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CLIMATE NOTES

CLIMATE PROTECTION INITIATIVE

A CLIMATE AND ENVIRONMENTAL STRATEGY FOR U.S. AGRICULTURE

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Executive Summary

If the Kyoto Protocol to the United Nations Framework Convention on Climate Change were ratified by the U.S. Senate and a national program to reduce greenhouse gas emissions put in place, some studies have suggested that American farmers would suffer dire economic consequences.

This report disputes that contention. We find that the implementation of policies that address climate change will not be an economic disaster for U.S. agriculture. Because energy costs are a small share of production expenses, the magnitude of price changes expected under the Kyoto Protocol would reduce net cash returns by less than one percent. With the right policy setting, net cash returns could be positive.

Under the Kyoto Protocol, 42 "Annex 1" (developed) countries agreed to make binding commitments to reduce greenhouse gas emissions by an average of 5 percent below 1990 emissions levels during the first commitment period in 2008–2012. U.S. negotiators agreed to a cut of 7 percent below its 1990 levels.

To fulfill this commitment, it is widely expected that the U.S. government would institute a "cap-and-trade" system. Under such a system, the government in 2008 and thereafter would "cap" total greenhouse gas emissions at 93 percent of the 1990 total. It would then allocate these emissions by auctioning off permits called "Carbon Emission Rights" (CERs) equal to its international commitment. In other words, fossil fuel producers, for example, would have to pay for the right to produce and sell a given amount of fossil fuels. In turn, these permits may be traded between existing firms depending on need and opportunities for cost-effective GHG reductions. For example, a firm that wanted to release large amounts of CO_2 might have to buy additional CERs, while a firm able to make cost-effective reductions in CO_2 emissions would be able to offer its surplus CERs for sale. Additional CERs could be purchased from other countries to extend the U.S. cap, if necessary.

Producers would pass the cost of buying CERs along to consumers in the form of higher prices for fossil-fuel-based energy. Government revenue from the initial auction could be used to offset comparable reductions in income taxes or other sources of government revenue, so the program could be made revenue-neutral.

What would such a program mean for American farmers? First, it would mean slightly higher costs for energy derived from fossil fuels. In addition, it would mean higher costs for fertilizer and pesticides—because of the energy required to produce these products and because they are derived from fossil fuels.

We find, though, that policies could be devised that would help farm income, enhance the environment, and also reduce agricultural greenhouse gas emissions, while cutting soil erosion and nutrient pollution. Programs to cost-effectively reduce agriculture's emissions could help reduce the nation's total emissions of greenhouse gases, thus providing some additional room under the cap for other emissions. This could help maintain a healthy economy while still honoring the U.S. commitment under the Kyoto Protocol.

One possibility would be to implement a nutrient trading program under the Clean Water Act, which would allow

point-source dischargers to meet their permit obligations by paying farmers to reduce their nitrogen loads to the nation's waterways. When nitrogen surpluses are reduced, nitrous oxide emissions are also cut, so nutrient trading can improve water quality, reduce greenhouse gas emissions, and give farmers an increase in net cash returns even with higher energy prices.

Extending the Conservation Reserve Program is another policy option that would raise farm revenue and provide environmental benefits. Higher rental rates of about 20 percent would induce an increase of about 6 million acres in the program, cut greenhouse gas emissions from agriculture by about 5 percent, reduce soil erosion and nutrient loads, and more than offset the impact of higher energy prices from a carbon emissions trading system.

Kyoto may also present an opportunity for farmers to sequester carbon in soils and sell the credits generated by such activities, since the top 3 feet of America's farmlands can store vast amounts of carbon. However, this approach should be implemented cautiously because the uncertainties are great. And, while the physical potential of carbon-sequestering activities related to agricultural land use may be quite large, the cost of producing soil carbon offsets is not particularly cheap, so it is likely that the economic potential of such offsets is quite limited.

There are a wide variety of agricultural practices associated with emissions or capture of greenhouse gases. The right policy set could yield benefits to protect the climate and improve other environmental conditions such as water quality, thereby helping farmers deal with a difficult and highly contentious issue. A package that consisted of increased investment in the Conservation Reserve Program, nutrient trading under the Clean Water Act, adequately funded and performance-based conservation subsidies, and research could provide enhanced water quality, soil quality, wildlife habitat, and climate benefits. Fortunately, opportunities are available if the United States decides to take advantage of the synergies that are possible. What is needed now is a broad strategy to address agriculture's environmental challenges.

Introduction

At a 1997 meeting in Kyoto, Japan, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) completed negotiations for legally binding reductions in six greenhouse gases (GHGs) that are released by human activities and trap heat in the atmosphere. The Kyoto Protocol calls for the higher-income countries of the world to reduce their net emissions of GHGs to reduce the risk of changes to the Earth's climate.

The United States emits about 24 percent of the world's greenhouse gases. Except for a few small oil-producing countries like Kuwait and the United Arab Emirates, the United States releases more carbon dioxide emissions per person than any other country (World Resources Institute, 1998). Under the Kyoto Protocol, 42 "Annex 1"[1] countries agreed to make binding commitments averaging a cut of 5 percent from 1990 emission levels during the first commitment period, 2008–2012. The U.S. negotiators agreed to a cut of 7 percent from the base year of 1990, the European Union to 8 percent, and Canada and Japan to 6 percent. To date, 84 countries have signed the treaty and 22 have ratified it. The Kyoto Protocol has yet to be submitted to the U.S. Senate for ratification.

Carbon dioxide is the most important GHG produced by human activities. The U.S. Environmental Protection Agency (USEPA) estimates total emissions of GHGs in the United States in 1998 were 1,834 million metric tons[2] carbon equivalent (MMTCE).[3] Of this total, carbon dioxide emissions account for 1,468 MMTCE or 80 percent, principally from fossil fuel combustion for electricity, transportation, residential, commercial, and industrial consumption. Methane is the second most important gas for the United States, with emissions of 181 MMTCE, followed by nitrous oxide at 119 MMTCE and the family of hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulphur hexaflouride (SF_6) at 40 MMTCE. Other chlorofluorocarbons and hydrofluorochlorocarbons are also GHGs but are controlled under the Montreal Protocol as stratospheric ozone depleting gases. The gases in the Kyoto Protocol are not ozone depleting (USEPA, 2000).

In addition, the nation's forests on balance take about 211 MMTCE of carbon dioxide out of the atmosphere (USEPA, 2000). This carbon dioxide is converted to plant biomass and sequestered in trees and products made from wood.

Table 1 U.S. Greenhouse Gas Emissions. U.S. Total, Emissions from Agricultural Production, and the Share of Agricultural Production in the U.S. Total

	U.S. Total (MMTCE)	Agricultural Production Emissions (MMTCE)	Agricultural Production's Share of Total (percent)
Carbon Dioxide	1,494	28[4]	2
Methane	181	60	33
Nitrous Oxide	119	88	74
HFCs, PFCs, and SF_6	40	~0	0
Land Use Change and Forest Sinks	(211)	?[a]	?
TOTAL (Net)	1,623	176	11

Sources: USEPA, 2000; Lal et al., 1998.
[a]Estimates vary from about -15 to +16 MMTC per year.

Agricultural production accounts for a small share of total carbon dioxide emissions, but is a major source of methane and nitrous oxide, as shown in Table 1. Agriculture accounts for about one third of methane and three quarters of nitrous oxide emitted in the United States by anthropogenic activities. Emissions from agricultural production account for roughly 11 percent of all U.S. emissions.[5]

Carbon dioxide emissions from farming come from energy use and changes in soil carbon stocks. Lal et al. (1998) estimate that about 43 MMTCE are produced by agricultural production, with 28 MMTCE derived from direct and indirect energy use and another 15 MMTC from soil carbon losses. Direct energy use includes diesel, gasoline, LP gas and natural gas, and indirect includes the production of farm inputs. Direct energy use accounts for 15 MMTCE released and indirect accounts for 13, with fertilizer production comprising 73 percent of this category.

