Integrating Agricultural and Forestry GHG Mitigation Response into General Economy Frameworks: Developing a Family of Response Functions*

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April 2002

Seniority of authorship is shared by McCarl and Gillig.

* This research was sponsored by funds from the Texas Agricultural Experiment Station and the Department of Energy.

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Abstract

This study develops a family of response functions for characterizing potential responses to greenhouse gas mitigation policies by the agriculture and forestry. Specifically, these functions give estimates of greenhouse gas sequestration and emission reductions in forestry and agriculture along with level of sectoral output given a carbon price, demand for agricultural goods, and energy price. The data are developed by repeatedly running an agricultural and forestry sector model then fitting functions to the resultant output. In addition, alternative policies are examined in terms of the types of greenhouse gas offsets allowed.

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There has been a recent increase in concern over the Greenhouse Gas (GHG) climate change forcing issue. According to the Intergovernmental Panel on Climate Change (IPCC), buildups in the atmospheric concentrations of GHGs will affect global climate, stimulating warming (IPCC, 2001a and 2001b). In turn, a number of societal groups are entertaining the possibility of actions directed at somehow reducing concentrations through mitigation actions. A large effort has been amassed to investigate the costs of mitigation largely structured around the assessment of compliance with the Kyoto Protocol (KP) as typified by the efforts under the Stanford Energy Modeling Forum (Weyant, 1999).

One characteristic across these analyses is a lack of in depth treatment of agricultural and forestry (AF) sector options[1]. In particular, emission mitigation can be achieved through AF efforts by employing sink strategies, biofuel production or emissions management relative to carbon, methane (CH_4) or nitrous oxide (N_2O). Agricultural and forestry participation is partially covered in recent work by Babiker et al. (2002) where the sink part only deals with the business as usual allocation in the Kyoto negotiations and the non CO_2 part is treated in a relatively simplistic fashion. Sohngen and Mendelsohn (2001) also cover such issues in a forestry context integrating with the Nordhaus (2001) DICE/RICE model but do not deal with agriculture or biofuels in depth.

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[1] The range of potential options is discussed in McCarl and Schneider (1999 and 2000).

Inclusion of agricultural and forestry options is a complex endeavor. A number of the alternative mitigation strategies are directly competitive (for example crop land based strategies like conservation tillage adoption, afforestation and biofuel production are mutually exclusive on an acre of land) and are misleading when treated independently. Furthermore, there are important market interactions that cause interactions between strategies. For example, afforestation of an acre that was producing corn reduces available feed and may stimulate production of feed elsewhere as well as intensification (increased fertilized or irrigation), or reduced livestock herd size all of which have GHG, economic and environmental implications.

Thus, proper inclusion of AF reactions requires a detailed examination of the underlying sectoral interactions. This study develops response functions from an AF sector model that embodies many of the complexities of agriculture for use in more general economy wide exercises. To develop such functions we ran the AF sectoral model multiple times under alternative levels for the carbon equivalent price, the general level of demand for agricultural commodities and the fuel price to generate data on the simultaneous production of GHG offsets and traditional AF commodities along with information on sectoral performance. Finally, we fit functions to those data to encapsulate the results in a compact form. In turn, these functions are hopefully usable in integrated assessment modeling to reflect the possible role the AF might play and the effects of allowing sinks into the GHG offset accounting system.

Another aspect of the study involved GHG strategies allowed. Considerable debate has gone on in the KP arena regarding what counts and what does not count. We considered alternative rules involving the extent of activities allowed in terms of traditional forest management, biofuels and agricultural soil sequestration.

AF Sector Model Used and Data Generation

In order to generate data from which the response functions can be estimated we use an Agricultural Sector Model. Specifically, we use a mathematical-programming-based, price-endogenous model called ASMGHG (Baumes, 1974, Chang et al 1992, McCarl et al., 2001), Schneider (2000). In addition, ASMGHG was expanded to include carbon sequestration possibility forestry data using results from the Forest and Agricultural Sector Optimization Model (FASOM) (Adams et al., 1996) under alternative carbon prices.

ASMGHG depicts production, consumption and international trade in 63 U.S. regions. It depicts markets for 22 traditional crops, 3 biofuel crops, 29 animal products, and more than 60 processed agricultural products. ASMGHG simulates the market and trade equilibrium in these markets regionally or nationally in the U.S. and for some commodities in 28 major foreign trading partners[2]. ASMGHG deals with production and sequestration of three greenhouse gases — CO_2, CH_4, and N_2O. All gasses are treated as a carbon equivalent basis so that ASMGHG can consider tradeoffs among the gasses. This is set up using the IPCC 100-year global warming potentials. In particular, 1, 21, and 310 are used for carbon dioxide, methane, and nitrous oxide, respectively. In turn, all of these items are multiplied by the proportion of carbon in a unit of CO_2 (12/44) to convert to a carbon equivalent (CE) basis.

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[2] Additional details on ASMGHG can be found at http://agecon.tamu.edu/faculty/mccarl/asm.html under the title "*Brief Technical Summary of ASMGHG ala 2001*".

The forestry addition to ASMGHG includes results from FASOM under alternative prices formed so that they are the average of the carbon increment in the first 30 years of the FASOM run with an objective function coefficient that reflects the welfare gained from forest products less the costs of land in agriculture.

When ASMGHG is run, output is created on the level of AF sector GHG emissions and sequestration; U.S. consumer, producer and rest of the world (ROW) welfare; environmental indicators; agricultural and forestry GHG mitigation practice usage; and agricultural prices and agricultural production.

Allowed Mitigation Strategies

There are a number of questions regarding what will and will not count toward allowed GHG mitigation in the agricultural and forestry sectors (i.e. in the KP only afforestation, reforestation, and deforestation seem to count among a number of possible actions in the forest sector). To investigate these issues, this study looks at scenarios with and without certain items counting with respect to forest and agricultural alternative. The specific factors examined are:

Forestry Alternatives

1. allowing carbon only from afforestation, with charges for deforestation, and
2. allowing carbon payments to apply to any change in forest carbon above and beyond 1990 levels on existing, reforested or afforested lands with charges for deforestation

Agricultural Alternatives

1. imposing a carbon price/sequestration payment across all possible agricultural emissions and sinks modeled in ASMGHG,

2. imposing a carbon price/sequestration payment across all possible agricultural emissions and sinks, except for gases released or saved by biofuel production,
3. imposing a carbon price/sequestration payment only on all agricultural CO_2 ignoring methane and nitrous oxide consequences, and
4. imposing a carbon payment only for agricultural carbon from sequestration (i.e. soil carbon, tree carbon, and pasture generated carbon).

Permanence Discounting

1. treating all emissions and sequestration on an equal footing., and
2. discounting sink emissions for permanence (25% for Tree carbon and 50% for soil carbon),

These alternatives are then varied in 13 combinations as identified in Table 1.

Response function estimation

ASMGHG is a large and complex model containing close to 50,000 variables and 5,000 constraints. As such it is not suitable for direct incorporation into a general economy wide CGE model. Consequently, we decided to run the model under a number of alternative possible signals from the CGE model and generate data on responses then encapsulate that data into a set of response functions that could be incorporated into a CGE. This entailed making four main decisions.

1. Definition of the items that will convey information from the CGE.
2. Definition of the levels over which to vary those items.
3. Definition of the items for which response functions are to be estimated.
4. Selection of functional form.

Signals – Independent variables

The signals we chose to use from the rest of the economy that will constitute the independent variables in the estimated functions are carbon and fuel prices plus the level of agricultural demand domestically and internationally. In the regression since we use a log form we enter a 1 for the zero carbon price cases rather than a zero.

