C-AGG Workshop on COMET Tools
Summary Document
Monday, February 13, 2017

WORKSHOP GOALS AND OBJECTIVES

On February 13, 2017, C-AGG participants and stakeholders met with COMET tool developers and DayCent and DNDC modelers in Fort Collins, CO to learn up-to-date information on completed and planned enhancements to the COMET tools and the DNDC and DayCent models since the March 2016 C-AGG–CSU–USDA workshop on *Enhancing COMET-Farm & modeling tools to reduce voluntary market transaction costs for agricultural offset projects*. The workshop goals were to learn about tool and model enhancements since the March 2016 workshop, and to solicit C-AGG stakeholder reactions and suggestions for future priorities and development.

Tool and model enhancements discussed include:

- Changes made to the COMET tools since the March 2016 workshop, and estimated completion dates for additional enhancements underway or planned in the future, including:
    - COMET-Planner Updates
        - addition of a new meta model for potential use of COMET-Planner as a quantification methodology to support the California Department of Food and Agriculture (CDFA) Healthy Soil Program;
    - COMET-Farm Updates
    - USDA report *Quantifying GHG Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory* (July 2014) Updates
        - Whether/which report updates are anticipated to be included in the COMET tools
        - Transparent identification of the estimation methodologies and supporting literature behind the COMET tool calculations
            - Particularly for nitrous oxides (N_2O)
            - Including for uncertainty calculations
- Changes made to the DNDC model since the March 2016 workshop, and estimated completion dates for additional enhancements underway or planned in the future.

High level summary of outcomes

- USDA has developed a new soil N_2O meta model and an associated uncertainty calculation approach to replace the hybrid N_2O methodology in the USDA 2014 Methodology Report. The methodology will be deployed in COMET-Farm by mid-April 2017. The new approach includes scaling factors to incorporate management practices that are known to reduce soil N_2O emissions.
- Many of the enhancements and updates to COMET-Farm recommended by C-AGG stakeholders at the February 2016 workshop are approaching completion, while some are scheduled for completion throughout 2017 or 2018.

- Robust uncertainty calculations for COMET-Farm GHG emissions reduction estimations—identified as a high priority for C-AGG stakeholders—are planned for completion and availability by June 2017.
- Completion of the API is planned for public release in June 2017. The API is working quite well in the current test phase, and will support some desired applications, including the ability to batch upload and process data from multiple fields through COMET-Farm.
- COMET-Planner allows GHG benefits of conservation practices to be estimated.
    - The tool allows for regional specificity rather than simply state-wide averages of GHG estimations, and has been aligned with COMET-Farm and the USDA entity-scale GHG inventory methods for greater consistency.
    - Implementation options for NRCS Conservation Practice Standards have been added.
    - A beta version for CA is ready for roll-out, pending completion of DayCent updates in April 2017.
    - CSU aims to release a version that covers the entire US in the winter 2017.
    - The tool is validated to regional scales, although CA is one of the areas where validation has been the weakest.
- The DNDC model update/rewrite has focused to date on rewriting the science code, resulting in a reduction in the lines of science code by about half, and improved model performance which has reduced execution time by ~90%. A considerable amount of work remains to modernize the entire DNDC code-base, develop user interfaces, rewrite the GUIs, and complete additional work. The model developers are looking to raise funds to complete some of the remaining work.
- Additional C-AGG input was requested for some of the updates and enhancements underway or planned; and C-AGG stakeholders discussed additional future priorities for tool and model development.

WORKSHOP WELCOME AND INTRODUCTIONS

Keith Paustian of CSU welcomed workshop participants to Colorado, and noted that the goal of the current workshop is to continue to solicit C-AGG stakeholder input and suggestions on COMET tool development and future needs and direction.