Methane emissions reported in USEPA's most recent inventory (USEPA, 2000) are about 60 MMTCE per year. While the actual volume of methane (CH_4) emitted is much smaller than carbon dioxide (CO_2) emissions, methane has a Global Warming Potential (GWP) of 21, meaning that each molecule of CH_4 is expected to trap 21 times more heat over a 100-year period than a molecule of CO_2. The main contributors to methane emissions include animal digestion at 34 MMTCE per year, manure management at 23, and rice cultivation at 3.

Nitrous oxide, N_2O, is an even more powerful gas than methane, with a GWP of 310. About 88 MMTCE of nitrous oxide emissions come from agricultural production each year, with 49 MMTCE coming from direct emissions. The largest components of this category are the application of synthetic fertilizers, and nitrogen fixation by crops. The application of sewage sludge and animal manures, and the cultivation of organic soils are much smaller. When nitrogen is lost through volatilization, leaching and runoff, some share of it is in the form of nitrous oxide (USEPA, 2000).

One of the unique aspects of carbon dioxide is that it can be taken out of the atmosphere by plants and sequestered in plant biomass, plant products, or soils. The first time this characteristic was used to offset carbon dioxide emissions was in 1989, when the AES company, an independent power provider, sponsored an agriculture and forest management project in Guatemala at the recommendation of the World Resources Institute (Faeth et al., 1994). Since that time there have been numerous projects of this sort. The Department of Energy (1999) sponsors a registry for such projects.

The USEPA inventory (USEPA, 2000) recognizes the offsetting ability of land use change and forestry activities and estimates that about 211 MMTCE were removed from the atmosphere in 1998 in this way. The latest inventory does not make a similar estimate for agricultural activities. Agricultural soils have a tremendous amount of carbon stored in them. Kern (1994) estimates that, prior to cultivation, the area under major field crops in the contiguous United States has a carbon pool of about 8,300 MMTC in the top 30 cm. Soil carbon losses due to cultivation amount to roughly 1,300 MMTC, leaving a current pool of 7,000 MMTC. An estimate by Lal et al. (1998) is much larger. Considering the top 1 meter of soil, they think the carbon pool is 15,600 MMTC, with a loss to the atmosphere of perhaps 5,000 MMTC since cultivation began. They suggest that this loss could be replaced over the next 50 years through the adoption of best management practices (BMPs).

The current annual change in soil carbon is not known with any degree of certainty but it is thought to be relatively small and may be negative. The range of reported estimates vary from a loss of 15 MMTC per year, as reported by Lal et al. (1998), to a maximum gain of 24 MMTC, as reported by the U.S. Government (USG) in its August 2000 submission to the UNFCCC. The U.S. submission reports a "central tendency" of 16 MMTC per year sequestered on cropland and another 8 MMTC on grazing land.

The Cost of Climate Protection

If the United States ratifies the Kyoto Protocol, a large increase in energy efficiency and low-carbon technologies will be needed to achieve the required reductions. Emission reduction requirements are measured from the 1990 baseline level, which is a net of about 1,650 MMTCE for the United States. With the 7 percent cut that the United States agreed to, by 2010 annual GHG emissions would have to be cut by roughly 650 MMTCE per year compared to expected emissions (Laitner, 1999). This could represent a reduction in net emissions of as much as 30 percent from the 2010 base year. In 1998, the United States was about 11 percent above 1990 levels (USEPA, 2000).

Fossil fuels are a key driver of the U.S. economy. Because coal, oil, and natural gas combustion is the dominant source of GHGs, there will be costs associated with the changes that will be necessary if the Kyoto Protocol is ratified. There could be health and environmental benefits as well, including reductions in smog, acid rain, and other conventional pollutants, not to mention reduced risk of climate change itself.[6]

Various estimates have been made of these costs and benefits to the U.S. economy; the range varies quite dramatically. Depending on the assumptions made in the economic modeling of a policy to address climate change, the results can show a net cost or a net gain. Almost all models use various levels of carbon taxes to represent the implementation of a carbon trading system, mostly because that is a fairly easy way to test the models, and because the results turn out to be the same economically.

Models that make worst-case assumptions—including an inefficient response by the economy; no availability of non-carbon fuels no matter the price; no international trading of carbon emission rights; no air quality benefits from reduced use of dirty fuels; and no damages from climate change—show a much higher cost to the economy from carbon taxes to limit fossil fuel consumption. On the other hand, models that make best-case assumptions—that the economy will respond efficiently; that at some price non-carbon fuels will become available; that international trading of carbon permits will be allowed; that cleaner fuel use will produce better air quality; and that policies to avert climate change will do so—produce a lower implementation cost. With all the above best-case assumptions captured, economic models show a net economic gain (Repetto and Austin, 1996).

Fortunately, the best-case assumptions are more likely than the worst-case assumptions. The U. S. economy has a high degree of capital and labor mobility and should be able to adapt fairly efficiently. It is widely recognized that energy efficiency and less consumption of coal—the most carbon-dense fuel—would reduce conventional air pollutants such as particulates, NOx, and sulfur dioxide. Renewable fuels are becoming more widely available, from corn-based ethanol to wind and photovoltaics. Clearly, with the right incentives, non-carbon or renewable fuel sources like wind, geothermal, solar, and landfill gas are available. The magnitude of climate damages are uncertain, but the scientific community, as embodied in the Intergovernmental Panel on Climate Change, has stated that human-caused climate change is highly likely (IPCC, 1996). Finally, the Kyoto Protocol does allow international trading of carbon; the near-certain choice for domestic implementation would be a carbon trading program.

The U.S. government has undertaken a number of studies to evaluate the costs of meeting the Kyoto Protocol targets. A comparison was made of four models used by the government, each of them running scenarios that mimicked a full global carbon trading program with 40–75 percent of the U.S. emission reductions resulting from international trading (Laitner, 1999). The results showed an effect on U.S. GDP between -1.7 percent to +0.6 percent from the expected GDP in 2010. At worst, this represents about 9 months worth of growth in the U.S. economy at current rates.[7] Without any international carbon trading, the maximum effect on the U.S. economy estimated by this group of models was a decline of 4.2 percent.

The level of carbon permit price required to achieve the necessary reductions is a measure of the expected difficulty of achieving the Kyoto goal. Two of the four models reported carbon taxes (or permit prices) of $23 per ton of carbon embodied in fuels, the other two reported $50 and $130 per ton.

As noted in the discussion above, the assumptions in the models make all the difference in the outcome. Two of the models are basically the same, except that one uses more generous assumptions about the level of investments in technology improvement and the resulting pace of change. This version of the model still requires a carbon tax of $23 per ton to achieve emissions cuts, but also shows an economic gain due to savings in the nation's fuel bills.

A recent survey of economic models compared various levels of trading opportunity to meet Kyoto objectives (Weyant and Hill, 1999). The results all show the same trend—the costs are very much lower for the United States if a full global trading scheme for emission rights is allowed, which Kyoto does. Of the nine models reporting results for the United States, four show carbon permit price levels of $25 or less per ton with global trading, three between $25–$50 per ton, one at $90, and one at $110.

Kyoto's Impact on U.S. Agriculture

Any policy that aims to constrain the release of GHGs will have effects on each sector of the U.S. economy, including agriculture. Just as results for the economic impacts of climate policies on the U.S. economy vary according to the assumptions and models used, the same is true of analysis done for agriculture.