Levels over which to vary signals

Since the response functions are to be estimated econometrically and in turn used in CGE models a wide range of settings for the signals passed from the general economy is desirable. Specifically, ASMGHG was used to simulate results under 405 settings (scenarios) of these independent variables including 15 alternative carbon prices ($0, $5, $10, $20, $30, $40, $50, $60, $70, $80, $90, $100, $200, $300, and $400 per ton of CE); 3 levels of fuel prices for ethanol and energy (at 80%, 100%, and 120% of base levels), 3 levels of demand for agricultural products (at 90%, 100%, and 110% of 1997 demand levels), and 3 levels of demand for exports (at 90%, 100%, and 110% of 1997 demand levels). In addition to the 405 systematic scenarios, another 100 scenarios were randomly drawn from the ranges above for each of the 4 items to build degrees of freedom for parameters applied to each of the 4 varied factors.

Response Functions Estimated

A family of response functions will be estimated from the ASMGHG data. These fall into a number of classes.

1. *Quantity of GHG emissions and sinks*. The GHG coverage includes CO_2, CH_4, and N_2O. Separate emissions and sink functions by gas are reported since these items are

expected to move in different directions with respect to carbon price and the net emissions minus sequestration goes from positive to negative in some cases.

a. In terms of emissions, CO_2 emissions associated with sectoral activity arise from the use of fuel, more intense tillage, fertilizer manufacture, pesticide manufacture, irrigation pumping, ethanol production and offsets, biofuel production and offsets, grassland development, and afforestation/forest management with a separate function estimated for each. Associated CH_4 emissions arise from enteric fermentation, manure, rice, biomass power plus plants production, and corn ethanol processing. Finally, N_2O emissions arise from fertilizer use, manure, residue burning, biomass production and use, and corn ethanol processing.

b. In terms of sinks, we estimate functions for CO_2 in forests and CO_2 in agricultural soil. CO_2 sinks in forests is a result of conversion of land from agriculture to forest where carbon is then stored in the forest soil and growing trees. CO_2 sinks in agricultural soil involves the agricultural carbon sequestration in which carbon is retained in agricultural soil and the grass carbon emissions savings from crop land transfer to pasture or grassland.

2. *Agricultural production, exports, imports and prices*. Functions forecasting how a Fisher index number for total agricultural production, exports levels, import levels and prices changes with the signals are estimated.

3. *Land Use, allocation and valuation*. Functions forecasting total land use for crops, biofuels, pasture and forest along with land rental rates and choice of tillage practices.

4. *Welfare distribution*. Functions forecasting total welfare for consumers' producers' and foreign interests.

5. *Environmental indicators*. These functions forecast levels of environmentally related items and cover usage of irrigated crop land, irrigation water; nitrogen, phosphorus, potassium, pesticides, and fossil fuels along with levels of water and wind erosion.

Definitions of the dependent and independent variables are presented in Table 2

Functional Form

The general estimation approach involves 2 parts — a base functional form choice and accompanying model specification and a set of procedures for incorporation of policy regarding allowable GHG offsets.

Base model specification

Estimated response functions summarizing the ASMGHG results together with the definitions of variables are presented in Table 2. A set of these response functions are conceptually specified as:

$$\mathbf{Y} = f(\mathbf{x}, \varepsilon),$$

where **Y** is a vector of dependent variables, **x** is a vector of independent variables, and **ε** is a vector of error terms for each item in the **Y** vector. All functions are estimated with a multiplicative functional form,

$$\mathbf{Y_k} = \mathbf{A_k} \prod_i \mathbf{x_i}^{\beta_{ki}} \varepsilon_k$$

where A_k is the intercept term associated with the *k*th response function and β_{ik} is a vector of estimated parameters associated the vector **x** of signals. The base functions with all of the independent variables held at the base level (0 for carbon price and 100 for the others) depict the ASMGHG output under a zero carbon price with 1997 energy price, domestic demand, and export demand levels.

Incorporation of allowed mitigation strategies

The availability of mitigation options will shift the potential contribution for agriculture and forestry to mitigate GHG emissions. For example, if afforestation is the only forest strategy allowed then the potential falls relative to a case where both existing and new forested lands could be used and the ultimate peak level of mitigation is much less. Thus, the second estimation concern involves the choice of a functional form that will adequately reflect the allowed mitigation strategies. This study uses a case-by-case estimation of the response function according to the mitigation policy. The 13 mitigation policies identified in Table 1 in fact can be framed by 6 categories of mitigation policies. An adaptation of these mitigation policies can be shown as:

$$\mathbf{Y_{km}} = \mathbf{A_{km}} \prod_i \mathbf{x_i}^{\beta_{kim}} \varepsilon_{km}$$

where **Y**, **A**, **x**, β, and ε are previously defined but now each of the functions is separately estimated under each mitigation policy *m* listed at the bottom part of Table 1. This yields a total number 228 regressions to be estimated covering 38 dependent variables shown in Table 1 and each is estimated under 6 different mitigation policies (Table 1).

Model Simplification

An initial experimentation found the ASMGHG data generation task would have taken a month or more of computer time. Consequently, we chose to use an aggregated version. In that version the 63 U.S. regions depicted within ASMGHG were aggregated into the 10 farm production regions typically used by USDA. The results represent sectoral response under 1997 conditions and give a regional depiction of the economy under a zero carbon price with 1997 demand and fuel prices and no GHG mitigation.

Results

Illustration of GHG supply curve

To illustrate the basic nature of ASMGHG results we first chose to graph the results. In particular, model responses in the form of mitigation supply curves related to CO_2, CH_4, and N_2O gas emissions, sequestration, and total offset are graphed in Figures 1, 2, and 3 in which the carbon prices vary from \$0 to \$400 per ton of CE but other variables are maintained at the base level. Figure 1 portrays emission offsets through alterations in fossil fuel, fertilizer use, afforestation, livestock manure management etc. Figure 2 shows the carbon from sinks arising from forested acreage expansion, reduced tillage adoption, agricultural soil sequestration, and emission savings from biofuel production. Figure 3 shows the total emission reduction disaggregated by major agricultural GHG components under different mitigation strategies and carbon equivalent prices.

Response Function Results

A total of 228 response functions were estimated using ordinary least square estimation procedure. The full set of econometric results are reported in the Appendix Tables 1-5 but entail more than 1000 numbers[3]. As a consequence we will only make general statements about the overall results and then will limit discussion of the effects of all variables on one policy scenario (the one where all offset possibilities are allowed) and then will look at selected elasticities if changing the rules on what is allowed or whether a discount is applied.

In general, the regressions had good structural fits according to the goodness-of-fit statistic (R^2) with the exception of those for land values and use of tillage methods. The few poor fits are likely caused by functional form choice (McCarl and Schneider, 2001 show that tillage use rises then falls as more land is diverted out of the sector to biofuels and forestry and a multiplicative functional form cannot replicate such behavior). Fortunately, the functions critical for inclusion into a CGE economy wide framework did work much better (emissions, sequestration, total production and commodity price).

Turning now to the results for the *AllCarb* scenario, a rise in the carbon price leads to expected decreases in emissions and increases in sinks. Agricultural production is negatively affected, as are exports while agricultural prices and imports are positively affected. Crop and pasture land use falls with higher carbon prices while biofuel and tree acreage rises as do land values. Conventional tillage tends to fall with no-tillage and conservation tillage rising. Welfare is increased for producers but decreased for consumers and overseas interests. Finally, all of the environmental accounts show improvement with reductions in total crop land, irrigated land and chemical use.

Responses to demand shifts depend in part on their source. Shifts in domestic demand have larger effects as the majority of the consumption is domestic and a demand shift of our demand index (set at 100) depicts a larger underlying quantity shift. Export results also reflect the grain dominated export mix and thus act differently from the domestic mix which also contains fruit, vegetable and livestock products. Domestic demand shift tend to increase GHG emissions and decrease sinks. This occurs as crop land use goes up as does production and prices with exports falling. All the environmental indices rise. Export increases tend to increase nitrous oxide and sinks again reflecting land competition and increased grain

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[3] These are also available in a spreadsheet form from the author's web site.

demand. The livestock related methane account goes down some reflecting feed competition and a smaller herd. Production and prices rise as does producer welfare. Consumer welfare falls. The environmental impact indices all rise. Responses to fuel price increases increase agricultural prices and producer welfare, but decrease conservation tillage. CO_2 emissions and sinks respond to fuel prices positively but the magnitude of the effect on sinks is larger than that on emissions.

