topic. Substantial evidence suggests that global temperatures have risen since the industrial revolution, especially during the latter half of the 20th century (National Research Council 2000; IPCC 2001). Temperature rise has been linked to atmospheric concentrations of greenhouse gases (Intergovernmental Panel on Climate Change - IPCC, 2001). IPCC argues that control of atmospheric concentrations of greenhouse gases (GHG) through net emissions reduction is needed to mitigate climate change.

Energy consumption and production is the major United States GHG emission source accounting during 1999 for 85% of total emissions on a carbon equivalent basis (EPA, 2001). If society sees the need to restrict total GHG emissions, it is clear that the energy usage will be subject to corresponding policies.

Many have pointed out that agricultural and forestry management practices can reduce net emissions by removing carbon from the air through photosynthetic processes and storing (sequestering) it in a carbon sinks. This can be done, among other possibilities, by altering agricultural soil management practices, generally reducing tillage intensity, or by expanding forested area or the size of forested stands (IPCC, 2002; Antle and Mooney 2002; Lal et. al. 1998; McCarl and Schneider 1999, 2000). In 1999 agricultural activities were estimated to account for 7.2 percent of all US GHG emissions, while total net sequestration from land-use, land-use change and forestry was 15 percent of total US carbon emissions (EPA 2001). Some argue that U.S. cropland can fulfill 30 percent of the U.S. share of world emissions under the Kyoto protocol (Lal et. al. 1998, Sandor and Skees, 1999).

Environmental externalities (Baumol and Oates, 1975) arise under and are altered by choice of GHG mitigating strategies. In addition to generating emission offsets, agricultural carbon sequestration practices also influence the environment by for example reducing erosion, or improving land quality, wildlife habitat, and water quality (McCarl and Schneider, 1999, Plantinga, 2003). Externalities also arise when emissions are reduced directly by the energy industry (Burtraw et. al 1999, 2003). For example, an action to reduce CO_2 emissions from power plants would simultaneously reduce emissions of Nitrogen oxides compounds and in turn diminish consequent pollution induced health effects (Burtraw 2000, Burtraw et. al. 2003).

Consideration of externalities in the GHG mitigation arena has largely been discussed on an opportunity by opportunity sectoral specific basis (Burtraw et al. 1999, McCarl and Schneider 1999, Plantinga and Wu 2003). Here we discuss the role of externality consideration in terms of the total socially optimal portfolio of mitigation responses. We also examine empirical magnitudes of externalities and what policy adjustments might be made to accommodate externality considerations.

Externalities and emission mitigating portfolios

To examine how the socially optimal portfolio of net GHG emission reduction (mitigation) is affected by externalities we need an economic framework that portrays portfolio composition. To do this we will use the classic externalities model advanced in Baumol and Oates (1975).

Suppose that society decides to reduce net emissions and formulates rules that permit a mixed portfolio of sequestration and emission reductions to participate in the effort (as foreseen in the IPCC or Kyoto Protocol documents). Thus, suppose that a hypothetical emitter, nominally a coal burning electric power plant, is obligated to satisfy binding emission constraints under a tradable permits regime (Hanley, Shogren , and White 1997). Now suppose this power plant can: a) reduce emissions or b) purchase sequestration offsets. Emission reductions could arise by lowering the rate of emissions per unit power generated or by generating less. Burtraw et. al. (1999, 2003) argue that such activities also reduce air pollution and thus generate positive externalities. On the other hand, when sequestration is employed, agricultural external benefits arise but emissions and power plant pollution remains higher resulting in higher externality costs. Under either case, net emissions of GHGs decrease relative to a “do nothing” strategy but net externalities may or may not decrease.