There have only been a few studies done on the economic impact of Kyoto on agriculture. All the studies take estimates of economy-wide costs of carbon taxes or permits and apply them to either sectoral models or sectoral financial budgets. In the latter category are two studies that show dramatic economic impacts. The first of these, entitled *The Kyoto Protocol, Potential Impacts on U.S. Agriculture: An Assault on an American Institution*, was undertaken by Sparks Companies, Inc. (no date) and was co-sponsored by the American Farm Bureau, the American Corn Growers, the National Cattleman's Beef Association, the United Fruit & Vegetable Association, and the National Grange.

This study combines all of the worst-case assumptions noted above. For example, the study authors use a high carbon permit price assumption that is not consistent with the Protocol or the common understanding of how it would be implemented. As noted above, most models that test global trading, a central element of the agreement, produce price estimates between $14 and $50 per ton, with two as high as $110 per ton. In contrast, the Sparks study uses a permit price of $177 per ton, with the justification that "the bulk of the carbon emissions will come from changes in domestic use." While the Kyoto Protocol encourages domestic action, no limits have been placed on international permit trading.

The application of a high carbon permit price in itself could be expected to produce a significant adverse effect. However, this study also uses a methodology called partial budgeting that amplifies the impact by implicitly assuming that farmers would not respond to changes in input or output prices. Cost of production budgets are inflated by 10 percent to account for higher energy prices. Revenues are deflated by 2.5 percent on the assumption that production would remain constant, yet demand would decline and prices would fall. The approach assumes that the preferred policy would strictly limit international trading, that the entire cost increase would be passed along to farmers, and that they would simply eat the loss in income without making any rational adjustments to reduce their use of energy or energy-intensive inputs. The net result of these assumptions is a 53 percent decline in farm net income.

We know from past experience, however, that farmers make significant adjustments to reduce energy use and that technologies for energy savings can be developed and will be adopted if the incentives are right. For example, between 1974–1976, gasoline and diesel fuel use together averaged 6.6 billion gallons per year consumed for farm use. In 1992–1994, this average dropped by 28 percent to about 4.8 billion gallons per year (USDA, 1997).

Another study done by the Heartland Institute (Francl et al., 1998) estimated the change in farm production expenses under two scenarios, again using the partial budgeting approach. The authors say that they "...use the

Box 1 Revenue Recycling

A greenhouse-gas trading program would operate through government provision of permits equal to the cap specified under the Kyoto Protocol for the United States. If the cap in 2008 were equal to 1,450 MMTCE, then the government would provide "carbon emission rights" in this amount. Carbon dioxide or other GHGs from controlled sources such as coal and oil could not be released without an associated permit.

To minimize administrative burden, permits would most likely be applied at the wellhead or minemouth, where energy resources are extracted, and then the price of the permits would be passed along downstream. If the permits are "grandfathered," (that is, given away to current emitters based upon historical emissions) the coal and oil companies would experience windfall profits. If the permits were auctioned, they would generate significant revenues for the government. Subsequently, permits could be traded between companies, and the market would determine the price depending on the ability of the economy to make adjustments and to generate or purchase additional permits from elsewhere (for example, a soil carbon or forestry offset project).

Economic modelers assume that a carbon tax or permit revenues are returned in a lump-sum rebate to taxpayers. The idea is to separate the impacts of the climate policy tested by making it revenue-neutral. Revenues could be returned by lowering capital gains, labor, or personal taxes to offset the impact of higher energy costs. None of the scenarios of the United States' agriculture sector tested by us or any other analysts assume that revenues would be "recycled" in this way. For this reason, the results are all skewed toward greater economic impact.

Sources: Hanson and Laitner, 2000; Repetto and Austin, 1997; Goulder, 1995; Oates, 1994.

Clinton Administration's estimate of 25 cents per gallon of gasoline as a low estimate, and 50 cents per gallon of gasoline as a high estimate…to produce the most conservative estimate of the cost of the Kyoto Protocol to U.S. agriculture…."

These levels of gasoline tax do not, however, correspond to the Administration's estimates published earlier that year. The Administration Economic Analysis (AEA, 1998) reports the change in gas prices in 2010 to be 3.5 cents to 5.5 cents per gallon, corresponding to a range of carbon permit price of $14 to $23 dollars per ton. Based upon the carbon content of gasoline, a tax of 25 cents per gallon would equate to a permit price of $103 per ton and a 50-cent tax would be $206 per ton. Francl et al. use cost estimates that are 7 to 9 times higher than the Administration's reported costs.

Based on these price increases, Francl et al. conclude that Kyoto implementation would increase production expenses by 6 to 12 percent and reduce net farm income by $10 billion to $20 billion, or 24 to 48 percent. We adjusted the estimates that Francl et al. produced by using gas prices actually reported by the Administration. The adjusted figures show a much smaller impact on farm income—in the range of 2 to 7 percent.

In contrast to partial budgeting approaches, studies that use sectoral models report very small economic impacts from higher energy costs even when high permit prices are assumed. The models represent thousands of options for producing the commodities represented. There is therefore significant opportunity for profit-maximizing adjustments.[8] A study by McCarl, Gowen, and Yeats (1997) compared the effects of a $25, $50, and $100 per short ton carbon permit price ($27.50, $55, and $110 per metric ton). They project that these price increases would cost U.S. agriculture $450 million, $850 million, and $1.6 billion annually—a decline of 0.14 to 0.5 percent.

The USDA's assessment (1999) of the costs associated with Kyoto implementation found a drop in net cash returns of $371 million (or 0.5 percent) with a permit price of $23, and a loss of $763 million (or 1 percent of returns) with a permit price of $50. The results of these last two studies are roughly the same and are much lower than the results produced by Sparks or Francl et al. In a review of the recent literature, McCarl and Schneider (2000) conclude that "…the results of more complete studies reveal energy taxes are likely to have little agricultural sector impact."[9] When appropriately analyzed, results clearly demonstrate that the Kyoto Protocol would not be "an assault on an American institution," as the treaty has been characterized.

A Climate Strategy for Agriculture

To date, studies evaluating the economic impacts of climate policies on U.S. agriculture have only considered the effect of changing energy prices though taxes or carbon permit prices that would result from a cap-and-trade system. However, because agricultural emissions come from a relatively broad variety of sources and agriculture has the potential to act as a carbon sink, a broader set of policies could be applicable. Further, agricultural GHG emissions are associated, both positively and negatively, with other environmental issues that are at the forefront of concern, particularly water quality, where there are a number of incentive programs in place that could help.

What would a climate strategy for U.S. agriculture look like? What policies or combination of policies might help agriculture to contribute most effectively to reduce the risk of climate change while minimizing the cost to farmers, and perhaps even making them financially better off? The elements of such a strategy should have the following characteristics:

- *It should be market-based* to allow least-cost remediation opportunities to be widely used, thereby keeping costs down for everyone.
- *It should support the achievement of the environmental goal,* a reduction in net GHG emissions for the U.S. economy.
- *It should support other environmental goals,* including improved soil tilth, reduced nutrient and pesticide runoff and leaching, reduced soil erosion, and improved wildlife habitat.
- *It should be cost-effective,* with the sum of benefits greater than the cost.

To help answer this question, we used the USDA's USMP model to explore a wide variety of policy options in order to evaluate their relative merits. The World Resources Institute (WRI) has used the model for other work, including a study of policy options for the 1996 farm bill (Faeth, 1995), and is currently exploring options to address nutrient loading and hypoxia in the Gulf of Mexico. While the USDA's Economic Research Service (ERS) is primarily responsible for maintaining and updating the model, WRI and ERS have cooperated on model development. In particular, we have worked together to add production options, including tillage and crop rotations; to disaggregate cropping regions; and to simulate the environmental impacts of each production practice and the Conservation Reserve Program.[10] The model provides estimates of conventional economic indicators for the sector, including prices, costs of production, revenues, and net cash returns. It also projects environmental effects of policy changes including soil erosion, the value of related offsite damages, nutrient losses, GHG emissions, soil carbon flux, and energy use, including that embodied in inputs.