Effects of Different Policies

The effects on policy choices on the potential for GHG reductions can be examined using these functions. Figure 4 shows how policy alteration affects net GHG mitigation. The expected results are obtained. The largest quantity of GHG offset consistently appears with the *AllCarb* scenario where everything goes. Referencing activity at a $100 per ton carbon price the results show

1. Elimination of biofuels leads to about a 25% reduction in mitigation potential.
2. Restriction of forestry attention to afforestation and deforestation reduces potential mitigation by about 10%.
3. A sequestration only strategy which also eliminates existing forestry management can reduce potential mitigation by more than ½.
4. Not a lot is lost with elimination of the non CO_2 strategies (about 3%)

Conclusions

This study estimates a family of response functions summarizing agricultural response to GHG mitigation efforts for inclusion into general economy wide studies. Namely, functions predict the effects of the carbon prices, fuel prices, domestic agricultural demands, and foreign agricultural demand on GHG emission reductions and sequestration, agricultural production, and prices, mitigation practices employed, sectoral welfare and environmental indicators. The functions indicate that sinks will increase and emissions decrease as a carbon market develops. It is also shown that mitigation policy alternatives have effects on the magnitude of the changes in the GHG emissions and sequestration with rules on biofuels and forests being critical factors. The analysis also indicates that the rest of the sector is influenced by carbon policies with total production and consumer welfare being negatively correlated with prices, environmental indicators and producer welfare being positively correlated.

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Table 1. Mitigation policy definition

Mitigation policy	Restrict Forest attention to Afforestration/ Deforestation	Pay for all increases in forest Carbon	Discount Sinks for Permanence Concerns	In agriculture only pay for carbon from sequestration, do not count other gasses	Do not pay for carbon saved through Biofuel production
AffDef	X	-	-	-	-
AllCarb	-	X	-	-	-
NoBiof	-	X	-	-	X
OnlyCO2	-	X	-	-	-
OnlyCO2 &NoBiof	-	X	-	-	X
Permanence & AffDef	X	-	X	-	-
Permanence & AllCarb	-	X	X	-	-
Permanence & NoBiof	-	X	X	-	X
Permanence &OnlyCO2	-	X	X	-	-
Permanence & SeqOnly	-	X	X	X	-
SeqOnly	-	X	-	X	-
AffDef & Permanence & SeqOnly	X	-	X	X	-
AffDef & SeqOnly	X	-	-	X	-

Acronym	Description
AffDef	Restricting forest carbon to aff/deforestation only (with zero meaning all forest carbon counts)
AllCarb	Allowing for existing carbon
NoBiof	Prohibiting carbon payments to biofuels
OnlyCO2	Restricting carbon payments to CO_2 gas only ignoring nitrous oxide and methane
Discount	Applying discounting to sinks emission
Sequest	Restricting carbon payments in agriculture to sequestration only

Table 2. Variable definitions and magnitudes

Variable	Definition	Unit	Base	Average
---------- **Dependent** ----------				
GHG Emissions:				
CO_2	CO_2 emissions	MMTCE	51.94	32.18
CH_4	CH_4 emissions	MMTCE	59.76	54.02
N_2O	N_2O emissions	MMTCE	38.71	35.86
GHG Sequestration in Sinks:				
CO_2	CO_2 sequestration	MMTCE	22.09	141.68
CH_4	CH_4 sequestration	MMTCE	0.001	1.64
Agricultural Market conditions:				
Agricultural Price Index	U.S. all goods including crop and livestock prices	Fisher index	100	116.7
Agricultural Production Index	U.S. all goods including crop and livestock production	Fisher index	100	92.7
Agricultural Exports Index	U.S. all goods including crop and livestock exports	Fisher index	100	84.9
Agricultural Imports Index	U.S. all goods including crop and livestock imports	Fisher index	100	102.9
Agricultural and Forestry Land related data:				
Crop land	Acres of crop land farmed	10^6 acres	330.10	235.62
Crop land rent	National average Crop land rental rate	$/acre	42.63	105.27

Pasture land	Acres of pasture land used	10^6 acres	435.43	407.54
Pasture land rent	National average Pasture land rental rate	$/acre	19.13	21.40
Forest land	Acres afforested	10^6 acres	0.0	72.77
Biofuel crop land	Acres devoted to biofuel crops	10^6 acres	0.0	21.70
Conventional tillage	Crop acres treated with conventional tillage	10^6 acres	171.86	76.14
Conservation tillage	Crop acres treated with conservation tillage	10^6 acres	8.19	8.18
No-tillage	Crop acres treated with no-till practices	10^6 acres	63.88	173.6
Welfare:				
Producer Welfare	U.S. producer welfare	Million $	24.67	62.97
Consumer Welfare	U.S. consumer welfare	Million $	1183.03	1167.0
Rest of the World	The rest of the world welfare	Million $	250.75	249.59
Environmental Indicators:				
Irrigated land	Total area of irrigated land	10^6 acres	42.79	35.218
Irrigation water use	Total irrigation water use	10^6 acre-ft	69.81	60.076
Nitrogen fertilizer	Total nitrogen fertilizer use	10^6 tons	13.45	13.10
Phosphorus fertilizer	Total phosphorus fertilizer use	10^6 tons	3.49	3.35
Potassium fertilizer	Total potassium fertilizer use	10^6 tons	5.14	5.00
Pesticide	Total pesticide use	10^6 dollars	8871.81	9297.1
Fossil fuel	Fossil fuel use	10^6 dollars	2445.00	2096.3
Erosion	Water and wind erosion	10^6 tons	1337.29	403.64
------------------------------------ **Independent** ------------------------------------				
Carbon Price	Carbon price representing a tax on emissions	$/ton of CE	1	1 to 400

	and a subsidy on sequestration			
Fuel Price	Fuel price in percent relative to the 1997 base price	%	100.0	-
Agriculture Demand	Quantity of domestic agricultural demand in percent relative to the 1997 base demand. This represents a demand curve shifter i.e. demand is higher by 10%, in turn ASMGHG determines the exact demand and price level some where on the shifted demand curve.	%	100.0	-
Exports	Quantity of excess demand (ROW demand) in percent relative to the 1997 base demand	%	100.0	-

Table 3. *AllCarb* Scenario Estimate Parameters

Dependent Variables	Intercept	Carbon Price	Agriculture Demand	Exports	Fuel Price	R^2
GHG Accounts:						
CO2 source emissions[a]	19.6450	-0.1725	0.1844	-0.0322*	0.0904	0.879
CO2 emissions from fertilizer, irrigation and fuel use[b]	0.6034	-0.0757	0.3951	0.2459	0.2360	0.901
CH4 source emissions	85.3070	-0.0742	0.0303*	-0.0252*	-0.0428	0.785
N2Osource emissions	9.9328	-0.0653	0.1477	0.0886	0.0975	0.763
CO2 sinks[c]	7.6185	0.5122	-0.1824	0.0866*	0.2752	0.918
CO2 offset from biofuel	0.000001	3.457	-0.985	-1.243	2.850	0.733
Soil carbon sequestration	18.2158	0.1590[d]	0.0777	0.1331	0.0581	0.904
Agricultural Prices and Production:						
Price	12.9690	0.1309	0.1208	0.1365	0.1086	0.685
Production	72.1472	-0.0642	0.0810	0.0106*	0.0147*	0.732
Exports	2.4464	-0.1826	-0.2640	1.2012	-0.0194*	0.589
Imports	18.2478	0.0197	0.3122	0.0129*	0.0324	0.603
Welfare:						
U.S. Producer Welfare	0.0228	0.5828	0.3046	0.5198	0.3350	0.713
U.S. Consumer Welfare	856.9744	-0.0146	0.0998	-0.0108	-0.0097	0.693
Rest of the World Welfare	13.8110	-0.0049	-0.0063	0.6313	0.0080	0.992
Agricultural and Forestry Practices:						
Crop land	72.894	-0.062	0.159	0.145	0.037	0.560
Crop land rent	0.0047	0.5149	0.4991	0.7097	0.4689	0.738
Pasture land	1183.0475	-0.0459	-0.0552	-0.0917	-0.0460	0.812
Pasture land rent	0.3130	0.0098*	0.1811*	0.3134	0.4079	0.123
Forest land	0.0017	2.1517	0.1785	0.0508	-0.1275	0.816
Biofuel crop land	0.0832	1.2779	-0.7345	-0.3433	1.0101	0.864
Conventional tillage	42.4698	-0.0866	-0.0752*	-0.0410*	0.1512	0.116
Conservation tillage	0.9750	0.0875	0.5551	-0.1357*	-0.0378*	0.147