Offset purchases occur when the purchaser has a higher marginal cost of abatement than the supplier. Following Baumol and Oates (1975) suppose $C_N(n)$ and

$C_A(a)$ are the private marginal GHG emission reduction and sequestration cost functions for the power plants (N) and the agricultural/forestry (A) parties. Graph 1a shows the situation where the horizontal axis is the share of emissions offset by the agricultural forestry entity running from zero where all is offset by the power plant to 100% where all is offset by the agricultural/forestry AF entity. If the power plant reduces all of the emissions it encounters the highest costs and as its share decreases so do costs. Similarly, the AF entity has lowest cost when it does not sequester and encounters higher costs with more sequestration. Given these cost curves and tradable permits, in the absence of externality consideration, the private market cost minimizing emission reduction would involve the power plant reducing emissions by *n* and AF by *a*.

Now let us introduce externalities. Suppose that use of AF strategies generates positive external benefits (as argued in Marland, McCarl and Schneider 1999, Plantina and Wu 2003, and Pattanyak et al 2001). Thus the marginal cost function $C^S_A(a)$ considering externalities shifts downward reflecting an offsetting of the private costs by the externality benefits. Thus in graph 1b the social AF marginal cost function $C^S_A(a)$ *is below* the private marginal cost function $C_A(a)$. Simultaneously suppose that reducing emissions from power plants generates positive external benefits (as argued in Burtraw 1999). Thus in graph 1b $C_N(n)$ shifts downward as portrayed by $C^S_N(n)$[1].

In turn, the socially optimal portfolio shares of emission reductions shifts. In graph 1b, the AF sequestration external benefits happen to be larger than the power plant emission reduction external benefits so the shift in the AF share of offsets increases with the power plant share decreasing. On the other hand if the external benefits from power plant emission reductions were greater than the AF sequestration activity external benefits then the power plant share would increase and the agricultural share decrease. The key is that whether or not AF (or conversely power plant) sequestration strategies

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[1] The distance between C_N and C^S_N would equal to positive co-effects of direct emission reductions.

grow from a social optimality standpoint, depends on the relative magnitudes of the externality benefits from AF sequestration and from energy sector emission reductions.

Correction of market outcomes

As shown above and classically developed in many places (e.g. Baumol and Oates, 1975), the presence of externalities can lead to market failure and it may be socially desirable to have policy interventions to adjust market outcomes. Implementing private market subsidies or taxes that reflect net externality benefits (NEBs) from sequestration could correct the market failure (neglecting transactions costs which will be addressed later). Namely, if AF sequestration NEBs exceed those from emissions reductions then either subsidizing AF carbon sequestration offsets or taxing non-agricultural emissions permit trading may be appropriate policies.

The main idea is that governmental intervention may be needed to achieve desirable externality outcomes from a social welfare perspective to correct market failure. However, before such a policy could or should be implemented the following questions need to be addressed. Namely,

- How much subsidization is appropriate?
- Is the difference in externality benefits large enough that there are significant welfare gains to be had?

We discuss these questions empirically below.

Size of subsidy/tax

Minimization of social costs of complying with total emission caps, which correspond to distributed emission permits, would involve consideration of the technological costs of AF sequestration versus emission reductions by power plants and others along with consideration of the relative externality benefits. Suppose that it is not socially optimal for an AF entity to sequester to the maximum of their ability and that power generators can only have positive emissions (no zero emissions), implying an interior solution for social cost minimization. It can easily be shown that under such conditions socially optimal distribution of emission reductions and sequestration levels occur when the following is satisfied.

$$C'_A + NE'_A = C'_N + NE'_N \qquad (1)$$

where $C^{'}_A$ and $C^{'}_N$ are marginal costs of sequestration and emission reduction for sequestration *(A)* and power generation activities *(N)*, while $NE_A^{'}$ and $NE_N^{'}$ are marginal externality values from sequestration and emission reduction.