Debbie Reed of C-AGG thanked participants for joining and provided a historical context for the meeting. Collaborative work with USDA on agricultural GHG quantification methodologies began in 2010 when C-AGG engaged in a dialogue with USDA about the work that culminated in the 2014 publication of the USDA GHG Quantification Methodologies Report. The report provided a collaborative opportunity for C-AGG stakeholders to work with USDA to support development of scientific GHG quantification methodologies important for agricultural offsets in carbon markets. In February 2016 C-AGG, CSU and USDA hosted a joint workshop in Sacramento that preceded the current C-AGG workshop; the 2016 workshop was an opportunity to discuss how the suite of COMET tools and process models such as DNDC and DayCent could be enhanced for market-based purposes and to identify market-based challenges that enhancements to the tools and models might help address. Reed summarized high-level recommendations from C-AGG stakeholders at the 2016 workshop as a reminder of what progress is being reported at the current workshop.

Adam Chambers of USDA NRCS noted that USDA has been working with environmental markets for at least ten years. Conservation finance is being mobilized to further market development, since environmental markets are in early stages of formation. Appropriate quantification tools are important determinants of and contributors to market formation. The ability to quantify multiple ecosystem services such as GHG emissions reductions and improved water quality with a single tool or multiple compatible tools would be beneficial.

Reed concluded that C-AGG has long supported programmatic investments in agricultural GHG and environmental service quantification tools and models as long-term investments which have the benefit of becoming more rigorous over time with the addition of new data. Such front-end infrastructure investments support market development and help harmonize important ecosystem impact quantification needs.

SESSION 1: ESTIMATION METHODOLOGIES AND SUPPORTING LITERATURE FOR COMET TOOL N_2O AND UNCERTAINTY CALCULATIONS, AND PLANNED UPDATES TO THE USDA REPORT *QUANTIFYING GHG FLUXES IN AGRICULTURE AND FORESTRY: METHODS FOR ENTITY-SCALE INVENTORY*

Soil N2O Meta Model. Mark Easter of CSU presented an update on the development of an N_2O meta model and uncertainty method calculator in COMET-Farm. He provided a timeline for improving the N_2O meta model, the associated uncertainty method, and their deployment in COMET-Farm.

Soil N_2O is notoriously difficult to measure, and development of a USDA model to estimate changes in N_2O has been challenging. Implementation issues were encountered with the original N_2O quantification methodology included in the 2014 USDA Quantification Methodologies report. To address this CSU developed a soil N_2O meta model.

Design of the N_2O meta model is essentially complete, and the uncertainty method design will be completed 16 February 2017. Testing and evaluation will occur 16 February to 17 March 2017, with a goal to deploy the model in COMET-Farm during the period 17 March to 14 April 2017. The uncertainty method will include two structural uncertainty elements: DayCent model structural uncertainty and meta model structural uncertainty; and two input uncertainties: PRISM weather model uncertainty—West, Central, East—and SSURGO soils data uncertainty. These will be combined into a Monte Carlo Markov chain.

Once the team has completed this process, they will host a webinar for C-AGG and other stakeholders to provide more specific updates. Asked whether the model can detect bias versus error, Easter noted that the model is constructed around a bias-corrected version of the DayCent model output so that bias correction is included in the meta-model.

USDA Soil N_2O Quantification Methodology. Chris Dorich of CSU presented on the updated USDA N_2O quantification methodology. Because the estimation ability of the USDA 2014 report methodology was not great, an improved version is being developed in concert with Ernie Marx, Steve Del Grosso, and Stephen Ogle. The new methodology is a multiple regression model.

Dorich described current N_2O estimation methods, including the IPCC tiered approaches. The use of 'complex' process based models such as DayCent and DNDC are equivalent to IPCC Tier 3 approaches. The rationale behind the new USDA method is to create a user-friendly model that incorporates some of the complexity of a

process based model, such as simulating interactions between soils, management systems and climate—which include/require many data points—with a hybrid approach that utilizes field data to more accurately predict outcomes based on fertilizer application rates. The model applies scaling factors to incorporate management practices that are known to reduce soil N_2O emissions. The scaling factors include slow release fertilizer use, PRP (managed manure is accounted for in the N inputs, not a scalar), nitrification inhibitors, no-till, and residue removal. Other scalars can be added. The resulting estimations still require improvement to be consistent with the EPA US National GHG Inventory, which the team believes can be achieved using a multiple regression model based on US National Inventory results that have been validated with field site data.

