Background Document for Joint C-AGG/NNWQT Workshop
7 March 2017

SCOPE

The goal of the March 2017 joint C-AGG/NNWQT Workshop is to convene the water quality and carbon trading communities to explore the status of quantification methodologies (QM) in the two markets and determine whether common approaches and characteristics exist or can be identified.

Future joint workshops will investigate the challenges and opportunities to stack water quality and GHG credits from agricultural and working lands projects and determine whether two tangible benefits or one greater benefit can be realized from one mitigation practice or practice change.

Workshop #1 (7 March 2017)

Objectives:

1. Share ecosystem market and carbon market quantification tools and experiences to highlight challenges, exchange lessons learned, and identify whether common tools exist.
2. Identify opportunities to broaden dialogue to include a variety of ecosystem service programs and determine whether quantification tools extend to those programs.
3. Define a research agenda of next steps to harmonize and refine quantification approaches and to identify or develop common tools and methodologies.

Future Workshops (TBD)

1. Review the current barriers and challenges to expanding the use of environmental service markets.
2. Explore the potential for creating integrated models or modeling platforms to quantify multiple environmental benefits of conservation actions on working lands.

Ultimately, our joint goal is to advance the adoption of credit stacking for GHG emissions reductions and water quality enhancements as ecosystem service credits generated by the agricultural and working lands sectors. Achieving this goal will require the development and support of methodological, policy and related advances necessary for the widespread adoption of voluntary, incentive-based agricultural sector GHG mitigation and ecosystem service opportunities.

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BACKGROUND DOCUMENT: CARBON MARKETS AND WATER QUALITY TRADING MARKETS

A key element to any ecosystem service market is the ability to quantify and verify the environmental benefits of management actions made on the ground. Challenges to selecting appropriate quantification methods include appropriateness of scale, level of rigor, availability of data, transferability, and complexity of use. In the United States, carbon and water quality markets are in developmental stages and provide opportunities for agricultural producers to receive payments for implementing practices that improve environmental outcomes. The evolution of these two fields of ecosystem service markets has differed and has led to differentiated approaches to quantifying project outcomes. However, both carbon and water quality trading proponents continue to face similar challenges in selecting appropriate methods of quantifying ecosystem service benefits. Examination of the requirements and conditions that have led to the development and use of quantification methods in each of the respective fields provides an opportunity to share lessons learned, identify differences and commonalities, and to explore the potential for more integrated quantification approaches.

Credit Stacking

Credit stacking is the practice of generating multiple beneficial credit types for a single practice or action on the same site. For example, credits may be stacked by developing carbon offsets for a livestock digester project that captures and destroys methane, a potent GHG, while also developing renewable energy credits (RECs) from the electricity that can be generated from the captured methane. Credit stacking should be explicitly condoned by each market that is issuing the credits.

In the case of carbon markets, there are three voluntary carbon offset registries operating in the U.S., the American Carbon Registry (ACR), the Climate Action Reserve (CAR), and the Verified Carbon Standard (VCS). ACR is currently drafting policy on credit stacking, which is expected by the summer of 2017. CAR includes verbiage on credit stacking at the methodology-level, indicating what types of credits may be stacked based on the project type or activity. At this time the VCS program documents do not indicate a policy on credit stacking.

Most water quality trading markets currently do not include explicit provisions for credit stacking. The current lack of programs considering credit stacking is due in large part to a lack of demand. Through an NRCS Conservation Innovation Grant (CIG), the Electric Power Research Institute is exploring the potential for credit stacking of multiple credit types in the Ohio River Basin trading program**.**

Carbon Market Methodologies

Greenhouse gas (GHG) emissions reduction credits in the form of carbon offsets have been traded in voluntary and compliance markets, both internationally and domestically, for some time. Buyers for carbon offset credits can include any number of interested parties, whether they are regulated entities required to reduce emissions with support of a trading scheme or simply participants in a voluntary effort to reduce and/or offset GHG emissions or their 'carbon footprint'. Carbon trading programs can allow for the purchase of credits from almost anywhere, or within defined jurisdictions with similar program requirements and rules (as is the case for California and the Western Climate Initiative), as long as the credits are supported by an approved, methodologically valid approach. This is due to the global nature of GHG emissions and the need for global reductions in atmospheric concentrations of GHG.

Measurement and verification of GHG emissions and carbon sequestration from agricultural and land use systems are essential underpinnings to credible carbon markets. No one single measurement or estimation technique is sufficient to develop a comprehensive GHG measurement or monitoring system for terrestrial ecosystems. Measuring or quantifying GHGs from agricultural systems is challenging in comparison to measuring GHGs from stationary industrial sources. Not only does farmland cover an enormous amount of varied terrain and climates, but emissions are highly variable in both space and time.

IPCC GHG Accounting Methodologies

The United Nations (UN) International Panel on Climate Change (IPCC) has published numerous methodology reports on the issue of GHG measurements in agriculture and has recommended procedures for consistent approaches in quantifying GHG fluxes. The IPCC has classified methodological accounting approaches in three different Tiers, which vary in complexity according to the quantity of information required and the degree of analytical complexity (IPCC, 2003, 2006).

Tier 1 is the basic method, frequently utilizing IPCC-recommended country-level default values, while Tiers 2 and 3 are each more demanding in terms of complexity and data requirements. Progressing from Tier 1 to Tier 3 generally represents a reduction in the uncertainty of GHG estimates, though at a cost of an increase in the complexity of measurement processes and analyses.

> **Tier 1 Emission Factors –** simple methods with national-level or international-level default values.
>
> **Tier 2 Emission Factors –** similar to Tier 1, but with country-specific emissions factors and other values/data. Represent an intermediate level of complexity and require locally specific data.
>
> **Tier 3 Emission Factors –** the most complex and require the most specific data, and may include the use of models.

Currently, carbon sequestered or emitted, or emissions of nitrous oxide (N_2O) or methane (CH_4) from agricultural systems can either be measured directly using on-the-ground technologies, quantified indirectly through proxy variables or remote sensing techniques, or predicted using process models, including complex biogeochemical process models.

Each approach and technology has unique constraints related to costs, limitations, sampling design requirements and thus resulting levels of uncertainty, as well as ease of use and ability to scale. The implication for carbon markets has been that a variety of techniques across a range of scales are used for measurement and estimation purposes and to cross-check measurements or estimation methodologies for verification approaches as a means to overcome limitations of any one approach and to ensure market integrity. Table 1 summarizes the range of quantification methods and some additional considerations for use.

TABLE 1: APPROACHES TO QUANTIFYING GHG EMISSION REDUCTIONS FOR CARBON MARKETS

Quantification methods	Considerations
Direct measurement	• Examples include direct measurement of soil carbon or gas chamber methods for soil GHG flux. • Chamber measurements are inexpensive and provide good measures of GHG fluxes, but capture only very small areas within fields and systems being monitored. Extrapolation to field scales is highly complex, so chambers are more suited to research applications, for instance, measuring related differences between treatments and not absolute field-scale fluxes. Chamber methods are highly labor-intensive, require continuous sampling and trained users, and cannot be used under water or snow or in tall growing vegetation. • Direct soil carbon measurements can be highly accurate, but capture only very small areas within fields and systems. Extrapolations to field scales is highly complex. Direct soil measurements are very expensive (due to the number of measures required to adequately represent a field), highly labor-intensive; require repeated sampling, trained users and laboratory analyses; and soil carbon changes are generally only detectable over time scales of years, rather than annually. • Flux towers and aircraft detection of GHG concentrations are very expensive, require trained users for accuracy, and are mostly used in the research realm.
Measured indirectly through proxy variables	• Remote sensing (RS) technologies can monitor changes in above ground biomass from grazing, for instance, as a proxy for below-ground soil carbon sequestration. Information on grassland management, rangeland condition, or rangeland deterioration can be monitored through remote sensing using proxy variables. New satellites and improved spectral analyses are leading to enhanced capabilities of RS for land-based GHG estimation and monitoring.
Estimated using remote sensing techniques	• Remote sensing data are being increasingly utilized to estimate and monitor changes in land-based GHG emissions and sequestration. Satellite imagery with improved spatial resolution, ability to make observations regardless of cloud cover, and improved spectral analyses are leading to enhanced capabilities for land-based GHG estimation and monitoring. • Remote sensing is spatially explicit, broad in extent, uniform over the entire area sampled, repeatable over time, and capable of appraising an entire landscape, allowing incorporation of more detailed information into regional analyses of carbon dynamics. • Process-based models can be combined or integrated into RS to produce more accurate estimates of GHG fluxes. • Satellite imagery requires interpretation by skilled users.