Private cost minimization for a power plant would consider costs of emission reductions and payments for exceeding the levels of emissions allowed by held emission permits. Private cost minimization for use of AF units would involve technological sequestration costs, including opportunity costs, payments, including carbon price and subsidy, received for sequestering or emitting below the levels allowed by held emission permits, and market transactions costs involved with permit acquisition. Suppose that power plants emit only positive levels of emissions (no power plant sequestration possible). Assuming an interior solution for cost minimization for agricultural participants, meaning that it is not privately optimal to sequester to the maximum of their ability, i.e. carbon payments that they receive do not offset all of the opportunity costs of sequestration, it can be easily shown using equation (1) that

$$k = NE'_A - NE'_N = C'_N - C'_A \qquad (2)$$

where k represents the subsidy (or tax) per unit AF offset sold. Hence, in case of interior solution, optimal level of subsidy would equal to the difference of marginal costs and the difference in co-effects simultaneously. This implies that not only do we have to calculate the differences of marginal costs and net externalities, we also have to figure out at what combination of mitigation levels among agricultural and non-agricultural entities do these differences equal one another (Point G on Graph 1b)[2].

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[2] Possibilities for corner solutions include situations where it is socially optimal for agriculture to sequester to its maximum abilities, and where it is socially and/or privately optimal for power generators to not emit any. These scenarios are unlikely to be materialized and, therefore, are skipped in this analysis.

There are three points to be made here about computing the tax/subsidy in (2). First, the calculation is complicated by diversity and multiplicity of AF external effects such as improved wildlife habitat, biodiversity implications, improved soil and water quality, development of recreation sites, and possibly more. Each of these external effects is difficult and time-consuming to appraise in terms of dollar values. Evaluation of most of these co-effects requires application of advanced estimation techniques such as non-market valuation, travel costs analysis, crop production simulation, etc. (Plantinga 2003, Ribaudo 1989, Pattanayak at al 2001, Matthews et al 2002). In addition, direct emission reductions by power plants could also result in multiple externality benefits such as reduced NOx emissions (Burtraw et al 2003) and subsequent human and wildlife health benefits, less strain on the environment at nuclear waste facilities such as Yucca Mountain in Nevada, etc. In order for the subsidization of sequestration to be economically justifiable the magnitude of the benefits gained from subsidization need to exceed the government expenditures plus transaction costs (McCann and Easter, 2000) of estimating the subsidy/tax levels and implementing the corrective policy. This could be an expensive proposition as argued by Alston and Hurd (1990).

Second, externality benefits are likely to vary across geographic regions for the same offset strategy particularly in regard to AF sequestration. For example, reducing tillage intensity in Texas would result in different externality benefits as compared to reducing tillage intensity in Nevada. This suggests that the subsidy calculation needs to be carried out on a case by case basis in order to correctly reflect the values of sequestration externalities. However, such strategy may turn out too costly and therefore unacceptable.

Third, externality benefits are likely to be spread across sectors, economic actors and geography in terms of monetized and non monetized items. Sequestration activities in remote regions could result in diverse external effects on biodiversity, soil and water characteristics, among other things, (Matthews et al 2002, Pattanayak et al 2001), which could be difficult to compare to one another in terms of monetary values. For example, altered mix of bird population, caused by afforestation, is problematical to appraise relative to prior bird mix.

Empirical magnitude of externality benefits

Externality benefits arise on both the AF sequestration and power plant emission reduction sides. Each has been the subject of some empirical work.

Carbon sequestration in forests or agriculture can generate multiple and diverse externality benefits. Agricultural sequestration can improve water quality due to reduced erosion and application of agricultural chemicals as well as altering species habitat. Ribaudo estimated (1989) that water quality damages from erosion and agricultural chemicals ranged from $0.57 per ton of eroded soil in the Northern Plains to $7.06 (in 1989 dollars) in the Northeast. Plantinga and Wu, (2003) estimate that conversion of Wisconsin agricultural land into forests would offset 32-42% of the carbon sequestration costs through the reduced erosion benefits. Inclusion of habitat based hunting and non-consumptive wildlife benefits increased their estimate to about 78% of sequestration costs. Matthews et.al. (2002) found that sequestration activities, such as aforestation, affected habitat and in turn biodivesity, showing that converting agricultural land into forests in Southern Carolina, Maine and Southern Wisconsin resulted in altered bird populations. Pattaynek et al (2001) estimated that sequestration program improved water quality with an improvement in swimmability and aquatic habitat. In addition, AF carbon sequestration can be viewed as a supplementary device for providing pecuniary externalities in terms of economic support to farmers (Marland, McCarl and Schneider 1999; Antle, 2000).