No-tillage	27.6201	0.0036*	0.1426	0.1927	0.0655	0.013
Environmental Indicators:						
Irrigated land	0.0460	-0.0535	0.6301	0.3243	0.5287	0.395
Irrigated water use	0.2387	-0.0542	0.5549	0.3276	0.3613	0.591
Nitrogen fertilizer	820.0268	-0.0487	0.2701	0.1750	0.1981	0.638
Phosphorus fertilizer	448.8914	-0.0638	0.2368	0.1412	0.1125	0.603
Potassium fertilizer	583.1322	-0.1040	0.2142	0.1359	0.2027	0.477
Pesticide	1296.0572	-0.0406	0.2523	0.1555	0.0554	0.421
Fossil fuel	474.0567	-0.0860	0.1946	0.1497	0.0492	0.735
Erosion	631.3700	-0.3158	0.1598	-0.0052*	-0.0247*	0.954

* Asterisk indicates insignificant from zero at a 0.10 significant level based on a one-tail test.

[a] CO_2 source emissions arise from the use of fuel, more intense tillage, fertilizer manufacture, pesticide manufacture, irrigation pumping, ethanol production and offsets, biofuel production and offsets, grassland development, and afforestation/forest management.

[b] CO_2 source emissions arise from the use of fuel, fertilizer manufacture, pesticide manufacture, and irrigation pumping.

[c] CO_2 sinks are for CO_2 in forests and CO_2 in agricultural soil sequestration and biofuel offsets.

[d] Rather than using the CD function, the 4th order polynomial function is used to estimate the agricultural soil carbon sequestration (ASC) which is more reasonable given that the ASC increases as the carbon prices, but then decreases (in our case the cut off point is about $90 per ton of CEq). The carbon price parameter represents a change in the overall ASC with respect to the carbon prices. The completed estimated parameter for this function is

$$\begin{aligned} ASC = {} & 18.2158 + 0.7096*\text{Carbon Price} - 0.007*\text{Carbon Price} + 2.35\text{E-}05*(\text{Carbon Price})^3 \\ & - 2.59\text{E-}08*(\text{Carbon Price})^4 + 0.0777*\text{Agricultural Demand} + 0.1331*\text{Exports} \\ & + 0.0581*\text{Fuel Price}. \end{aligned}$$

Table 4. Economic and environmental implication under alternative carbon prices and *AffDef* mitigation

	Base[a]	50	80	100	200	300	400
Greenhouse gas emissions and sinks (10^6 Metric Tons of CEq):							
CH4 source emissions	59.765	56.956	52.637	50.096	46.339	44.647	43.152
CO2 source emissions	51.948	34.165	25.005	24.537	22.609	22.326	21.996
N2Osource emissions	38.714	37.117	35.687	34.108	31.229	30.069	28.931
CH4 sinks	0.001	0.761	1.975	2.312	5.047	5.963	6.365
CO2 sinks	22.092	100.565	162.532	213.501	287.757	306.730	314.452
Soil carbon sequestration	20.741	65.108	69.332	64.874	55.428	52.694	65.108
CH4 net emission	59.764	56.195	50.662	47.784	41.292	38.685	36.787
CO2 net emission	29.856	-66.400	-137.527	-188.964	-265.147	-284.405	-292.456
N2O net emission	38.714	37.117	35.687	34.108	31.229	30.069	28.931
Agricultural price and production (Fisher index):							
Price	100.0	105.87	112.87	123.29	152.26	167.15	185.99

Production	100.0	96.05	91.63	87.87	80.03	76.84	74.29
Exports	100.0	95.27	90.12	82.4	45.82	36.55	51.27
Imports	100.0	100.21	100.83	103.1	103.86	110.34	112.93
Agricultural and forestry practices (10^6 acres):							
Crop land	330.09	283.36	289.27	274.76	232.17	222.47	216.52
Pasture land	435.43	423.39	389.56	381.70	374.43	370.48	366.27
Forest land	0.00	21.47	92.34	157.74	184.02	184.02	184.02
Biofuel crop land	0.00	9.56	24.08	27.84	69.45	83.11	89.11
Conventional tillage	171.86	52.11	63.53	64.98	102.48	114.91	119.28
Conservation tillage	8.19	7.44	6.41	9.35	10.72	11.41	11.40
No-till	63.88	200.66	203.77	189.63	156.59	147.07	142.05
Economic Welfare ($\$10^6$):							
U.S. producer welfare	24.67	31.70	41.88	58.99	133.54	209.83	286.90
U.S. consumer welfare	1183.03	1189.15	1171.03	1162.92	1136.74	1118.05	1099.50
Rest of the world welfare	250.75	250.54	250.23	264.98	247.36	246.39	245.93
Total welfare	1458.450	1471.390	1463.140	1486.890	1517.640	1574.270	1632.330
Environment Attributes (10^6 units):							

Nitrogen fertilizer	13.42	13.51	13.45	12.85	11.52	11.15	10.88
Phosphorus fertilizer	3.49	3.49	3.48	3.27	2.85	2.71	2.63
Potassium fertilizer	5.14	5.35	5.43	5.07	3.73	3.35	3.18
Pesticide fertilizer	8,871.81	9,547.67	9,977.77	9,397.34	8,407.72	78,790.71	7,649.63
Fossil fuel	2,445.00	2,156.70	2,143.23	2,045.57	1,697.11	1,623.53	1,576.43
Erosion	1,337.29	316.17	281.85	255.85	219.51	202.61	197.38

[a] Base depicts results under a zero carbon price with 1997 energy price, domestic demand, and export demand levels while 50, 80, 100, 200, 300, 400 depict results under $50, $80, $100, $200, $300, and $400 per ton of CE price with other values being at the Base levels.

Table 5. Emission implication under alternative demand, energy prices, and exports and *AffDef* mitigation

		U.S. Agricultural Demand		Energy Price		Exports	
	Base	90%	110%	80%	120%	90%	110%
CH4 source emissions	59.765	59.127	59.175	59.667	58.818	59.549	59.382
CO2 source emissions	51.948	52.108	52.449	49.774	52.720	52.805	51.741
N2Osource emissions	38.714	38.716	39.081	38.058	39.963	38.599	39.003
CO2 sinks	22.092	22.951	23.452	22.000	28.201	22.212	23.979
Soil carbon sequestration	20.741	20.175	21.076	21.436	22.303	19.436	21.399
CH4 net emission	59.764	59.126	59.174	59.666	58.817	59.548	59.381
CO2 net emission	29.856	29.157	28.997	27.774	24.519	30.593	27.761
N2O net emission	38.714	38.716	39.081	38.058	39.963	38.599	39.003

[a] Base depicts results under a zero carbon price with 1997 energy price, domestic demand, and export demand levels while 80%, 90%, 110%, and 120% depict results under 80%, 90%, 110%, and 120% percentage change from the Base levels.