Predicted using empirical and process-based models	• Models can push the boundaries of measurement beyond a field or farm scale. Models vary in complexity; can scale up point measurements to the farm or entire landscape scale; and can enable an ecosystem view of GHG emissions, incorporating multiple variables into quantification. • Empirical models use field measurements to develop statistical relationships between soil and agricultural management factors. Process-based or mechanistic models simulate biogeochemical processes that control the production, consumption, and emission of GHG in soils or agricultural systems. • Models must be suitable to region of use and sufficient local data must be available for model calibration and validation. The level of complexity of models can vary widely, but all require a moderate to high level of training and technical capacity amongst users. Modeling platforms that utilize simplified dashboards as user interfaces are in use and under development, allowing models to run in the background. Such platforms or tools have associated pros and cons; pros include ease of use and thus ability to scale projects; cons include lack of specificity and thus certainty that models calibrated and validated for specific regions can deliver. • Calibration, validation, and sensitivity analysis of models can be data, time, and cost intensive. • A benefit of models is that over time they provide data that is more robust, because as more GHG measurements are taken and as further research is done and additional data are incorporated into models, models more accurately estimate changes in GHG emissions and sequestration and thus, net GHG emissions.

Source: Adapted by C-AGG from Coalition on Agricultural Greenhouse Gases, **Carbon and Agriculture: Getting Measurable Results**, Version 1, April 2010.

The evolution of carbon markets in the US has in many ways been preceded or led by the development of robust carbon offset methodologies for the agricultural and land use sectors. Currently there are 17 agricultural offset methodologies available for use in voluntary and compliance markets, with the latter limited to two methodologies in the CA cap-and-trade program (at present). Table 2 lists the methodologies according to voluntary and compliance markets, and for the former, by registry. The range of quantification methodologies is quite variable, as indicated in the table. The GHG tracked or credited varies with the methodology and the GHG of impact, and the geographic region for which the methodology can be used may be limited by the GHG quantification method or some other criteria. The current rate of project registration and market activity reflects the early stages of market development as well as other market challenges, such as low buyer demand and high project development and implementation costs, coupled with low prices for carbon credits.

TABLE 2: CARBON MARKET METHODOLOGIES AND ASSOCIATED (RELEVANT) METRICS

Voluntary Market Registry: American Carbon Registry				
Methodology Name	**Quantification Methodology (IPCC Tier and Tool or Model)**	**GHG Credited**	**Geographic Boundary**	**Project & Market Activity: # registered credits awarded**
N_2O Emissions Reductions through Reduced Use of Fertilizer on Agricultural Crops (MSU-EPRI Methodology)	Category 1: IPCC Tier-2 Equivalent Category 2: Tier 1 Category 3: Tier 2	N_2O only	Projects eligible in all countries, however separate quantification methodology for North Central Region	1 project: 2 tonnes registered
Emissions Reductions in Rice Management Systems	Tier 3	CH_4 only	Arkansas, California, Louisiana, Missouri, Mississippi	2 projects, currently undergoing validation and verification
Avoided Conversion of Grasslands and Shrublands to Crop Production (ACoGS)	Tier 3	CO_2 only	US or Canada	1 project: 39,383 tonnes registered
Grazing Land and Livestock Management (GLLM)	Variable, scale-dependent	CO_2, CH_4 and N_2O	Projects eligible in all countries	No projects to date
Methodology for GHG Emission Reductions from Compost Additions to Grazed Grasslands (Version 1.0)	Allows for Use of Tier 2 or Tier 3	CO_2 only	Projects eligible in all countries	No projects to date
N_2O Emissions Reductions through Changes in Fertilizer Management (Version 2.0)	Tier 3	N_2O only	Projects eligible in all countries	No projects to date

Voluntary Market Registry: Climate Action Reserve (CAR)				
Methodology Name	**Quantification Methodology (IPCC Tier and Tool or Model)**	**GHG Credited**	**Geographic Boundary**	**Project & Market Activity: # registered credits awarded**
Nitrogen Management Project Protocol (version 1.1)	Tier 2 (direct GHG emissions) Tier 1 (indirect GHG emissions)	N_2O only	US	No projects to date
Grassland Project Protocol (Version 1.0)	Tier 2 (check?)	CO_2, CH_4 and N_2O	US	3 projects listed
Rice Cultivation Project Protocol (Version 1.1)	Tier 3	CH_4 only	California	No projects to date
US Livestock Project Protocol (biogas/methane digesters) (Version 4.0)	Tier 2	CH_4 only	US (separate protocol available for Mexico)	65 projects: ~2.6M tonnes registered

Voluntary Market Registry: Verified Carbon Standard (VCS)				
Methodology Name	**Quantification Methodology (IPCC Tier and Tool or Model)**	**GHG Credited**	**Geographic Boundary**	**Project & Market Activity: # registered credits awarded**
Adoption of Sustainable Agricultural Land Management (Version 1.0)	Tier 3	CH_4 only	Projects eligible in all countries	1 project: 21,565 tonnes registered
Soil Carbon Quantification Methodology (Version 1.0)	Tier 3	CO_2 only	Projects eligible in all countries	No projects to date
Methodology for Sustainable Grassland Management (SGM)	Tier 3	CO_2, CH_4 and N_2O	Projects eligible in all countries	No projects to date
Quantifying N_2O Emissions Reductions in US Agricultural Crops through N Fertilizer Rate Reduction	Tiers 1 and 2 depending on location	N_2O only	US	No projects to date
Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing	Tier 3	CH_4 only	Projects eligible in all countries	No projects to date

CA Compliance Market: ARB Methodologies				
Methodology Name	**Quantification Methodology (IPCC Tier and Tool or Model)**	**GHG Credited**	**Geographic Boundary**	**Project & Market Activity: # registered credits awarded**
Capturing and Destroying Methane from Manure Management Systems - Livestock Projects	Tier 2	CH_4 only	US	~84 projects: ~1.5M tonnes registered
Compliance Offset Protocol Rice Cultivation Projects	Tier 3 (DNDC)	CH_4 only	Arkansas, California, Louisiana, Missouri, Mississippi	No projects to date

WATER QUALITY TRADING

Water quality trading (WQT)—sometimes referred to as nutrient trading—is an innovative, market-based approach that provides pollution dischargers an alternative to installing onsite technology in order to meet regulatory obligations as established under the Clean Water Act (CWA), by working with other sources off site to generate equal or greater pollutant reductions. Generally, WQT transactions involve point sources—those with a definitive location of discharge such as municipal wastewater facilities, utilities, and factories—and nonpoint sources—those for which it is difficult to identify direct levels or contributions of pollution such as agricultural, grazing, and forestlands. Due to the nature of nonpoint sources, the ability to quantify pollution reductions is key to water quality trading.