On the power plant side, Burtraw et al. (1999, 2003) report that reduced CO_2 emissions also lead to reduced NO_x emissions and estimate that this generates health benefits equivalent to $3.00 per ton of carbon equivalent offset when carbon emission tax is set at $10 per ton, corresponding to 30% of the carbon price (which on the margin should equal the cost of the emission offset). Furthermore, Burtraw et al estimate that inclusion of costs saving emerging from reduced investment in NO_x and SO_2 abatement yields additional benefits bringing total ancillary benefits to about 50% of the carbon tax rate. Felzer et al (2003) argue that ozone damages, the incidence of which is affected by emissions from fossil fuel combustion, influence forestry product markets, water quantity and quality, nutrient cycling, and recreational opportunities. In addition, Flezer et al argue that, increased ozone damage will reduce terrestrial carbon uptake, which will increase atmospheric GHG concentration and will increase GHG mitigation costs. They estimate that the policy for reducing emissions from fossil fuel combustion would bring about additional 5-20% savings in GHG mitigation efforts if we account for the fact that regulation of emissions from fossil fuel combustion would reduce ozone damage and thereby increase carbon sequestration. Consequently GHG mitigation policies will not need to be as stringent to meet the same atmospheric CO_2 goals. The Public Services Commission of Wisconsin estimated that the negative externality values associated with per ton emission of carbon dioxide, methane, and nitrous oxide were \$15, \$150, and \$2,700 correspondingly (EIA, 1995)[3]. Adams et al (1986) also show large agricultural benefits from decreased ozone concentrations.

It is important to recognize the broad assumptions that have been made in setting up the above externality effects estimates on both, sequestration and direct emission reduction sides. On agricultural sequestration side Plantenga and Wu's (2003), as well as Ribaudo's (1989), estimates assume perfectly elastic demand for reduced erosion, hunting and non-consumptive uses of wildlife. However demand is likely to be downward sloping with respect to increased levels. This would reduce the values of the estimated external benefits derived from AF sequestration. On direct emission reduction side, Burtraw's (1999, 2003) estimates do not reflect downward sloping demand for clean air and do not reflect the externality costs that could emerge from increased energy scarcity due to decreased energy production. Felzer et al's (2003) estimates do not reflect the possibility of optimal trading between CO_2 and non-CO_2 GHGs. Therefore, they overestimate the costs of GHG mitigation policy.

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[3] Corresponding similar values were estimated for Massachusetts and California using marginal costs of pollution control (society's willingness to pay) as proxies to externality values. The applicability of these estimates however, is questionable under the context of this paper.

Is Externality based Intervention Justified?

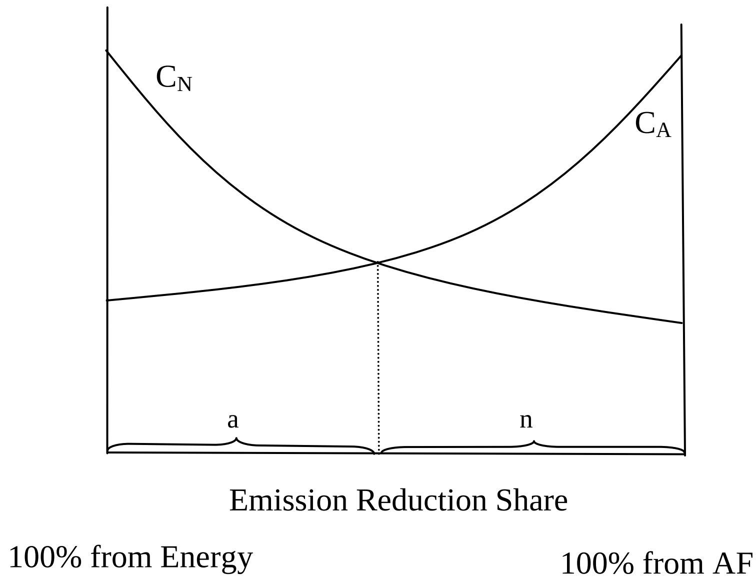
Although external benefits arise both, from AF sequestration and from power plant emission reductions, the question as to whether policy should be formed to subsidize one type of activity as opposed to the other is certainly in order. The magnitudes of the empirical estimates of the externality benefits generated to date are not so disparate to lead us to the conclusion that the gains from their calculation exceed the costs that might arise due to improper actions stimulated by bad or incomplete estimates plus the transactions costs of generating those estimates. This may be a situation much like the standard recommendation that secondary benefits not be considered when appraising water projects (Kraynick and Stoevenor, 1979; Griffin, 1998). There is a potential welfare gain but the cost and scale of an effort needed to nail it down coupled with the inherent uncertainty probably preclude the formation of policy based on such estimates.

