Stanford LawSchool | Law and Policy Lab

Data Progress Needed For Climate-Smart Agriculture

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I. EXECUTIVE SUMMARY

In the U.S. and globally, the agricultural sector is a major source of the greenhouse gasses (GHGs) that are causing climate change. More than 10% of the U.S.'s total GHG emissions are attributable to the agriculture sector, due to emissions driven primarily from two powerful GHG sources: methane from livestock, and nitrous oxide from fertilizer use. Once-enormous emissions of carbon dioxide from cropland and pastures also continue to occur, but at much reduced rates.

Encouragingly, however, there is strong interest in the U.S. in expanding "climate-smart" farming and ranching practices that can help maintain and grow carbon stocks in soils and trees (agroforestry) and reduce methane and nitrous oxide emissions.[1] Many commentators are bullish that the deployment of practices such as cover cropping, low or no tillage, nutrient management, and agroforestry[2] can significantly reduce agriculture's carbon footprint.[3] Voluntary carbon markets have taken notice and some farmers are being paid to engage in climate-smart practices. In addition, major food processors and retailers focused on reducing the carbon footprint of their supply chains are incentivizing farmer-suppliers to engage in such practices.

Forward progress in this area, however, is constrained by major data and analytical gaps that prevent accurate and verifiable quantification of how much climate-smart farming and ranching practices are growing carbon stocks in soils and biomass or reducing methane and nitrous oxide emissions. Experts are skeptical of claims regarding the accumulation of carbon in soils and reduced GHG emissions from livestock and nutrient management practices. They cite the lack of reliable, consensus-based measurement, monitoring, reporting & verification protocols (hereinafter referred to as "measurement and monitoring" or "MMRV" protocols) for specified agricultural practices. Also largely absent is access to the data that underlie measurement and monitoring protocols – creating additional doubt about whether practices are, in fact, generating claimed environmental benefits.[4] As a result, there are major questions regarding the validity of agricultural-based carbon offsets emanating from voluntary carbon markets as well as Scope 3 supply chain carbon footprint estimates for agricultural commodities. Simply put, the lack of practical and scientifically sound approaches for confirming that specified practices generate claimed benefits, and the lack of access to confirmatory data, pose major systemic impediments to rewarding farmers and ranchers for deploying climate-smart practices.

The good news is that due to recent action by Congress and the Administration, the U.S. has a historic opportunity to address the measurement and monitoring and data management deficiencies that are dampening incentives for farmers and ranchers to deploy climate-smart practices. In particular, the Inflation Reduction Act (IRA) appropriated nearly $20 billion for existing agricultural programs that incentivize climate-smart practices—while, for the first time, explicitly requiring the Secretary of Agriculture to make an evidence-based determination that funded practices "*directly improve soil carbon, reduce nitrogen losses, or reduce, capture, avoid, or sequester carbon dioxide, methane, or nitrous oxide emissions.*"[5]

Congress backed this directive by earmarking $300 million to "quantify" and "monitor and track" carbon dioxide, methane, and nitrous oxide sequestration and emissions reductions by "collect[ing] field-based data" and using the data to "assess the … emissions outcomes associated with [IRA-funded] activities."[6] It singled out methane emissions for special attention, mandating that the Secretary "[prioritize] proposals that utilize diet and feed management to reduce enteric methane emissions from ruminants."[7]

In parallel, USDA Secretary Vilsack is moving forward with President Biden's climate-smart agriculture and forestry initiative, as called for in the President's Climate Executive Order.[8] Notably, the USDA has launched a $3.1 billion "Partnerships for Climate-Smart Commodities" program (hereinafter referred to as the "Commodities Partnership" program) that will fund and evaluate more than 140 climate-smart agriculture and forestry pilot projects in all 50 states.[9] A primary thrust of the pilot projects is to test out innovative measurement and monitoring technologies and methodologies that can more definitively validate the environmental benefits associated with climate-smart practices – with the prospect of garnering a market premium for agricultural products produced using such practices.[10]

It is vital that the Administration, acting through the USDA and with the support of the White House, the U.S. Digital Service, other governmental and philanthropic entities, and the agricultural and scientific communities, take full advantage of these new authorities, programs, and funding. This is the U.S.'s collective opportunity to identify, verify, and deploy cost-effective measurement and monitoring protocols that will put climate-smart practices on a data-rich, science-backed footing – delivering a bright, remunerative future for farmers and ranchers all around the U.S.

The Bezos Earth Fund commissioned preparation of this report with David J. Hayes in cooperation with Stanford Law School's Law & Policy Lab. The report is the product of an interdisciplinary policy practicum conducted with graduate students at Stanford University under the auspices of Stanford Law School. Following multiple interviews and an extensive review of relevant materials, the report identifies a suite of recommendations that address fundamental concerns about the adequacy of existing measurement and monitoring protocols and confirmatory datasets for climate-smart practices. Implementing the positive vision reflected in these recommendations will enable farmers and ranchers to obtain durable financial incentives that will expand the adoption of climate-smart agricultural practices and materially reduce the U.S. agricultural sector's carbon footprint while generating a host of environmental and economic benefits.

Specific recommendations discussed in this report and proffered to the White House and the USDA include:

(1) Launch a USDA **Ag-Methane Reduction Initiative** and a **Nitrous Oxide Demonstration Project** that will accelerate the adoption of agricultural practices and accompanying measurement and monitoring protocols that target methane and nitrous oxide emissions. As the largest sources of climate-damaging GHGs from agricultural activities, they should be prioritized for early reductions.

    (a) The **Ag-Methane Reduction Initiative** would (1) prioritize federal funding for research that focuses on reducing enteric fermentation-related methane emissions from livestock and related measuring and monitoring protocols; (2) identify and track all significant advances in enteric fermentation, manure and rice management, and other methane-related research and testing activities in the U.S. and globally, including the development of measurement and monitoring protocols associated with these activities; and (3) review and update historical measurement and monitoring protocols and emission factors associated with manure management practices.

(b) The **Nitrous Oxide Demonstration Project** would (1) prioritize federal funding for research regarding fertilizer application practices that optimize both fertilizer efficacy and emissions reductions; and (2) fast-track testing and training in applying the N balance method of measuring and monitoring nitrous oxide emissions for fertilizer use.

(c) **Funding**. Because methane and nitrous oxide emissions together account for nearly 90% of the agriculture sector's carbon footprint, we recommend that at least $150 million of the $300 million in IRA GHG measurement and monitoring funds be invested in the Ag-Methane Reduction Initiative and Nitrous Oxide Demonstration Project. These two project areas are in catch-up mode as soil-related research, testing and modeling activities have received the large majority of the USDA's research-related funding for many years. Those priorities need to be rebalanced for the USDA to make major progress on the agriculture sector's climate challenges.

(2) Launch a two-phase **Soil Carbon Measurement and Monitoring Plan** that includes:

(a) A **Soil Carbon Measurement Technology Review** that will oversee the analysis of available soil carbon measurement and monitoring options, including new technologies and methodologies that have become available in recent years and are being test piloted through the Commodities Partnership program; and

(b) A **National Soil Carbon Monitoring Program** that will utilize soil carbon protocols recommended by the Soil Carbon Measurement Technology Review to establish region-specific baselines of soil carbon concentrations against which changes in carbon stocks in soils will be measured and verified.

(c) **Funding**. For reasons explained in Recommendation (1)(c), we recommend that the USDA deploy no more than $150 million in IRA measurement and monitoring funds to conduct a baseline analysis and to monitor identified test plots on a periodic basis.

(3) Establish a **Climate-Smart Protocol Clearinghouse** that creates a consolidated public inventory of protocols that are used throughout the agricultural community and its partners to measure and monitor carbon removals and methane and nitrous oxide reductions from specified agricultural practices. The Climate-Smart Protocol Clearinghouse will provide a platform for exchanging information about protocol development and deployment, creating the opportunity for the USDA, scientists, practitioners, and the farming community to coalesce around protocols that are widely

accepted as reliable and appropriate norms for measuring and monitoring incremental carbon removals and methane and nitrous oxide reductions.

(4) Establish an **Agriculture GHG Data Management System** that will collect and organize GHG measurement and monitoring data in accessible anonymized formats to facilitate public review, analysis, and benchmarking of agriculture measurement and monitoring protocols. The Agriculture GHG Data Management System will implement the goals of White House's proposed "Federal Strategy to Advance an Integrated U.S. Greenhouse Gas Monitoring & Information System"[11] for the agricultural sector.

(a) The USDA should work with the White House GHG Measurement and Monitoring Working Group, the U.S. Digital Service, and philanthropic partners to evaluate options for how to structure the Agriculture GHG Data Management System, how to administer it (including, potentially, through a quasi- or non-governmental entity in partnership with the federal government), how to ensure that data is anonymized to protect farmer privacy interests, and how to establish ground rules for data submission to maximize the data's interoperability with other agricultural datasets.

(b) **Funding**. To ensure that data generated through taxpayer-supported federal funding is made available to the scientific community and the public, we recommend that at least 1 percent of grant funding associated with GHG quantification efforts be allocated to support the public availability of anonymized farm practice data through the Agriculture GHG Data Management System. Accessibility to publicly-funded datasets (and voluntarily-provided anonymized private data sets) will enable researchers and policymakers to help identify and incentivize the most efficacious climate practices.

(5) Engage in extensive farmer and rancher **outreach and technical assistance** to encourage broad-based adoption of climate-smart practices.

(6) Develop a strong implementation infrastructure at the USDA that matches the climate-smart agriculture initiative's level of ambition by:

(a) Establishing an **Advisory Committee of outside experts** that will provide the Secretary of Agriculture with on-going scientific input regarding the formation and implementation of: Ag-Methane Reduction Initiative and Nitrous Oxide Demonstration Project; the National Soil Carbon Technology Review; the National Soil Carbon Monitoring Plan; the Climate-Smart Protocol Clearinghouse; and the Agriculture GHG Data Management System; and

(b) Creating a high-level **USDA Climate-Smart Strike Team** in the Office of the Secretary that has overall responsibility to organize and execute on all aspects of the Secretary's climate-smart agriculture initiative.

Taking these steps will enable the USDA to bring the many USDA bureaus involved in this cross-cutting initiative under a unified, high-level command structure that reports directly to the Secretary. Actuating this action plan also will give the USDA command structure ready access to world-class experts who can guide the enterprise all along the way.

II. METHODS FOR MEASURING AND MONITORING CARBON IN SOILS AND METHANE & NITROUS OXIDE EMISSIONS NEED IMPROVEMENT

The USDA has based its climate-smart agriculture initiative on specific agricultural practices that have been shown, as a general matter, to produce climate and other important benefits. Cover-cropping, rotational grazing, and low- or no-tillage practices are among the most widely recognized of these practices.[12]

Taking a practice-based approach makes sense. Both the USDA and the broader agricultural community have invested heavily in identifying and developing beneficial farming and ranching practices over time and through extensive deployment. One of those key investments has been the USDA's development of COMET and other complex models that produce generalized estimates of benefits associated with certain practices. These models have served the agricultural community well, but they were not designed to identify GHG-specific removals or emissions nor were they calibrated with a testing regime that enables them to reliably do so within narrow bands of certainty. *See* Appendix A.

