Economic Potential for Agricultural Non-CO2 Greenhouse Gas Mitigation: An Investigation in the United States

Bruce A. McCarl
Department of Agricultural Economics
Texas A&M University

U. A. Schneider
Departments of Geosciences and Economics
Hamburg University

Dhazn Gillig
Department of Agricultural Economics
Texas A&M University

Hengchi Lee
Department of Economics
Western Ontario University

Francisco de la Chesnaye
U.S. Environment Protection Agency
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Abstract

This paper addresses the economic potential of U.S. agriculture and forestry to mitigate emissions considering carbon, nitrous oxide and methane focusing to a large extent on the possibilities for Non CO2 strategies both independently and in an overall approach. It also reports on an examination of the dynamics of non-CO2 mitigation strategies.

The paper reports results from a multi-period analysis of agricultural and forestry response to prices for GHG offset production. The model used is called FASOMGHG and is a 100 year forest and agriculture model. It covers GHG mitigation activities in 11 U.S. regions and 63 U.S. Sub-State regions, 28 foreign regions for 8 commodities, plus world market for 50+ other commodities. The 100 year period is simulated in decadal time steps. The forestry and agricultural sectors are linked through land and some commodity transfers. The model has rather detailed coverage of agricultural carbon and non-CO2 plus forest carbon management alternatives.

Using FASOMGHG, marginal abatement curves are generated under alternative policy scenarios. The model results give overall and component response at varying carbon equivalent prices revealing an “optimal” portfolio of agricultural greenhouse gas emission related management alternatives. We also observe model results on commodity and factor prices, levels of production, exports and imports, management choices, resource usage, and environmental impacts.

Empirically carbon equivalent prices were varied from $0 per metric ton to $100 as constant real price for 100 years. The possible contributions of the gasses were treated both collectively and independently. In particular scenarios where run where only one of CO2, CH4 and N2O were eligible for payments followed by scenarios when non CO2 gasses were all that were eligible and then where all gasses were eligible.

A number of potential insights arise from the model analysis:

- **Non CO2 gasses can be a significant player although they are somewhat less than one half as important as sequestration**
- **NonCO2 gasses actions are persistent growing over time while sequestration saturates and diminishes**
- **Competition exists between strategies and independent assessments can be misleading**
- **Independent nonCO2 strategies cause significant leakage in the CO2 category**
- **Enteric fermentation and fertilization based N2O management are highly complementary with CO2 management**

More can be found on this type of analysis in the carbon related writings of McCarl and others that can be found on agecon.tamu.edu/faculty/mccarl.
Assesses the economic potential of U.S. agriculture and forestry to mitigate emissions considering carbon, nitrous oxide and methane

Focus on the role of Non CO2 strategies both independently and in an overall approach

Examine the dynamics of non-CO2 mitigation strategies
A carbon or GHG sequestering sink

Offsetting net GHG emissions

Operating in a mitigating world

EMISSION REDUCERS

Globally

- Ag and forestry emit 70% of N2O
- Ag and forestry emit 50% of CH4
- Ag and forestry emit 5% or 20% (including tropical deforestation) of CO2
Emission accounting

- Manure emissions
- Enteric fermentation
- Rice cultivation

Mitigation Strategies

- Less rice acreage
- Fewer animals
- Liquid manure management
- Change feeding

Figure 1: U.S. Source of CH4 Emissions in Tg CO2 Eq.

ROLES OF U.S. AG & FORESTRY: N2O

Emission accounting

- De-nitrification
- Air volatilization
- Livestock manure emissions

Mitigation Strategies

- Change of crop mix
- Less Nitrogen fertilization
- Choice between N-fertilizer types

Figure 1: The U.S. Nitrous Oxide Emissions 1990-2020

Source: U.S. EPA
Multi-period analysis of ag/forest response

Marginal abatement curve giving overall and component response at varying carbon equivalent prices

Also wish to observe commodity and factor prices, levels of production, exports and imports, management choices, resource usage, and environmental impacts
MODELING APPROACH

- 100 year forest and agriculture model - FASOMGHG
- Covers GHG mitigation activities in U.S. regions (across 11 regions and 63 U.S. Sub-State regions), 28 foreign regions for 8 commodities, plus world market for other commodities.
- Simulates 100 years in decade time steps.
- Depicts sector linkage mainly through land transfers.
MODELING APPROACH

- When run with a price solution reveals a “optimal” portfolio of agricultural greenhouse gas emission related management alternatives.
- Rather detailed coverage of agricultural carbon and non-CO2 plus forest carbon management alternatives.
FASOMGHG REGIONS
GHG ACTIVITIES IN FASOMGHG