In comparison to carbon markets, WQT is a more nascent space in the US and abroad. While markets for water quality have been around since the early 1990s, the field as a whole has not seen wide implementation or high volumes of transactions. There are a number of challenges that new WQT markets face, including uncertainty about actual pollution reduction achieved if monitoring is limited and perception that some polluters are not doing their share to reduce pollution. Program administrators, agencies, and researchers continue to refine methodologies and procedures to quantify pollution reductions. Such efforts will improve confidence in the outcomes of WQT, but will also enhance our ability to measure the positive outcomes of conservation practices to address water quality more generally.

Due to the complex dynamics of most watershed systems, WQT markets are often spatially limited to a particular geographic area. These systems may be quite large as is the case for the Chesapeake Bay and Ohio River Basin trading programs, both of which include multiple states. The feasibility of a trading market may also be governed by the available scientific information. In many cases, WQT programs are developed using watershed science developed as part of a Total Maximum Daily Load (TMDL) analyses. TMDLs are pollutant budgets developed as part of the Environmental Protection Agency's Impaired Waters Program[1]. These analyses provide the scientific underpinnings for how pollutants, sources, and water bodies behave and interact within a given watershed.

While TMDLs and other watershed models can provide necessary information regarding the dynamics of the overall system, sources of pollutant contributions, and the acceptable limits of those sources, the calculation of credits or benefits of pollution reduction from projects needs to be quantified at the field scale where agricultural best management practices and other projects to reduce pollutants entering surface water systems occur. In WQT, quantification typically takes three forms in 1) direct monitoring, 2) modeling, and 3) pre-determined rates. Table 3 provides a brief explanation and considerations for each of these approaches.

Table 3. Approaches to Quantifying Water Quality Benefits

Quantification methods	Considerations
Direct monitoring	• Direct monitoring or measurement can reduce uncertainty of measuring water quality benefits and eliminate or minimize the need for uncertainty factors. Direct monitoring may be the best option under conditions where there are a limited number of variables affecting water quality and technology exists to cost-effectively monitor. • Factors such as cost of technology, cost of installation and maintenance of instrumentation, time of implementation and calibration, and base condition assessments make direct monitoring the most resource intensive of methods. • It may be difficult to causally link and track reduction associated with an individual project from their point of generation to the point of compliance.
Models	• Models can be a cost effective option for estimating nonpoint source edge-of-field and edge-of-stream water quality benefits. Models can vary in complexity and may be built specifically for a program or may be adapted from more universal models using localized parameters and data. • Models must be suitable to the watershed or area of the trading program and sufficient local data must be available for calibration and validation. • The level of complexity of models can vary widely, but all require a moderate to high level of training and technical capacity amongst users. • Calibration, validation, and sensitivity analysis of models can be data, time, and cost intensive.
Pre-determined pollution reduction rates	• Pre-determined rates (often expressed as a ratio or percentage) provide a high level of repeatability and predictability because there is no need to very inputs, models, or monitoring. • Consistent application of pre-determined rates requires low-to-moderate technical expertise and low cost of implementation. • Pre-determined rates may not be as sensitive to site or system-specific conditions. Initial costs for developing pre-determine rates may be high requiring significant data and research.

[1] Section 303(d) of the Clean Water Act provides that state, territories, and authorized tribes are required to establish priority rankings for waters listed as impaired and develop plans to address the identified issues.

Direct monitoring involves measuring water quality chemistry (e.g., river turbidity or temperature) directly at the edge of field where BMPs are installed or end-of-pipe for facility upgrades. Direct monitoring is most commonly used when trading occurs between two point-source dischargers. For non-point sources, direct monitoring is less common due to the cost and time associated. Although direct monitoring provides the greatest degree of accuracy among the three approaches, it may be limited in agricultural field settings as multiple variables are likely to influence water quality conditions, making it difficult to isolate the pollution reductions associated with BMP installation.

Modeling is a more common approach to quantifying water quality benefits, particularly for non-point sources. Models can be either mechanistic—predict outcomes based on an understanding of internal physical, chemical, and/or biological processes, or empirical—regression equations that match observed relationships seen in experimental data. Models provide a degree of accuracy, but bring with them uncertainty due to built-in assumptions of conditions, data availability, and other common factors. In addition, modeling approaches require calibration, validation, and updating. The complexity of quantification models can range from simple spreadsheets to complex computer simulations requiring specialized knowledge.

Table 4. Examples of Water Quality Trading Quantification Methods

Quantification model	Pollutants	Description	Example Trading Program
RUSLE2	Sediment/Nutrients	Predictive model containing both empirical and process-based science. Outputs rill and inter-rill erosion by rainfall and runoff.	Southern Minnesota Beet Sugar Cooperative
SNAP-Plus	Sediment Phosphorus	Software that brings together statistical models and indices including RUSLE2, Wisc. P Index, P and K balancing, and SNAP2000 (previous statistical model)	Wisconsin
Spreadsheet Tool for Estimating Pollutant Load (STEPL)	Sediment/Nutrient	Customizable spreadsheet-based model uses algorithms based on runoff volume and pollutant concentrations. Annual sediment load calculated based on the Universal Soil Loss Equation and delivery ratio.	Ohio River Basin Trading
Nutrient Tracking Tool	(Phosphorus/ Nitrogen)	Field scale model developed to estimate nutrient and sediment loss reductions resulting from conservation practices.	Maryland
Universal Soil Loss Equation (USLE) and predetermined rates	Sediment/ Phosphorus	Simple equation used to predict average annual soil loss caused by sheet and rill erosion. Can be used with pre-determined pollutant reduction rates to estimate nutrient reductions from BMP implementation.	Idaho

Most modeling efforts employed in water quality trading programs today are based on watershed models designed for a number of applications.

One of the most significant challenges to utilizing models for WQT is their limited ability to accurately estimate benefits of projects at the field scale. Many models used in WQT programs today are down-scaled watershed models that may have a limited sensitivity to accurately capture field scale conditions. Although more accurate models are available, their utility is balanced with their practicality, including the need for specialized knowledge and data.

Some programs have developed standard or pre-determined effectiveness rates for qualified BMPs. Pre-determined rates are much simpler than models for quantification of water quality credits. However, pre-determined rates can have significant initial costs as they are often derived from scientific studies including measured data, iterative modeling exercises, and peer-reviewed literature. Additionally, pre-determined rates need to be calibrated or validated to specific watershed conditions. Like models, pre-determined rates have a degree of variability and uncertainty associated with them and require periodic updating based on additional information.

MOVING THE DISCUSSION FORWARD

Carbon and water quality trading markets have evolved as separate but parallel fields within the space of ecosystem services. While major characteristics of each market make them unique in many ways, they often look to the same land base—and sometimes, the same activities—to produce environmental benefits. Academics and policy experts in the field of ecosystem services have discussed in some detail the potential to stack credits, but we have yet to see the demand for such programs develop. However, for those at the cross-roads of these individual market programs—intermediaries, project developers, advisors, and landowners—this means having to calculate and account for multiple benefits in multiple ways. As a critical piece to the further development of ecosystem service programs, are there opportunities to support the field through development of coordinated and/or harmonized quantification tools and procedures? By quantifying ecosystem services from land use activities, is it possible to increase the value of individual credits even short of monetizing stacked credits, by showing the aggregated value of the impact? And if so, will the cost of measuring and verifying multiple impacts that are not all monetized, but which might increase the value of a single credit, be supported by the increased value of that credit (particularly if the rigor of demonstrating the associated impacts is not as high as that of the monetized credit)? What lessons can we draw from two of the more developed fields in the ecosystem service space—carbon markets and water quality trading?