To provide a baseline for comparison with the other studies and our own analysis to follow, we start by looking at the implications of an international carbon trading program as envisioned in the Kyoto Protocol. As noted above, most models that have considered global trading project a carbon permit price at or below $50 per ton (Weyant and Hill, 1999). We consider the numbers projected by the Administration's Economic Analysis (1998) of $14 and $23 per ton, as well as values of $50 and $100 per ton. These prices are imposed on direct use of energy in all field operations such as tilling, harvesting, fertilizer and chemical applications, as well as the energy embodied in the production of fertilizers and chemicals. Table 2, which provides the results of these tests, shows how implementation of permit prices would compare to the 2010 baseline.

Not surprisingly, we show numbers very similar to the USDA's analysis. The minor differences result primarily from the use of an updated baseline for the scenario base year of 2010 (USDA, 2000). The higher energy prices reflected by the $14, $23, $50 and $100 per ton permit prices translate to energy price increases averaging 3, 5, 11, and 22 percent higher over the 2008–12 commitment period compared to what they would have been without Kyoto in that period. The effect on net cash returns for agriculture is small, from -0.4 to -1.4 percent. *(See Figure 1 and Table 2.)*

Table 2 **Impacts of Carbon Permit Prices on Agricultural Indicators**

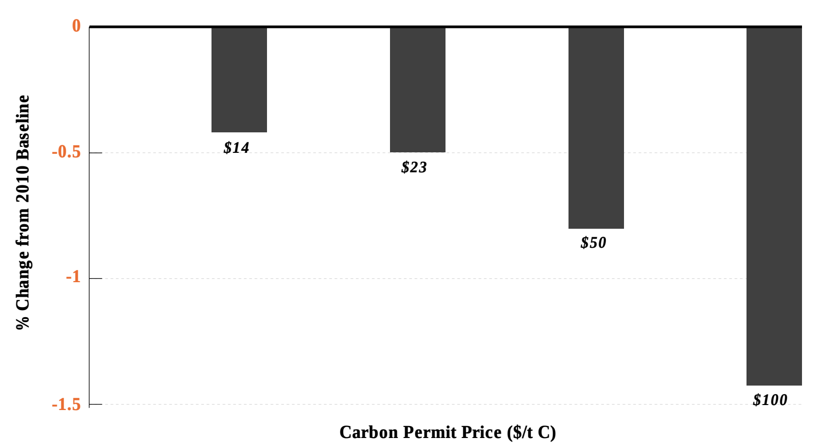
	2010 Baseline	$14/t C	$23/t C	$50/t C	$100/t C
		Percent Change from Baseline			
Cash Receipts ($Billions/yr.)	223	0.1	0.2	0.3	0.5
Variable Cost ($Billions/yr.)	116	0.6	0.8	1.3	2.2
Net Cash Returns ($Billions/yr.)	106	-0.4	-0.5	-0.8	-1.4
Crop Acreage (million acres)	342	-0.3	-0.4	-0.6	-1
Corn Price ($/bu.)	3.20	0.3	0.3	0.6	1
Wheat Price ($/bu.)	4.65	0	0	0.2	0.4
Soybeans Price ($/bu.)	7.55	0.1	0.1	0.1	0.1
CO_2 & N_2O emissions (MMTCE/yr.)	49	-0.2	-0.3	-0.6	-1
Carbon Sequestered (MMT/yr.)	13	0.3	0.4	0.7	1
Net GHG Emissions (MMTCE/yr.)	36	-0.5	-0.6	-1	-2
Sheet & Rill Erosion (Million tons/yr.)	1,100	-0.1	-0.2	-0.3	-0.5
N lost to water (Million tons/yr.)	6	-0.2	-0.2	-0.4	-0.6
P lost to water (Million tons/yr.)	0.6	-0.2	-0.2	-0.3	-0.5

Source: World Resources Institute. Most values are rounded off.

The level of change is relatively straightforward to explain. Taking the case of the $23 per ton permit as an example, if energy costs, both direct and indirect, account for roughly 15 percent of farm production expenses, a 5 percent increase in that subset of costs would result in an increase of about 0.8 percent in total variable costs compared to the baseline. However, the higher costs induce a small decline in cropped acreage as marginally profitable lands are withdrawn from production and put into conservation programs, or rangeland, rather than incur the financial loss. About 0.3 percent, or a little more than 1 million acres, go out of production. This in turn causes crop prices to rise, about a penny on a bushel of corn and soybeans, and no change on wheat. Cash receipts go up, dampening the impact of the rise in production costs.

In this model, we captured a subset of all agricultural emissions. For each cropping practice, we developed budgets from USDA farm surveys for various tillage and crop rotations in production regions. We generated a unique GHG emissions profile based upon the use of energy and inputs for each specific practice. For carbon dioxide emissions, we used coefficients based on the use of diesel fuel and energy in the production of fertilizers and chemicals. We also derived nitrous oxide emissions from fertilizer use, applying the same method as the USEPA inventory and calibrating to their estimate. We were unable to make estimates of other GHGs from crop production, such as N_2O releases from

Figure 1 **Change in Net Cash Returns With Various Carbon Permit Prices**



Box 2 **Agricultural Trade and Competition**

One of the main concerns commonly expressed about the Kyoto Protocol is that the differences in responsibility for emission reductions between the developed and developing countries will lead to unfair competition and a loss in market share for the United States. This concern has been expressed with regard to trade in agricultural commodities important to the United States. This is largely an unfounded worry, however, as most of the U.S.'s export competitors have agreed to binding GHG reductions under the Kyoto Protocol. Annex 1 countries account for about 70 percent of world trade in agricultural commodities. In addition, Argentina, a particularly important trade competitor for agricultural goods, agreed to a voluntary commitment to reduce its greenhouse gas emissions when it hosted the Fourth Conference of the Parties in 1998.

For the major grains, trade is dominated by countries whose emissions would be regulated under Kyoto. For wheat, corn, and soybeans, Annex 1 countries account for 87, 73, and 62 percent, respectively, of the total value of exports in 1998. Argentina accounts for 9, 15, and 7 percent of the world's export value of wheat, corn, and soybeans. When Argentina's exports are included, the export value of wheat, corn, and soybeans from countries that have agreed to GHG reductions comes to 95, 87, and 70 percent.

In the modeling we did for this report, we were unable to make any energy cost adjustments for countries other than the United States, essentially assuming that only the United States would have to comply with Kyoto. To the extent that competing exporters would have to meet Kyoto commitments, economic impacts in the United States would be lower.

Source: United Nations Food and Agriculture Organization (1998).

legumes, residue burning, or methane releases from rice, nor any emissions from livestock production, because the analytical techniques do not exist or do not produce reliable estimates.