The new USDA N_2O methodology is currently being used in COMET-Farm and the uncertainty methodology is in the process of being added. Moving forward, the model needs to show predictable results at field sites to show that it tracks well against the IPCC model. Currently the DayCent model performs well at the field scale but is difficult to use. The team noted they are committed to using the modeling approach that provides the most precise results and is transparent in application. The models are not built to promote certain practices, but rather to show the results of practice implementation.

SESSION 2: COMET-FARM UPDATES & ENHANCEMENTS

Mark Easter of CSU noted that COMET-Farm is not a model but rather a modeling platform that accesses a full suite of models. Easter provided the following updates on COMET-Farm enhancements compared to the list of recommendations from the 2016 C-AGG/CSU/USDA workshop.

COMET-Farm Update/Enhancement	C-AGG Stakeholder Comments	Status/Estimated Completion Date
Robust uncertainty calculations associated with COMET-Farm GHG estimates	Identified by C-AGG stakeholders as a key requirement for market applications	June 2017
Additional CSU Notes: ▪ A Monte Carlo Markov Chain-based approach is being used for uncertainty calculations ▪ All AFOLU/Livestock Source/Sub-source Categories are being added ▪ The method is being aligned with the 2014 USDA Quantification Methods Report		
Ability to batch upload and process data for multiple fields through COMET-Farm	Identified by C-AGG stakeholders as a requirement to support offset project aggregation	In review, planned for public release June 2017
Additional CSU Notes: ▪ The Application Program Interface (API) allows batch uploads; COMET-Farm can execute the data and return it in an output file ▪ 20 million test runs showed the API tool to work quite well ▪ Functionality will be limited by how much data can be simultaneously processed ▪ To address processing limitations CSU is developing a fee-based approach to accommodate various user categories. Access for some users will be fee, but access for commercial users above a certain threshold will incur fees to cover maintenance and upkeep costs		
Field test with famers and landowners to identify their needs		In process in NY, VT, CA

COMET-Farm Update/Enhancement	C-AGG Stakeholder Comments	Status/Estimated Completion Date
Ability to run scenario analyses across landscapes to produce more robust pre-project calculations based on soil type, weather data, and potentially other factors that have a large impact on GHG fluxes	Identified by C-AGG stakeholders as beneficial for estimating project outcomes during project planning and recruitment, and to make business case for projects	Available Spring 2017 in COMET-Planner 2.0
Enable quantification at all spatial scales (i.e., site, region, jurisdiction)		Now possible with the API
Sync NRCS maps (latitude, longitude, hectares, boundaries) with tool, so they can be easily pulled into a project scenario		Process has been developed and is implemented in VT; with landowner's permission NRCS files can be uploaded directly
Make the tool easier for farmers to run which could be accomplished by creating APIs to the precision agriculture equipment they are using on-farm to collect data		Drag-and-drop crop rotations completed; COMET- Farm API completed; Completion date for conservation practice additions not specified.
Additional CSU Notes: ▪ Drag-and-drop function for crop rotations for certain crops in certain regions has been added using USDA data to populate the system. ▪ The tool uses NRCS tillage definitions ▪ Users can input their own fertilizer rates ▪ CSU plans to add a dropdown list of common conservation practices so a user can define the process and set up a full scenario analysis to pre-populate the tool and then define specifics for the site		
Consider branding COMET-Farm for use as a top-down identification tool	C-AGG stakeholders urged caution to not limit the ability of the tool to scale in the future	Addressed with the API
Additional CSU Notes: ▪ Easter noted that the community needs tools that allow for quick assessments over time in addition to tools for estimating tons of potential offset credits that a project might generate.		
Allow the tool to facilitate multi-emission source mitigation projects since this is a likely scenario for projects in the future to make them more financially viable	C-AGG stakeholders suggested multi-ecosystem service impacts be included in the future to enhance economic viability	Comprehensive scope of GHG source/sub-source category assessments in the COMET tools makes this possible
Update N_2O quantification methodology, add uncertainty calculations		April 2017
DayCent Model Update	DayCent model is one of the models behind COMET platform	April 2017

