# Carbon Dew Coordinated Response To: The Draft Federal Strategy to Advance Greenhouse Gas Emissions Measurement and Monitoring for the Agriculture and Forest Sectors

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September 9, 2023

Submitted on 2023-08-07 to https://www.regulations.gov/docket/USDA-2023-0009 (Comment Tracking Number ll1-2lii-lbi8), and to https://www.federalregister.gov/documents/2023/07/12/2023-14158/federal-strategy-to-advance-measurement-and-monitoring-greenhouse-gas-measurement-and-monitoring-for#:~:text=The%20draft%20Federal%20Strategy%20to,and%20verification%20(MMRV)%20of%20GHG (Comment Tracking Number 111-2raz-gsnj).



Community of Practice
Fair & Equitable Climate Solutions
Anchored by Direct Atmospheric Measurements

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## INTRODUCTION

The Carbon Dew Community of Practice compliments the draft Strategy to Advance Greenhouse Gas Emissions Measurement and Monitoring for the Agriculture and Forest Sectors, and appreciates the opportunity to provide input and feedback. Our community's vision is to anchor fair and equitable climate solutions in direct atmospheric measurements, and our mission is to facilitate technology transfer by providing a medium for public and private entities to work together towards common goals. We strive to translate surface-atmosphere science into real-world impacts and innovate industry practices with the best-available science. To achieve this, we support the integration and coordination of existing capabilities and resources for enhancing the measurement and quantification of GHG emissions and removals.

With this in mind, we would like to use this opportunity to suggest potential areas of improvement for the Draft Strategy. Thank you for considering these improvements, and we hope these suggestions contribute to the success of the strategy.

Carbon Dew is open and free for everyone to join, and additional information is available at www.carbondew.org.

# SUMMARY OF SUGGESTIONS

The strategy draft addresses in detail the remote sensing and proximal methodologies (e.g., dbh and other allometric inventories, various modeling, emission factors, emissions estimates, and estimated fluxes, etc. ) for GHG monitoring of the Agriculture and Forest Sectors. The strategy draft can substantially benefit by adding a detailed section on the direct measurements (e.g., amount of GHG add to or removed from atmospheric air at the field/forest level scale via eddy covariance approach, at the soil level scale via soil chamber approach, their derivative methods, etc.) over different types of land use (e.g., croplands, pastures, animal enclosures, clear-cuts, forested areas, etc.). Additionally, we would like to emphasize the importance of directly measuring water use including irrigation, as water use has a substantial carbon footprint of its own.

Such direct monitoring could utilize a network of direct measurement ground stations (e.g., direct flux stations) that tune spectral and/or structural remote sensing data in near-real time. This GHG monitoring approach would then be combined with remote sensing and modeling in a way similar to how multiple automated weather stations currently tune remote sensing weather products and weather models in near-real time to create weather observations and predictions anywhere. This will not include GHG forecasting per se, although the forecasting may become possible as a result of the adoption of such an approach.

In its present form, the draft strategy will provide a comprehensive overall national picture and may also allow identifying the biggest emitters, but we believe in its current form it will not be able to provide locally actionable GHG information to the producer or regulator on how to select, implement and verify the improvements in the farming practices or forest management.

In contrast, creating a GHG monitoring approach where ground flux stations tune remote sensing products and models in near-real time will provide such actionable local information, because it is both spatially and temporary contiguous (e.g., real-time data exist even in places and during times with no inventory or direct flux measurements). This information then can be used for GHG management and decision-making on a local scale by US federal, state, and local regulatory entities, as well as US businesses, and even individual citizens (if presented in a form similar to the current weather apps.). This, in turn, will create a set of high-quality information flows to allow both top-down (regulatory) and bottom-up (grassroots) societal responses on improving food and forestry production while reducing its carbon footprint.

GHG flux data measured directly improves and complements existing carbon accounting frameworks used in the land sector, including the key advantage of better baselining due to the high granularity of historical data series, with the idea of using historical primary data from EC networks when modeling carbon baseline scenarios. Such a method improves upon current baselining approaches, often built on assumptions on practices in the business-as-usual scenario with limited utilization of historical primary data (e.g., land cover classification from historical remote sensing imagery). Tracking carbon fluxes on the ecosystem level also allows applying a more holistic approach to understanding agricultural and forest systems' carbon cycling, can help reduce the complexity and uncertainty inherent in the individual measurement of each carbon pool, and improve associated existing management practices and develop more effective new ones.

Furthermore, this data information will lay the foundation for an accurate, just, and equitable carbon market based on the best scientific methodology available to date. This then will create a new and balanced economic powerhouse, where economic interests and climate interests are naturally aligned and balanced to provide optimal solutions over time. Finally, this will place the US in a leadership position in climate response through agricultural and forest practices, with the US's approach adopted globally.