We will explore these and other questions at the Joint Workshop with C-AGG and the NNWQT on March 7th in Sacramento, CA.

APPENDIX - CURRENTLY APPROVED METHODOLOGIES FOR AGRICULTURAL OFFSETS IN VOLUNTARY AND COMPLIANCE CARBON MARKETS IN THE US

VOLUNTARY CARBON REGISTRIES

1. American Carbon Registry (ACR)
2. Climate Action Reserve (CAR)
3. Verified Carbon Standards (VCS)

American Carbon Registry (ACR)

The **American Carbon Registry (ACR)**, an enterprise of Winrock International, is the first private voluntary GHG registry in the US. Founded in 1996 as the Greenhouse Gas Registry by Environmental Resources Trust, ACR has over 15 years of experience in development of rigorous, science-based carbon offset standards and methodologies as well as operational experience in high quality carbon offset issuance, serialization and transparent on-line transaction and retirement reporting.

ACR has several approved and pending methodologies related to agricultural offset activities, including the following:

Approved ACR Methodologies

N_2O Emissions Reductions through Reduced Use of Fertilizer on Agricultural Crops

The ACR Methodology for Quantifying Nitrous Oxide (N_2O) Emissions Reductions from Reduced Use of Nitrogen Fertilizer on Agricultural Crops details requirements for quantifying GHG emission reductions by reducing the amount of nitrogen used to fertilize crops.

- **Developed by**: Michigan State University (MSU) and the Electric Power Research Institute (EPRI).
- **Scope:** The scope of this methodology is limited to on-farm reductions in N fertilizer rate associated with the management of N-containing synthetic and organic fertilizers that reduce net N_2O emissions from annual or perennial cropping systems. Emissions reductions and crediting for project activities occur by reducing the N fertilizer rate during the crediting period, when compared to the baseline (pre-project) period.
- **3 Quantification Methodologies for 3 Project Categories**:
    - *Category 1:* Proposed projects located in the U.S. North Central Region (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin) that involve corn in row-crop systems such as continuous corn and rotations of corn-soybean or corn-soybean-wheat. Projects in this category use Method 1, ***an IPCC Tier 2-equivalent relationship between N_2O emissions and N application rates developed by MSU, to calculate N_2O emissions reductions.*** Only the corn component of a rotation is eligible for crediting. Projects located within the NCR boundary that involve crops other than corn, including crops in rotation with corn, are eligible under Categories 2 and 3.
    - *Category 2:* Proposed projects located worldwide that include fertilized agricultural crops may submit empirical data published (or accepted to be published) in peer-reviewed scientific journals documenting that the use of the ***Tier 1 emission factor*** (EF_1 = 1.0% [0.01]; IPCC 2006) is conservative ***for calculating N_2O emissions at the project site(s)***. ACR will engage experts to review the data.
    - *Category 3:* Proposed projects located worldwide that include fertilized agricultural crops may use a new project-specific emission factor if project proponents demonstrate using empirical

data published (or accepted to be published) in peer-reviewed scientific journals that the ***use of a new Tier 2 emissions factor is conservative for calculating N_2O emissions at the project site(s)***. ACR will engage experts to review the data.

Emissions Reductions in Rice Management Systems

The ACR Methodology for Emissions Reductions in Rice Management Systems was developed in a modular fashion with a globally applicable parent methodology; a regionally calibrated module for CA; and a regionally calibrated module for the US mid-south region.

- **Developed by**: Environmental Defense Fund (EDF) in partnership with the California Rice Commission (CRC), Applied Geosolutions, LLC, and Terra Global Capital LLC.
- **Scope & Quantification Methodologies:** project activities that involve a change in rice production management. The methodology is modular in structure, lending itself to applicability in rice-growing regions around the world.
    - ***Parent methodology:*** The parent methodology provides definitions, applicability criteria, project boundary definition, baseline and additionality requirements, quantification methods, monitoring and verification requirements, and uncertainty calculations for all modules. The methodology defines Rice-Growing Regions, geographic regions in which the climate and rice management practices are relatively homogeneous, and over which the ***DNDC model*** (the main quantification tool in this methodology) is calibrated and validated.
    - ***CA methodology:*** Eligible activities include: (1) removal of rice straw from the field after harvest; (2) replacing water seeding with dry seeding; and (3) early drainage at the end of the growing season. Project Proponents who implement practices that increase Nitrogen use efficiency concurrently with these practices can combine this methodology with an ACR methodology for nitrous oxide emissions from fertilizer management in order to receive credits from reducing nitrous oxide emissions in addition to methane and/or carbon dioxide.
    - ***Mid-South region of the U.S. methodology:*** Eligible activities under the Mid-South module (which includes the MS River Delta in AK, MS, and MO; and the Gulf Coast area in LA) include: 1) removal of rice straw from the field after harvest; 2) early drainage at the end of the growing season; 3) intermittent flooding during the growing season; and 4) increased water and/or energy use efficiency, achieved through measures including but not limited to: convert contour levees to precision or zero grade; use of side inlet/poly piping systems; use of more efficient diesel pumps; switch from diesel to electric pumps; use of soil moisture sensors to tailor flood to water needs. Project Proponents who implement practices that increase Nitrogen use efficiency concurrently with these practices can combine this methodology with an ACR methodology for nitrous oxide emissions from fertilizer management in order to receive credits from reducing nitrous oxide emissions in addition to methane and/or carbon dioxide.
- **Quantification Methodology:** Baseline and project emissions are quantified using a version of the DNDC model that has been specifically calibrated for rice projects; this is an IPCC Tier 3 methodology.
- **Uncertainty:** Projects must apply an uncertainty deduction factor to account for model structural uncertainty and ensure conservative crediting. The structural uncertainty represents the uncertainty inherent in the DNDC model and is set using independent validation data (directly measured daily methane fluxes on benchmark sites) available at the time of methodology publication. Additional data will become available in the future, allowing the structural uncertainty deduction factors to be updated. In addition, as more fields are registered, structural uncertainty should decline, so the structural uncertainty deduction depends on the number of fields in all projects registered on ACR. Project proponents must always use the most recent version of structural uncertainty deduction factors.

Avoided Conversion of Grasslands and Shrublands to Crop Production (ACoGS)

The methodology estimates the emissions avoided from preventing the conversion of grasslands and shrublands to commodity crop production. The removal of project lands from the supply of potential cropland is expected to create leakage effects in the form of market leakage. A default market leakage estimate is proposed to account for these effects. Standardized values for leakage and baseline determination are specific to the United States and Canada.

- **Developed by:** The methodology was developed by Ducks Unlimited, The Nature Conservancy, The Climate Trust, Environmental Defense Fund, and Terra Global Capital LLC.
- **Scope:** Grassland and shrubland soils are significant reservoirs of organic carbon that, if left uncultivated, will continue to store this carbon below ground. Grassland and shrubland ecosystems may also support greater plant biomass than annual cropland, especially below ground. In addition to the avoided cultivation and oxidation of soil organic carbon, several crop production practices, such as fertilizer application, may also be avoided. Livestock, primarily cattle, are anticipated to be common in the project scenario and their associated emissions from enteric fermentation and manure deposition are accounted for.
- **Quantification Methodology:** Process-based biogeochemical models, such as DNDC, DAYCENT, APEX, and others, may be used to estimate changes in various carbon pools and GHG sources in this methodology. Model validation must be employed to indicate whether models may be used for estimating each pool and source. In addition to process-based models, peer-reviewed empirical models calibrated to the Project Region may also be applied for relevant pools and sources. It is intended that common biogeochemical models of ecosystems, including but not limited to DAYCENT, DNDC, and APEX, be considered eligible models, as long as they are validated for the Project Region and meet the uncertainty criteria as specified in the methodology.
- **Uncertainty:** Output from models should include estimates of uncertainties associated with all pools and sources. In cases where variances are not included in model outputs, additional uncertainty analyses should be performed (e.g., Monte Carlo simulations). In cases where input variances can be calculated through Monte Carlo simulations, then these shall be performed and reported as well.