We estimated changes in soil carbon based upon simulations of each cropping system using the USDA's EPIC model, a biophysical and environmental model (Williams et al., 1989). The simulated values are calibrated to national estimates produced by Eve, Paustian, Follett, and Elliott (2000). Other environmental indicators in the model—such as soil erosion, nitrogen, and phosphorus losses—were also generated using EPIC.[11]

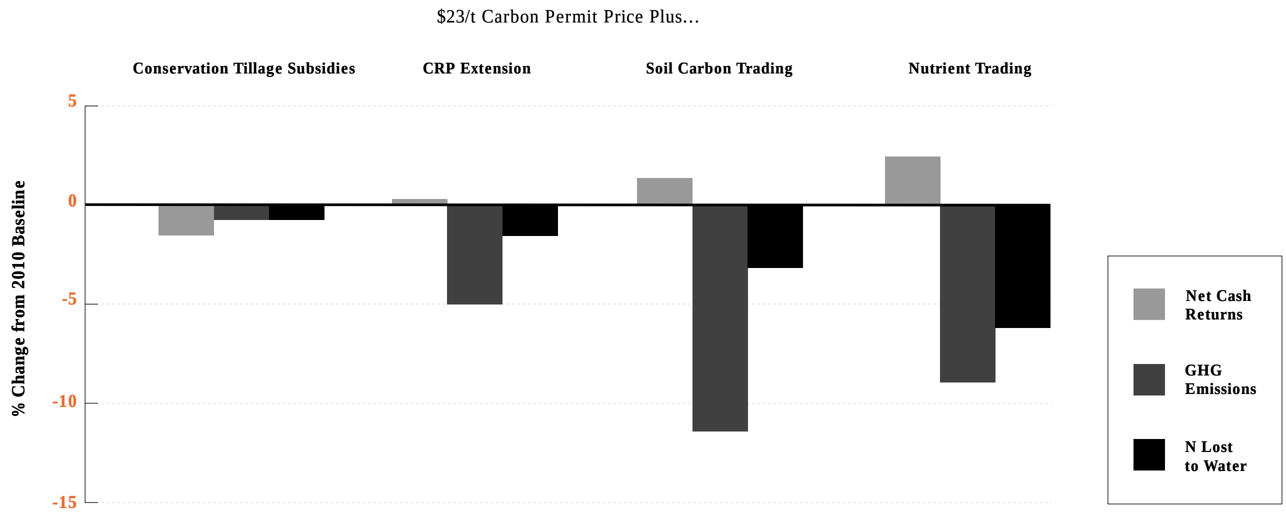
GHG emissions go down as a result of the price rises represented here. The changes in CO_2 and N_2O emissions are roughly proportional to the decline in crop acreage. Though not reported in the table, there is a somewhat greater reliance on conservation tillage, as almost all the reduction in acreage comes from acres tilled without conservation practices due to their higher energy requirements. We also show an increase in soil carbon sequestered from the base of about 13 MMTC per year on cropland and CRP. These two together produce a net reduction in GHGs roughly a third greater than just the change in crop acreage.

Kyoto Plus

In addition to a carbon permit trading system, there are other policies that could support emission reductions or sequestration of carbon in the agricultural sector. We consider a few of the most prominent and promising, combining each of them individually with a $23 per ton carbon permit price. The results are reported in Figure 2 and Table 3. The scenarios include the following:

- *Conservation tillage subsidies.* Subsidies on conservation tillage practices have been a standard conservation policy for many years. In this scenario we simulate a program that offers $25 per acre per year[12] for mulch, ridge, and no-till production systems. There is no cap on expenditures and no limit on where or how the acreage shifts can occur.

Figure 2 **Kyoto Plus Results**



- *Conservation Reserve Program Extension.* As the name suggests, the CRP is a program intended to put cropland in reserve for conservation purposes, including soil erosion, water quality, and wildlife habitat. The CRP also has the benefit, and was initially supported, because the withdrawal of land from production cuts supply and boosts crop prices. Because CRP acres are not plowed, are planted to a cover crop, and receive no fertilizer or pesticides, this land use produces little erosion or nutrient loads, uses no energy, and can sequester significant amounts of carbon during the life of the contract. In this test, we increase the rental rate by 20 percent.

- *Soil carbon trading.* Soil carbon is not yet accounted for under the Kyoto Protocol, though carbon sequestration on agricultural soils could be allowed under Article 3.4 at some time in the future. This article allows the parties to include "additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils…." Trading of emission reductions is allowed, including activities that sequester carbon through afforestation, reforestation, or control of deforestation. This test assumes that each ton of soil carbon sequestered by a new activity, additional to the baseline, would generate a credit that would be traded for $23.

- *Nutrient trading.* Various state and local agencies are exploring nutrient trading between point sources like municipal and industrial discharges, and nonpoint sources like farmers. Farmers could adopt various practices to reduce nutrient loads to surface waters, thus generating a credit that could be applied against a point source permit and allowing that discharger to meet an environmental obligation in a much less expensive manner (Faeth, 2000). New regulations released by the USEPA in July encourage states to develop nutrient trading programs. The idea is essentially the same as that being considered under the soil carbon trading system, but for a different media and pollutant. We assume that each pound of nitrogen load reduced from the baseline generates a payment of $1.[13] Because reduced soil nitrogen surpluses lead not only to improved water quality but also reduced N_2O emissions (Robertson, et al., 2000) this policy option has relevance to climate change.

Conservation Tillage Subsidies. A number of meetings and conferences have been held over the last few years to discuss the potential of agricultural soils to sequester carbon to help address climate change.[14] A popular proposal at such meetings is the notion of offering subsidies for conservation

Table 3 **Results of Policy Tests Coupling a Carbon Trading System with Other Options (Percent change compared to the 2010 baseline, Table 2, column 1)**

	$23/t Carbon Permit Price Plus...			
	Conservation Tillage Subsidies (@ $25/ac/yr)	CRP Extension (20 percent increase in rental rate)	Soil Carbon Trading (@ $23/t C)	Nutrient Trading ($1/lb N)
Cash Receipts	-0.2	0.6	0.9	1.5
Variable Costs	0.5	0.8	0.5	0.9
Net Cash Returns	-1	0.4	1.4	2.1
Crop Acreage	~0	-2	-4	-4
Corn Price	-1	3	3	7
Wheat Price	-0.4	1	3	4
Soybeans Price	-0.5	1	2	3
CO_2 & N_2O Emissions	-0.3	-1	-4	-5
Carbon Sequestered	-1	7	19	8
Net GHG Emissions	-0.1	-4	-12	-9
Sheet & Rill Erosion	-1	-1	-2	-3
N Lost to Water	-0.2	-1	-3	-6
P Lost to Water	0.2	-1	-3	-6

Source: World Resources Institute. Most values are rounded off.

tillage practices. Field studies have shown that practices such as no-till and mulch tillage, which reduce erosion by leaving more plant residue on the surface, can also enhance soil carbon storage (Lal et al., 1998; Robertson et al., 2000).

While conservation tillage can undoubtedly have positive environmental benefits, a program that targets a best management practice without regard to specific environmental outcomes may not necessarily deliver the intended results. In the scenario we tested, the subsidy serves to reduce the cost of production for conservation tillage practices, making them relatively more attractive, as intended. The subsidy helps to offset the effect of higher energy prices and there is essentially no change in crop acreage compared to the baseline. At $25 per acre, we show an increase in conservation tillage of 16 million acres, about 5 percent of cropland in the 10 major field commodities captured in the model.

However, this produces an adverse effect on farm income. Production costs are slightly lower relative to the scenario with only the carbon permit trading program (Table 2, column 3). Crop prices are lower than the baseline without Kyoto (Table 2, column 1) because more acreage stays in production. The smaller change in acreage produces a somewhat greater loss in net revenues, about 1 percent. A subsidy on conservation tillage does produce the effect of lowering GHGs from agriculture, but not due to soil carbon storage, which actually declines. The reason is that our simulated results for soil carbon sequestration using the USDA's EPIC model show that some conventional tillage combinations can sequester more carbon than conservation tillage practices, depending on the crop grown. If no-till soybeans are planted in the place of conventional tillage corn, for example, less carbon will be sequestered because the soybean crop will produce less biomass. The GHG benefit of moving to conservation tillage comes from reduced energy and fertilizer use as crop rotations adjust as well. The program does have the effect of reducing soil erosion by about 12 million tons per year, but at a relatively high cost, again because of the lack of targeting.

