RESOURCES for the FUTURE

Measurement Gaps in Mitigating US Agricultural Greenhouse Gas Emissions

Issue Brief 23-04 by **Emily Joiner** and **Michael Toman** — September 2023

Key Points

- Reliable estimates of reductions in greenhouse gas (GHG) emissions achieved through government policies are essential for assessing their impacts and for tracking progress in decarbonizing the agricultural sector.
- The US Department of Agriculture (USDA) and its partners have developed capacities for estimating total agricultural GHG (ag-GHG) emissions at the state and national level and for supporting farmers and ranchers to estimate reductions in their GHG emissions from changes in agricultural practices.
- The Inflation Reduction Act provides funding for further development of USDA's capacity for measuring, monitoring, verifying, and reporting agricultural GHGs at different spatial scales.
- The estimates of national ag-GHG emissions and of reductions in emissions from changes in agricultural practices are limited by data and modeling gaps.
- An improved capability to evaluate aggregate reductions in GHGs from Farm Bill measures and other policies should be a top priority.

1. Introduction

The US Department of Agriculture (USDA) has identified "combating climate change to support America's working lands, natural resources, and communities" as a central goal for the agency (USDA 2023a, 9). An important part of achieving that goal is supporting changes in agricultural practices that reduce greenhouse gas (GHG) emissions. In that context, reliable estimates of the reductions in GHG emissions achieved through USDA programs or other government policies are necessary for assessing the impacts of results-based policy interventions and for tracking progress in decarbonizing the sector.

This issue brief, which is part of a series about **agricultural GHG (ag-GHG) policies**, describes how estimates of ag-GHG emissions from farming and ranching activities in the US are constructed and provides some observations on improving the estimates.

2. Approaches to Greenhouse Gas Estimation

USDA and its partners have developed capacities for estimating total US GHG emissions from agriculture and changes in emissions from a specific farm or ranch from a change in agricultural practices. The estimates include GHGs from onsite burning of fossil energy, as well as process emissions from cropping and animal husbandry.

The GHGs produced by agricultural activities include carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). CO_2 emissions come from decomposition of soil organic matter when land is converted to agricultural uses, as well as from changes in soil carbon stored in existing agricultural soils (increases imply reduced net emissions, while decreases add to emissions). N_2O emissions primarily come from nitrogen applied to soils in fertilizers and less so from manure. CH_4 emissions come mainly from farm animals and their manure. The complexities of how agricultural inputs (like fertilizer) and byproducts (like manure) interact with soils and the atmosphere make it difficult to estimate GHG emission levels and, therefore, to predict reductions in emissions from policy interventions.

A centerpiece in USDA's approach for estimating ag-GHG emissions is an ecological model called **DayCent** that is used to estimate CO_2, N_2O, and CH_4 emissions from soils. DayCent is designed to work at a spatial scale as small as one square meter, but estimates can be scaled up to state and national levels through statistical analysis across a national sample of land areas USDA maintains in its **National Resource Inventory**.

For cropland emissions not covered by DayCent and for animal husbandry, USDA computes emissions using emission factors (emissions per unit of output), averaged at the national or regional scale. Box 1 provides additional information on emission factors and the emissions estimation methodologies that utilize them. USDA's estimates of national GHG emissions from agriculture are included in the annual National Greenhouse Gas Inventory published by the US Environmental Protection Agency (USEPA 2023, Chapter 5).

3. Methods for Estimating Reductions in Ag-GHG Emissions from Changes in Farm- and Ranch-level Agricultural Practice

Farmers and ranchers can obtain estimates of potential reductions in their GHG emissions from changes in agricultural practices using an online USDA tool called **COMET-Farm** (USDA NRCS 2023a; Eve et al. 2014). The tool provides estimates for combinations of various emissions-reducing practices, including the ones supported by the conservation programs in Title II of the Farm Bill. Thus, this tool is a way to support farmers and ranchers enrolling in those conservation programs. The baseline for assessing GHG reductions is a business-as-usual scenario without implementation of the specified practices.

Models inevitably rely on assumptions and data inputs that can lead to errors in estimates. COMET-Farm requires assumptions about how practices to reduce ag-GHGs are implemented. Actual emissions

Box 1: Emission Factors and Emissions Estimation Methods

The Intergovernmental Panel on Climate Change (IPCC) has established procedures for calculating emissions based on different levels of data availability (Aalde et al. 2006). The Tier 1 method is the least sophisticated. Tier 1 emissions calculation relies on applying default emission factors without any spatial differentiation. Tier 1 methods make simplifying assumptions about the emitting activity and the level of emissions, such that emissions increase predictably in proportion to the level of emitting activity. These methods can lead to the systematic underestimation of emissions (Del Grosso et al. 2022).

Tier 2 emissions calculation requires data specialized to the region where the emissions are being estimated. The Tier 3 approach is the most complex, relying upon detailed models with very localized data.

Emissions calculated using Tier 2 or 3 methods are considered to be more accurate than Tier 1 emissions estimates (IPCC 2019, 2023). The USDA and EPA national inventories use Tier 3 methods based on DayCent to estimate N_2O formation, changes in soil carbon on croplands and grazed lands, and CH_4 from rice production. When crops or management decisions fall outside of the scope of DayCent, lower Tier methods are used instead (USEPA 2023).

reductions will differ from model estimates if there is variation in how practices are implemented over different geographic areas or under different policy interventions, such as the Title II programs.

Another USDA tool, **COMET-Planner,** assesses the emissions reduction impacts (and environmental co-benefits) of practices at a larger spatial scale than the farm and ranch scale of COMET-Farm. To accomplish this, COMET-Planner uses emissions estimates averaged over multi-county areas. While useful for its stated purpose of providing generalized estimates of GHG emissions reductions in the conservation planning process, COMET-Planner is not able to provide estimates at the policy level or for entire regions. More detailed estimates of emissions reductions, and corresponding estimates of implementation costs, are needed to provide reliable impact assessments for policy analysis. Accordingly, development of a capacity to make such assessments should be a top priority.