Nonetheless, because the USDA continues to use COMET for high-level tracking of climate-smart practice outputs,[13] many companies seeking to monetize agricultural climate benefits rely on COMET and other USDA-sponsored models as a foundational (and sometimes exclusive) measurement and monitoring tool for claiming climate benefits.[14] This is unfortunate. As explained in Appendix A, these models do not provide a sound basis for quantifying and monetizing incremental increases in carbon sequestration in soils or decreases in methane and nitrous oxide emissions.

A better alternative is using measurement and monitoring protocols that specify sampling and analytical techniques designed to detect changes in carbon, methane, or nitrous oxide levels. Many protocols specify methods to obtain representative field-based and remote sensing data so that a baseline can be established and subsequent changes in conditions can be monitored. If baseline testing is done in representative region-specific soil conditions (for soil carbon), representative livestock feeding, manure management or other practice conditions (for methane emissions), and representative nutrient management conditions (for nitrous oxide emissions), changes can be tracked and verified in those same fields and conditions, with results then scaled up and verified by using a combination of emission factors, GHG-specific modeling, and follow-up spot checking.

Many researchers and practitioners – knowing that better GHG quantification is needed – have been laying the groundwork for taking this approach. Often with the help of new measurement technologies and methodologies, they have been developing new protocols that can more accurately and/or cost-effectively track changes in carbon levels in soil and emission levels of methane and nitrous oxides. Particularly noteworthy developments highlighted in this report include new methods to measure and monitor methane emissions from livestock; an exciting new nitrous oxide measurement protocol; and the emergence of new soil carbon measurement and monitoring options.

A number of key steps are needed, however, to accelerate the effective use of GHG measurement and monitoring protocols so they can fill the data and analytic gaps that are holding back the monetization of climate-smart farming and ranching practices. Those key steps include: (1) prioritizing attention on practices and protocols that target methane and nitrous oxide emissions; (2) addressing systemic challenges associated with soil carbon protocols; and (3) establishing a mechanism that will enable the USDA and interested stakeholders to coalesce around a small number of protocols that can become accepted GHG measurement and monitoring norms. Each of these issues is addressed in this report, in turn.

III. PRIORITIZING ATTENTION ON METHANE AND NITROUS OXIDE PRACTICES AND PROTOCOLS

Historically, the regenerative agriculture movement has focused primarily on adopting practices that promote healthy soils like cover cropping, reduced tillage, and the like. These practices can help hold and potentially increase soil carbon concentrations over time, potentially generating multiple benefits that may include increased yields, reduced erosion and run-off, and increased biodiversity and resilience.[15]

Somewhat overshadowed, unfortunately, have been the farming and ranching practices that can yield more significant climate benefits by reducing methane and nitrous oxide emissions insofar as these two powerful greenhouse gasses are responsible for nearly 90% of the agriculture sector's carbon footprint.[16] *See* Figure 1.

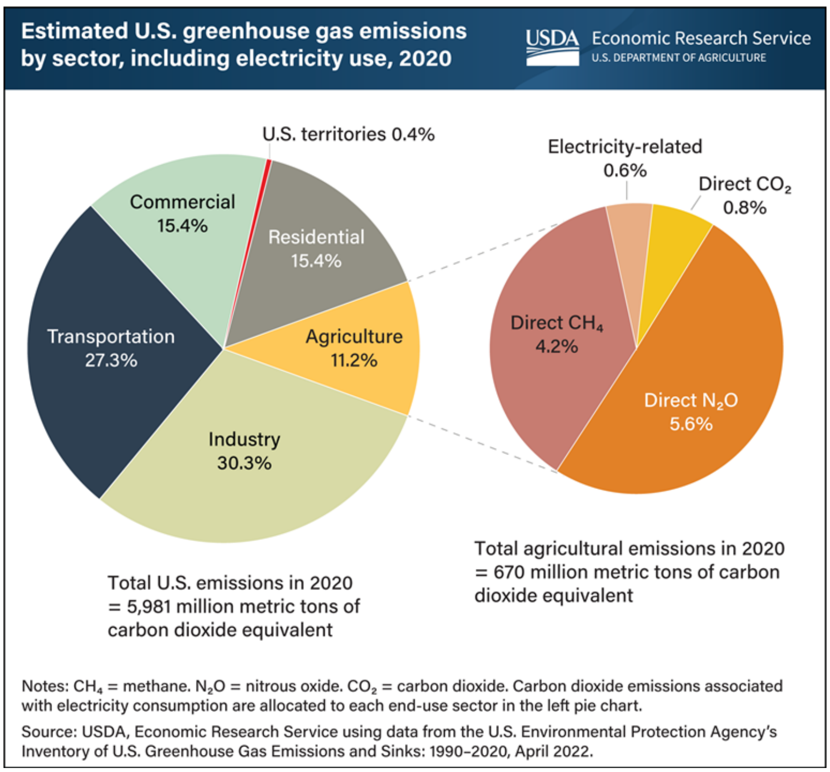

Figure 1. The above pie chart displays estimates of U.S. GHG emissions by sector in 2020. Over 10% of the U.S.'s total GHG emissions are attributable to the agricultural sector. Of agricultural emissions, 37.5% are direct methane emissions, 50% are direct nitrous oxide emissions, and approximately 7% are direct carbon dioxide emissions.

Source: USDA, *Economic Research Service using data from U.S. Environmental Protection Agency's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020*

Now, however, investments in reducing ag-related methane and nitrous oxide emissions are ramped up sharply in recent years due to U.S. and global commitments to reduce methane emissions from all major sources[17] and the recognition that nitrous oxide is 300 times more powerful a greenhouse gas than carbon dioxide.

This situation presents a unique opportunity for the USDA to use its new funding sources and authorities to jumpstart climate-smart practices and related measurement and monitoring protocols that can deliver a major climate win.[18] Each GHG is addressed below, in turn.

Methane

Methane emissions from agriculture come mainly from enteric fermentation in ruminants, manure management, and rice cultivation. Lesser sources are farmland conversion from wetlands, or practice changes that result in methane fluxes from changes to the soil. However, the dominant sources of methane are enteric fermentation (69.7%) and manure management (24.36%), together accounting for 94.06% of methane from agricultural sources in 2019, with flooded rice accounting for 5.89%.[19]

Methods for estimating changes in methane emissions are detailed in the USDA's Quantifying Greenhouse Gas Fluxes in Agriculture ("Blue Book"), which defines the methods and models used in the COMET model. The approaches used for manure management, enteric fermentation, and animal housing rely predominantly on IPCC Tier 2 (Beef Cattle and Manure), or IPCC Tier 1 (other ruminants) methodologies, with dairy emissions categorized separately.[20] One new model developed to simulate environmental impacts from dairy farm production is the Ruminant Farm Systems (RuFaS) model, which modularizes different elements of the whole dairy farm and provides life-cycle estimates for total methane emissions across the different on-farm stages of feed production, enteric fermentation, and manure management.[21]

The actual measurement approaches prescribed in the Blue Book are rigorous, peer reviewed, and take different animal life stages, behaviors, and production systems into account in measurement or estimation. Most enteric fermentation measurement has relied on respiration chambers, internal tracer techniques, or micrometeorological approaches. Each of these approaches has its own specific drawbacks, with the cost of implementation being a primary obstacle throughout. On the manure management side, measurement and monitoring has been more challenging due to the difficulty of measuring atmospheric concentrations from a relatively diffuse source. Flux chambers have been proposed as an alternative approach to measurement, but only as a means of measuring relative differences rather than emissions factors. Additionally, the nature of manure stockpiles or retention ponds means that the number of measurements required for confidence "can be very large."[22]

A number of promising technologies have emerged in recent years to measure and monitor how much changes in livestock diet and feed and manure management options can reduce emissions from enteric fermentation and manure – the predominant sources of methane from agricultural activities. For example, new practices relevant to enteric fermentation include improvements to respiration chambers, higher resolution sensors, wearable devices, and drone-based portable measurement tools that could improve the baseline assumptions in enteric fermentation models. Technology companies are actively partnering with large scale dairies and agri-food businesses to test out many of these new practices, using new measurement and monitoring tools described in Appendix B.[23]

Reported results are remarkable. They claim up to 80% reductions in livestock-related emissions, revealing an opportunity to generate significant climate benefits – and financial rewards for farmers and ranchers. This opportunity should expedite research and data-gathering projects that are combining new practices such as diet and feed-related livestock regimes with new methane measurement and monitoring protocols that can quantify their results. As noted above, Congress explicitly mandated that enteric fermentation projects be a priority for funding under the IRA.[24]

The USDA also is investing in collaborative international enteric fermentation-focused activities, including the Enteric Fermentation Research and Development Accelerator – which is part of the Agriculture Innovation Mission for Climate (AIM) initiative – and the "Pathways to Dairy Net

Zero" initiative which will have a primary focus, as it must, on reducing methane emissions from livestock.[25]

To tie together these activities and reinforce the USDA's commitment to reduce methane emissions from the agriculture sector, we recommend that the USDA:

> Launch **an Ag-Methane Reduction Initiative** that will accelerate the adoption of agricultural practices and accompanying measurement and monitoring protocols that target methane emissions. The Ag-Methane Reduction Initiative would:
>
> (1) prioritize federal funding for research that focuses on reducing enteric fermentation-related methane emissions from livestock and related measuring and monitoring protocols;
>
> (2) identify and track all significant advances in enteric fermentation, manure and rice management and other methane-related research and testing activities in the U.S. and globally, including the development of measurement and monitoring protocols that associated with these activities; and
>
> (3) review and update historical measurement and monitoring protocols and emission factors associated with manure management practices.

Nitrous Oxide

To estimate soil direct nitrous oxide emissions, the Blue Book recommends "using results from process-based models like DAYCENT and DNDC and measured nitrous oxide emissions in combination with scaling factors based on U.S. specific empirical data."[26] These methods are theoretically powerful but are "expensive, inaccurate, and difficult to scale," rendering them effectively unusable.[27] Similarly, direct measurement of nitrous oxide is prohibitively costly to conduct at scale, necessitating "a dense network of continuously running sensors" that would likely be infeasible for most operators. And process-based models, as explained earlier, require large amounts of input data that are usually lacking, are not scalable, and have not been sufficiently calibrated and validated.[28]

As with methane, however, recent attention on nitrous oxide emissions' major contribution to agriculture's carbon footprint, and rising fertilizer prices due to geopolitical factors including the war in Ukraine, have triggered a renewed commitment to deploying nutrient management practices that will materially reduce nitrous oxide emissions and – just as importantly – identifying and deploying cost-effective mechanisms to measure and monitor resulting emissions reductions. (For nitrous oxide emissions, the challenge has always been on the measurement and monitoring side, given the recognized relationship between using less fertilizer and reducing emissions.[29])

A key new development has been the development of the Nitrogen Balance Framework – "N balance method" for short – for measuring and monitoring nitrous oxide emissions from fertilizer use. The N balance method uses a simple equation that takes nitrogen input information that farmers already have on hand (fertilizer, manure, legumes), and subtracts out nitrogen removals (in the form of harvested cash crops and animal feed) to identify the amount of nitrogen that is at risk of loss through airborne or water emissions. Figure 2 illustrates this equation.

Figure 2: This graphic illustrates the core variables of the N balance method.

Source: *Making the Invisible Loss of Nitrogen Visible, for Farm and Future*, ENV'T DEF. FUND, fig. (Feb. 18, 2021), https://www.edf.org/ecosystems/making-invisible-loss-nitrogen-visible-farm-and-future.