COMET-Farm Update/Enhancement	C-AGG Stakeholder Comments	Status/Estimated Completion Date
Add specialty crops in CA		March-June 2017
Additional CSU Notes: ▪ CSU has an ongoing partnership with CA Department of Food and Agriculture (CDFA) to add in specialty crops, but is waiting on completion of latest DayCent model updates		
Shift from NARR weather model to PRISM		April 2017
Extend the modeling future time horizon to 20 years		June 2017
Add a Life Cycle Extension	These tools are intended to add scenario-planning capabilities for project planning and development. For example, if conversion to no-till is being considered for an aggregated project the tool would support quantification estimates for 100 different farms in a single view; or support quantification at individual field levels.	Summer 2017
Add an Aggregator Extension		2018
Consider including DNDC in addition to DayCent in COMET-Farm platform	C-AGG stakeholders indicate that DNDC is already being used for project development in carbon markets and has been approved for use in rice and nutrient management offset protocols	Under discussion
Integrate APEX model for water quality assessments		Proof of concept, late 2017, to focus first on Chesapeake Bay and upper Ohio River Basin
Interoperability between COMET-Farm and COMET-Planner		Planned for 2017-2018
Ability to estimate economics/cost savings of practice change		May be outside the tool scope, but a conceptual design is in progress.
Create a repository/archive for documents/images/documentation that can support verification	C-AGG stakeholders seek streamlined project documentation and report generation	Conceptual design in progress
Allow photos from field to be uploaded to a cloud-based system and used as evidence of activities occurring.	C-AGG stakeholders desire an ability to view non-proprietary non-CBI farmer-driven model inputs and pictures, run calculations, and generate a report that shows GHG emissions changes.	Conceptual design in progress

COMET-Farm Update/Enhancement	C-AGG Stakeholder Comments	Status/Estimated Completion Date
Create multiple customized dashboard views for different users (e.g., farmers, project developers, verifiers) within the tool		Conceptual design in progress
Provide an option to import RS data	C-AGG stakeholders desire this ability for larger projects in particular, given costs associated with processing RS images	More C-AGG stakeholder input desired to identify what is most important
Add Hawaii and Alaska		2018

Q&A and discussion covered the following:

- **Quantification of reversals.** Are the COMET tools able to quantify reversals of emissions reductions/sequestration? This is a two-part issue.
    - COMET tools are not capable of predicting the *probability* of a reversal.
    - If a reversal is known to occur, it would be helpful if the tool could quantify that reversal. Because COMET-Farm reports project averages over 10 year cycles, C-AGG stakeholders asked how reversals would be quantified and reported.
    - The COMET team noted that the Tool can model reversals, but this is not automated in terms of the project scenario compared to the baseline. This could possibly be engineered, but creating landscape level data for reversals would be hard to build into the tool right now.
    - A C-AGG webinar was suggested to further discuss these needs.
- **Double-counting**. How can a project ensure there is no double counting that would allow a landowner or someone else to claim credit for an activity more than once (i.e. in different projects or in more than one claim)? In the voluntary carbon market space the registries ensure that offsets are closely tracked; ACR and CAR confer and share information across their registries to ensure no double-counting. However, if a project is not in a voluntary offset registry or is participating in a market-based approach outside of or in addition to voluntary carbon markets there is no single or universal tracking mechanism. Without a universal registry, there is a problem with potential double counting as there are currently multiple systems operating within the US—for instance, voluntary carbon markets and sustainable supply chain initiatives (in which claims are being made, rather than credits sold—but potentially on the same acres, and/or for the same practices or outcomes).
    - Participants noted that projects would need to track temporal shape files of project boundaries on a master map as a way to ensure that there is no double counting. While not a technically difficult activity, in practicality it will be challenging to put in practice due to privacy concerns and to difficulty identifying and accessing all the projects underway in different venues. This is something the community needs to remain aware of.
    - COMET-Farm does not enable tracking for purposes of flagging or avoiding double-counting.
    - Double-counting was highlighted as an important topic for C-AGG to address within its stakeholder community.