# SPECIFIC SUGGESTIONS

### 1. Include a section on direct flux measurements of GHGs and evapotranspiration (ET)

While the present draft strategy extensively covers remote sensing and proximal methodologies for GHG monitoring, we suggest adding direct GHG flux measurements over specific areas or territories using the eddy covariance method (EC). The draft should also emphasize the importance of directly measured water use, including irrigation and watershed management. These practices have a substantial carbon footprint of their own, and real-world managing carbon in agricultural and forest systems will inevitably include the need to manage water.

The approach proposed in this response can be implemented by establishing multiple ground flux stations, that tune GHG and ET remote sensing products and models in near-real time. By adopting a similar paradigm to national weather monitoring, this GHG and ET monitoring approach can provide actionable information on a local scale.

To provide further technical details on the direct flux measurements, the eddy covariance (EC) is a micrometeorological technique that uses high-frequency measurements of vertical wind speed and concentrations of heat, $H_2O$, $CO_2$, $CH_4$, $N_2O$, and other gases to quantify fluxes between the land surface and atmosphere, providing continuous in situ monitoring including agricultural and forest applications (Burba, 2022). Several characteristics make these measurements well-suited for complementing and enhancing the GHG monitoring techniques outlined in the draft report:

- *Direct quantification:* EC provides real-world ground truthing of modeled emissions and uptake estimates by directly measuring fluxes. This can help improve or validate bottom-up inventory approaches.
- *Continuous monitoring:* Towers provide sustained, long-term quantification of fluxes. This enables assessing emission trends and verifying reported changes over time scales from minutes to decades.
- *Process attribution:* High-frequency EC data can be analyzed to attribute net fluxes to specific processes (e.g., respiration, photosynthesis). This provides valuable process-level detail that can further improve or validate process-based models.
- *Impartial applicability:* EC can quantify fluxes from any land surface source/sink, from agriculture to forests to cities. This avoids disciplinary bias. EC can be used for the monitoring of all key GHGs considered in this draft.
- *Scalability:* EC measurements can be scaled from individual facilities to landscapes using aircraft and satellites. This allows reconciliation across scales.
- *Reliability:* EC techniques have been used for decades across the globe in over 2100 locations. Researchers have collaborated in numerous networks to optimize and standardize measurement and data protocols. EC is thus a proven technology with a long track record.

Historical barriers have in the past impeded the utilization of EC data in operational applications, including temporal continuity and latency, non-self-describing data formats, source attribution, and violation of mass and energy conservation. Fortunately, structural innovations are underway to increase automation and yield demonstrable progress, including two-fold improvements in data availability and quality (e.g., Sturtevant et al., 2022), and sub-week data latency reduction (e.g., Papale, 2020; NCAR-NEON workshop). FLUXNET Committees work to overcome remaining EC challenges by providing self-describing, cloud-compatible data formats, contextual metadata, and data QA/QC based on artificial intelligence.

An innovation of particular interest for integration in the federal strategy is high-resolution Flux Mapping, which determines geolocated emission and removal fluxes at decameter and sub-hourly resolution across the squarekilometer areas (Metzger, 2018). Flux Mapping provides ultimate time, space, and process attribution for emission and removal fluxes, increasing statistical power by 10-100 times per EC station (https://tinyurl.com/flux-tower-mapping). It has also been shown to let EC fulfill mass and energy conservation (Xu et al., 2020), and can provide powerful, independent ground truth allowing arbitrage inconsistencies among current measuring, monitoring, reporting, and verifying (MMRV) approaches. Within the MMRV framework outlined in the report, Flux Mapping-enabled EC measurements could contribute in several strategic ways:

- *Science and Research:* EC Flux Mapping provides unmatched process-level data on how GHG fluxes respond to environmental factors, management activities, and mitigation practices. This can improve understanding of emission dynamics and help identify effective practices.
- *Models, Methods, Tools:* EC Flux Mapping data help parameterize, constrain, and validate models by providing measured fluxes for comparison. This reduces uncertainty and builds confidence in modeled estimates.
- *Monitoring and Verification:* As a direct measurement, EC Flux Mapping provides continuous monitoring capable of verifying bottom-up estimates of GHG exchanges. A network of instrumented towers, aircraft, and satellites could provide nationwide verification data
- *Reporting and Analysis:* EC Flux Mapping enables GHG source/sink attribution and hot spot identification for inclusion in GHG reports and analyses. Data could also reveal mitigation impacts.

In addition, Flux Mapping allows flux measurements from towers to be scaled up to landscape levels using airborne and satellite data. This could help meet inventory, program, and national-scale reporting needs within the framework.

Overall, Flux Mapping overcomes the limitations of raw EC data, transforming measurements into robust GHG information. This aligns well with the report's goals of reducing uncertainty, improving process understanding, continuously monitoring fluxes, and generating actionable GHG data. Investing in Flux Mapping infrastructure could significantly enhance capabilities across the MMRV framework.