Grazing Land and Livestock Management (GLLM)

The ACR modular Grazing Land and Livestock Management (GLLM) GHG Methodology is designed to ensure the complete, consistent, transparent, accurate and conservative quantification of GHG emission reductions associated with a GLLM project.

- **Developed by**: Winrock International.
- **Scope:** The methodology focuses on five primary GHG sources, sinks and reservoirs (SSRs) affected by livestock production—enteric methane, manure methane, nitrous oxide from fertilizer use, fossil fuel emissions, and biotic sequestration in above- and below-ground biomass and soils—and provides accounting modules for each of these, leaving producers the flexibility to design their emission reduction activity. The modular structure allows Project Proponents (livestock producers or the project developers/aggregators representing them) to select the modules relevant to their particular baseline and project activities.
- **Quantification:** To improve usability and cost effectiveness, the methodology also provides a graduated approach in which the complexity and data requirements of the required GHG accounting methods correspond to the scale of impacts expected in a particular SSR; for micro- and small impacts, simplified accounting methods are provided.
- **Uncertainty:** In choosing key parameters or making assumptions based on information that is not specific to the project circumstances, such as in the use of default data, the Project Proponent should select values that will lead to a conservative estimation of net emission reductions and removal

enhancements, taking into account uncertainties. If uncertainty is significant, the Project Proponent should choose data that tends to under-estimate, rather than over-estimate, net emission reductions and removal enhancements.

Methodology for Greenhouse Gas Emission Reductions from Compost Additions to Grazed Grasslands (Version 1.0)

This methodology accounts for the carbon sequestration and avoided GHG emissions related to compost additions to grazed grasslands. Adding compost to grazed grasslands has been demonstrated to be an effective way to increase soil carbon sequestration and avoid emissions related to the anaerobic decomposition of organic waste material in landfills. Grazed grasslands represent a large portion of agricultural working lands, and a number of recent studies have highlighted that, globally, grasslands are in a state of degradation.

- **Developed by:** Terra Global Capital with support from the Environmental Defense Fund, Silver Lab at the University of California Berkeley, and the Marin Carbon Project.
- **Scope:** The methodology provides a quantification framework for emissions reductions from a number of activities including avoiding anaerobic decomposition of organic material used in compost production, directly increasing soil organic carbon (SOC) content by applying compost to grazed fields, and indirectly increasing SOC sequestration through enhanced plant growth in amended fields. Apart from the economic benefit of increased forage production, applying compost to grazed grasslands also has many environmental co-benefits such as improved soil quality, decreased risk of water and wind erosion by increasing soil aggregation, and increased nutrient and water availability for vegetation.
- **Quantification:** This methodology requires the use of a model to predict direct and indirect changes in SOC under the baseline and project scenarios. This methodology does not prescribe a specific model. The model can be either a process-based biogeochemical model (PBM) such as the DAYCENT or DNDC models, or an empirical model such as a Tier-2 Empirical Model that is shown to be effective for the conditions of the Project Parcels. It is up to the project proponents to demonstrate that the model is sufficiently accurate for the Project Parcels. Under the baseline scenario, the model is used to simulate any on-going changes to SOC, including potential continuing loss of SOC. Under the project scenario, the model is used to simulate the amount of compost carbon that is stored in recalcitrant SOC pools, and any indirect changes in SOC due to an increase in net primary production and under specific grazing management strategies. *Even though empirical models and PBMs have been shown to be highly valid across a wide range of management practices and geographic areas, soil samples and field measurements are required to validate the models for use in specific Project Parcels. As a consequence, this methodology requires monitoring by periodic (10 year) analyses of soil samples for model validation at different times throughout the project's lifetime.*
- **Uncertainty:** The uncertainty deduction shall have two components: one component related to the inherent, or structural, uncertainty from the model, and another component related to the variability of the input data, such as the variability of the N content in the compost, or the soil texture. Each of the three potential quantification approaches contains a section on how to calculate structural uncertainty. The structural uncertainty shall further be adjusted for aggregation. The input uncertainty shall be calculated using a Monte Carlo approach and using a 90% confidence level. The two sources of uncertainty (structural uncertainty and input uncertainty) shall be summed to calculate total uncertainty.

N_2O Emissions Reductions through Changes in Fertilizer Management (Version 2.0)

The methodology details requirements for quantification of GHG emissions reductions in the agriculture sector resulting from changes in how fertilizer is applied and used.

- **Developed by:** Winrock International

- **Scope:** This methodology is applicable to Agricultural Land Management (ALM) ACR project activities that involve a change in fertilizer management including changes in fertilizer rate, type, placement, timing, use of timed-release fertilizers, use of nitrification inhibitors, and other factors.
- **Quantification:** It incorporates site specific data into a peer-reviewed, tested, and highly parameterized model, the Denitrification-Decomposition (DNDC) model, to quantify direct N_2O emissions as well as indirect emissions from leaching and ammonia volatilization. (Note: ACR scientific peer review currently underway for v2.1 will improve the flexibility of the methodology by providing eligibility criteria for other GHG quantification models in addition to DNDC. Upon final approval v2.1 will replace v2.0.)
- **Uncertainty:** Will vary depending on the model used and the inherent structural uncertainty of the model as demonstrated through the model validation and calibration process. For more information on how uncertainty is quantified, please review sections 4.8.1 through 4.8.7 of the methodology.

Climate Action Reserve (CAR)

The **Climate Action Reserve (CAR)** encourages action to reduce GHG emissions by ensuring the environmental integrity and financial benefit of emissions reduction projects. The reserve establishes high quality standards for carbon offset projects, oversees independent third-party verification bodies, issues carbon credits generated from such projects, and tracks the transaction of credits over time in a transparent, publicly-accessible system. CAR has developed and approved several protocols for agricultural offset project types. To review all CAR protocols and their development status *click here*.

Agricultural Protocols

Nitrogen Management Project Protocol (Version 1.1)
(Note: the Minimum Data Standard is currently under revision) CAR's Nitrogen Management Project Protocol provides guidance on how to quantify, monitor, and verify GHG emissions reductions from improving nitrogen use efficiency in crop production. To access a one-page Nitrogen Management Project Protocol Summary in pdf form click here.

- **Developed by:** Climate Action Reserve
- **Scope:** This version of the Nitrogen Management Project Protocol includes only one method for quantifying N_2O emission reductions from reducing N application rates, which is applicable only to N rate reductions for corn in the Corn Belt, or the North Central Region, as it is called in this protocol.
- **Quantification:** The quantification methodology for direct N_2O emission reductions (Section 5.3.1) resulting from reductions in N application rate is based on the MSU-EPRI ***Tier 2 emission factor methodology,*** developed for corn cropping systems in the North Central Region of the U.S, The quantification methodology for leaching, runoff, and volatilization N_2O emission reductions (Section 5.3.2) is adapted from the MSU-EPRI adaptation of the IPCC ***Tier 1 methodology*** for calculating indirect N2O emissions.
- **Uncertainty:** The total primary effect GHG reductions (Mg CO_2e) for the entire project area are calculated and adjusted for uncertainty as described in the methodology.