SESSION 3: COMET-PLANNER UPDATES & ENHANCEMENTS

Amy Swan of CSU highlighted that the COMET-Planner tool was created to estimate GHG benefits of conservation practices. Version 1.0 of COMET Planner included IPCC Tier 1 and 2 estimates using IPCC climate zones in the US. CSU updates underway include:

- Alignment of COMET-Planner GHG reduction estimates with COMET-Farm and the USDA entity-scale GHG inventory methods. COMET-Planner examines regions on a county-level, adds in a cropland data layer, and brings in other data sets (such as typical planting and harvest dates). Conservation and baseline scenarios are processed through the COMET-Farm API, so users get the same output they would get from COMET-Farm. Output is then aggregated out to the region to generate average GHG emission reductions for each implementation practice for each region. This allows for regional specificity rather than simply state-wide averages.
- Improving the spatial resolution of estimates from the sub-national scale to MLRA. This more fully aligns COMET-Planner with COMET-Farm for greater consistency and improves the resolution to sub-national scale (up to 200 regions). With the COMET-Planner revisions it becomes a meta-model of the models behind COMET-Farm.
- Adding implementation options for Conservation Practice Standards. The team interpreted NRCS Conservation Practice Standards for likely conservation scenarios and compared those to a baseline. The web portal has been redesigned to make it easier for users to group major conservation practices, and the model is able to better estimate the combined effects of these practices. The user selects the practice, the NRCS practice standard, and can then add the interpreted conservation implementation option.
    - The beta version is ready for use in CA.
    - The team aims to have the tool ready for use across the entire US by winter 2017.
    - The aim is to include livestock, but this will be difficult to implement.
    - Specific practices for rice cultivation, orchards, vineyards and organic soils are not available yet.

Q&A and discussion covered the following:

- Five – six times more users have accessed COMET-Planner compared to COMET-Farm. No specific information exists to identify demographics or the types of users accessing the tools.
- COMET-Planner is useful for providing an aggregated result but cannot provide field-specific data that many users are looking for.
- COMET-Planner will be rolled out first in CA (it is now only in beta version) and then for the remainder of the US (by winter 2017). The new version includes common combinations of conservation practices, but the challenge has been retaining the tools' "four-click" functionality. One of the limits of COMET-Planner is that is only associated with NRCS conservation practices.
- Participants asked if the COMET Tools have been validated and calibrated to specific regions. The models behind the tools have been validated to regional scales, although CA is one of the areas where validation has been the weakest.

SESSION 4: DNDC MODEL UPDATES & ENHANCEMENTS

Justin Fisk of Applied GeoSolutions (AGS) provided a summary of work completed to date to update the DNDC model code as well as enhancements underway and planned for the future. The model was developed ~30 years ago and since then many updates and additions were made to the model including the development of crop-specific and region-specific DNDC modular offshoots.

Fisk, a software developer, has been rewriting much of the original DNDC code. The original code was research grade but buggy and required rewrites to incorporate modern software technology and to remove dead-end or duplicative code. The rewrite has been time-consuming due to the many lines of code and a need to test after removing code to ensure continued integrity. The process required creation of an automated test harness and comprehensive test cases to compare the new version to a reference version.

The rewrite is utilizing modern software practices such as an emphasis on code modularity, reducing code coupling, and unit testing; including cleaner, more understandable code; and reducing the amount of code. To date the rewrite has focused on science code, resulting in a reduction in the lines of science code from 125,000 to about 60,000; redesigning data structures to be more flexible; eliminating hard-coded limits on management events, crops, soil layers; eliminating memory leaks and corruption; and making the model cross-platform so it can be coupled with other models. The process to date has improved model performance by reducing execution time ~90%. The rewrite of the GUIs will follow.

Additional upgrades in progress include multi-processor and distributed computing support (support for larger/more complex simulations, automated cluster processing, configurable output formats, easier visualization, easier access to output data from other applications); better developer-level documentation; and additional test units.

Moving forward, AGS still has a great deal of work to modernize the entire code-base, develop user interfaces, integrate manure components into the new version, create new tools to select and process inputs/outputs, and reduce the human overhead of model calibration and validation. AGS is looking to raise an additional $150,000 to support this continued work.

When completed the developers will make the model available under a free license for non-commercial research use to encourage a vibrant research community and allow registered users access to code repository.