Appendix Table 1. GHG emissions and sink estimation results

Independent Variable	AffDef	AllCarb	NoBiof	OnlyCO2	Discount	Sequest
CO2 Emissions[a]						
Intercept	14.980	19.645	42.373	29.284	53.964	34.267
Carbon Price	-0.158	-0.172	-0.189	-0.151	-0.172	-0.051
Agriculture Demand	0.224	0.184	0.115	0.186	0.098	0.037
Fuel Price	0.095	0.090	0.168	0.086	0.063	0.117
Exports	-0.030*	-0.032*	-0.187	-0.123	-0.122	-0.090
R^2	0.901	0.879	0.850	0.883	0.913	0.572
CO2 Emissions[b]						
Intercept	0.4966	0.6034	0.4318	0.6150	0.9163	1.2220
Carbon Price	-0.0615	-0.0757	-0.1275	-0.0616	-0.0619	-0.0046
Agriculture Demand	0.4241	0.3951	0.4440	0.4093	0.3750	0.2510
Fuel Price	0.2384	0.2360	0.2895	0.2448	0.2190	0.2409
Exports	0.2444	0.2459	0.2530	0.2144	0.1853	0.1997
R^2	0.870	0.902	0.797	0.903	0.907	0.932
CH4 Emissions						
Intercept	68.869	85.307	84.781	90.136	69.430	94.178
Carbon Price	-0.055	-0.074	-0.055	-0.063	-0.072	-0.024
Agriculture Demand	0.059	0.030*	0.026*	0.044	0.064	-0.005*
Fuel Price	-0.043	-0.043	-0.030	-0.047	-0.04	-0.030
Exports	-0.024*	-0.025*	-0.042	-0.052	-0.017*	-0.051

R^2	0.669	0.785	0.699	0.710	0.733	0.615
N2O Emissions						
Intercept	8.372	9.933	9.223	10.182	9.143	9.701
Carbon Price	-0.048	-0.065	-0.042	-0.052	-0.064	-0.015
Agriculture Demand	0.170	0.148	0.141	0.161	0.181	0.125
Fuel Price	0.100	0.097	0.129	0.102	0.089	0.119
Exports	0.084	0.089	0.066	0.060	0.080	0.069
R^2	0.670	0.763	0.779	0.720	0.748	0.717
CO2 Sinks[c]						
Intercept	13.380	7.618	7.003	12.490	8.514	45.146
Carbon Price	0.458	0.512	0.397	0.502	0.540	0.386
Agriculture Demand	-0.281	-0.182	-0.110	-0.293	-0.276	-0.195
Fuel Price	0.317	0.275	0.194	0.283	0.325	0.027*
Exports	0.057*	0.087*	0.171	0.080*	0.053*	0.011*
R^2	0.926	0.918	0.891	0.91	0.932	0.710
CO2 Sinks[d]						
Intercept	0.00042	0.000001	NA	0.001	0.00001	NA
Carbon Price	2.920	3.4568	NA	3.580	3.552	NA
Agriculture Demand	-1.545*	-0.9853*	NA	-3.029	-1.450*	NA
Fuel Price	2.754	2.8496	NA	3.202	2.412	NA
Exports	-1.845*	-1.2428*	NA	-1.740*	-0.962*	NA
R^2	0.701	0.733	NA	0.716	0.726	NA
Soil carbon sequestration[e]						
Intercept	7.993	18.216	12.906	15.568	4.710	20.684

Carbon Price	0.272	0.159	0.181	0.156	0.195	0.160
Agriculture Demand	0.082	0.078	0.101	0.089	0.112	0.051
Fuel Price	0.152	0.133	0.165	0.152	0.160	0.126
Exports	0.058	0.058	0.071	0.064	0.046	0.078
R^2	0.808	0.904	0.873	0.876	0.884	0.432

[a] CO_2 source emissions arise from the use of fuel, more intense tillage, fertilizer manufacture, pesticide manufacture, irrigation pumping, ethanol production and offsets, biofuel production and offsets, grassland development, and afforestation/forest management.

[b] CO_2 source emissions arise from the use of fuel, fertilizer manufacture, pesticide manufacture, and irrigation pumping.

[c] CO_2 sinks are for CO_2 in forests and CO_2 in agricultural soil sequestration and biofuel offsets.

[d] CO_2 sinks are biofuel offsets. Note that under the *NoBiof* and *Sequest* mitigation policies there is no CH_4 saving from biomass power plants due to a lack of incentive tax to do so.

[e] Rather than using the CD function, the 4th order polynomial function is used to estimate the ASC which is more reasonable given that the ASC increases as the carbon prices, but then decreases (in our case the cut off point is about $90 per ton of CEq). The carbon price parameter (C) represents a change in the overall ASC with respect to the carbon prices. The completed estimated parameter for the carbon price is

for *AffDef*: $1.0154C - 0.0103C^2 + 3.623E\text{-}05C^3 - 4.126E\text{-}08C^4$

for *AllCarb*: $0.7097C - 0.0070C^2 + 2.351E\text{-}05C^3 - 2.589E\text{-}08C^4$

for *NoBiof*: $0.5785C - 0.0050C^2 + 1.699E\text{-}05C^3 - 2.043E\text{-}08C^4$

for *OnlyCO2*: $0.6429C - 0.0062C^2 + 2.043E\text{-}05C^3 - 2.228E\text{-}08C^4$

for *Sequest*: $0.5285C - 0.0046C^2 + 1.534E\text{-}05C^3 - 1.677E\text{-}08C^4$.

Appendix Table 2. Agricultural price and production estimation results

Independent Variable	AffDef	AllCarb	NoBiof	OnlyCO2	Discount	Sequest
Agricultural Price Index						
Intercept	19.807	12.969	12.711	13.535	16.190	12.141
Carbon Price	0.093	0.131	0.067	0.114	0.128	0.027
Agriculture Demand	0.073	0.121	0.149	0.114	0.084	0.183
Fuel Price	0.109	0.109	0.107	0.110	0.108	0.111
Exports	0.130	0.137	0.159	0.147	0.131	0.155
R^2	0.569	0.685	0.605	0.631	0.644	0.430
Agricultural Production Index						
Intercept	59.545	72.147	68.494	71.197	64.059	71.816
Carbon Price	-0.046	-0.064	-0.035	-0.054	-0.062	-0.015
Agriculture Demand	0.101	0.081	0.061	0.089	0.101	0.041
Fuel Price	0.016*	0.015*	0.035	0.016	0.013*	0.031
Exports	0.014*	0.011*	0.003*	-0.002*	0.016*	0.003*
R^2	0.614	0.732	0.688	0.671	0.688	0.574
Exports Index						
Intercept	1.023	2.446	0.650	2.001	0.575	0.822
Carbon Price	-0.124	-0.183	-0.023	-0.149	-0.166	-0.002
Agriculture Demand	-0.174	-0.264	-0.319	-0.276	-0.250	-0.349
Fuel Price	-0.031*	-0.019*	0.001*	0.002*	-0.015*	0.028*
Exports	1.249	1.201	1.408	1.201	1.472	1.346

R^2	0.473	0.589	0.448	0.51	0.556	0.414
Imports Index						
Intercept	20.372	18.248	19.467	19.698	22.104	25.047
Carbon Price	0.013	0.020	0.002	0.016	0.017	0.005
Agriculture Demand	0.306	0.312	0.329	0.319	0.307	0.300
Fuel Price	0.035	0.032	0.021	0.028	0.023	0.029
Exports	0.001*	0.013*	0.007*	-0.001*	-0.010*	-0.027*
R^2	0.464	0.603	0.475	0.467	0.474	0.459

* Asterisk indicates insignificant from zero at a 0.10 significant level based on a one-tail test.