Conclusion

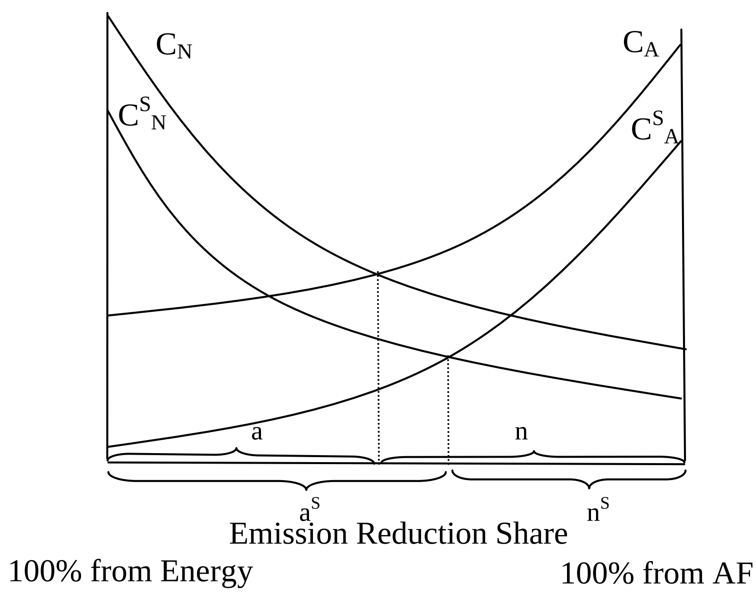
This paper discusses the economic balance between the externality benefits of agricultural sequestration and energy sector emission reductions from a social perspective and examined preliminary evidence for implementation. From a social perspective optimal strategy depends not only on costs of abatement but also on externality benefits. The optimal portfolio of sequestration and emissions reductions depends on the relative magnitudes of their net externality benefits. Currently, monetary values of external benefits from sequestration and direct emission reductions both fall in the range of 50% and 78% of the costs of emission control alternatives respectively. These estimates, considering the assumptions used in their calculations, may be close enough to being equal so as to not justify allocating actions to alter the sequestration/emission reduction mix.

Perhaps at this time it would be best if selected case studies continue to quantify magnitudes of externality benefits but that policy implementation be kept in abatement until a compelling evidence of likely beneficial results from a subsidization process arises. It is probably also worthwhile urging policy makers to realize that externality issues are involved whether emissions are reduced or sequestration promoted. This would help provide some balance in the face of the widely heard claims of benefits advanced by sectoral experts particularly in our experience in terms of sequestration activities.

Graph 1a. Market equilibrium without externality consideration



Graph 1b. Implications of Externality Consideration



References:

Adams, R.M., S.A. Hamilton, and B.A. McCarl, "The Benefits of Pollution Control: The Case of Ozone and U.S. Agriculture," American Journal of Agricultural Economics, 68(4), 886-893, 1986.