We also tested this scenario with the assumption that farmers would make an extremely large (and unrealistic) shift to conservation tillage based upon the subsidy offered.[15] The purpose of the test was to see what might happen if a huge amount of cropland went into conservation tillage and was taken out of conventional tillage. The results of the test again show the problem with programs that support best management practices as opposed to environmental performance.

In the test with the model as normally used, conservation tillage increases by about 16 percent in response to a $25 per acre subsidy. With the adjustment, the increase is 130 percent and conservation tillage comprises about 70 percent of the cropland covered in the model, or 241 million acres. Cropland acreage increases by less than 1 percent. Production of feedgrains goes up and prices decline. This induces an increase in livestock production and a withdrawal of about 14 percent of the land in the Conservation Reserve Program. While more carbon is sequestered in cropland soils as a result of the increase in conservation tillage, less is sequestered in the CRP, resulting in a small net loss in carbon sequestered in soils. The net reduction in GHG emissions of about 1 percent comes mostly from reduced use of energy and fertilizers. The program costs more than $3.4 billion annually. There are significant gains in other environmental indicators, particularly soil erosion, which declines by 12 percent, and phosphorus runoff, which declines by 4 percent.

Conservation Reserve Program

Greater incentives for the Conservation Reserve Program address some of the difficulties presented by the conservation tillage subsidies, because CRP land always produces net GHG benefits relative to cropland, even though the extent of the benefit varies. A 20 percent increase in rental rates induces an increase in CRP of about 6 million acres, or about 1.5 percent of U.S. cropland. Under this scenario, we project a cut in net GHGs from agriculture of about 4 percent compared to the baseline without Kyoto. The reduction comes mainly from a 7 percent increase in carbon sequestration, from about 13 to about 14 million tons per year. GHGs from CO_2 and N_2O go down in proportion to the cut in crop production, a little over 1 percent. Nitrogen and phosphorus losses to water show a similar decline for the same reason.

The addition of the CRP extension to the $23 per ton carbon permit price shifts the economic outcome from slightly negative to slightly positive, basically balancing out the effect of higher energy prices. The cut in crop supply pushes crop prices up between 1 and 3 percent, adding 0.6 percent to cash receipts. Production costs are a bit higher than previously for livestock because feed costs are up; net cash returns show an increase of 0.4 percent compared to the 2010 baseline without any climate policy.

Soil Carbon Trading

A market in soil carbon sequestration credits, as we tested here, has the benefit of strengthening both the economic and environmental outcome when added to higher energy prices. The result is based largely on a major shift of 14 million acres out of cropland and into the Conservation Reserve Program on the assumption that farmers would reap the benefit of CRP enrollment by selling carbon credits. Prices increase on the tightening of supply, cash receipts go up, and farmers realize a gain in net cash returns of more than 1 percent, compared to a loss with the higher energy prices alone.

The amount of carbon sequestered goes up by about 2.5 MMTC from the base of 13 MMTCE. This is a large relative gain of 19 percent, but a small absolute gain. Emissions from energy and fertilizer use go down by 4 percent, for a net change in GHGs of -12 percent. Sheet and rill erosion and nutrient losses also decline.

The outcome hinges largely on the CRP shift. We have not constrained enrollment in this scenario, to see what the upper limit might be. We show an increase of 14 million acres, which would push enrollment beyond the current cap of 36 million acres.

Higher enrollment of course implies a higher cost to the government for the program. The addition of soil carbon trading is something of a mixed blessing as CRP program costs would go up by about $550 million per year, but the average rental rate would be lower as the income generated from the sale of credits would mean that farmers would be willing to accept a lower payment for enrollment since there is a source of income from the land. This scenario raises a critical policy question: who owns the credits generated on land leased by the public? Should farmers be able to sell carbon credits generated on land being rented by the government? Or, should the government be able to recoup some of its investment by sharing in the benefits generated?

If a soil carbon trading program only rewarded sequestration on cropland, the outcome paradoxically generates a smaller net GHG reduction than higher energy prices by themselves. With this scenario, the economic indicators are essentially no different than the case with the permit price alone. There is a small shift of crop acreage out of production and small decline in direct and indirect energy use and N_2O emissions. The absolute increase in carbon sequestration is only 2 percent of the case where CRP credit payments are allowed.

This result can be explained by the small net change in revenues that would be expected under a carbon trading program with a $23 permit price. If the net gain in carbon sequestered per acre is 0.2 to 0.4 tons per acre of carbon per year, that would translate to increased revenues of $5 to $10 per acre per year. Typically, farmers require a larger financial inducement to convince them to shift production practices.[16] However, when coupled with a CRP rental payment, the financial return looks attractive and the results are much more dramatic.

Nutrient Trading

We find that a trading program for nutrients under the Clean Water Act would be more effective in improving most of the indicators we are concerned with here. In the United States, there are more than 3,400 waterways impaired by nutrients. Nitrogen is the principal culprit in the eutrophication of the nation's estuaries and in the creation of the "dead zone" in the Gulf of Mexico. Much of the nutrient load comes from agricultural sources (Faeth, 2000).

Under the Clean Water Act, point source dischargers must have permits and adopt technologies to reduce nutrient emissions. Over the next 20 years, EPA estimates that almost $140 billion in capital costs will be needed for municipal treatment works and related needs. The Association of Metropolitan Sewerage Agencies (AMSA) and the Water Environment Federation say that another $190 billion will be needed by local governments to replace aging facilities and collection systems, not including operation and maintenance costs (AMSA/WEF, 1999). This scenario assumes that point sources could pay farmers to reduce their nitrogen loads and take credit against their permits under the Clean Water Act. The price of each pound of nitrogen lost to water by runoff or leaching is set at $1.

The results are good not only for the environment but also for farmers. Compared to the 2010 baseline, receipts go up by 1.5 percent, and production costs by not quite 1 percent. This nets out to a gain in net cash returns of 2.1 percent, even with the carbon permit price of $23 per ton applied. The addition of nutrient trading shifts the loss to a gain.

Each environmental indicator except carbon sequestered shows much greater improvement than the previous tests, and this indicator shows an improvement equal to the CRP extension scenario. The improvement is a result of a shift in land use and a reduction in conventional tillage. First there is a 4 percent decline in cropped acres. About 46 percent of this goes into the CRP because this land use produces relatively large reductions in nitrogen losses while still generating an income for the farmer. Most of this land comes out of conventional and moldboard tillage practices, increasing the relative share of conservation tillage. We have assumed that nitrogen reduction credits could be earned from CRP acres. This source of income increases the financial attractiveness of CRP relative to cropping, so program enrollment goes up even though rental rates do not. There is an additional cost to the government of $295 million for the new acres enrolled to fill out the program.

These changes in production cause energy and fertilizer emissions to go down by 5 percent and soil carbon sequestration to go up by 8 percent, thus providing a net reduction in GHGs of 9 percent, or about just over 3 million tons per year. In addition, nitrogen lost to water goes down by 6 percent, phosphorus losses by 6 percent, and sheet and rill erosion by 3 percent.

The current version of the model implicitly assumes that farmers cannot do a better job of managing nutrients, a very conservative assumption. While the model captures various rotations and tillage practices, it does not have alternative nutrient management strategies incorporated. If it did, there would be less of a shift in crop acres, as fertilizer use would change as well as tillage and crop rotations.

This scenario points out the synergies between water quality improvements and GHG reductions. Water quality concerns are at the top of the agricultural sector's environmental agenda. A well-targeted water quality program aimed at reducing nutrients and using market-based mechanisms to provide flexibility and reduce the costs of meeting the nation's water-quality goals could also provide climate co-benefits.