Grassland Project Protocol (Version 1.0)
CAR's Grassland Project Protocol (GPP) provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with projects that avoid the loss of soil carbon due to conversion of grasslands to cropland, as well as other associated GHG emissions.

- **Developed by:** Climate Action Reserve
- **Scope:** For the purpose of this protocol, the GHG reduction project is defined as the prevention of emissions of GHGs to the atmosphere through conserving grassland belowground carbon stocks and

avoiding crop cultivation activities on an eligible project area, as initiated by the recording of a perpetual conservation easement or an eligible transfer of ownership. The project area must be grassland, as and it must be suitable for conversion to crop cultivation. The project area must have been in continuous grassland cover for at least 10 years prior to the project start date. The baseline scenario for all AGC projects is conversion to crop cultivation. The project lifetime for an AGC project is up to 150 years. This includes the crediting period, which may be up to 50 years and the permanence period, which is the 100 years following the crediting period.

- **Quantification:** GHG emission reductions from an avoided grassland conversion project are quantified by comparing actual project emissions to the calculated baseline emissions. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary that would have occurred in the absence of the project. In the case of grassland projects, the baseline emissions include the loss of belowground organic carbon through conversion to cropland, as well as the GHG emissions from crop production. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary. Project emissions include GHG emissions from grassland maintenance and grazing, as well as any leakage of baseline conversion activities. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions. ***Quantification of baseline emissions is done through the use of default emission factors developed through a probabilistic composite modeling approach.*** This approach greatly simplifies the quantification and monitoring of grassland projects, as compared to an approach based on site-specific sampling and modeling.
- **Uncertainty:** Calculated using discount factors based on the cropland premium for the county in which the project area is located. As the cropland premium decreases, uncertainty around the likelihood of baseline conversion increases.

Rice Cultivation Project Protocol (Version 1.1)

CAR's Rice Cultivation Project Protocol provides guidance on how to quantify, monitor, and verify GHG emissions reductions from changes in water and residue management in rice cultivation. Version 1.0 of the Rice Cultivation Project Protocol uses the DNDC biogeochemical process model to quantify emissions reductions achieved through the application of approved rice cultivation project activities in California. CAR provides guidance in applying an accuracy deduction for structural uncertainty associated with the use of the DNDC model in a guidance paper available in pdf format at the above link.

- **Developed by:** Climate Action Reserve
- **Scope:** Currently, this protocol only applies to Rice Cultivation projects located in the California Sacramento Valley (CSV) rice growing region. For the purpose of this protocol, a GHG reduction project (project) is defined as the adoption and maintenance of one or more of the approved rice cultivation project activities7 that reduce methane (CH4) emissions.
- **Quantification:** Due to the complexities involved with accurately quantifying GHG emissions resulting from the biogeochemical interactions that occur in cropped rice field systems, this protocol relies on the application of the Denitrification-Decomposition (DNDC) biogeochemical process model for quantification of baseline and project GHG emissions to quantify associated emission reductions. Because of the significant geographic variability related to soil types, climate, and cultivation management practices, the DNDC model must be properly validated for the geographic area and for all relevant cultivation practices in order for the model to perform with an acceptable degree of certainty. Therefore, this protocol will apply only to the regions and practices for which the DNDC model has been explicitly validated with measured data. While this version of the RCPP is valid only in specified rice growing regions, the Reserve expects to periodically update the protocol to expand the geographic

scope to include other U.S. rice growing regions as data and model calibration results become available.

- **Uncertainty:** When calculating primary emissions reductions, this protocol requires project developers to account for two types of uncertainty: model structural uncertainty and soil input uncertainty. Inherent in biogeochemical models (like DNDC) are uncertainties due to imperfect science in the models. This uncertainty is often referred to as model structural uncertainty, and roughly quantifies how well the model represents reality. Because physical and chemical properties of soil have a significant impact on CH_4 and N_2O production, consumption, and emissions, further variability and uncertainty is also introduced to the model in the sampling of soil data and the subsequent modeling of GHG emissions using such data. This is known as soil input uncertainty. The protocol requires that project developers account for both types of uncertainty by applying the appropriate uncertainty deductions to the modeled primary emission reductions. The soil input uncertainty deduction must be calculated by project developers for each field based on results from DNDC to model baseline and project scenario emissions for that field. The model structural uncertainty deduction is provided by the Reserve.

US Livestock Project Protocol (biogas/methane digesters) (Version 4.0)

CAR's US Livestock Project Protocol provides guidance to calculate, report, and verify GHG emissions reductions associated with installing a manure biogas control system for livestock operations, such as dairy cattle and swine farms.

- **Developed by:** Climate Action Reserve
- **Scope:** For the purpose of this protocol, the GHG reduction project is defined as the installation and operation of a biogas control system that captures and destroys methane gas from anaerobic manure treatment and/or storage facilities on livestock operations. The biogas control system must destroy methane gas that would otherwise have been emitted to the atmosphere in the absence of the project from uncontrolled anaerobic treatment and/or storage of manure.
- **Quantification:** GHG emission reductions from a livestock project are quantified by comparing actual project emissions to baseline emissions at the project site. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary that would have occurred in the absence of the livestock project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary during the reporting period. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions. To support project developers and facilitate consistent and complete emissions reporting, the Reserve has developed an Excel-based calculation tool. This tool is available to all Reserve account holders and their designated representatives. The Reserve *recommends* the use of the Livestock Calculation Tool for all project calculations and emission reduction reports. The current methodology for quantifying the GHG impact associated with installing a BCS requires the use of both modeled reductions as well as the utilization of *ex-post* metered data from the BCS to be used as a check on the modeled reductions.
- **Uncertainty:** To maintain consistency with international best practice, the Reserve requires the modeled methane emission reduction results to be compared to the *ex-post* metered quantity of methane that is captured and destroyed by the BCS. The lesser of the two values will represent the total methane emission reductions for the reporting period.

Verified Carbon Standard (VCS)

Verified Carbon Standard (VCS) is a GHG accounting program used by projects around the world to verify and issue carbon credits in voluntary markets. VCS was founded in 2005 by business and environmental leaders who identified a need for greater quality assurance in voluntary markets. The VCS founding partners—the

Climate Group, the International Emissions Trading Association (IETA) and the World Economic Forum—convened a team of global carbon market experts to draft the first VCS requirements. The World Business Council for Sustainable Development (WBCSD) joined the effort soon after. One of several project categories credited by VCS is Agriculture and Forestry (AFOLU) projects.

VCS currently credits two relevant project types within AFOLU:

1. Agricultural land management projects (ALM), and
2. Avoided Conversion of Grasslands and Shrublands projects (ACOGs).

The following relevant AFOLU methodologies have been approved by VCS, and are available for use by project developers:

VM0017 -- Adoption of Sustainable Agricultural Land Management, Version 1.0

This methodology quantifies the GHG emission reductions of sustainable land management practice activities that enhance aboveground, belowground and soil-based carbon stocks of agricultural areas. The methodology applies input parameters to analytic, peer-reviewed models to estimate the organic soil carbon density at equilibrium for each of the identified management practices in each land use category. This methodology is applicable to projects that introduce sustainable management practices to an agricultural landscape where the soil organic carbon would have remained constant or decreased in time without the intervention of the project.