- Multiple GHG mitigation strategy setup
- Detailed GHG emission accounting
  - Forest carbon
  - Soil carbon
  - N2O
  - CH4
  - Fuel use carbon emissions
- National GHG balance
- GWP weighted sum of all GHG accounts
- GHG Policy implementation
## NON-CO2 SOURCES IN FASOMGHG

### N2O
- Commercial Fertilizer
- Livestock Manure
- Sewage Sludge
- Fixing Crops
- Crop Residues
- Histosol
- Pasture/range/paddock livestock
- Volatilization
- Leaching and Runoff

### CH4
- Enteric Fermentation
- Manure Management Systems
- Rice Cultivation
- Agricultural Residue Burning
<table>
<thead>
<tr>
<th>Strategy</th>
<th>Basic Nature</th>
<th>CO2</th>
<th>CH4</th>
<th>N2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop Mix Alteration</td>
<td>Emis, Seq</td>
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<td></td>
<td>X</td>
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<tr>
<td>Crop Fertilization Alteration</td>
<td>Emis, Seq</td>
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<td>Crop Input Alteration</td>
<td>Emission</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Crop Tillage Alteration</td>
<td>Emission</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Grassland Conversion</td>
<td>Sequestration</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated /Dry land Mix</td>
<td>Emission</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Biofuel Production</td>
<td>Offset</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Afforestation</td>
<td>Sequestration</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Existing timberland Management</td>
<td>Sequestration</td>
<td>X</td>
<td></td>
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<tr>
<td>Deforestation</td>
<td>Emission</td>
<td>X</td>
<td></td>
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<tr>
<td>Stocker/Feedlot mix</td>
<td>Emission</td>
<td></td>
<td>X</td>
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<tr>
<td>Enteric fermentation</td>
<td>Emission</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Livestock Herd Size</td>
<td>Emission</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Livestock System Change</td>
<td>Emission</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Manure Management</td>
<td>Emission</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Rice Acreage</td>
<td>Emission</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</tbody>
</table>
CALIBRATION

(a) N2O

(b) CH4
Experiments

- Prices varied from $0 per ton to $100 as constant real price for 100 years
- Gasses treated collectively or independently
  - CO2 only – single gas
  - CH4 only – single gas
  - N2O only – single gas
  - CH4 and N2O – Non CO2 gasses
  - All gasses – CH4+CO2+N2O

Observed items

- Amount of major strategies used
- Prices, welfare
ECONOMIC POTENTIAL

Economic potential: how much one would get if this was the only gas paid for.
ECONOMIC POTENTIAL

**Economic potential:** how much one would get if this was the only strategy employed or if only non-CO2 was paid.

![Graph showing economic potential for different gases](image-url)

- **Single-Gas**
- **Non-CO2**

**Axes:**
- Y-axis: $/Ton of CO2
- X-axis: NON-CO2 Emission reduction in MMT of CO2 Equivalent

**Legend:**
- CH4&N2O
- CO2
- CH4
- NO2
COMPETITIVE vs. ECONOMIC POTENTIAL

Results do not add up due to competition and complementarity.
Portfolio Composition

Multi-Gas

Single-Gas (CO2)

Two-Gas

All forest the big one
Paying for CO2 only about same as including NonCO2
Paying for non CO2 only can do strange things to CO2
Portfolio Shares

N2O

CH4

Multi-Gas

Two-Gas

Enteric and fertilizer very complementary with CO2
Manure unaffected by multi gas
**INDIVIDUAL vs. MULTIGAS IMPLEMENTATION**

- Joint implementation achieves more quantity reduction at the same price => interaction effects

- Individual implementation overstates reduction => land competition
DYNAMICS OF GHG MITIGATION

Multi-Gas

(a) at $5/ton of CO2

(b) at $15/ton of CO2
Sequestration saturates
Biofuels and non CO2 grow in long run
Biofuel dominates at high price

Multi-Gas

(c) at $50/ton of CO2

(d) at $80/ton of CO2
WELFARE IMPACT

- U.S. Consumers lose
- U.S. Producers gain
- ROW lose

U.S. Consumer

U.S. Producer

ROW

Carbon Price ($/metric ton of CO2)

change from BASE (billion $)
ECONOMIC INDICATORS

- Trade off between emission reduction and agricultural price and production
ENVIRONMENTAL IMPACTS