Principal Findings

What lessons can we draw from the analysis presented here? There are four key findings that are significant for implementation of the Kyoto Protocol and any related domestic policies.

1. Implementation of the Kyoto Protocol will not be an economic disaster for U.S. agriculture.

Even with emission commitments from 2008–2012 limited to the developed economies of the world, the levels of carbon permit prices most likely to result from Kyoto implementation would affect farm income by a few percent at worst. Energy use, both direct and indirect, is an important component of production costs, but it does not dominate by any means. Further, farmers do have opportunities to adjust production systems, to a much greater extent than even we show here, to avoid paying higher energy bills. It is simply wrong to assert that the Kyoto Protocol is an assault on American agriculture.

2. Trading in carbon sequestration could be an opportunity, but a small one.

For all the interest in soil carbon trading, and the extraordinarily high estimates of the potential for carbon sequestration in agricultural soils, the economics do not appear to be particularly favorable for a large amount of offsets. It may be true that soils could potentially be a reservoir for many gigatons of carbon. However, the economic potential does not line up in the same way. The largest increase in soil carbon sequestration we could produce with the policy runs we tried was an annual increase of about 3 MMTC. That's around 0.5 percent of the 650 MMTCE annual reductions that the United States would be looking for under Kyoto.

3. Incentives to reduce net emissions of all greenhouse gases would help to capture synergies between water quality benefits and GHG reductions.

Policy discussions, at least in agricultural circles, have been fairly myopic in focusing almost exclusively on soil carbon sequestration. A broader view of the landscape shows that larger opportunities for cost-effective reductions exist with carbon dioxide emissions from direct and indirect energy use and nitrous oxide emissions. A quick look back at the gases released by agriculture confirms this, as nitrous oxide emissions comprise the largest component. Recent agronomic research shows the same result and confirms the importance of a comprehensive approach (Robertson et al., 2000). Further, water quality issues are prominent for agriculture, since the sector is responsible for most of the nutrient loading in the United States. The opportunity for synergy between water quality and climate is large.

4. Programs that pay for environmental performance improvements will yield the most cost-effective solutions.

Programs that subsidize best management practices have been a staple of farm programs for many years. The premise has always been that BMP funding would deliver the environmental goods. This assumption can fail, as conservation tillage subsidies that we tested appear to do here. A much better option would be to reward the desired gain, not a proxy for it. Measurement problems are of course an issue, but it would be better to deal with those than spend a lot of money on a program that does not meet the intended objective.

Recommendations

1. Congress should approve funding to better understand the opportunities for cost-effective GHG reductions in the agricultural sector.

The risks of global climate change are real, as are the risks to the agricultural sector. Prudent investments to get the U.S. economy on a pathway to the necessary emission reductions and climate protection are warranted. Agriculture can and should play a part. Understanding the nature of the opportunities and their relative costs and benefits is a key step in this process.

- Research should focus on much more than carbon sequestration. In fact, that may not even be a priority funding area compared to nitrous oxide and methane emissions. Most importantly, greater understanding of the reductions possible in nitrous oxide and methane emissions, as well as carbon sequestration, from different crop and animal practices in different regions of the United States is needed. Attention to only one aspect, such as soil carbon, will likely mean that other potential changes in emissions will be overlooked.

- Further, we need to know what practices could provide the best opportunities for reductions that help farmers deal with other management issues, so that the greatest benefits can be captured and incentives can be appropriately designed.
- Finally, cost-effective yet reliable estimation methods to measure changes in agricultural emissions or sequestration need to be developed so that our confidence in emissions reductions, and subsequently their value, can be increased.

2. The USDA should develop and implement a pilot GHG-trading program for agriculture.

Our results do not show great economic potential for carbon offsets, but we do show the potential for gains in other gases. Some observers suggest that the physical potential may be enormous. For a relatively small amount of money, the whole notion could be tested to find out. The USDA now provides hundreds of millions of dollars to promote the adoption of best-management practices, and billions of dollars in CRP rental payments. A small share of that money, perhaps $10 million or $20 million for five years, should be used to create and implement a market-based environmental services program that would include all GHGs. Some funds should be used to set up an administrative system, to apply estimation methods, to verify results, and to work out rules for permanence, baselines, and additionality. Most of the money should be used to purchase reductions from farmers in an effort to see how such a system might work in practice and what market prices might look like. The system should operate through the Internet and use market software to create competition.[17] A pilot would help the USDA assess opportunities to move toward markets for all their environmental subsidy programs, hopefully resulting in much more cost-effective conservation programs. The credits generated under such a pilot would not count for anything; the pilot would simply be an experiment in better environmental policy management.

3. Farm income subsidies should be shifted to support programs that help farmers reduce environmental problems caused by agriculture.

In 1996, farm income support programs were changed so that payments were based on historical payments rather than production. Cutting the link between commodity prices and income payments was a useful change that will encourage the adoption of cropping rotations and less monoculture, which is a good outcome environmentally. However, the next step needs to be taken—a much greater share of the billions of dollars spent on unrestricted farm income support should be tied to environmental remediation efforts. Farmers and the nation should come to a compromise to continue support payments, but link the payments to environmental improvements. The programs should employ market-based mechanisms such as auctions, which ensure that the greatest environmental benefit is achieved for the money spent.

4. Permits for carbon emissions rights should be auctioned and the revenues returned to the public.

The working assumption on Kyoto implementation is that it will be implemented using a "cap-and-trade" system where emissions are capped at the Kyoto target. Permits would most likely be applied at the wellhead or minemouth, where energy resources are extracted. The price of the permits would then be passed along downstream. If the permits were "grandfathered," (given away) the coal and oil companies would reap an extraordinary windfall. Instead, the permits should be auctioned by the government and the revenues returned to the public through lower taxes. Kyoto implementation should not be an opportunity to simply raise taxes. None of the scenarios tested by us or any other agricultural analyst assume that revenues would be "recycled" in this way, so all the results are skewed toward greater economic impact. If the revenues were returned, the economic impacts, of course, would be much less. The agricultural sector should get its share of the revenues generated by auctions to oil companies and other energy firms through lower income, employment, or capital gains taxes, or even through greater investment in research and conservation programs that would help agriculture adapt to climate change.

5. Nutrient trading programs should be vigorously encouraged by USEPA.

Various states are moving forward with trading programs or pilots to evaluate the opportunities for a flexible, market-based approach to water quality management. Studies show that the costs of Clean Water Act regulation can be cut dramatically by approaches that permit nutrient trading between point sources and between point and nonpoint sources (Faeth, 2000). Nutrient trading, especially in nitrogen, can not only reduce the cost of meeting regulatory obligations, but can also provide co-benefits, including reductions in GHGs and erosion. It is too early for national implementation yet, but a set of pilots in various settings should be aggressively pursued with technical and financial resources from federal agencies.

6. Agricultural soils should only be included in Kyoto's Article 3.4 if both soil carbon removals and emissions are accounted for and reasonable certainty in measurement protocols, permanence, and additionality can be assured.

The largest emissions from agricultural sources, including nitrous oxide, methane, and carbon dioxide from fossil fuel use are already captured in the "basket" of gases that are defined under the Kyoto Protocol. Soil carbon sequestration on agricultural soils is not yet accounted for, but could be under Article 3.4. This article allows the parties to include "additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils…." If removals by agricultural soils are included, then emissions from soils must also be included. While this is perhaps an obvious point, the language is not clear and it would be a mistake to only count removals.