- **Developed by:** BioCarbon Fund, World Bank
- **Scope:** This methodology proposes to estimate and monitor greenhouse gas emissions of project activities that reduce emissions in agriculture through adoption of sustainable land management practices (SALM) in the agricultural landscape. In this methodology, SALM is defined as any practice that increases the carbon stocks on the land. Examples of SALM are (but are not limited to) manure management, use of cover crops, and returning composted crop residuals to the field and the introduction of trees into the landscape. The methodology is applicable to areas where the soil organic carbon would remain constant or decrease in the absence of the project.
- **Quantification:** The methodology in its current form is applicable only for use of Roth-C model. The estimates of uncertainty and Activity Baseline and Monitoring Survey (ABMS*a*) in the current methodology are adapted for the Roth-C model only. Application of the methodology for use of other models will require at a minimum, revisions to estimates of uncertainty and ABMS specific to the model applied.
- **Uncertainty:** The project proponent shall use the CDM EB approved *General Guidelines for Sampling and Surveys for Small-Scale CDM Project Activities* with a view to reducing uncertainty of model input parameters. The project proponent will estimate the uncertainty of the agricultural input parameters to the soil organic model using the ABMS. If the project area is stratified, the sampling effort should represent the relevant strata in the sample frame. Where there is no specific survey guidance from national institutions, the project proponent shall use a precision of 15% at the 95% confidence level as the criteria for reliability of sampling efforts. This reliability specification shall be applied to determine the sampling requirements for assessing parameter values. The sampling intensity could be increased to ensure that the model parameters estimated from the ABMS lead to the achievement of a desired precision of 15% at the 95% confidence level) for the estimate of greenhouse gas emission reductions from the project. The project proponent should calculate the soil model response using the model input parameters with the upper and lower confidence levels. The range of model responses demonstrates the uncertainty of the soil modeling.

VM0021 -- Soil Carbon Quantification Methodology Version 1.0

This modular methodology is designed to be applicable to ALM projects, including changes to agricultural practices, grassland and rangeland restorations, soil carbon protection and accrual benefits from reductions in erosion, grassland protection projects and treatments designed to improve diversity and productivity of grassland and savanna plant communities. The associated modules provide methods for quantifying and monitoring changes in carbon accrual in and emissions from soils as well as from other GHG pools and sources that may be affected by AFOLU projects.

- **Developed by:** The Earth Partners
- **Scope:** This methodology provides methods for the quantification of soil carbon, as well as methods for quantifying changes in vegetation and litter pools which can be impacted by project activities, as compared with the baseline scenario. This methodology is focused on addressing the following key variables:
  - Estimating the amount of carbon in the soil, litter, and living vegetation pools at the start of the project;
  - Monitoring and documenting changes in soil carbon and the other carbon pools over time under the project scenario;
  - Projecting changes in soil carbon and other pools under the baseline scenario;
  - Estimating emissions of nitrous oxides and methane from soils, and,
  - Estimating project leakage.
  - The methodology has been designed using a modular approach. This methodology document lays out the steps required to fulfill estimation, projection and quantification requirements for projects wishing to register credits under the VCS. The methodology calls on the associated modules for specific techniques and options for estimating or projecting the GHG impacts of changes in specific pools and emissions.
- **Quantification:** stratified soil carbon sampling; non-C GHG estimations are variable, and can range from Tier 1 to Tier 3.
- **Uncertainty:** Estimated carbon emissions and removals arising from AFOLU activities have uncertainties associated with the measures/estimates of: area or other activity data, carbon stocks, biomass growth rates, expansion factors, and other coefficients. It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines (2006), IPCC GPG-LULUCF (2003), expert judgment, or estimates based on sound statistical sampling. Alternatively, indisputably conservative estimates of values can also be used, which will allow proponents not to calculate uncertainties for those variables, provided that the values used are based on verifiable literature sources or expert judgment. In this case the uncertainty is assumed to be zero for that variable.
  - Associated modules include methods for adjusting estimated values of carbon pools where uncertainties exceed specified limits. However, this module provides a procedure to combine uncertainty information and conservative estimates allowing the estimation of overall ex-post project uncertainty.

VM0026 -- Methodology for Sustainable Grassland Management (SGM)

The methodology aims to estimate GHG emission reductions and carbon sequestration in grasslands, by applying sustainable grassland management practices (SGM). Regarding carbon sequestration, carbon stock enhancement within the project boundary in above ground and soil organic carbon (SOC) pools is considered. This methodology is applicable to projects that introduce SGM into a grassland landscape subject to conditions such that SOC would remain constant or decrease in the absence of the project. Where biogeochemical models can be demonstrated to be applicable in the project region, they may be used to estimate SOC pool changes. Where such models are not applicable, the methodology provides for the use of direct measurement methodologies to estimate SOC pool changes.

- **Developed by:** United Nations (UN) Food and Agriculture Organization (FAO)

- **Quantification:** Tier 3 (models where available; or direct soil C sampling)

VM0022 -- Quantifying N_2O Emissions Reductions in US Agricultural Crops through N Fertilizer Rate Reduction

This methodology quantifies emissions reductions of nitrous oxide from US agriculture, brought about by reductions in the rate of nitrogen fertilization to annual cropping systems. The methodology encourages the application of economically optimum nitrogen rates that do not deleteriously affect yield and specifies the use of verifiable best management practices for nitrogen application, which are specific to the crop, soil, and environmental conditions encountered.

- **Developed by:** Michigan State University
- **Scope:** The methodology provides procedures to estimate the GHG emissions reductions and removals from the adoption of sustainable grassland management practices, such as improving the rotation of grazing animals between summer and winter pastures, limiting the timing and number of grazing animals on degraded pastures, and restoration of severely degraded land by replanting with perennial grasses and ensuring appropriate management over the long-term.
- **Quantification:** Dependent on which US state the project is located, the methodology utilizes either the generally accepted ***IPCC Tier 1 default emission factor*** or an empirically derived, regional emission factor (***equivalent to an IPCC Tier 2 factor***) to calculate N_2O emissions reductions directly associated with a reduction in the nitrogen application rate from inorganic and organic fertilizers, either singly or in combination. This approach is straightforward and transparent and may be considered as a practical, short- to medium-term solution to help reduce N_2O pollution from agriculture and as a precursor to more complex Tier 3 modeling approaches under development.
- **Uncertainty:** The methodology requires that all parameters used to estimate emissions and removals are conservative. Where conservative estimates are used that are based on verifiable literature sources or expert judgment, for the purposes of calculating uncertainty, it is not required to estimate a confidence interval for the parameter and uncertainty may be considered to be zero. Guidance on conservativeness of default parameters is given in the CDM EB *Guidelines on Conservative Choice and Application of Default Data in Estimation of the Net Anthropogenic GHG Removals by Sinks*. Where parameter values are derived from sample surveys undertaken within the project area, and the sample size is large (i.e., >30), a conservative estimate of baseline carbon sequestration by carbon pools or project emissions by GHG sources is given by adopting a value that represents the upper bound of the 95 percent confidence interval (i.e., sample mean + 1.96 × standard error), while a conservative estimate of baseline emissions by GHG sources or carbon sequestration by carbon pools in the project scenario is given by adopting a value that represents the lower bound of the 95 percent confidence interval (i.e., sample mean - 1.96 × standard error).

VM0032 -- Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing

This methodology quantifies the GHG emission reductions and removals from activities that introduce sustainable adjustment of the density of grazing animals and the frequency of prescribed fires into an uncultivated grassland landscape. The methodology shows how to determine additional carbon offsets through grassland soil sequestration and/or reduction in methane emissions as a result of reducing fire frequency and altering the density and/or activities of grazing animals.