Scientists at the Environmental Defense Fund (EDF) have pioneered use of the N balance method and demonstrated, using ground truth data, that it closely tracks nitrous oxide emissions for a wide range of crop types, both synthetic and organic nitrogen applications, and for a representative range of regions, soil types, and climates.[30] As a result, a number of leading scientists have recommended the N balance method for quantifying nitrous oxide emissions in agriculture and identifying policy-relevant thresholds and opportunities.[31] EDF has worked directly with crop commodity organizations, crop advisors, agricultural data management developers, and other partners and stakeholders to implement and further test how the N balance method fares on real farms.[32] These partners include the Farmers Business Network, Iowa Soybean Association, National Corn Growers Association, and United Soybean Board.[33] The combination of its simplicity, private sector buy-in, co-benefits for farmers, and scientific validation suggest the N balance method should be prioritized as a promising nitrous oxide measurement and monitoring protocol.

Based on these observations, we recommend that the USDA:

> Launch **a Nitrous Oxide Demonstration Project** that will accelerate the adoption of agricultural practices and accompanying measurement and monitoring protocols that target nitrous oxide emissions. The Nitrous Oxide Demonstration Project would:
>
> (1) prioritize federal funding for research regarding fertilizer application practices that optimize both fertilizer efficacy and emissions reductions; and
>
> (2) fast-track testing and training in applying the N balance method of measuring and monitoring nitrous oxide emissions for fertilizer use.

We also recommend that at least half of the $300 million designated in the IRA for measurement and monitoring be allocated to the Ag-Methane Reduction Initiative and Nitrous Oxide Demonstration Project:

Funding. Because methane and nitrous oxide emissions together account for nearly 90% of carbon dioxide equivalent of the agriculture sector's carbon footprint, we recommend that a minimum of $150 million of the $300 million in IRA GHG measurement and monitoring funds be invested in the Ag-Methane Reduction Initiative and Nitrous Oxide Demonstration projects. These two project areas are in catch-up mode as soil-related research, testing and modeling activities have received the large majority of the USDA's research-related funding for many years. Those priorities need to be rebalanced for the USDA to make major progress on the agriculture sector's climate challenges.

IV. SYSTEMICALLY ADDRESSING SOIL CARBON MEASUREMENT AND MONITORING PROTOCOLS

Measuring and monitoring carbon concentrations in soils presents a uniquely challenging task. Different soil types in different regions of the country can have widely variant carbon profiles. Carbon concentrations in soils can even vary significantly within an individual field. As a result, sampling at a high enough density to limit analytical variance and uncertainty is time intensive and costly – particularly when using the traditional "gold standard" soil sampling process of obtaining soil cores from fields and sending them off for lab testing.[34]

In addition to the heterogeneity problem, meaningful accumulations of carbon in working soils typically occur very slowly over multiple years and even decadal time-frames.[35] Meanwhile, carbon losses can easily occur. For both reasons, some soil carbon protocols require on-going sampling over a multi-year time scale.

Together, these factors have eliminated or severely limited the availability of reliable baseline data against which changes in soil concentrations due to good soil management practices can be measured and monitored. Unmoored from baseline conditions, subsequent soil carbon sampling activities using traditional methods arguably offer only random data points that cannot support meaningful conclusions about sequestered carbon quantities or trends. This is a key reason why respected commentators recently called for the rescission of the soil carbon protocols that the USDA's Natural Resources Conservation Service (NRCS) has developed for soil carbon – CEMA 218 and CEMA 221.[36] These commentators concluded that continued use of CEMA 218 and 221 will "undermine existing standards for soil carbon quantification, lead to wasteful taxpayer spending, and contribute to widespread greenwashing."[37] *See* Appendix C for more details.

Against this troubling backdrop, new technologies and methodologies are emerging to improve carbon soil measurement and monitoring. For example, new applications of soil spectroscopy – an already well-established technology in the research domain – are generating measurements of soil carbon concentrations at a fraction of the cost of traditional analysis.[38] In addition, startups are working on leveraging spectroscopy to create scalable soil carbon measurement and monitoring solutions. One such company, Yard Stick, is developing a probe to capture instant estimates of soil carbon in lieu of traditional soil sampling.[39] Likewise, in-field and satellite remote sensing, although still relatively nascent technologies that need further validation, could help validate and parameterize models and provide additional soil carbon data at scale.[40]

The USDA's Climate-Smart Commodities Partnership program will help accelerate soil carbon measurement innovation by piloting several innovative measurement and monitoring approaches. On March 8th, 2023, our Stanford research group hosted a webinar[41] that featured USDA-funded projects that will be testing innovative measuring and monitoring technologies and methodologies. On the hardware side, companies such as Yard Stick and EarthOptics are developing hardware technology that could replace conventional soil sampling methods and reduce the cost of acquiring ground truth soil data. Similarly, companies such as Perennial and HabiTerre are leveraging large datasets by combining soil samples with remote sensing and satellite imagery to build models that do not depend on commonly used biogeochemical models. These approaches require less dependence on ground truth data, which has its benefits in being less intrusive to farmers but raises the dual challenge of scalability and accuracy.

In addition to this activity, some researchers and companies have been independently developing their own measurement and monitoring protocols in collaboration with voluntary carbon market registries and/or as one of several inputs into proprietary "decision-making" software programs that companies are using to generate climate-smart practice "scores" for clients. Data generated under these protocols, however, are often not available for public scrutiny. In that regard, the growth of proprietary datasets and software tools that purport to predict specific GHG outcomes – but whose datasets and software assumptions cannot be publicly viewed and verified[42] – creates an increasingly serious impediment to the development of soil carbon and other GHG sampling protocols that can become trusted, industry-wide norms.

Based on these observations, we recommend that the USDA initiate a two-phase process for improving soil carbon measurement and monitoring:

> **Phase One** entails the USDA's establishment of a **Soil Carbon Measurement Technology Review** that will oversee the analysis of available soil carbon measurement and monitoring options, including recent new technologies and methodologies that are being test piloted through the Commodities Partnership program.
>
> The USDA should contract with a well-respected organization, such as a National Laboratory or respected environmental consultancy, to conduct the review with expert assistance. The review should recommend a limited number of protocols that would be utilized to identify baseline carbon soil concentrations under the National Soil Carbon Monitoring Program referenced below. Protocols will be recommended based on cost-effectiveness, scalability, accuracy, and repeatability (given the need for on-going changes).
>
> **Phase Two** entails the USDA's establishment of a **National Soil Carbon Monitoring Program** that will utilize soil carbon protocols recommended by the Soil Carbon Measurement Technology Review to establish region-specific baselines of soil carbon concentrations against which changes in carbon stocks in soils will be measured and verified.
>
> In cooperation with land grant colleges and USDA Climate Hubs, regional test plots should be selected for baseline testing for biophysically defined agroecological zones that have similar soils, climate, and agricultural potential or constraints.[43] The USDA should deploy remaining IRA measurement and monitoring funds (following the priority allocation described in Section III above) to conduct a baseline analysis and to monitor identified test plots on a periodic basis.

V. ESTABLISHING A MECHANISM TO FACILITATE ADOPTION OF LEADING GHG MEASUREMENT & MONITORING PROTOCOLS

As illustrated above, GHG measurement and monitoring protocols of varying quality are proliferating. And more are on their way as new technologies and methodologies move from the lab to the field. Adding to the confusion and uncertainty, some companies are pushing proprietary measurement and monitoring strategies that they claim are superior, but which are not available for general scrutiny.

This status quo is unacceptable. For climate-smart agriculture to achieve its ambition, a consensus must develop around a small number of accurate and cost-effective GHG measurement and monitoring protocols that farmers and ranchers can literally bank on.

Congress recently reinforced this point when it asked the Secretary of Agriculture to help identify and sort through the numerous GHG measurement and monitoring protocols that are creating confusion in fledgling voluntary environmental markets. Specifically, in the recently enacted Omnibus Budget Law, Congress asked the Secretary of Agriculture to consider pulling together a list of protocols and related information that he deems to be "widely accepted."[44]

Congress has correctly put its finger on a major impediment to securing the remuneration of farmers' and ranchers' adoption of climate-smart practices by pointing to the lack of agreed-upon measurement and monitoring protocols that, if followed, could confirm that the practices produce expected results and merit compensation.

Given the seriousness of this obstacle, we recommend that the Secretary act on Congress' suggestion and as soon as practicable:

> The USDA should establish a **"Climate-Smart Protocol Clearinghouse"** that creates a consolidated public inventory of protocols that are used throughout the agricultural community and its partners to measure and monitor carbon removals and methane and nitrous oxide reductions from specified agricultural practices.
>
> The Secretary should use the USDA Climate-Smart Protocol Clearinghouse as a platform for exchanging information about protocol development and deployment and creating the opportunity for the USDA, scientists, practitioners, and the farming community to coalesce around protocols that are widely accepted as reliable and appropriate norms for measuring and monitoring GHGs.

We further recommend that the Clearinghouse be divided into three parts for protocols related to methane, nitrous oxide, and carbon removals via agricultural soils and trees (agroforestry), respectively. As discussed above, the USDA has an opportunity to utilize its Ag-Methane Reduction Initiative and Nitrous Oxide Demonstration Project and the Soil Carbon Measurement Technology Review and its National Soil Carbon Monitoring Program to facilitate the identification of a small number of respected, consensus protocols for each GHG.

VI. ESTABLISHING AN AGRICULTURE GHG DATA MANAGEMENT SYSTEM

A successful climate-smart agriculture initiative must be based on the implementation of clearly prescribed climate-smart farming and ranching practices where on-the-ground results are supported by solid datasets generated in accordance with scientifically sound, consensus-based measurement and monitoring protocols.

Unfortunately, available data confirming that specified agricultural practices generate quantifiable carbon gains or reduced GHG emissions are generally poor. Current estimates of carbon dioxide emissions from land use and land-use change have uncertainties of +/- 75%.[45] Estimates of methane emissions from agriculture have uncertainties up to +/- 70%.[46] Uncertainties are even higher for nitrous oxide, despite agriculture's status as the largest emission source of nitrous oxide.[47]

Activity-level data that matches specific practices with GHG impacts – such as soil sampling data that may show carbon accumulations from cover cropping or reduced tillage practices – are not generally accessible, despite major USDA funding of soil sampling work over many years. At best, these datasets are fragmented across a variety of disparate sources and locations, with limited or no availability to researchers.[48] And because new activity-level data often are being generated by private parties in service of voluntary carbon markets or supply chain reviews, these data also are typically not available for public review.