## 2. Enable locally actionable GHG information

The current draft provides a comprehensive national perspective and can identify regions with the highest emissions. However, to facilitate local GHG and water/ET management and decision-making, it is crucial to implement a monitoring approach where direct ground measurements tune remote sensing products and models in near-real time. By presenting this information in a format similar to current weather apps, it can be utilized by federal, state, and local regulatory entities, businesses, and even individual businesses, farms, and citizens. Further, this information can also allow (early) detection of biotic and abiotic stress in vegetation (e.g., Berger et al., 2022) and allow informed management activities contributing to increased food and forestry production, thus having synergies beyond the GHG monitoring objective (Jungmann et al., 2022).

## 3. Establish high-quality information flows

The distributed network of flux towers provides powerful ground truth data for building consistent and scalable carbon MMRV tools that address a number of challenges that exist with current methods used to monitor land carbon currently, i.e., expensive, manual, self-reported data, biased. Utilizing carbon flux data reduces the complexity and uncertainty inherent in the individual measurement of each carbon pool and offers an accurate, holistic perspective on ecosystem carbon fluxes.

In contrast to measuring carbon pools individually, focusing on ecosystem-level carbon fluxes allows for an efficient and effective assessment of the overall effect of actions on an ecosystem's carbon balance. This allows for effective prioritization of carbon sequestration activities in agriculture, forestry, and nature-based solutions projects.

Implementing the suggested monitoring approach will create a set of high-quality information flows and an information layer that allows for both top-down (regulatory) and bottom-up (grassroots) societal response. This data foundation will also contribute to the development of accurate, just, and equitable carbon and water markets, based on the best available scientific methodology. As a result, the United States can assume a leadership position in climate response through agricultural practices and forest management, with the potential for global adoption of this approach.

### 4. Refer to existing emission and evapotranspiration monitoring systems

To enhance the strategy's effectiveness, it would be beneficial to reference and learn from established monitoring systems at different scales, such as NEON, LTER, LTAR, DeltaFlux, Parallel 41 ET Network, etc. in the U.S. and CarbonWatch and ICOS abroad. Incorporating international experiences, in addition to domestic ones, will enrich the strategy and broaden its applicability (Running et al., 1999; Gurney and Shepson, 2021).

### 5. Highlight contributions from US communities

Give prominence to the contributions made by US communities, such as FLUXNET and AmeriFlux, in the field of direct monitoring and subsequent data processing standardization and organization. By acknowledging their valuable efforts, the strategy can benefit from the expertise and experiences of these academic groups.

### 6. Implement AI-based data quality tools specific to directly measured GHG emission and ET

Consider the need for AI-based data quality assessment, data integrity checks, and automatic bias correction for data streams. These tools should possess the ability to evaluate the quality of data and integrate it into physical, chemical, or data-driven AI models, accompanied by quantifiable uncertainties.

## PARTNERSHIP OPPORTUNITIES

***CarbonDew CoP:***

We can serve as a liaison between academic and non-academic groups, leveraging the expertise of over 70 organizations.

***Collaborate with FLUXNET and AmeriFlux:***

Foster partnerships with these academic groups and individuals associated with FLUXNET and AmeriFlux. Their involvement and profound expertise can significantly facilitate knowledge sharing and cooperation in the field of GHG monitoring.

***Engage NEON, LTER, DeltaFlux, LTAR, and Parallel 41 Networks:***

Establish partnerships with NEON (National Ecological Observatory Network), LTER (Long Term Ecological Research), DeltaFlux (University of Arkansas/USDA-ARS), and Parallel 41 ET Network (UNL/Water for Food Global Institute) as liaisons to both academic and non-academic groups. These partnerships can contribute to the implementation of the proposed strategy and enhance its effectiveness.

***Collaborate with AI innovators specializing in carbon and GHG evaluations, such as CarbonSpace:***

Engage with CarbonSpace, which has developed operational AI-based carbon monitoring, reporting, and verification tools utilizing EC and remote sensing data. CarbonSpace has successfully facilitated the integration of direct flux measurements as a component of an accurate and comprehensive approach to monitoring the environmental performance of agricultural and other areas, using the methodology outlined in Zhuravlev et al. (2022).

***Collaborate with FFAR:***

Partner with the Foundation for Food and Agriculture Research (FFAR) as they can connect parties with funding opportunities open to both academic and non-academic agricultural enterprises. This collaboration can help support the implementation of the strategy.

***Leverage State and National Mesonet Programs:***

Consider leveraging existing frameworks like State and National Mesonet Programs, a Program of Record within NOAA's NWS (National Weather Service). These programs can provide a solid infrastructure, hardware maintenance, and data strategies to deliver publicly available network information in real time. Adapting and utilizing these frameworks can facilitate the dissemination of GHG and ET monitoring information.

# CONCLUSIONS

Incorporating these suggestions into the Federal Strategy to Advance Greenhouse Gas Emissions Measurement and Monitoring for the Agriculture and Forest Sectors will enhance its scientific rigor, and differentiation from other proposals, and provide local actionable information. It will also pave the way for accurate, just, and equitable carbon and water markets, positioning the United States as a global leader in climate response through agricultural and forestry practices.

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