The company **Indigo Agriculture** employs modeling tools built on DayCent for the measurement of the impacts of reduced tillage or cover cropping on soil carbon. These tools support suppliers of carbon credits in the voluntary market (Mathers et al. 2023). A forthcoming issue brief in this series will focus on voluntary carbon markets as a mechanism for reducing ag-GHG emissions.

4. Improving Ag-GHG Estimates

The 2022 Inflation Reduction Act (IRA) includes $300 million for USDA to improve quantification and evaluation of soil carbon storage and ag-GHG emissions. USDA has published a draft strategy for utilizing the funding to improve data across farm and ranch, policy, and national scales (USDA 2023b). The future improvements in measuring, monitoring, reporting, and verifying ag-GHG emissions will increase integration of existing USDA data, non-federal data, and newly developed data sources. These efforts will provide better estimates of how changes in agricultural practices can reduce ag-GHGs at various spatial scales. To implement these improvements, the Soil Carbon Monitoring and Research Network will systemically measure agricultural and forest carbon across the United States, and the Greenhouse Gas Research Network will undertake intense daily monitoring at a few dozen sites to cover enteric emissions, animal housing and manure facility emissions, and crop and pastureland emissions (USDA NRCS 2023b). IRA funding also will be used to improve temporal and spatial detail in data on national conservation activities, provide better data on how conservation practices are used, and support more useful technical guidance for use in ag-GHG reduction activities.

5. Supply Chain and Other Emissions

The focus of the previous sections has been on measuring ag-GHGs that occur on farms and ranches from agricultural processes and onsite energy use, known as “Scope 1” emissions. Researchers and decisionmakers are also interested in two other measurement-related topics: the effects of changes in agricultural practices on GHG emissions elsewhere in the economy and supply chain emissions from agricultural production.

An example of the former topic is the effect of reduced fertilizer use on upstream GHG emissions from fertilizer manufacturing. To enable preliminary inquiry into this topic, agencies involved in producing the National Greenhouse Gas Inventory could provide more disaggregated emissions estimates for the manufacturing sector to break out emissions from fertilizer manufacturing. However, predicting how agricultural practice changes, such as reduced fertilizer use by farmers, will impact upstream emissions, like those from the manufacturing sector, is not straightforward. A drop in US fertilizer demand, driven by less frequent fertilizer applications, would have the effect of lowering fertilizer prices. Lower prices would create an incentive for US farmers to buy, and potentially use, more fertilizer. Ultimately, this could result in a rebound effect that would dampen the emissions reductions from lower initial demand. In addition, fertilizer price reduction from a decline in US demand could see farmers in other countries make up for that demand as they aim to increase their own agricultural productivity. In this way, the supply of fertilizer would likely remain constant, and emissions avoided by farmers in the US could leak out in other parts of the world.

In assessing GHG emissions across the supply chain of farm or ranch production, two categories, or **scopes**, of emissions beyond Scope 1 are commonly distinguished. "Scope 2" emissions arise from the offsite production of energy used on the farm or ranch. A farmer or rancher's use of biogas produced from their anaerobic digester instead of natural gas would reduce the Scope 2 emissions of their operation. "Scope 3" emissions include all the other indirect emissions in the supply chain, such as the emissions generated by manufacturing the fertilizer used on fields.

In the absence of comprehensive policies for reducing national GHG emissions, advocates encourage emitters to seek reductions across their supply chains, not just in emissions from their immediate operations. Leaving aside the incentives for such actions, measuring the emissions impacts across the supply chain is challenging for two reasons. One is the presence of rebound effects, noted above. The other is that quantifying the levels of supply chain emissions is inherently complex. Scope 2 emissions from electricity purchases depend on where and when the electricity was generated. Identifying Scope 3 emissions from other upstream and downstream sources is even more complicated and involves some inherently arbitrary assumptions.

6. References

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Appendix: Sources of Complexity in Estimating Ag-GHG Emissions Sources

Emissions and sequestration of CO_2 depend on complex soil chemistry and on the microbes that live in the soil. Soil carbon storage can change autonomously, which amplifies uncertainty about how changing cropping practices affects ag-GHGs. The Natural Resources Conservation Service and other experts recommend cover cropping and changes in tillage practices for maintaining or increasing soil carbon storage. However, there is uncertainty around the effects on soil carbon storage of both practices across different soil types and climate zones (Ogle et al. 2019, Blanco-Canqui 2022).

N_2O formation in soil depends on the amount of nitrogen fertilizer applied, the moisture and temperature of the soil, and the microbes the soil contains. N_2O formation also depends on the presence (or absence) of plants capable of fixing nitrogen in soil through their roots. These factors make expectations about N_2O formation difficult to generalize. There can also be interactions between soil carbon and nitrogen application through management practices. For example, a farmer might respond to concerns about no-till agriculture lowering their yields by increasing fertilizer application.

CH_4 emissions from animals result from enteric fermentation inside the stomachs of ruminants (cattle, sheep, goats) and from the decomposition of manure from all species. Scientific knowledge makes possible the estimation of digestive emissions and manure production for specific ruminant species, and CH_4 from manure decomposition can be estimated based on the quantity of manure, ambient temperature under which decomposition occurs (higher temperature means more rapid decomposition), and the type of manure management system (if any). Farmers and ranchers can reduce CH_4 by using an anaerobic digester to collect the CH_4 as biogas, as opposed to an alternative manure management system like a lagoon (USDA 2022).

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