Appendix Table 3. Agricultural and forestry land related estimation results

Independent Variable	AffDef	AllCarb	NoBiof	OnlyCO2	Discount	Sequest
Crop Land Usage						
Intercept	66.580	72.894	72.444	55.281	45.297	54.406
Carbon Price	-0.054	-0.062	-0.004	-0.057	-0.066	-0.016
Agriculture Demand	0.181	0.159	0.085	0.189	0.225	0.138
Fuel Price	0.035	0.037	0.046	0.046	0.042	0.059
Exports	0.137	0.145	0.173	0.161	0.177	0.174
R^2	0.609	0.560	0.349	0.603	0.641	0.764
Crop Land Rental Rate						
Intercept	0.018	0.005	0.004	0.011	0.015	0.008
Carbon Price	0.366	0.515	0.286	0.492	0.490	0.281
Agriculture Demand	0.296	0.499	0.534	0.324	0.231*	0.523
Fuel Price	0.452	0.469	0.441	0.417	0.454	0.378
Exports	0.772	0.710	0.905	0.778	0.749	0.824
R^2	0.613	0.738	0.760	0.745	0.698	0.761
Pasture Land Usage						
Intercept	1030.159	1183.047	1353.448	1302.038	1328.963	1237.795
Carbon Price	-0.035	-0.046	-0.039	-0.042	-0.042	-0.018
Agriculture Demand	-0.038	-0.055	-0.065	-0.048	-0.059	-0.070
Fuel Price	-0.046	-0.046	-0.027	-0.051	-0.050	-0.035
Exports	-0.089	-0.092	-0.131	-0.116	-0.109	-0.111
R^2	0.700	0.812	0.733	0.767	0.749	0.743

Pasture Land Rental Rate						
Intercept	0.460	0.313	0.075	0.174	0.139	0.062
Carbon Price	0.022	0.010*	-0.126	0.244	-0.006*	0.114
Agriculture Demand	0.122	0.181	0.385	0.078*	0.231	0.275
Fuel Price	0.404	0.408	0.417	0.387	0.469	0.369
Exports	0.288	0.313	0.488	0.421	0.381	0.540
R^2	0.121	0.123	0.485	0.773	0.130	0.756
Afforested Land						
Intercept	122.086	0.002	0.007	0.032	0.014	0.035
Carbon Price	0.952	2.152	2.130	2.109	2.015	2.063
Agriculture Demand	-0.604	0.179	0.358*	0.376*	0.124*	0.521*
Fuel Price	-0.160	-0.127	0.093*	-0.053*	0.013*	-0.009*
Exports	-0.300	0.051	-0.622*	-0.812*	-0.479*	-0.980*
R^2	0.836	0.816	0.800	0.805	0.826	0.762
Biofuel Crop Land						
Intercept	11.142	0.083	NA[a]	4.875	2.040	NA[a]
Carbon Price	0.996	1.278	NA[a]	1.264	1.334	NA[a]
Agriculture Demand	-1.240	-0.734	NA[a]	-1.450	-1.240	NA[a]
Fuel Price	0.905	1.010	NA[a]	0.963	0.941	NA[a]
Exports	-0.546	-0.343	NA[a]	-0.497	-0.487	NA[a]
R^2	0.779	0.864	NA[a]	0.834	0.842	NA[a]
Conventional Tillage						
Intercept	182.921	42.470	72.557	63.642	88.565	25.233
Carbon Price	-0.050	-0.087	-0.212	0.062	0.035	-0.220

Agriculture Demand	-0.267	-0.075*	0.123	-0.223	-0.253	0.273
Fuel Price	0.138	0.151	-0.027*	0.144	0.171	-0.023*
Exports	-0.035*	-0.041*	-0.004*	0.035*	0.029*	0.080*
R^2	0.042	0.116	0.812	0.059	0.023	0.581
Conservation Tillage						
Intercept	0.604	0.975	0.164	0.814	7.535	1.694
Carbon Price	0.052	0.087	0.076	0.061	0.023	0.090
Agriculture Demand	0.558	0.555	0.308	0.556	0.704	0.112
Fuel Price	-0.087*	-0.038*	0.043*	-0.112*	-0.086*	0.169
Exports	0.043*	-0.136*	0.429	-0.017*	-0.633	-0.006*
R^2	0.098	0.147	0.131	0.073	0.078	0.220
No Tillage						
Intercept	10.304	27.620	16.426	16.836	10.259	36.055
Carbon Price	0.103	0.004*	0.088	0.016	0.050	0.069
Agriculture Demand	0.234	0.143	0.161	0.221	0.273	0.068*
Fuel Price	0.074*	0.066	0.092	0.086	0.056*	0.091
Exports	0.215	0.193	0.203	0.193	0.232	0.130*
R^2	0.324	0.013	0.685	0.049	0.116	0.171

* Asterisk indicates insignificant from zero at a 0.10 significant level based on a one-tail test.

[a] The *NoBiof* and *Sequest* mitigation policies are excluded in the Biofuel land impacts since under these policies there is no CH_4 saving from biomass power plants due to a lack of incentive tax to do so.

Appendix Table 4. Welfare estimation results

Independent Variable	AffDef	AllCarb	NoBiof	OnlyCO2	Discount	Sequest
US Producer Welfare						
Intercept	0.120	0.023	0.030	0.058	0.046	0.058
Carbon Price	0.385	0.583	0.485	0.570	0.499	0.483
Agriculture Demand	0.069*	0.305*	0.184*	0.082*	0.088*	0.190*
Fuel Price	0.322	0.335	0.259	0.286	0.348	0.233
Exports	0.578	0.520	0.711	0.607	0.611	0.601
R^2	0.568	0.713	0.664	0.720	0.649	0.676
US Consumer Welfare						
Intercept	823.380	856.974	833.057	842.606	832.828	819.173
Carbon Price	-0.010	-0.015	-0.006	-0.012	-0.015	-0.002
Agriculture Demand	0.107	0.100	0.103	0.105	0.108	0.102
Fuel Price	-0.009	-0.010	-0.009	-0.009	-0.009	-0.009
Exports	-0.014	-0.011	-0.014	-0.014	-0.014	-0.012
R^2	0.597	0.693	0.849	0.700	0.679	0.963
Rest of the World Welfare						
Intercept	13.571	13.811	13.471	13.670	13.382	13.160
Carbon Price	-0.003	-0.005	-0.001	-0.004	-0.005	0.000
Agriculture Demand	-0.004	-0.006	-0.008	-0.004	-0.003	-0.007
Fuel Price	0.008	0.008	0.009	0.009	0.008	0.011

Exports	0.631	0.631	0.634	0.630	0.634	0.637
R^2	0.990	0.992	0.999	0.994	0.993	0.998

* Asterisk indicates insignificant from zero at a 0.10 significant level based on a one-tail test.

Appendix Table 5. Environmental Estimation Results

Independent Variable	AffDef	AllCarb	NoBiof	OnlyCO2	Discount	Sequest
Irrigated Land Usage						
Intercept	0.035	0.046	0.012	0.069	0.193	0.196
Carbon Price	-0.058	-0.054	-0.354	-0.034	-0.019	0.007
Agriculture Demand	0.652	0.630	0.942	0.600	0.486	0.405
Fuel Price	0.531	0.529	0.718	0.532	0.499	0.506
Exports	0.364	0.324	0.324	0.264	0.172	0.251
R^2	0.487	0.395	0.685	0.579	0.356	0.867
Irrigation Water Use						
Intercept	0.232	0.239	0.044	0.394	0.824	1.744
Carbon Price	-0.050	-0.054	-0.328	-0.040	-0.026	0.004
Agriculture Demand	0.565	0.555	0.854	0.522	0.456	0.285
Fuel Price	0.356	0.361	0.565	0.353	0.320	0.310
Exports	0.327	0.328	0.385	0.259	0.185	0.202
R^2	0.664	0.591	0.637	0.744	0.471	0.886
Nitrogen Fertilizer						
Intercept	696.253	820.027	588.854	677.296	563.173	649.038
Carbon Price	-0.032	-0.049	-0.007	-0.037	-0.052	0.004
Agriculture Demand	0.288	0.270	0.255	0.288	0.325	0.235
Fuel Price	0.204	0.198	0.247	0.218	0.195	0.245
Exports	0.172	0.175	0.185	0.172	0.204	0.179