This absence of a comprehensive, accessible, activity-level dataset that defines GHG baselines with real-time data and tracks changes due to farming and ranching practices poses another serious barrier to quantifying – and therefore monetizing – climate benefits. We need to do better. As the National Academies explained in a recent report, climate change is accelerating the need for increasingly strong datasets that provide more granular measurements of GHG emission source data. Factors in play include: "(1) [the] rapidly increasing demand from a range of users for trusted information about GHG emissions across multiple sectors and geographic scales;[49] (2) [the] development of many new approaches for quantifying GHG emissions that aim to address this increasing demand; and (3) a growing and rapidly evolving institutional landscape, including public, private, and academic entities seeking to provide better GHG emissions information."[50]

The U.S. Needs a GHG Data Depository to Facilitate the Collection and Coordinated Analysis of Activity-Based and Atmospheric GHG Data

The National Academies have concluded that new mechanisms are needed to facilitate the collection and coordinated analysis of both activity-based ("bottom-up") and atmospheric-based ("top-down") GHG data.[51] Its recent report calls for "the creation of a coordinated repository or federation of repositories across the global community, enabling adherence to a set of minimum common pillar attributes" including (1) data usability and timeliness, (2) information transparency; (3) evaluation and validation; (4) completeness; (5) inclusivity; and (6) communication.[52]

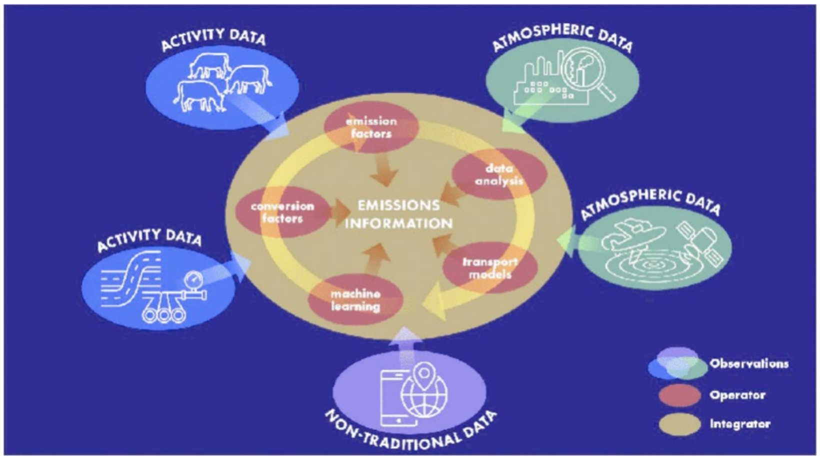

Figure 3. A hybrid approach to quantifying GHG emissions leverages multiple data sources and novel technologies to produce more complete and accurate estimates. This approach involves the combination and complete integration of activity- and atmospheric-based data.

Source: NAT'L ACADS. OF SCIS., ENG'G, AND MED., GREENHOUSE GAS EMISSIONS INFORMATION FOR DECISION MAKING: A FRAMEWORK GOING FORWARD 3 fig. S-1

Creation of a coordinated repository for GHG data "could facilitate the integration of multiple types of data at various spatial scales and make the information accessible to decision makers and users in ways that meet their needs," as visualized in Figure 3.[53] A coordinated repository could, among other things, provide a much-needed standardization function by encouraging (and, in the case of government-funded data, requiring) that submitters adopt "data formats and metadata to facilitate comparability and interpretability across scales."[54]

The White House recently released a paper that echoed the National Academies' call for "[a]n integrated U.S. GHG monitoring and information system" that would "take advantage of advanced measurement technologies and the growth of GHG observational data to provide enhanced spatial resolution of data products across the United States."[55] The System would "integrate Federal and non-Federal…data and reflect transparency in both data and methods" using both "bottom-up" and "top down" approaches collected in an "information repository" that follows the six pillars of good data management identified in the National Academies report.[56]

A large group of prominent climate scientists issued a recent report published by Indiana University that makes the same point. It emphasizes that GHG measurement and monitoring data should feed into an information network that enhances and expands the capacity of key stakeholders to research and analyze practice outcomes, particularly in nature-based applications like agriculture.[57]

The Time-Sensitive Opportunity to Establish an Agriculture-Centric GHG Data Management System

With this background in mind, it is clear that the USDA has a unique and time-sensitive opportunity to launch an agriculture-centric GHG data depository that prioritizes the collection and management of GHG activity-based data related to specific climate-smart practices.

The opportunity is unique because the USDA is on the cusp of financing extensive new GHG data gathering activities under the IRA, the Commodities Partnership program, and on-going conservation program investments.

Under the IRA, as discussed above, the USDA must demonstrate that the nearly $20 billion in new climate-smart spending will produce quantifiable increases in carbon uptake in soils and reduced methane and nitrous oxide emissions. Such a determination must be backed with new data; reliance on current models is not sufficient, as discussed above. The IRA also includes a parallel but separate mandate to spend $300 million "collect[ing] field-based data to assess the carbon sequestration and reduction in carbon dioxide, methane, and nitrous oxide emissions outcomes associated with [climate-smart conservation] activities."[58]

In addition to new GHG data generated under the IRA, a raft of new GHG data also will be generated under the $3.1 billion dollar Commodities Partnership program – a program that from the start has emphasized the importance of developing and demonstrating – through data collection and analytics – new and improved approaches for measuring and monitoring GHG emissions reductions and soil carbon increases.

Without an Agriculture GHG Data Management System, how will all of this important new GHG practice-based data – which is being counted on to support a burgeoning, market-driven climate-smart business – become available for review and synthesis?

In addition to new data, the USDA has been financing soil carbon data collection activities for decades. A new Agriculture GHG Data Management System could – and should – take in this large volume of soil carbon and other GHG-relevant data that has been generated for the USDA over many years – making additional, rich, deep datasets available for analysis on an anonymized basis. And, finally, creating a centralized and accessible database will counter the troubling trend of claiming confidentiality over GHG measurement and monitoring data.[59]

Setting Up an Agriculture GHG Data Management System

We recommend that the USDA seek out philanthropic support to work with it, the U.S. Digital Service, and the leadership of the White House GHG Measurement and Monitoring Interagency Working Group to structure and launch the Agriculture GHG Data Management System.

Regarding how such a System might be structured, at least four options should be reviewed, including establishment of: (1) a centralized data infrastructure operated by the USDA, (2) a centralized data infrastructure operated by a non-governmental intermediary, (3) a data linkage hub operated by a non-USDA agency in the federal government, or (4) a contractual model with relevant partners.[60]

Because the GHG Data Management System will need to accommodate both public and private GHG data, be scalable, and have reliable sources of funding and strong systems of accountability,[61] many experts recommend that such a system should be set up as a public/private collaborative. Partnering with well-respected businesses, NGOs, and quasi-governmental organizations such as the Farmers Business Network, the National Fish & Wildlife

Foundation, the Foundation for Food and Agricultural Research, and/or Data Commons, for example, could bring a variety of important technical data management skills and credibility to the table.

Given the urgency to move forward with this initiative, we recommend that the White House and the USDA reach out to potential philanthropic partners to evaluate options for where to host the Agriculture GHG Data Management System, how to administer it (including, potentially, through a quasi- or non-governmental entity in partnership with the federal government), how to ensure that data is anonymized to protect farmer privacy interests, and how to establish ground rules for data submission to maximize the data's interoperability.

There are several existing data management systems that should be reviewed for potential benchmarking purposes. Of particular relevance is the National Science Foundation's National Ecological Observatory Network (NEON), where data is collected from a single agency using a top-down approach.[62] In 2021 NEON partnered with the Environmental Data Initiative (EDI) to promote the accessibility and usability of their data for the use of environmental science research.[63]

In the international arena, the International Methane Emissions Observatory, developed by the United Nations Environment Programme (UNEP), is a potentially instructive model.[64] IMEO promotes methane reductions by interconnecting data, research, reporting and implementation and constructing a global public record of verified methane emission sources. IMEO is a useful system because it uses and compiles data from a wide range of sources, including direct measurement from scientific sources, remote sensing data, and national inventories. IMEO also uses aggregated data to identify gaps and determine where more research is needed to understand methane emissions. IMEO thus serves as a model for a data hub that incorporates data from multiple sources into an actionable dataset that can be used to direct research and policy decisions.

Based on these observations, we recommend that the USDA, in consultation with the U.S. Digital Service and the White House-led GHG Measurement and Monitoring Interagency Working Group and with the assistance of philanthropy:

> Establish an **Agriculture GHG Data Management System** that will collect and organize GHG measurement and monitoring data in accessible anonymized formats to facilitate public review, analysis, and benchmarking of agriculture measurement and monitoring protocols. The Agriculture GHG Data Management System will implement the goals of White House's "Federal Strategy to Advance an Integrated U.S. Greenhouse Gas Monitoring & Information System"[65] for the agricultural sector.
>
> (a) The USDA should work with the U.S. Digital Service, the White House-led GHG Measurement and Monitoring Working Group, and philanthropic partners to evaluate options for how to structure the Agriculture GHG Data Management System, how to administer it (including, potentially, through a quasi- or non-governmental entity in partnership with the federal government), how to ensure

that data is anonymized to protect farmer privacy interests, and how to establish ground rules for data submission to maximize the data's interoperability.

(b) **Funding**. To ensure that data generated through taxpayer-supported federal funding is made available to the scientific community and the public, we recommend that at least 1 percent of grant funding associated with GHG quantification efforts be allocated to support the public availability of anonymized farm practice data through the Agriculture GHG Data Management System.

VII. ENGAGING IN EXTENSIVE OUTREACH AND TECHNICAL ASSISTANCE TO ENCOURAGE EQUITABLE & BROAD-BASED ADOPTION OF CLIMATE-SMART PRACTICES

Establishing strong measuring and monitoring requirements and a complementary data system are necessary but not sufficient prerequisites to a successful climate-smart agriculture initiative. The nation's farmers and ranchers stand poised to be part of the climate solution, but the burden of knowledge acquisition, risk management and place-based implementation must be distributed throughout the broader network of agricultural professionals to ensure the climate-smart initiative moves forward with speed and scale. Simply put, the program's long-term success is equally dependent on supporting farmers and ranchers as they work to deploy climate-smart practices, with strong attention to equity throughout the process.

There is no one-size-fits-all approach to decreasing emissions and increasing sequestration: farmers need tailored recommendations for practices that are effective at delivering climate benefits, have neutral or positive impacts on productivity and are in alignment with their philosophies of farming. While sophisticated decision-support tools can narrow down the feasible options, person-to-person technical assistance (TA) is essential in increasing adoption of new technologies on the farm.

Expanding the capacity of the national cooperative extension service, Federally Recognized Tribes Extension Program (FRTEP), Sustainable Agriculture Research and Education program (SARE) and other trusted entities such as the National Association of Conservation Districts is one way to increase support for climate-smart agriculture adoption on a field-by-field basis.

Growing the USDA's TA workforce is also necessary and will contribute to the USDA's equity goals, ensuring that farmers of all sizes, backgrounds and types of agriculture have access to timely and relevant information from which to make production decisions aligned with climate goals. In the absence of widespread TA availability, farmers with greater resources will be primed to be early adopters while those with less capacity may miss time-limited opportunities to participate in the climate-smart initiative.

It also is imperative that the USDA consider how its treaty responsibilities to Tribal Nations factor into determinations of target audiences for the climate-smart initiative. Creating specific programs to engage Tribal governments and individual Native farmers and ranchers provides an opportunity to continue the work of addressing past inequities while coordinating efforts to ensure high quality climate-smart practices on federal trust land.

VIII. GEARING UP FOR SUCCESS

The Secretary of Agriculture and his team have demonstrated strong leadership in developing the blueprint for the Administration's climate-smart agriculture and forestry initiative and launching its implementation.

As discussed in this report, the Administration now has a major challenge and opportunity to build the strong and durable scientific, technical, and practical foundation that is needed for climate-smart agriculture to generate meaningful and sustainable financial rewards for farmers and ranchers.