(a) NPK Nutrient

(b) Erosion

Carbon Price ($/metric ton of CO2)
FUTURE DIRECTION AND CHALLENGES

Better Livestock Enteric and fertilizer

New forestry data

Transactions cost and discounts
## Appendix: CALIBRATION

### Table 1. Comparison NONCO₂ emissions from agriculture using FASOMGHG to EPA estimation in MMT of CO₂

<table>
<thead>
<tr>
<th></th>
<th>2000 Baseline</th>
<th>2010 Projection</th>
<th>2020 Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EPA</td>
<td>FASOM</td>
<td>% Deviate</td>
</tr>
<tr>
<td>N₂O:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural Soil Management:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Managed soils</td>
<td>177.3</td>
<td>153.7</td>
<td>-13.3</td>
</tr>
<tr>
<td>Pasture, Range, and Paddock livestock</td>
<td>41.0</td>
<td>36.3</td>
<td>-11.4</td>
</tr>
<tr>
<td>Indirect Emissions</td>
<td>79.8</td>
<td>73.1</td>
<td>-8.4</td>
</tr>
<tr>
<td>Manure Management</td>
<td>17.2</td>
<td>19.8</td>
<td>15.4</td>
</tr>
<tr>
<td>Agricultural Residue Burning</td>
<td>0.7</td>
<td>0.5</td>
<td>-21.5</td>
</tr>
<tr>
<td>Total N₂O</td>
<td>316.0</td>
<td>283.4</td>
<td>-10.3</td>
</tr>
<tr>
<td>CH₄:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enteric Fermentation</td>
<td>114.5</td>
<td>121.6</td>
<td>6.0</td>
</tr>
<tr>
<td>Manure Management Systems</td>
<td>38.9</td>
<td>30.0</td>
<td>-22.0</td>
</tr>
<tr>
<td>Rice Cultivation</td>
<td>7.5</td>
<td>9.4</td>
<td>25.8</td>
</tr>
<tr>
<td>Agricultural Residue Burning</td>
<td>0.9</td>
<td>1.0</td>
<td>22.0</td>
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<tr>
<td>Total CH₄</td>
<td>161.8</td>
<td>162.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Total non-CO₂</td>
<td>477.8</td>
<td>445.5</td>
<td>-6.7</td>
</tr>
</tbody>
</table>

**Source:** U.S. Greenhouse Gas Emissions and Sinks: 1990-2001, EPA; Personal communication with a personnel at EPA.
## Appendix: CALIBRATION

Table 2: Comparison N\textsubscript{2}O and CH\textsubscript{4} emissions from manure management using FASOMGHG to EPA estimation in MMT of CO\textsubscript{2}

<table>
<thead>
<tr>
<th></th>
<th>2000 Baseline</th>
<th>2010 Projection</th>
<th>2020 Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EPA</td>
<td>FASOM</td>
<td>EPA</td>
</tr>
<tr>
<td><strong>N\textsubscript{2}O Emissions:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>5.4</td>
<td>6.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Dairy</td>
<td>3.9</td>
<td>5.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Horses</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Poultry</td>
<td>7.2</td>
<td>7.0</td>
<td>8.7</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Swine</td>
<td>0.4</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Total N\textsubscript{2}O</strong></td>
<td>17.2</td>
<td>19.8</td>
<td>19.8</td>
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<tr>
<td><strong>CH\textsubscript{4} Emissions:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>3.4</td>
<td>1.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Dairy</td>
<td>11.8</td>
<td>10.1</td>
<td>15.8</td>
</tr>
<tr>
<td>Horses</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Poultry</td>
<td>2.6</td>
<td>3.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Sheep</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Swine</td>
<td>14.1</td>
<td>14.8</td>
<td>18.3</td>
</tr>
<tr>
<td><strong>Total CH\textsubscript{4}</strong></td>
<td><strong>32.7</strong></td>
<td><strong>30.0</strong></td>
<td><strong>41.5</strong></td>
</tr>
</tbody>
</table>

**Total**

|        | 49.8 | 49.9 | 61.4 | 73.2 | 68.2 | 79.6 |

**Source:** U.S. Greenhouse Gas Emissions and Sinks: 1990-2001, EPA; Personal communication with a personnel at EPA.
Table 3: Comparison CH4 emissions from enteric fermentation using FASOMGHG to EPA estimation in million metric tons of CO₂ equivalent

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EPA</td>
<td>FASOM</td>
<td>EPA</td>
</tr>
<tr>
<td>CH₄:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beef</td>
<td>91.7</td>
<td>91.5</td>
<td>101.7</td>
</tr>
<tr>
<td>Dairy</td>
<td>26.9</td>
<td>24.7</td>
<td>29.7</td>
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<tr>
<td>Horses</td>
<td>2.0</td>
<td>2.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Sheep</td>
<td>1.2</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Swine</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Total CH₄</td>
<td>123.7</td>
<td>121.6</td>
<td>136.2</td>
</tr>
</tbody>
</table>

Source: U.S. Greenhouse Gas Emissions and Sinks: 1990-2001, EPA; Personal communication with a personnel at EPA.