Alston J. M., and B.H. Hurd, "Some Neglected Social Costs of Government Spending in Farm programs." *American Journal of Agricultural economics*. 72 (1). Pp149:156. 1990.

Antle J.M., "Economic Feasibility of Using Carbon Sequestration Policies and Markets to Alleviate Poverty and Enhance Sustainability of the World's Poorest Farmers", Presented at the Expert Workshop on "Carbon Sequestration, Sustainable Agriculture and Poverty Alleviation, World Meteorological Organization, Geneva Switzerland, August 31, 2000

Antle, J.M. and S. Mooney. Designing Efficient Policies for Agricultural Soil Carbon Sequestration. Chapter in *Agriculture Practices and Policies for Carbon Sequestration in Soil*, edited by J. Kimble, CRC Press LLC, Boca Raton, FL, pp. 323-336. 2002.

Baumol W.J., and W. E. Oates. "*The Theory of Environmental Policy: Externalities Public Outlays, and the Quality of Life*". Prentice-Hall, INC. New Jersey, 1975.

Burtraw, D., A. Krupnick, K. Palmer, A. Paul, M. Toma, C. Bloyd. "Ancillary Benefits of Reduced Air Pollution in the US from Moderate Greenhouse Gas Mitigation Policies in the Electricity Sector." *Journal of Environmental Economics and Management*. 45, Pp. 650-673. 2003.

Burtraw, D., "*Innovation Under the Tradable Sulfur Dioxide Emission Permits Program in the U.S Electricity Sector.*" Resources for the Future Discussion Paper No. 00-38, 2000.

Burtraw, D., A. Krupnick, K. Palmer, A. Pul, M. Toman, C. Bloyd. "*Ancillary Benefits of Reduced Air Pollution in the U.S. from Moderate Greenhouse Gas Mitigation Policies in the Electricity Sector*". Resources for the Future. Discussion paper No. 99-51. 1999.

Energy Information Administration (EIA), *Electricity Generation and Environmental Externalities: Case Studies*, Office of coal nuclear and Alternative Fuels, Coal and Electric Analysis Branch, U.S. Department of Energy, Washington D.C. 20585, 1995.

Felzer, B.S. F., J. Reilly, J. Melillo, D Kicklighter, C. Wang, R. Prinn, M Sarofim, Q. Zhuang. Past and Future Effects of Ozone on Net Primary Production and Carbon Sequestration Using a Global Biological Model. Cambridge, MA, MIT Joint Program on the Science and Policy of Global Change. 1:42.

Gangadharan, L., "Transaction costs in pollution markets: An empirical study." *Land Economics*, 76 (4): Pp.601-614. NOV 2000

Griffing, R. C. "The Fundamental Principles of Cost-Benefit Analysis." *Water Resources Research*, 34(8): 2063-2071.

Hanley, N., Shogren, J., White, B., "*Environmental Economics in Theory and Practice*." Oxford University Press, New York, 1997

International Panel on Climate Change, Selected chapters from "*The Regional Impacts of Climate Change — An Assessment of Vulnerability*". Cambridge University Press, UK. Pp. 517. 1997. (http://www.ipcc.ch/pub/reports.htm , Accessed 06/16/03)

International Panel on Climate Change, "C*limate Change 2001: The Scientific Basis*". IPCC Third Assessment Report. 2001. Cambridge University Press, UK. Pp. 944. (http://www.ipcc.ch/pub/reports.htm, Accessed 06/16/03)

Lal, R., J.M. Kimble, R.F. Follett, and C.V. Cole. "*The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect.*" Pp128. Chelsea, MI: Sleeping Bear Press Inc., 1998.

Marland, G., B. A. McCarl, and U. Schneider, "Soil and Carbon Policy and Economics", in *Carbon Sequestration in Soils: Science Monitering and Beyond,* Edited By N.J. Rosenberg, R.C. Isaurralde, and E.L. Malone, Battelle Press, Columbus OH, 153-169, 1999.