This report lays out steps that will help the Administration to meet this goal. Getting from here to there, however, will require that the USDA – as the lead for the climate-smart agriculture and forestry initiative – bring a materially higher level of human and organizational resources to the effort. Today, the USDA simply does not have in-house expertise to meet the moment, nor is its balkanized institutional structure well-suited for the task that lies before it. Fortunately, the USDA does not have to build everything from scratch. There are federal agencies, NGOs, academic institutions, producers, and private companies that have valuable expertise in the issues that need to be tackled. The USDA can leverage that expertise to meet the time-sensitive nature of the challenge. Furthermore, the USDA can enhance its connections with equivalent research partners in Europe and globally to share data and coordinate remediation strategies.

To address both the challenges and opportunities presented by the Administration's ambitious climate-change agriculture initiative, we recommend that the USDA establish a strong implementation infrastructure needed for success. In particular, we recommend that the USDA:

> Establish an **Advisory Committee of outside experts** who will provide the Secretary of Agriculture with on-going scientific input regarding the formation and implementation of: Ag-Methane Reduction Initiative and Nitrous Oxide Demonstration Project; the National Soil Carbon Technology Review; the National Soil Carbon Monitoring Plan; the Climate-Smart Protocol Clearinghouse; and the Agriculture GHG Data Management System; and
>
> Create a high-level **USDA Climate-Smart Strike Team** in the Office of the Secretary that has overall responsibility to organize and execute on all aspects of the Secretary's climate-smart agriculture initiative.

Taking these steps will enable the USDA to bring the many USDA bureaus involved in this cross-cutting initiative under a unified, high-level command structure that reports directly to the Secretary. Actuating this action plan also will give the USDA command structure ready access to world-class experts who can guide the enterprise as it moves forward.

APPENDIX A

The COMET suite of products[66] is the primary GHG accounting system that the USDA relies on to estimate impacts across the three major GHGs (carbon, methane, nitrous oxide).[67] As part of the measurement and monitoring requirement for awardees of the Partnerships for Climate-Smart Commodities Program, funded projects are required to use COMET-Planner where applicable to tabulate commonly derived estimates of GHG emissions.[68] Externally, more than a dozen private companies have also developed carbon crediting procedures based on these USDA-funded models.

The widely used COMET model focuses primarily on three sources of GHG emissions: (1) soil-related emissions, as computed by the DAYCENT process-based model; (2) livestock-related emissions, estimated from the USDA Blue Book statistics;[69] and (3) energy-related emissions, using the stand-alone COMET-Energy tool.

Existing models like DAYCENT were built at a time when quantifying incremental accretions of carbon concentrations in soils or reduced methane and/or nitrous oxide emissions was not a mission-driving concern and when field testing options to measure and monitor carbon, methane and nitrous oxide fluxes were limited and expensive.

Evaluation of COMET's underlying methodology by the six pillars set forth in the National Academies report and the White House Federal Strategy document – (1) [data] usability and timeliness, (2) information transparency; (3) evaluation and validation; (4) completeness; (5) inclusivity; and (6) communication – show that COMET has significant shortcomings. Each pillar is discussed in turn.

Completeness Issues

Reliable baselines of GHG information have not been collected. Currently, COMET allows the user to establish a static baseline using historic land use and soil type data. These baselines are not accurate and cause the COMET model to predict benefits regardless of the practice inputs. As one respected science organization summarized: "One of the biggest challenges the NRCS faces is that quantifying GHG benefits means measuring the additional value of a practice change over the counterfactual (i.e. business-as-usual) scenario. This means that monitoring a project activity with 100% accuracy does not get us the correct answer. We need to compare the carbon sequestration or GHG emission in the project to what would have occurred in the absence of the implementation of the project."[70] Dynamic data-driven baselines that are representative are necessary for trust in emissions credits from private buyers.

Inadequate Coverage of Methane & Nitrous Oxide. "Land use–related [methane] and [nitrous oxide] cause more than half of the climate impacts from the land sector. However, only 2% of the credits issued for land-based projects from 1996 to 2021 aimed to reduce emissions of [methane], and practically none addressed [nitrous oxide]" (see Figure 4).[71] COMET similarly over-emphasizes soil carbon and under-emphasizes nitrous oxide and methane, the leading GHGs in agriculture. For nitrous oxide, this may be leading to net increases in emissions.[72] For

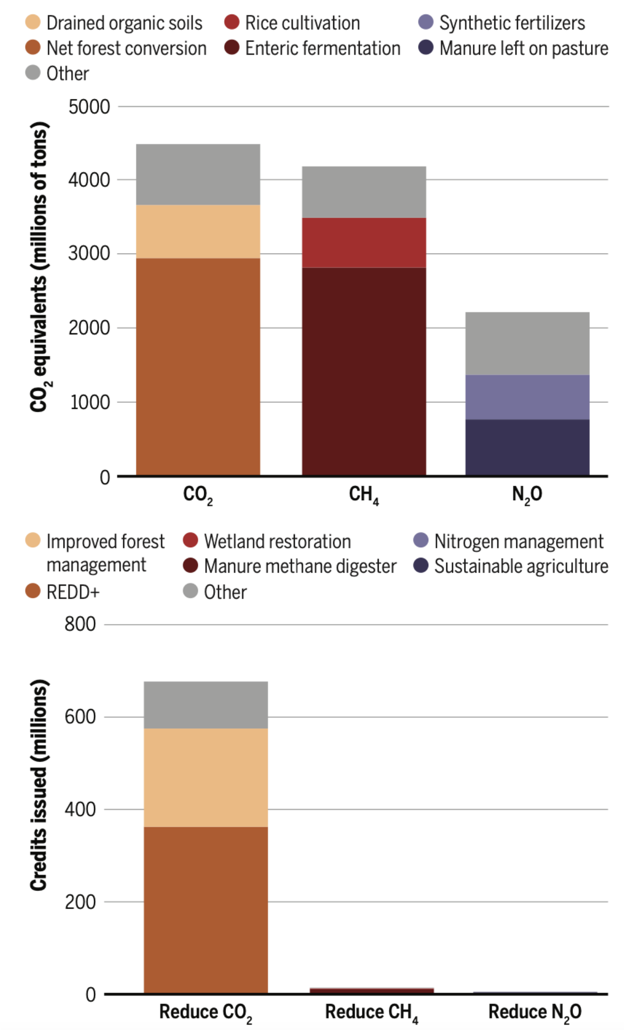

Figure 4: This chart illustrates that despite the significant amount of global methane and N2O emissions, only about 2% of credits are issued for reduction in methane and nitrous oxide emissions.

Source: Ruth DeFries et al., *Land Management can Contribute to Net Zero*, 376 Sci. 1163, 1164 fig. (2022).

methane, COMET fails to "accommodate a variety of herd types and management systems, cattle life cycle stages, and feed strategies,"[73] which limits its applicability for managing methane livestock emissions.

Evaluation and Validation Issues

There is insufficient evaluation of COMET's accuracy: In the largest validation study done on COMET, "[t]here [were] only about 100 locations with all the necessary data to calibrate a model. These locations only span a very limited range of agricultural practices and do not encompass all soil types or climates. This means that currently there are many blind spots across the United States where our models are not necessarily appropriate and uncertainty in model output is large."[74]

The results suggest that COMET is misestimating nitrous oxide emissions: Multiple evaluations of COMET indicate that it misestimates or underestimates nitrous oxide emissions.[75] Emerging evidence suggests that COMET systematically underestimates nitrous oxide emissions in agriculture.[76] These accuracy issues are problematic.

Information Transparency and Communication Issues

Evaluations with direct-measurement data are not standardized or well documented
Although the methods underlying COMET are laid out in the Blue Book, current evaluations of COMET's accuracy are not standardized or available in a centralized location. Instead, they are scattered across one-off publications. This is important because these validations are used to calibrate DAYCENT, the model underlying COMET. As a result, there is no transparency regarding how the model that farmers and ranchers are using to estimate emissions was calibrated, nor whether current evaluations are confirming model-projected outcomes.

COMET fails to make sources of uncertainty clear
Though DAYCENT provides uncertainty estimates, the underlying DAYCENT model provides no clarity regarding which modeling decisions are causing the largest sources of uncertainty.

Usability Issues

It is too difficult for non-technical users to estimate emissions accurately. Stakeholders involved in implementing monitoring for programs to reduce emissions in agriculture have informed us that it requires 5-10 years of experience in environmental modeling to use COMET with the correct assumptions, inputs, and settings to reliably estimate emissions. There is concern that inaccurate estimation of emissions using COMET is widespread because small changes in inputs can lead to widely varying estimates of emissions reductions that do not represent what is really happening in the field.

Inclusivity and Timeliness Issues

Inadequate coverage of emerging climate-smart practices
New climate-smart practices that did not exist when COMET was developed but have significant potential to reduce emissions in agriculture such as the application of biochar on soils or the use of feed additives for livestock are not covered by COMET.

As a final note, commentators have emphasized that when presented with a challenging and dynamic fact pattern, it is important not to rely heavily on a limited set of data or one or two models as the basis for extrapolation. That is why in the climate modeling context, researchers routinely analyze multiple models simultaneously to avoid over-reliance on a single model that may include serious calibration or analytical flaws. Unfortunately, with COMET dominating GHG analysis of agricultural practice outputs, the sector is over-relying on a single model backed by a limited dataset.

APPENDIX B

As noted in Section III, enteric fermentation in ruminants, manure management, and flooded rice are the primary drivers of agricultural methane emissions. It will be crucial to set clear guidelines for measurement across systems, incorporating new data collected from U.S. rice systems and emergent techniques being used by innovative companies to estimate enteric methane production and manure operations in livestock systems. Developers of emerging models such as RuFaS have begun some investments into experimental data evaluation, but efforts to quantify methane emissions are limited by the paucity of existing datasets.[77] These models also involve pilot testing on certain practices as a calibration framework. Ultimately, the strategies devised to build new models suggests that new modeling methodologies can fill important gaps in how we currently estimate GHG emissions. Strategic separation of RuFaS's whole-farm modeling into separate modules provides a useful framework under which to consider the modeling environment as a whole, where complicated relationships between inputs and outputs may be best served in smaller, verifiable modules.

We have established that rice production accounts for a small fraction of overall US agricultural methane emissions, and the Blue Book relies primarily on IPCC Tier 1 and Tier 2 approaches to model emissions from these fields. While there is certainly opportunity to improve these models with new data and vetted MMRV approaches, the focus of this section will be on livestock systems.

Given the scale and diffuse nature of the source, measurement and monitoring approaches for enteric fermentation and manure management are receiving significant attention from technology innovators and private investors. It will be important to validate and categorize these emergent approaches so coherent guidance can be developed. Some prominent approaches are outlined below.

Animal Sampling [Enteric]

- **Respiration Chambers:** These are enclosed chambers in which individual animals are placed to measure their methane emissions for an extended period, often 24 hours. The animal's feed intake and metabolism are closely monitored during the measurement period to provide accurate measurements.
- **GreenFeed® System:** An evolution of the respiration chamber, this is a patented and automated open air feeding system that captures and analyzes an animal's breath to measure its methane emissions. GreenFeed is a technology used to measure methane emissions from individual animals. The animal approaches the system, and a measurement unit collects and analyzes its breath. This approach is considered the gold standard by operations seeking to balance cost and accuracy but is protected IP.
- **Tracer Gas:** This involves introducing a known amount of a tracer gas such as sulfur hexafluoride or methane into the animal's diet. The tracer gas is then detected and measured in the animal's breath to determine the rate of methane emissions.
- **Laser Methane Detection:** These are handheld or stationary devices that use lasers to measure the concentration of methane in the air surrounding an animal. The sensors are placed in close proximity to the animal, and the measurements are taken in real-time.