R^2	0.545	0.638	0.887	0.633	0.715	0.922
Phosphorus Fertilizer						
Intercept	367.951	448.891	327.412	384.364	325.254	390.368
Carbon Price	-0.042	-0.064	-0.013	-0.053	-0.067	-0.007
Agriculture Demand	0.264	0.237	0.220	0.260	0.295	0.193
Fuel Price	0.118	0.112	0.149	0.125	0.111	0.149
Exports	0.133	0.141	0.156	0.132	0.155	0.141
R^2	0.485	0.603	0.847	0.592	0.639	0.863
Potassium Fertilizer						
Intercept	455.249	583.132	385.015	429.297	391.607	241.671
Carbon Price	-0.066	-0.104	0.015	-0.088	-0.109	0.001*
Agriculture Demand	0.253	0.214	0.175	0.256	0.290	0.197
Fuel Price	0.212	0.203	0.254	0.230	0.194	0.281
Exports	0.107	0.136	0.131	0.121	0.157	0.189
R^2	0.344	0.477	0.826	0.476	0.507	0.741
Pesticides						
Intercept	1051.085	1296.057	901.876	1035.980	668.999	1111.212
Carbon Price	-0.020	-0.041	0.027	-0.036	-0.046	-0.005
Agriculture Demand	0.279	0.252	0.213	0.281	0.342	0.221
Fuel Price	0.060	0.055	0.085	0.065	0.064	0.085
Exports	0.150	0.156	0.20	0.162	0.200	0.164
R^2	0.256	0.421	0.927	0.491	0.493	0.552
Fossil Fuel						
Intercept	415.794	474.057	400.239	435.815	348.070	419.425

Carbon Price	-0.067	-0.086	-0.020	-0.078	-0.098	-0.022
Agriculture Demand	0.214	0.195	0.146	0.212	0.251	0.145
Fuel Price	0.052	0.049	0.076	0.054	0.049	0.074
Exports	0.139	0.150	0.164	0.140	0.171	0.157
R^2	0.696	0.735	0.934	0.749	0.790	0.727
Erosion						
Intercept	742.240	631.370	381.208	778.658	467.117	296.813
Carbon Price	-0.334	-0.316	-0.314	-0.328	-0.370	-0.287
Agriculture Demand	0.100	0.160	0.150	0.177	0.153	0.228
Fuel Price	-0.011*	-0.025*	0.048	-0.025*	0.002*	-0.002*
Exports	0.019*	-0.005*	0.041*	-0.060	0.113	0.052*
R^2	0.969	0.954	0.958	0.965	0.956	0.679

* Asterisk indicates insignificant from zero at a 0.10 significant level based on a one-tail test.

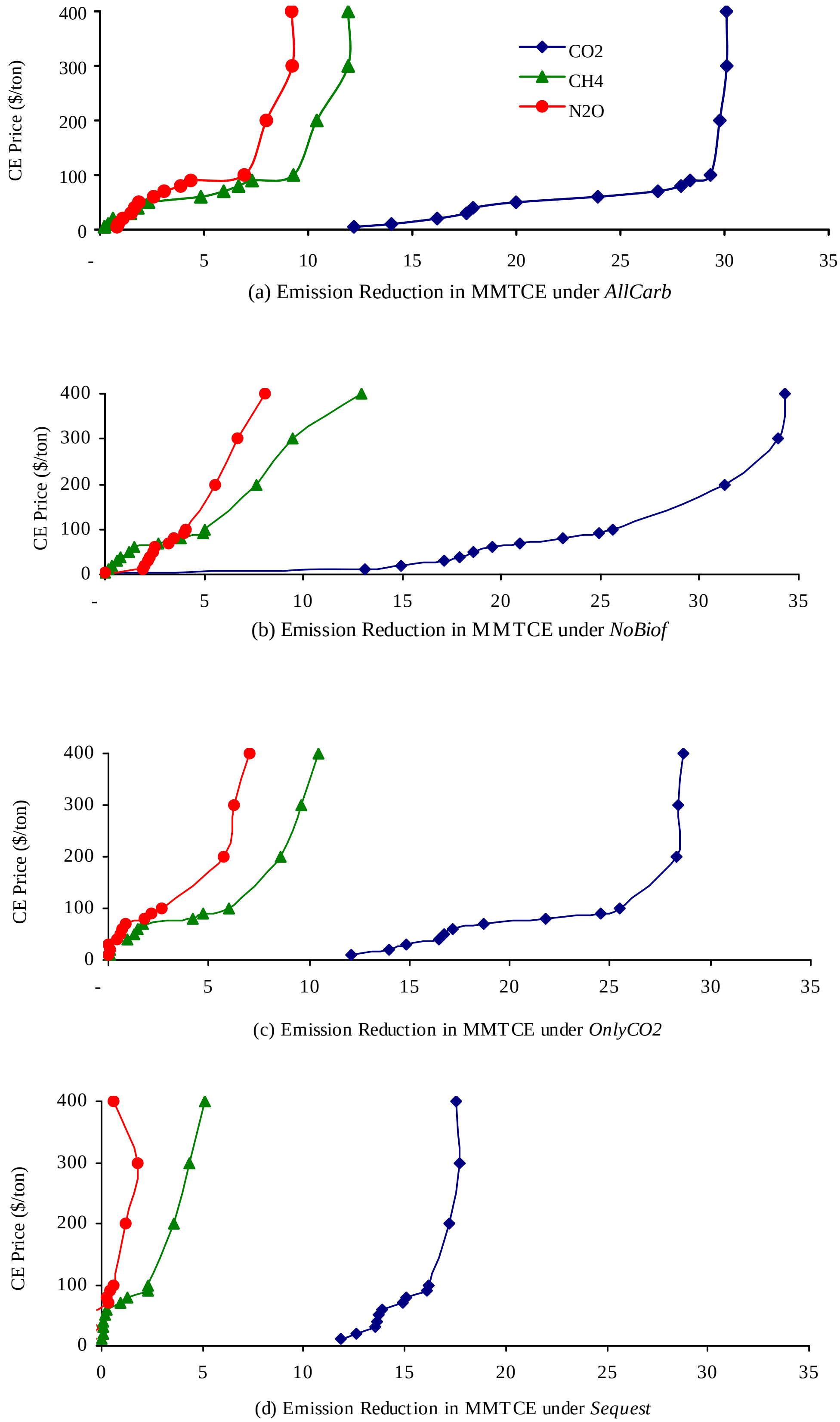


Figure 1. CE price and GHG emission reductions in million metric tons of carbon equivalents (MMTCE).