The main reason for the interest in including agricultural activities is to move toward soil carbon trading programs. While soil carbon trading does appear to have some potential, it is a second-best approach. Nitrous oxide and methane, the most important GHGs from agriculture, would not be addressed or accounted for in soil carbon offset activities. Further, soil carbon aggrades relatively slowly, but can degrade quickly, releasing stored carbon if good management practices are not maintained.

If countries wish to apply activities related to agricultural soils to their commitments, they should be required to establish and verify methods to estimate soil carbon stock changes that are reasonably accurate and reliable, and to establish rules to account for permanence and additionality.

7. Develop an environmental strategy for agriculture and implement it.

The agricultural sector faces a series of environmental challenges. The silver lining in this cloud is that there are significant synergies that exist. If the United States takes advantage of them, problems can turn into opportunities. Reductions in nutrient loads, soil erosion, and net greenhouse gas emissions, for example, move together under the right circumstances. Unfortunately, policy is fractured and program implementation methods are outdated. The United States needs to be much more strategic in its policy development. Rather than a piecemeal approach, the Administration and Congress should step back and look at the issues anew. A new agenda needs to be developed that is relevant not only for the environmental challenges we face today, but that will also work in the context of the economic and social challenges that also exist. The elements of this strategy should deal with research priorities, farm income supports, information technology, the development of markets for environmental services, and conservation incentive programs in the farm bill and the Clean Water Act.

Conclusion

The risks of climate change are real and increasing as the economy grows. Every year we release more greenhouse gases, which not only raise the probability of changing global patterns, but also pollute the air and, in agriculture's case, can be tied to water quality problems. The international community, including the United States, decided in 1992 that it was time to move forward to protect the climate. It reaffirmed this commitment with the Kyoto agreement in 1997.

While climate protection will not be free, the costs to the economy can be minimized with the right set of policies, including an international program to trade GHG emission rights. Such a program is now under development in international negotiations. The costs to the agriculture sector, a significant emitter of GHGs, will not be catastrophic, but instead appear to be minimal under the approaches now being pursued. Further, the right policy context could make the outcome an economic gain for farmers.

Companies in other industries, including oil, electric power, and transportation are coming to view the implementation of market-based climate policies as a business opportunity. BP-Amoco is experimenting with its own internal carbon trading program and has announced its intent to be the leading provider of solar panels within 10 years. The company's new brand is "beyond petroleum." General Motors is investing heavily in the development of electric cars powered by fuel cells that may be on the market in five years. Eleven major companies representing 7 percent of U.S. industrial energy use have recently come together to form a "green power market development group." The express purpose of the group is to support the development of 1,000 megawatts of new green power over the next 10 years (WRI, 2000).

These companies and many others see opportunity where most agricultural interests seem to see disaster. Yet, opportunities for the development of new markets and services do exist for agriculture. There may be limited opportunity for soil carbon sequestration, but there may be enormous potential for biofuels. Agriculture has vast resources that, at the right price and with the right technology, could be put into place to produce liquid fuels with no net GHG emissions. The market for renewable fuels as we move away from fossil fuels will be immense. There is also opportunity for wind power development in the Plains states. Farmers are now renting space in a number of areas for the placement of wind turbines, generating a rental rate of up to $85 per acre, while they simply plow around the structures.

However, none of these activities, whether they be soil carbon sequestration, no-till, wind turbines, or biofuels, will be encouraged without ratification of the Kyoto Protocol. There will be higher energy costs, but these will be far from crippling. There will also be opportunity, and with the right strategy that encompasses a broad context, agricultural incomes could increase. The international community and many industry leaders are moving forward to address the climate challenge. Those that are staking a leadership position believe they will profit by it. U.S. agriculture has much to offer if it can be a leader.

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NOTES

1. For the text of the Kyoto Protocol, a complete list of countries and their commitments, see the UNFCCC website, http:/www.unfccc.de/.

2. Unless otherwise noted, in this report we mean metric tons.

3. Different GHGs have different heat trapping ability, called "forcing factors." MMTCE is a common reporting unit that weights each gas according to its Global Warming Potential.

4. This 28 MMTCE includes emissions from fossil fuel used directly in operating farm machinery and indirectly for the production of farm inputs such as fertilizer and pesticides (Lal, et al., 1998).

5. The USEPA's inventory (2000) reports that agriculture is responsible for 8 percent of total U.S. GHG emissions. However, the inventory does not break out agricultural fossil fuel use nor changes in soil carbon.

6. For the sake of brevity we chose not to highlight the potential impacts of climate change on agriculture. For good summaries, see Adams, et al. (1999), or Rosenzweig and Hillel (1998).

7. Laitner, John A. "Skip", EPA Office of Atmospheric Programs. September 25, 2000, Personal communication. A growth rate of 3 percent from 2010 to 2020 equals a gain of 34.4 percent in GDP. A 2 percent reduction in GDP implies a gain of only 31.7 percent for a growth rate of 2.79 percent. Solving for t in years, to get 34.4 percent with a 2.70 percent growth rate implies 10.74 years, or about nine months more time necessary to reach the same GDP level.

8. Even with this scope of representation, these models still fall short of reality because they do not represent new technologies that could keep energy use and costs down, including nutrient management practices, rotational grazing systems, sustainable agricultural practices, and alternative fuels derived from biomass.

9. It is worth noting that none of these studies assume that the revenues generated by the sale of permits are returned to the agricultural sector in any way. A good deal of discussion in the economic and policy literature focuses on means to make trading schemes "revenue-neutral," for example by lowering incomes taxes by an equivalent amount.

10. Even though ERS and WRI both use the model and contribute to its development, ERS is primarily responsible for its maintenance. WRI and ERS do not collaborate on policy studies using the model. Neither party endorses the conclusions and recommendations the other derives from the use of the model. The model is freely available to anyone through the ERS. See Faeth (1995) for a more complete description of the model and its capabilities.

11. See Faeth, 1995, for a more complete discussion of the methods and data used.

12. In 1995, the average tillage subsidy paid to farmers for notil or reduced tillage practices was $13–15 per acre for 300,000 acres enrolled (USDA, 1996). This payment was based on a 75 percent cost-share, meaning farmers paid one-fourth of the cost. We chose a $25 per acre per year subsidy level to generate a model response large enough to evaluate for the purposes of this report.

13. We ran various values starting at $0.50 per pound of N and higher. At one dollar per pound we got a model response that was similar to the soil carbon trading program. We chose to report those values. There are no established prices for nitrogen offsets. We have looked at the cost of phosphorus trading (Faeth, 2000) to calculate the cost of remediation. The approaches are somewhat similar. In three case studies in the upper Midwest we found the cost of a trading program to be $1.75 to $4.36 per pound of P on a watershed basis.

14. As a few notable examples, the Meridian Institute hosted a series of meetings during the spring and summer of 2000; a recent conference on the topic "Carbon: Exploring the Benefits to Farmers and Society" in Des Moines, Iowa on Aug. 29–31, 2000 had nearly 500 people in attendance, and Pacific Northwest National Lab hosted a meeting on carbon sequestration in soils in St. Michaels, MD in 1998.

15. USMP uses upward-sloping cost-curves for each activity, so that the more an activity or practice comes into the solution, the higher the cost for the next acre brought in. We ran this test by adjusting the parameter that determines the slope of the cost-curve, so that the cost for the next acre goes up at a very slow rate. This test requires a recalibration of the model and the development of a new baseline, which is slightly different from the standard baseline.

16. The national average payment required by farmers in 1995 to enroll about 300,000 acres in notil systems in long-term agreements was $14.23 per acre (USDA, 1996).

17. WRI has created and is testing software to develop markets for trading in nutrient reductions in Michigan, the Chesapeake Bay, the Minnesota River, and the Lower Boise River watersheds. See http//:www.nutrientnet.org for the demo.

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