Remote Sensing [Enteric, Manure]

- **Satellite Based:** Modeled on infrared remote sensing approaches that are also used to detect methane hotspots near oil wells, refineries, and other fossil fuel infrastructure. The main disadvantage of this approach is its inability to accurately measure diffuse methane emissions in grazing systems. However, existing data sources such as MethaneSAT can be tapped to understand methane emissions from concentrated animal feeding operations, as their concentrated nature creates ‘hotspots’ similar to fossil fuel infrastructure.
- **Drone Based:** Drones are fitted with sensors that can be flown over grazing operations to measure methane concentrations in more diffuse production systems such as pasture or open grazing. Additionally, drone-mounted sensors can be employed to measure methane hotspots in more heterogeneous manure management systems where a multitude of sensors might otherwise be needed to get accurate measurements. This approach is more accurate than satellite-based remote sensing approaches but is costly.

APPENDIX C

Sound methodologies for measuring and monitoring soil carbon sequestration and nitrous oxide emissions are key–especially because of the relation between the two GHGs in response to agricultural practices. Soil carbon and nitrogen cycles are tightly coupled; for instance, fresh carbon inputs to the soil may affect soil pH and in turn affect the magnitude of nitrous oxide emissions.[78] So management practices designed to increase soil carbon stocks may also increase nitrous oxide emissions.[79] Without robust quantification of changes in both soil carbon and nitrous oxide emissions, practitioners run the risk of having any benefits from soil carbon sequestration being overestimated or offset from resultant increases in nitrous oxide emissions.[80]

Soil Carbon Methodologies

CEMA 218 requires that GHG reduction and carbon sequestration be quantified using COMET-Farm.[81] Aside from COMET-Farm's underlying flaws (discussed above in Section II and Appendix A), our conversations with COMET-Farm users and the literature suggest that using it appropriately requires years of familiarity.[82] Even with clear guidance documentation, a combination of technical and domain expertise is needed to avoid inadvertently misapplying or misinterpreting the outputs.[83] This context is not reflected in the existing Qualified Individual Requirements in CEMA 218, which merely require the person conducting the protocol to have completed one previous COMET-Farm assessment for the type of practice to be evaluated (with no guarantee that assessment was done properly) or to have completed a presentation and video series on COMET-Farm (which is no substitute for crucial domain expertise).

Additional detail is lacking in the steps for actual monitoring. CEMA 221 has a blanket recommendation for soil sampling that does not account for differences in project areas requiring differences in frequency and quantity of sampling. It recommends a fixed number of strata and samples.[84] But given the heterogeneity in project areas and the lack of specifications of project scale in this protocol, specifying a fixed number of strata and sampling efforts agnostic to the actual landscape and project "could result in woefully inadequate coverage" to detect meaningful changes in soil carbon with confidence.[85] Given the trade-off between intensive sampling practices and adoption,[86] the USDA need not adopt the most exhaustive sampling requirements, as encouraging producers to adopt novel practices is a priority. But at minimum, the protocol should be revised to guide operators on choosing and conducting a sampling strategy given their particular project area. CEMA 221 lacks basic guidance on these fundamental sampling design strategies that other existing protocols provide.[87]

The existing methodologies also are not conducive to comparison and validation of measurements. Neither CEMA 218 nor CEMA 221 asks the operator to specify a particular project scale, time scale or acceptable uncertainty level, which makes transparent tracking and comparison difficult. Nor do the existing protocols indicate if and how COMET-Farm estimates and direct soil samples should be compared with other sampling data (e.g., data from remote sensing) or estimates from other models. This misses out on technological developments for measuring soil carbon more efficiently.

Lastly, the methodologies do not reference key issues addressed by other protocols that are relevant to environmental justice and accurate accounting of GHG mitigation to prevent greenwashing. Safeguards like landowner protections and data privacy guidelines in other protocols center farmers, local communities, or landowners most impacted by the agricultural sector.[88] Other protocols also account for additionality, leakage, and durability in their estimates of GHG mitigation to ensure any downstream credits actually reflect environmental benefits.[89] The Omnibus Budget Act indicates a need for methods to address these issues, yet they are notably missing from the NRCS methodologies.[90]

Nitrous Oxide Methodologies

Changes in nitrous oxide emissions are particularly difficult to measure.[91] Nitrous oxide is mostly emitted in highly variable “hot spots” and “hot moments,” necessitating measurements at high spatial and temporal granularity to accurately capture changes in nitrous oxide emissions.[92] Indirect nitrous oxide emissions, which may occur when nitrate leaching leads to nitrous oxide emissions in another location, are even more difficult to estimate given uncertainty in both the amount of nitrogen lost and the amount of nitrogen converted to nitrous oxide.[93] "Practice as proxy" approaches are also flawed, as "the impact of a practice on nitrogen losses is highly variable over space and time" and dependent on many variables.[94] A practice that reduces nitrogen losses in one year may increase them in the next, just as a practice that reduces nitrogen for one field may increase them in the adjacent field.

APPENDIX D

The USDA's Partnerships for Climate-Smart Commodities initiative hopes to demonstrate that consumers will pay premium prices for farm-produced commodities that were produced in a "climate-smart" manner. The program is premised on the supposition that a climate-smart label will command consumer credibility and appeal to buyers who are concerned about climate change and sustainability, more generally -— much like the "organic" label currently in use in grocery stores.

This is an appealing proposition. Having the market reward farmers for engaging in climate-smart practices would provide direct and more sustainable payments than relying on federal subsidies or unregulated voluntary carbon markets.

In order for this plan to be successful, a "climate-smart" or "sustainably produced" label must be backed by solid evidence that specified farm practices are, in fact, producing meaningful climate and other sustainability benefits – the primary subject taken up in this report.

As the governmental authority with primary responsibility for the U.S. agricultural sector, the USDA will need to play a central role in developing and applying the criteria that producers will have to meet to earn a "climate-smart" label. It is beyond the scope of this paper to recommend the criteria that the USDA might identify as prerequisites for affixing a "climate-smart" or "sustainably produced" label on agricultural goods in the marketplace. In that regard, and as noted above, it is noteworthy that Congress already has established that as a condition of disbursing nearly $20 billion in new funding under the Inflation Reduction Act, the Secretary of Agriculture must make a "determination" that agricultural conservation programs are producing climate benefits such as practices that "directly improve soil carbon, reduce nitrogen losses, or reduce, capture, avoid, or sequester carbon dioxide, methane, or nitrous oxide emissions, associated with agricultural production. Congress also set aside substantial funds to help the Secretary develop measurement and monitoring protocols and collect related datasets that could provide foundational support to identifying and validating farm practices that should earn a climate-smart label.

Hence, implementing the recommendations laid out in this report should put the Secretary of Agriculture in a solid position to make the IRA-required determination and potentially justify a "climate-smart" label. By launching an intensive GHG data collection and analysis effort and making anonymized results available to the public in a data repository, the USDA should have the wherewithal to confirm what will be obvious to all – namely, that deploying specific farming practices will generate meaningful climate and other benefits that merit recognition and financial rewards.

The credibility to draw such conclusions will be a key to ensuring that IRA funds are deployed appropriately and opening up a new market for climate-smart commodities. Studies note that while nearly two-thirds of Americans are willing to pay more for climate-smart products, nearly three-quarters do not know how to identify such products.[95] This confusion is understandable as there are a myriad of labels and carbon credit claims in agriculture that are not backed up by reliable and replicable data.[96] Credits derived from different protocols also lead consumers of those credits to focus on getting the greatest number of credits for the least investment, which may push the protocols with the best standards out of the market.[97]

Development of the USDA “organics” label provides helpful context that can guide the USDA’s journey toward consideration of a marketing label for “climate-smart” or “sustainably produced” agricultural commodities. By way of background, a large number of private parties in the 1980s labeled their products as “organic” in the absence of any consensus standards for such a label – similar to climate-related claims that some food producers are beginning to claim.[98]

Congress stepped in and enacted the Organic Foods Production Act of 1990. The Act set generalized standards for how a product must be produced to earn an organic label (for example, without the use of pesticides), required the Secretary of Agriculture to establish a list of allowed and prohibited substances, and created the National Organic Standards Board.[99] Much as proponents of a climate-smart label hope, creating a uniform organic label led to a large increase in the number of organic farms, the acres dedicated to organic production, and the sales of organic products, driven by consumer’s willingness to pay more.[100]

Under the law, the National Organic Standards Board is advised by a Federal Advisory Committee Act made up of volunteers appointed by the Secretary of Agriculture who make recommendations on issues related to organic products. Current organic labeling standards and certification requirements were updated in 2023 by the USDA based on recommendations from the National Organic Standards Board, industry requests, and specific mandates included in the 2018 Farm Bill.[101]

In addition to certifying organically produced agricultural products, the USDA has additional certifications besides organics, such as the USDA grade shields for beef.[102] However, how the USDA certifies an “organic” product is more relevant to a potential “climate-smart” label than how it classifies meat grades because both focus on how the product is produced rather than its inherent grade.

In order to have a meaningful “climate-smart” label on agriculture, the USDA will need to create a system that defines and links performance in implementing climate-smart production practices to final products in an evidence-based and transparent way. This will not be an easy process. The current state of climate-smart agriculture is at a very similar stage as organic agriculture was before organic labeling standards were set, with some food labels already making “low carbon”-type claims in the absence of standards or widely accepted norms.