McCann, L., and K. W. Easter, "Transaction Costs of Policies to Reduce Agricultural Phosphorous in the Minnesota River." *Land Economics,* 75(3), 402-414. 2000

McCarl, B.A. and U.A. Schneider, "Curbing Greenhouse Gases: Agriculture's Role." *Choices*, First quarter, pp9-12, 1999.

McCarl, B.A. and U.A. Schneider, "Agriculture's Role in a Greenhouse Gas Emission Mitigation World: an Economic Perspective." *Review of Agricultural Economics*, 22(1), 134-159. 2000

Matthews, S., O'Connor, R., and A., J., Plantinga. "Quantifying the Impacts on Biodiversity of Policies for Carbon Sequestration in Forests." *Ecological Economics*. 40(1): 71-87. 2002.

National Research Council, Panel on Reconciling Temperature Observations, Climate Research Committee, Board on Atmospheric Sciences and Climate, Commission on Geosciences, Environment, and Resources. "*Reconciling Observation of Global Temperature Chang*e", National Academy Press, Washington, D.C. 2000 (http://books.nap.edu/about/availpdf.phtml Accessed 06/16/03)

Pattanayak S., T. Bondelid, B. Murray, D. Lawrance, J. Yang, B. McCarl, and D. Gillig. Water Quality Co-Benefits of Greenhouse Gas reduction Incentives in Agriculture and Forestry. Report prepared for U.S. Environmental Protection Agency. October, 2001.

Plantinga A. J., and J. Wu, "Co-Benefits from Carbon Sequestration in Forests: Evaluating Reductions in Agricultural Externalities from and Afforestation Policy in Wisconsin". *Land Economics*, 79(1), 74-85, 2003.

Ribaudo, M. O. "*Water Quality Benefits from the Conservation Reserve Program*." U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report 606. Washington, D.C. 1989

Sandor, R.L. and J.R. Skees. "Creating a Market for Carbon Emissions – Opportunities for U.S. Farmers". *Choices*. First quarter, 1999. Pp 13-17.

Schneider, U., "*Agricultural Sector Analysis on Greenhouse Gas Emission Mitigation in the United States*." Unpublished Ph.d. Dissertation, Department of Agricultural Economics, Texas A&M University, 2000.

Stavins, R.N., "Transaction Costs and Tradable Permits", *Journal of Environmental Economics and Management*, 29:133-148,1995

Stavins, R.N., "*Policy Instruments for Climate Change: How Can National Governments Address a Global Problem?*" Discussion Paper 97-11, Resources For the Future, Washington, DC, Pp. 39. 1997. (Available on line http://www.rff.org, Accessed 06/16/03).

Stavins, R.N., "What can we learn from the Grand Policy Experiment: Lessons from SO2 Allowance Trading", *journal of Economic Perspectives* 12(3): pp. 69-88, 1998.

Stoevener H. H., and R. G. Kraynick. "On Augmenting Community Economic Performance by New or Continuing Irrigation Developments", *American Journal of Agricultural Economics*, 61(5):1115-1123.

Tietenberg, T., M. Grubb, A. Michaelowa, B. Swift, Z.X.Zhang, and F.T. Joshua. "*Greenhouse Gas Emissions Trading. Defining the Principles, Modalities, Rules and Guidelines for Verification, Reporting and Accountability.*" United Nations Conference on Trade and Development. (UNTCAD/GDS/GFSB/Misc.6) Pp. 125. August 1998.

United States Environmental Protection Agency, "*Inventory of U.S. Greenhouse Gas Emissions and Sinks:1990-1999*", April 2001. (http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2001.html Accessed 06/16/03)

Watson, R.T. and the Core Writing Team (Eds.), *IPCC Third Assessment Report: Climate Change 2001: Synthesis Repor*t, IPCC, Geneva, Switzerland, September 2001. (http://www.ipcc.ch/pub/un/syreng/spm.pdf Accessed 06/16/03)

Wietzman, M., L., "Prices vs. Quantities." *Review of Economic Studies.* 41 (4): 447-91, 1974.