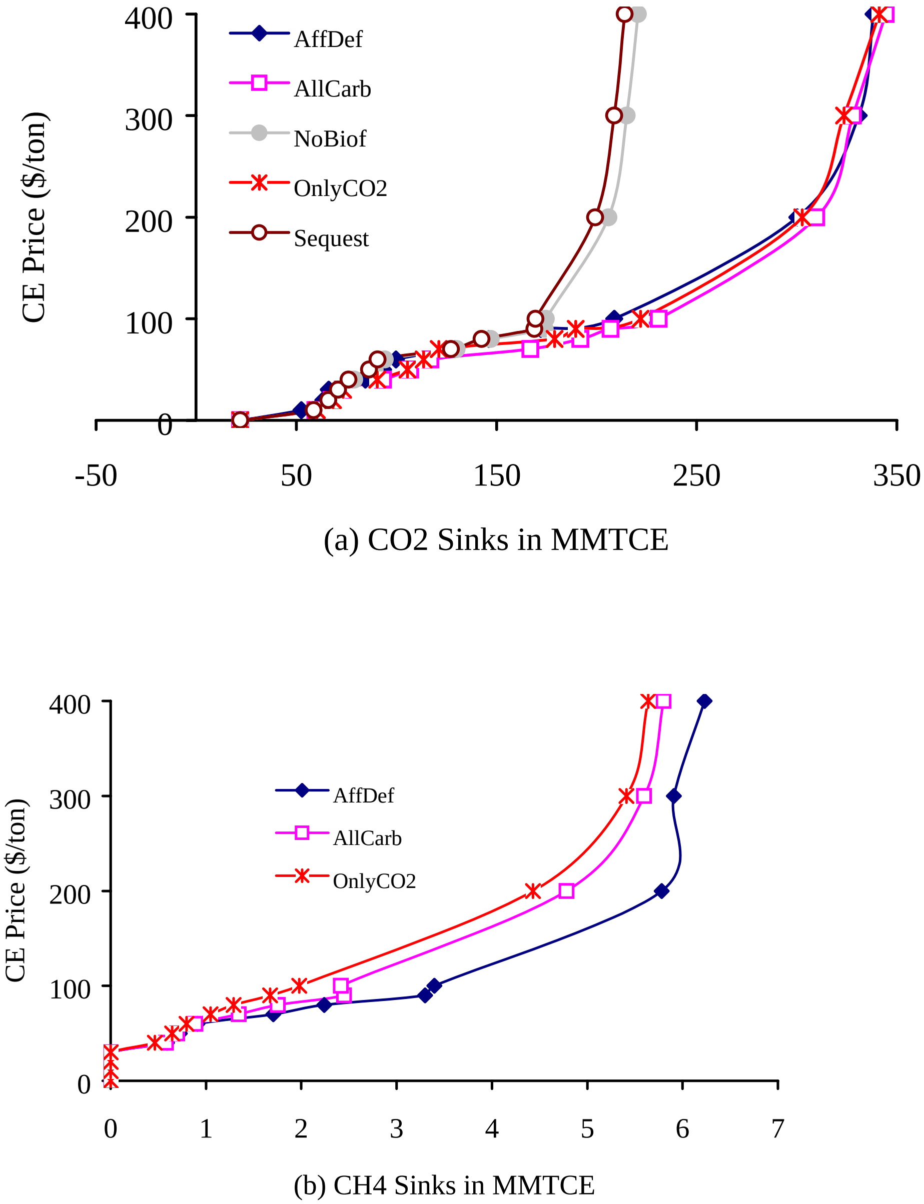
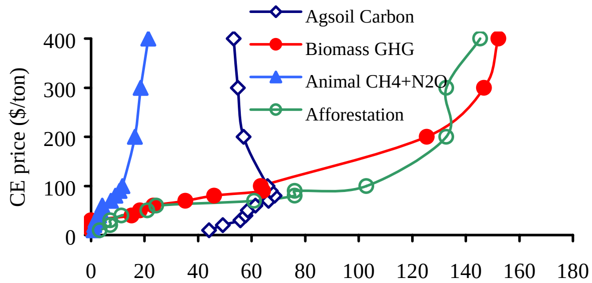
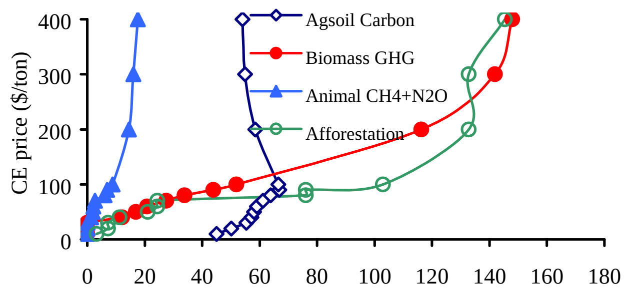


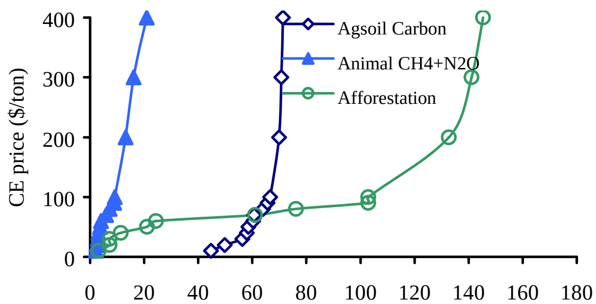
Figure 2. CE price and CO_2 and CH_4 sinks in million metric tons of carbon equivalents (MMTCE). The CH_4 sinks lines under *AffDef* and *Sequest* mitigation policy are overlapped.



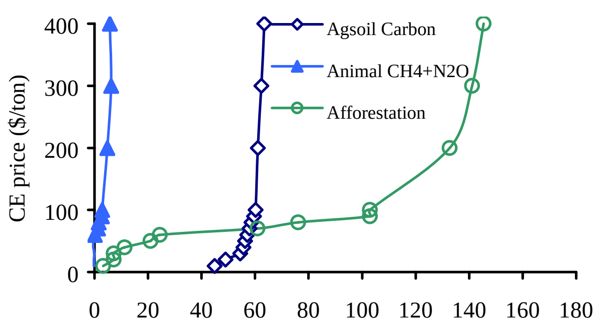
(a) Emission Reduction in MMTCE under *AllCarb*



(b) Emission Reduction in MMTCE under *OnlyCO2*



(c) Emission Reduction in MMTCE under *NoBiof*



(d) Emission Reduction in MMTCE under *Sequest*

Figure 3. Major agricultural GHG components in MMTCE for different carbon equivalent prices.

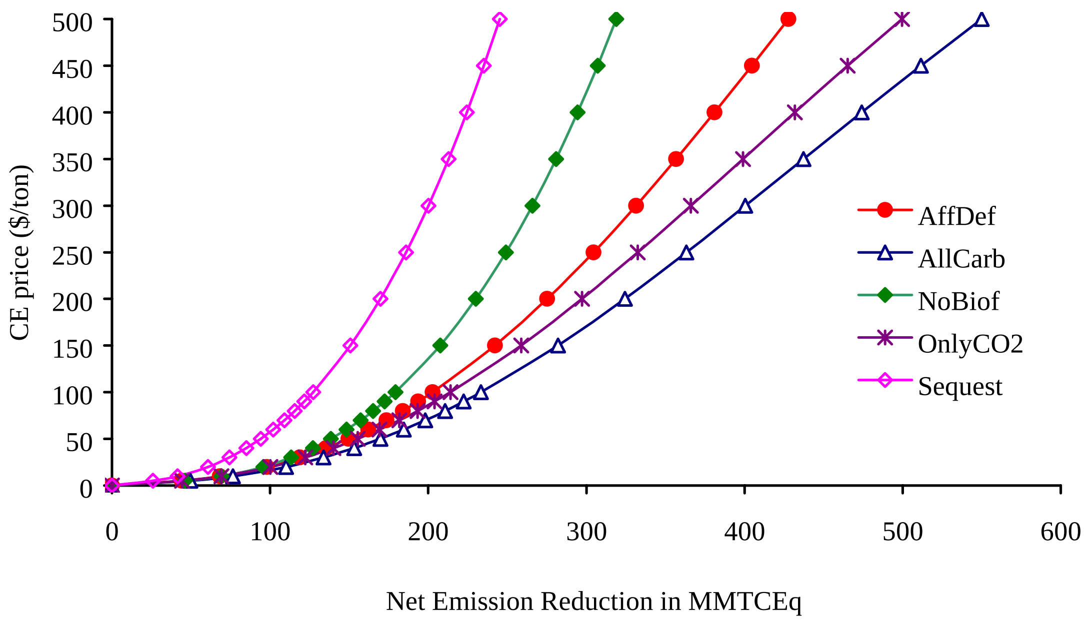


Figure 4. Net Emission Reduction in Million Metric Ton of Carbon Equivalent under Various Mitigation Policies.