Endnotes

1. *See generally* Bronson W. Griscom et al., *Natural Climate Solutions*, 114 PROC. NAT'L ACAD. SCIS. 11645, 11646, (2017) for a detailed scientific study on the emissions reduction potential of different climate-smart practices.
2. *See* American Society of Agronomy et al., Comment Letter on Request for Public Input About Implementation of the Inflation Reduction Act Funding (Dec. 21, 2022), https://www.regulations.gov/comment/NRCS-2022-0015-0451 (stating that agroforestry has the potential to "sequester 2.2-6.4 billion metric tons of CO2 per year while simultaneously delivering myriad benefits to soil, air, water, and wildlife."); EAGLE ET AL., AMBITIOUS CLIMATE MITIGATION PATHWAYS FOR U.S. AGRICULTURE AND FORESTRY: VISION FOR 2030 6 (Environmental Defense Fund and ICF, 2022) (highlighting agroforestry as one of the largest opportunities for emissions reduction or removal). We will address agroforestry's substantial opportunity for carbon sequestration in a follow-up report that will focus on the forestry side of the Administration's climate-smart agriculture and forestry initiative.
3. *See* U.S. DEP'T OF AGRIC., https://www.usda.gov/climate-solutions/climate-smart-commodities (last visited Mar. 12, 2023). In connection with the Partnerships for Climate-Smart Commodities program, the USDA has identified 15 climate-smart practices that "reduce greenhouse gas emissions or sequester carbon." The list includes: "Cover crops; Low-till or no-till; Nutrient management; Enhanced efficiency fertilizers; Manure management; Feed management to reduce enteric emissions; Buffers, wetland and grassland management, and tree planting on working lands; Agroforestry and afforestation on working lands; Afforestation/reforestation and sustainable forest management; Planting for high carbon sequestration rate; Maintaining and improving forest soil quality; Increase on-site carbon storage through forest stand management; Alternate wetting and drying on rice fields; Climate-smart pasture practices, such as prescribed grazing or legume interseeding; and Soil amendments, like biochar."
4. KIM NOVICK ET AL., THE SCIENCE NEEDED FOR ROBUST, SCALABLE, AND CREDIBLE NATURE-BASED CLIMATE SOLUTIONS IN THE UNITED STATES: FULL REPORT 9 (IND. UNIV. O'NEILL SCH. OF PUB. AND ENV'T AFFAIRS, 2022) ("More data is needed from a much more representative set of ecosystems to quantify where these practices succeed as climate solutions, alone and in combination.").
5. Inflation Reduction Act of 2022 § 21001(a)(1)(B)(iii), 136 Stat. 1818.
6. Inflation Reduction Act § 21002(a)(2).
7. Inflation Reduction Act § 21001(a)(1)(B)(ii).
8. Exec. Order No. 14008, 86 Fed. Reg. 7619 (February 1, 2021).
9. U.S. DEP'T OF AGRIC., https://www.usda.gov/climate-solutions/climate-smart-commodities (last visited Mar. 12, 2023).
10. *Id.* The concept is that agricultural commodities that carry a "climate-smart" or "sustainably produced" label would command higher prices from consumers, thereby enabling market-based rewards to flow back to farmer-producers. It is beyond the scope of this report to define a certification process for such a labeling scheme. However, *see* Appendix D for a short review of potentially relevant considerations.
11. GREENHOUSE GAS MONITORING & MEASUREMENT INTERAGENCY WORKING GRP., THE FED. STRATEGY TO ADVANCE AN INTEGRATED U.S. GREENHOUSE GAS MONITORING & INFO. SYS. 5 (2023), https://go.nasa.gov/USGGMIDraftFederalStrategy.
12. It is beyond the scope of this paper to delve into all of the current climate-smart practices identified by USDA. For a full reference list of climate-smart practices, *see* U.S. DEP'T OF AGRIC. NAT. RES. CONSERVATION SERV., NRCS CLIMATE-SMART MITIGATION ACTIVITIES, https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/climate/climate-smart-mitigation-activities (last visited Mar. 12, 2023).
13. *See* U.S. DEP'T OF AGRIC. NAT. RES. CONSERVATION SERV., USDA-NRCS-COMM-22-NOFO0001139, PARTNERSHIPS FOR CLIMATE-SMART COMMODITIES – BUILDING MARKETS AND INVESTING IN AMERICA'S CLIMATE-SMART FARMERS, RANCHERS & FOREST OWNERS TO STRENGTHEN U.S. RURAL AND AGRICULTURAL COMMUNITIES (2022). To illustrate, the USDA is requiring that all projects funded under the Commodities Partnership program use COMET-Planner as a common method for reporting results.
14. For example, Soil Metrics (now owned by Indigo) relies primarily on COMET, Regrow on DNDC, and CIBO Technologies on SALUS.
15. *See* Eric A. Davidson, *Is the Transactional Carbon Credit Tail Wagging the Virtuous Soil Organic Matter Dog?*, 161 BIOGEOCHEMISTRY 1, 4 (2022) (explaining that "even a modest gain in soil organic matter" can generate "[increased] resilience to climate change").
16. *See* EAGLE ET AL., *supra* note 2, at 11; Ula Chrobak, *Agriculture Emits a 'Forgotten Greenhouse Gas.' Scientists are Looking for Solutions in the Soil*, PBS NEWSHOUR (May 26, 2021, 12:11 PM), https://www.pbs.org/newshour/science/agriculture-emits-a-forgotten-greenhouse-gas-scientists-are-looking-for-

solutions-in-the-soil; Davidson, *supra* note 15, at 5 (pointing out that very few credits for methane or nitrous oxide reductions have been issued in voluntary carbon markets); *supra* Figure 1.
17. THE WHITE HOUSE, DELIVERING ON THE U.S. METHANE EMISSIONS REDUCTION ACTION PLAN, 1 (2022), https://www.whitehouse.gov/wp-content/uploads/2022/11/US-Methane-Emissions-Reduction-Action-Plan-Update.pdf; *see also* GLOBAL METHANE PLEDGE, https://www.globalmethanepledge.org (last visited Mar. 16, 2023) (explaining the Global Methane Pledge, which the US cofounded to "catalyze global action and strengthen support for existing international methane emission reduction initiatives").
18. *See supra* Figure 1.
19. THE WHITE HOUSE OFF. OF DOMESTIC CLIMATE POL'Y, U.S. METHANE EMISSIONS REDUCTION ACTION PLAN, 11 (2021), https://www.whitehouse.gov/wp-content/uploads/2021/11/US-Methane-Emissions-Reduction-Action-Plan-1.pdf.
20. MARLEN EVE ET AL., QUANTIFYING GREENHOUSE GAS FLUXES IN AGRICULTURE AND FORESTRY: METHODS FOR ENTITY-SCALE INVENTORY 5-14 (Marlen Eve et al. eds., 2014), http://usda.gov/oce/climate_change/estimation.htm [hereinafter Blue Book].
21. Tayler L. Hansen et al., *The Ruminant Farm Systems Animal Module: A Biophysical Description of Animal Management*, 11 ANIMALS 1373, 1373 (2021); *see* Appendix B for more details on RuFaS.
22. Blue Book, *supra* note 20, at 5-34.
23. *See id.* at 5-52. Because they are largely new, these emerging technologies and methodologies did not significantly (or, in some cases, as all) inform IPCC models, which were originally published in 2006, or the Blue Book, which was published in 2015. Indeed, the IPCC Tier 2 method simply "does not allow for estimating changes in enteric emissions related to changes in diet or management."
24. Inflation Reduction Act of 2022 § 21001(a)(1)(B)(ii), 136 Stat. 1818.
25. *Vilsack Highlights USDA's Climate Initiatives and Investments at COP27*, U.S. DEP'T OF AGRIC. (Nov. 12, 2022), https://www.usda.gov/media/press-releases/2022/11/12/vilsack-highlights-usdas-climate-initiatives-and-investments-cop27; *see also* PATHWAYS TO DAIRY NET ZERO, https://pathwaystodairynetzero.org/ (last visited Mar. 17, 2023).
26. Blue Book, *supra* note 20, at 3-58.
27. Environmental Defense Fund, *N-Visible*, ENV'T DEF. FUND, 2 (2020), https://www.edf.org/sites/default/files/documents/N-Visible-N-balance-framework-implementation-guide.pdf.
28. *Id.*
29. *See* Appendix C for more detail on the measurement and monitoring challenges for nitrous oxide emissions.
30. *See* Eileen L. McLellan et al., *The Nitrogen Balancing Act: Tracking the Environmental Performance of Food Production*, 68 BIOSCIENCE 194, 196 (2018); Tai M. Maaz et al., *Meta-analysis of Yield and Nitrous Oxide Outcomes for Nitrogen Management in Agriculture*, 27 GLOB. CHANGE BIOLOGY 2343, 2348-49 (2021).
31. *See* Eric D. Roy et al., *Hot Spots of Opportunity for Improved Cropland Nitrogen Management Across the United States*, 16 ENV'T RSCH. LETTERS, at 10 (2021); Kristell Hergoualc'h et al., *Improved Accuracy and Reduced Uncertainty in Greenhouse Gas Inventories by Refining the IPCC Emission Factor for Direct N2O Emissions from Nitrogen Inputs to Managed Soils*, 27 GLOB. CHANGE BIOLOGY 6536, 6547-48 (2021).
32. American Geophysical Union, *How Can We Quantify and Reduce Agricultural N2O Emissions at Scale?*, YOUTUBE (Jul. 27, 2022), https://youtu.be/v8X8cXnnb1o?t=1204.
33. *Id.*
34. EMILY E. OLDFIELD ET AL., AGRICULTURAL SOIL CARBON CREDITS: MAKING SENSE OF PROTOCOLS FOR CARBON SEQUESTRATION AND NET GREENHOUSE GAS REMOVALS 13 (Environmental Defense Fund, 2021).
35. *See id.* at 16-17; NOVICK ET AL., *supra* note 4, at 11 (explaining that it can take years to detect changes in carbon pools because they are quite large).
36. Environmental Defense Fund et al., Joint Comment in Response to Request for Public Input About Implementation of the Inflation Reduction Act Funding, (Dec. 21, 2022), https://www.regulations.gov/comment/NRCS-2022-0015-0399.
37. *Id.*
38. OLDFIELD ET AL., *supra* note 34, at 17.
39. *Id.*; *See also* YARD STICK, https://www.useyardstick.com/ (last visited Mar. 15, 2023).
40. OLDFIELD ET AL., *supra* note 34, at 18.
41. David J. Hayes et al., *Stanford Climate-Smart Agriculture Webinar*, STANFORD L. SCH. (Mar. 8, 2023), https://stanford.zoom.us/rec/share/04i7pWqyadrvR6JLjBli7Sr55tcoaLlAXZl4r8kar42QnyJIF-n60AxFrCAv3KC1.lW2CJaJbWmBgsz5g.