Asked how to update the new base DNDC model into the other DNDC versions, Fisk noted that many of those versions are older and can take advantage of the new API. Ideally, AGS would like to create a common model improvement process that the full community can share. The C-AGG community could help by giving recommendations on specific output fields and formats.

DISCUSSIONS AND NEXT STEPS

Ownership of the COMET Tools and Platform and IP

Participants asked who owns/operates and finances the COMET tools and the underlying models (e.g. DayCent).

- COMET-tools are currently funded by USDA on an annual basis, with a contract in place through July 2017; and another through July 2018 that CSU is working to finalize.
- The tools are public goods, and CSU owns the IP.
- If USDA funding for the tools were discontinued for any reason, CSU would look to continue to develop and maintain the tools and model(s) with philanthropic support and/or through commercial user fees. CSU is looking at a pricing structure for commercial users that can help finance maintenance and operation of the software and the platform.

C-AGG Stakeholder Priorities for Future Development

- C-AGG is collaborating with the only other environmental services community that has a market—water quality—and is looking to monetize additional ecosystem services (e.g., soil erosion and soil carbon). It would be beneficial if a new COMET tool could estimate changes in both carbon and water quality metrics, for instance by running RUSSEL2 to quantify how much soil erosion is avoided with the use of cover crops.
- How is soil health quantified? There are huge benefits to preserving soil carbon through certain management practices, and the ability to measure how much topsoil can be preserved with no- till or cover crop implementation would be helpful.
    - USDA NRCS maintains a conservation desktop (CDSI) and NRCS has mapped what the inputs would be and there is a 90% overlap between the drivers of the CDSI and the COMET tools.
- Can the COMET tools quantify the climate resilience of practices? The team is thinking about climate resilience in many of the conservation practices. What is not included is what will happen to existing carbon in soils with changes in climate and weather.
- Would it be useful for COMET to add in Global Climate Models (GCM) for forecasting purposes (i.e. to upscale or downscale results)? Would the market support this? The team doesn't see this possibility quite yet, but does see how organizations would want to be able to model this. New protocols that are under development are starting to look at future climate impacts on carbon sequestration especially in wetlands and forest methodologies. The issue is coming up but has not played a large role to date (yet) in soil carbon. The community discusses the uncertainty in models but tends to ignore the uncertainty in climate.
- What research is happening around carbon in warming soils? COMET did not add this in because they look ahead 10 years and models show that most of these projections don't show large risks for 10 years at least.
- Will any of the products be adversely impacted by higher volume calls by the API? CSU is working to ensure that computing capacity is evenly distributed amongst tool users at any given time, but there is a limitation on computing capacity.

- What is the possibility of adding a life cycle extension to COMET Farm? There are some benefits that accrue upstream such as with reduced fertilizer use (not having to manufacture fertilizer). The development team is looking to make the calculations more of a full life cycle simulation, especially for those companies who wish to model full life cycle analyses. CSU ideally would put together a working group to develop LCA extensions for COMET Tools. If farmers could put numbers to this reduction from a supply chain perspective, it would valuable, but likely not as valuable from the carbon markets side. One possible addition is an assessment of how manure reductions impact LCA.
- Carbon footprint intensity could be useful to include but the comparisons between products/crops/etc. could create issues for some industries.
- Can COMET Farm include yield responses? Some models can be calibrated according to yield. There is a benefit to higher yield if less land is in production, but it is important to look at avoided conversion.
- How do improved reporting and flexible baselines affect how the carbon markets look at baselines? If a conservation scenario (future) incorporates a standard baseline, how does the project scenario change? The improved reporting allows a user to set a year and change their project layout. C-AGG stakeholders expressed support for the new drag-and-drop functionality, but indicated it is important to have more information and transparency on the uncertainty calculations and outputs from COMET-Farm including the datasets behind new functions, such as drag-and-drop. COMET developers would like to work with C-AGG stakeholders and the voluntary carbon registries to ensure that the data reports are useful to them. This is a question of timing. CSU will send C-AGG stakeholders a list of model inputs so we can prioritize which uncertainty calculations we would like first.