42. *See* NOVICK ET AL., *supra* note 4, at 17 ("Many of the approaches and protocols being used to scope and evaluate carbon offsets lack transparency and cannot be externally examined because data and methods are not open source").
43. Emily E. Oldfield et al., *Crediting Agricultural Soil Carbon Sequestration*, 375 SCI. 1222, 1223 (2022) ("Under a regionally consistent framework, the regional unit could be a biophysically defined agroecological zone that has similar soils, climate, and agricultural potential or constraints (for example, the US Department of Agriculture's Major Land Resource Areas)...Standardization across regions would provide consistency, and yet incorporate parameters specific to each region as needed.").
44. Consolidated Appropriations Act of 2023, 136 Stat 4459, Div. HH, Tit. I, § 201(c) (2022).
45. NAT'L ACADS. OF SCIS., ENG'G, AND MED., GREENHOUSE GAS EMISSIONS INFORMATION FOR DECISION MAKING: A FRAMEWORK GOING FORWARD 50 (The Nat'l Acads. Press, 2022) [hereinafter NASEM Report].
46. *Id.*
47. *Id.* at 51.
48. *See, e.g.*, Keith Paustian et al., *Quantifying Carbon for Agricultural Soil Management: From the Current Status Toward a Global Soil Information System*, 10 Carbon Mgmt. 567, 581 (2019) ("While much of the data and many of the tools, technologies and collaborations needed already exist, the information is often fragmented and data availability is often limited. More coordination, greater transparency, and easier accessibility to the tools and data, among and between field scientists, remote sensing specialists, modelers and land managers, is needed.").
49. GHG data can serve a variety of use cases including (1) rolling up activity-based data into the EPA National GHG Inventory – the official tracking mechanism for meeting national and international climate change commitments; (2) validating payments for activity-based GHG removals or emission reductions to earn government incentive payments or market-based compensation; and (3) assisting all interested parties in identifying and potentially prioritizing activities that generate significant GHG removals or emission reductions.
50. NASEM Report, *supra* note 45, at 1.
51. *Id.* at 3-4.
52. *Id.* at 4.
53. *Id.* at 6 (suggesting that the federal government "bring data and methods into the public domain with standards on transparency and open principles (e.g., FAIR data principles [findable, accessible, interoperable, and reusable])."); *see supra* Figure 3.
54. NASEM Report, *supra* note 45, at 6.
55. GREENHOUSE GAS MONITORING & MEASUREMENT INTERAGENCY WORKING GRP., *supra* note 11, at 2.
56. *Id.* at 3, 7.
57. *See* NOVICK ET AL., *supra* note 4, at 24.
58. Inflation Reduction Act of 2022 § 21002(a)(2), 136 Stat. 1818.
59. *See, e.g.*, THE AGREE INITIATIVE ET AL., MODERNIZING AGRICULTURE DATA INFRASTRUCTURE TO IMPROVE ECONOMIC AND ECOLOGICAL OUTCOMES 5 (2022) ("Private companies have already proven the value of capturing and utilizing agricultural data, but the collection, integration, and use of data by the USDA has not kept pace").
60. *Id.* at 3.
61. *See id.* at 9-10.
62. *See Spatial and Temporal Design*, NATIONAL ECOLOGICAL OBSERVATORY NETWORK, https://www.neonscience.org/about/overview/design (last visited Mar. 16, 2023).
63. *NEON Program Enters Collaboration with Environmental Data Initiative*, OBSERVATORY BLOG (Aug. 4, 2021), https://www.neonscience.org/impact/observatory-blog/neon-program-enters-collaboration-environmental-data-initiative; *see also* ENVIRONMENTAL DATA INITIATIVE, https://edirepository.org/about/about-edi (last visited Mar. 16, 2023) ("The Environmental Data Initiative (EDI) provides key services and technical expertise to the scientific community that ensure environmental and ecological data are well curated and accessible for discovery and re-use well into the future...This material is... [funded] by the National Sciences Foundation.").
64. *See About IMEO*, UNITED NATIONS ENVIRONMENT PROGRAMME, https://www.unep.org/explore-topics/energy/what-we-do/methane/about-imeo (last visited Mar. 16, 2023).
65. GREENHOUSE GAS MONITORING & MEASUREMENT INTERAGENCY WORKING GRP., *supra* note 11.
66. COMET-FARM, https://comet-farm.com/ (last visited Mar. 16, 2023); COMET-PLANNER, http://comet-planner.com/ (last visited Mar., 16 2023).
67. The USDA also has financed the development of two other important models that are being used to estimate GHG removals and emissions from agricultural practices: DNDC and SALUS.
68. U.S. DEP'T OF AGRIC., *Partnerships for Climate-Smart Commodities FAQs*, U.S. DEP'T OF AGRIC., https://www.usda.gov/climate-solutions/climate-smart-commodities/faqs.

69. *See* Blue Book, *supra* note 20, at 5-30, 5-31.
70. Woodwell Climate Research Center, Request for Public Input About Implementation of the Inflation Reduction Act Funding, (Dec. 21, 2022), https://www.regulations.gov/comment/NRCS-2022-0015-0318.
71. Ruth DeFries et al., *Land Management can Contribute to Net Zero*, 376 SCI. 1163, 1164 (2022).
72. *See* Bertrand Guenet et al., *Can N2O Emissions Offset the Benefits from Soil Organic Carbon Storage?*, 27 GLOB. CHANGE BIOLOGY 237, 237 (2020) ("[A]gricultural soils are also an important source of nitrous oxide...and increasing SOC may influence N2O emissions, likely causing an increase in many cases, thus tending to offset the climate change benefit from increased SOC storage.").
73. Environmental Defense Fund et al., *supra* note 36.
74. Woodwell Climate Research Center, *supra* note 70.
75. *E.g.*, Stephen J. Del Grosso et al., *DAYCENT Model Analysis of Past and Contemporary Soil N2O and Net Greenhouse Gas Flux for Major Crops in the USA*, 83 SOIL AND TILLAGE RESEARCH 9, 14 (2005); Richard K. Gaillard et al., *Underestimation of N2O Emissions in a Comparison of the DayCent, DNDC, and EPIC Models*, 28 ECOLOGICAL APPLICATIONS 694, 701 (2018).
76. *See, e.g.*, Maximilian Eckl et al., *Quantifying Nitrous Oxide Emissions in the U.S. Midwest: A Top-Down Study Using High Resolution Airborne In-Situ Observations*, 48 GEOPHYSICAL RSCH. LETTERS, Mar. 2021, at 1.
77. *See* Innovation for Impact Fund, *2021: RuFaS (Ruminant Farm Systems) Dairy Model (IIF Momentum Funding*), CORNELL ATKINSON CTR. FOR SUSTAINABILITY, https://www.atkinson.cornell.edu/award/rufas-ruminant-farm-systems-dairy-model-iif-momentum-funding/ (last visited Mar. 16, 2023); Kristan Reed et al., *RuFaS Evaluation: An Iterative Approach*, http://box5318.temp.domains/~rufasorg/wp-content/uploads/2020/12/RuFaS_Evaluation-1.pdf (last visited Mar. 16, 2023).
78. Guenet et al., *supra* note 72, at 241.
79. *Id.*
80. *Id.* at 238; Emanuele Lugato et al., *Mitigation Potential of Soil Carbon Management Overestimated by Neglecting N2O Emissions*, 8 NATURE CLIMATE CHANGE 219, 219, 222 (2018).
81. Natural Resources Conservation Service, *Carbon Sequestration and Greenhouse Gas Mitigation Assessment: CEMA 218*, NAT. RES. CONSERVATION SERV., 1 (2022), https://www.nrcs.usda.gov/sites/default/files/2022-10/FY23_CEMA%20218_Carbon%20Sequestration%20and%20Greenhouse%20Gas%20Mitigation%20Assessment.pdf.
82. *See, e.g.*, CHRISTOPHER BONASIA ET AL., WHOLE FARM NET ZERO: APPROACHES TO QUANTIFICATION OF CLIMATE REGULATION ECOSYSTEM SERVICES AT THE WHOLE FARM SCALE 33 (The Univ. of Vt., 2022), https://agriculture.vermont.gov/sites/agriculture/files/documents/Water_Quality/PES/Whole%20farm%20net%20zero_VTPES%20Task%207.pdf ("There are many users utilizing the tool and this level of use requires more hours of expert involvement and more cloud storage space which adds to the overall cost of supporting COMET-Farm."); MICHELLE PEREZ ET AL., A Guide to Water Qualify, Climate, Social, and Economic Outcomes Estimation Tools: Quantifying Outcomes to Accelerate Farm Conservation Practice Adoption 50 (Am. Farmland Tr., 2020), https://farmlandinfo.org/wp-content/uploads/sites/2/2020/12/AFT_Outcomes_Tools_Web_4_21_21.pdf ("[I]t can be difficult to determine what information to enter when project farmers do not maintain such long records [of historical management data] or did not manage the field the entire time."); CAL. DEP'T OF FOOD AND AGRIC., FARMER AND RANCHER-LED CLIMATE CHANGE SOLUTIONS 15 (Cal. Dep't of Food and Agric., 2021), https://www.cdfa.ca.gov/oefi/climate/docs/cdfa_farmer_and_rancher-led_climate_solutions_meetings_summary.pdf ("Be cautious in recommending Carbon Management & Emissions Tool (COMET) Farm, or provide technical support to users. The interface is incredibly complex and time-prohibitive. The data outputs can be informative, but it is challenging to understand exactly how changes in GHG emissions relate to specific changes in agricultural management practices.").
83. OLDFIELD ET AL., *supra* note 34, at 19.
84. Natural Resources Conservation Service, *Soil Organic Carbon Stock Monitoring: CEMA 221*, NAT. RES. CONSERVATION SERV., 2-4 (2022), https://www.nrcs.usda.gov/sites/default/files/2022-10/FY23_CEMA%20221_Soil%20Organic%20Carbon%20Stock%20Monitoring.pdf.
85. OLDFIELD ET AL., *supra* note 34, at 16.
86. *Id.* at 30 ("[P]rotocols such as Verra's Soil Carbon Quantification Methodology (VM0021) have not seen any adoption since its publication in 2012. The methodology relies on Verra's Estimation of Stocks in the Soil Carbon Pool (VMD0021), which has extremely intensive sampling requirements that present a significant barrier to adoption.").
87. Jane Zelikova et al., *A Buyer's Guide to Soil Carbon Offsets*, CARBONPLAN (Jul. 15, 2021), https://carbonplan.org/research/soil-protocols-explainer. The CarbonPlan review highlights Verra Soil and B

Carbon, which reference or use VMD0021, as protocols with robust sampling requirements. The FAO protocol, which is cited in CEMA 2021 but not fully adopted, is referred to as having one of the most rigorous sampling requirements for their quantification requirements. These protocols provide significantly more guidance and detail with respect to stratification, pre-sampling, soil depth, frequency of sampling, and remodeling.

88. *Id.*

89. *Id.*; OLDFIELD ET AL., *supra* note 34, at 22, 34-35.

90. Consolidated Appropriations Act of 2023, 136 Stat 4459, Div. HH, Tit. I, § 201(c) (2022) (requiring that the Secretary publish a list of widely accepted protocols with documentation of "methods to account for additionality, permanence, leakage, and where appropriate, avoidance of double counting").

91. Guenet et al., *supra* note 72, at 245.

92. Environmental Defense Fund, *supra* 27, at 2.

93. Blue Book, *supra* note 20, at 3-60.

94. Environmental Defense Fund, *supra* 27, at 2.

95. *Consumers Rank Convenience & Fuel Retailers Low in Demonstrating Commitment to Environmental Friendliness*, CONVENIENCE STORE NEWS (Mar. 31, 2021), https://csnews.com/consumers-rank-convenience-fuel-retailers-low-demonstrating-commitment-environmental-friendliness.

96. Omanjana Goswami, *As the USDA Invests in "Climate-Smart" Agriculture, It's Hard to Follow the Money*, THE EQUATION (Dec. 8, 2022, 12:24 PM), https://blog.ucsusa.org/omanjana-goswami/in-climate-smart-agriculture-its-hard-to-follow-the-money/.

97. OLDFIELD ET AL., *supra* note 34, at 29.

98. *See, e.g.*, Adele Peters, *Horizon Will Become the First 'Carbon Positive' National Dairy in the U.S.*, FAST CO. (Mar. 3, 2020), https://www.fastcompany.com/90469745/horizon-will-become-the-first-carbon-positive-national-dairy-in-the-u-s.

99. *Organic Farming*, U.S. ENV'T PROT. AGENCY (Nov. 28, 2022), https://www.epa.gov/agriculture/organic-farming.

100. Terry Matlock, *Organic: A Thriving Agriculture Segment*, U.S. DEP'T OF AGRIC. (Jul. 29, 2021), https://www.usda.gov/media/blog/2020/10/28/organic-thriving-agriculture-segment; Andrea Carlson, *Investigating Retail Price Premiums for Organic Foods*, U.S. DEP'T OF AGRIC. ECON. RSCH. SERV. (May 24, 2016), https://www.ers.usda.gov/amber-waves/2016/may/investigating-retail-price-premiums-for-organic-foods/.

101. *USDA Publishes Strengthening Organic Enforcement Final Rule*, U.S. DEP'T OF AGRIC. (Jan. 18, 2023), https://www.usda.gov/media/press-releases/2023/01/18/usda-publishes-strengthening-organic-enforcement-final-rule.

102. Larry Meadows, What's Your Beef - Prime, Choice or Select?, U.S. DEP'T OF AGRIC. (Sep. 12, 2019), https://www.usda.gov/media/blog/2013/01/28/whats-your-beef-prime-choice-or-select.