- **Developed by:** Soils for the Future and Jadora International
- **Scope:** The project activities eligible to apply this methodology include any that manipulate number and type of domestic livestock grazing animals (e.g. cattle, sheep, horses, goats, camels, llamas, alpacas, guanacos, or buffalo) and/or grouping, timing and season of grazing (e.g., continuous unrestricted, planned rotational, bunched herd rotational or other means of restricting livestock access to forage in order to allow vegetation response) in ways that sequester soil carbon and/or reduce

methane emissions. Altering fire frequency and/or intensity, (e.g., shifting from late season to early season burning or changing prescribed burn schedules from one every other year to one every five years) in ways that increase carbon inputs to soil, is also an included activity. Increased fire may be used to shift plant species composition such that net carbon sequestration in soil increases (e.g., conducting a single burn to shift vegetation from shrubs to grasses), but the net increase in SOC must compensate for any losses in woody biomass and increases in methane (CH_4) and nitrous oxide (N_2O) emissions. Grassland restoration activities to improve livestock forage density (e.g. seeding of legumes or perennial grasses) that do not involve mechanical tillage of soil are allowed.

- **Quantification:** Projects may rely on measured or modeled approaches:
    - Measured approach: Emission reductions are quantified following a period in which enhanced soil sequestration and/or reduced methane emissions can be demonstrated. Such projects have a reduced uncertainty compared to those following a modeled approach, but projects that include soil sequestration activities may claim and verify emission reductions only after increases in soil carbon can be detected (likely every five or more years, depending on the productivity of the site).
    - Modeled approach: Emission reductions are quantified using a validated model after demonstrating management activities, which are known to sequester carbon and/or reduce methane emissions, have been implemented. Reduced emissions from sequestration and reduced methane emissions associated with these activities are then estimated by models with acceptable precision which have been validated for the project and re-calibrated at regular intervals thereafter (5 – 10 years, depending on the productivity of the site).
- **Uncertainty:** For the calculation of baseline emissions and reductions, uncertainty arises in the calculation of methane emissions only, because all other net emissions are conservatively assumed to be zero, unless increasing fire frequency is a proposed management activity. Uncertainty under the project scenario using a weighted uncertainty approach is determined by uncertainty in project emissions or in carbon stocks, weighted by the magnitude of each, for each year of the monitoring period.

CA GHG Cap-and-Trade Compliance Program

The state of **California's GHG Cap-and-Trade Program** is a central element of California's Global Warming Solutions Act (AB 32) and covers major sources of GHG emissions in the State such as refineries, power plants, industrial facilities, and transportation fuels. The regulation includes an enforceable GHG cap that will decline over time. The California Air Resources Board (ARB) will distribute allowances, which are tradable permits, equal to the emission allowed under the cap.

AB 32 Compliance Offset Program

ARB offset credits are greenhouse gas (GHG) emission reductions or sequestered carbon that meet regulatory criteria and may be used by an entity to meet up to eight percent of its triennial compliance obligation under the cap-and-trade program. Each ARB offset credit is equal to 1 metric ton of carbon dioxide equivalent ($MTCO_2e$) and can only be quantified using an ARB approved compliance offset protocol. Subarticle 13 of the cap-and-trade regulation details the legal requirements for compliance offset protocols, implementation and verification of offset projects, and issuance of ARB offset credits. Once an ARB offset credit is issued, it may be used for compliance up to applicable limits with the cap-and-trade program. Only ARB can issue compliance offset credits within the CA cap-and-trade program.

CA ARB Compliance Offset Protocols

To date, ARB has adopted four compliance offset protocols that may be used to generate ARB offset credits, including two agricultural offset protocols.

Capturing and Destroying Methane from Manure Management Systems- Livestock Projects

The Compliance Offset Protocol Livestock Projects provides methods to quantify and report GHG emission reductions associated with the installation of a biogas control system (BCS) for manure management on dairy cattle and swine farms. The protocol focuses on quantifying the change in methane emissions, but also accounts for effects on carbon dioxide emissions. The protocol is based on the Climate Action Reserve's Livestock Project Protocol Version 2.21 and includes some clarifications and updates from Version 3.0.2. Offset Project Operators or Authorized Project Designees that install manure biogas capture and destruction technologies use the methods contained in this protocol to quantify and report GHGs. The protocol provides eligibility rules, methods to quantify GHG reductions, offset project-monitoring instructions, and procedures for preparing Offset Project Data Reports. Additionally, all offset projects must submit to annual, independent verification by ARB-accredited verification bodies. Requirements for verification bodies to verify Offset Project Data Reports are provided in the Cap and Trade Regulation (Regulation). This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification of GHG emission reductions associated with a livestock digester project. The protocol is comprised of both quantification methodologies and regulatory program requirements to develop a livestock project and generate ARB or registry offset credits.

- **Developed by:** CA Air Resources Board (ARB)
- **Scope:** The protocol focuses on quantifying the change in methane emissions associated with the installation of a biogas control system (BCS) for manure management on dairy cattle and swine farms, but also accounts for effects on carbon dioxide emissions.
- **Quantification:** GHG emission reductions from a livestock project are quantified by comparing actual project emissions to baseline emissions at the project site. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary that would have occurred in the absence of the livestock project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary during the reporting period. Project emissions must be subtracted from the baseline emissions to quantify the project's total net GHG emission reductions.
- **Uncertainty:** Similar to the CAR Livestock protocol, projects are required to model the methane emission reduction results to be compared to the *ex-post* metered quantity of methane that is captured and destroyed by the BCS. The lesser of the two values will represent the total methane emission reductions for the reporting period.

Compliance Offset Protocol Rice Cultivation Projects

The Compliance Offset Protocol for Rice Cultivation Projects provides methods for quantifying reductions in methane emissions from flooded rice fields. Methane emissions are a result of anaerobic decomposition caused by the flooding of fields containing organic matter. The organic matter originates from soil amendments, plant residues, and root exudates. Methane production is affected by the duration of flooding, the rice variety, and the availability of crop residues and organic matter. All reductions must be fully documented, and accurately quantified.

The protocol uses the DeNitrification-DeComposition (DNDC) biogeochemical process model to quantify changes in N_2O and CH_4 emissions from three eligible practices: 1) replacing wet seeding with dry seeding, 2) early drainage at the end of growing season, and 3) alternate wetting and drying activities. Projects can be implemented in the major rice growing regions in California and the Mid-South (Arkansas, Missouri, Mississippi, Louisiana, and Texas) for which the DNDC model has been calibrated with empirical data.

The Offset Project Operator or Authorized Project Designee is required to use this protocol to quantify and report greenhouse gas (GHG) emission reductions. The protocol provides eligibility rules, methods to quantify GHG emission reductions, offset project monitoring instructions, and procedures for preparing Offset Project Data Reports. All offset projects are required to submit to independent verification by ARB-accredited verification bodies. Regulatory requirements for verification of Offset Project Data reports will be provided in the Cap-and-Trade Regulation.

- **Developed by:** CA Air Resources Board (ARB)
- **Scope:** This protocol includes three rice cultivation project activities designed to reduce GHG emissions that result from rice cultivation on fields in the California and Mid-South Rice Growing Regions. Eligible rice cultivation activities are dry seeding, early drainage in preparation for harvest and alternate wetting and drying.
- **Quantification:** GHG emission reductions from a rice cultivation project are quantified by comparing actual project emissions to project baseline emissions that would have occurred in the absence of the rice cultivation project. Total GHG emission reductions for each project for a reporting period must be quantified by subtracting secondary emission increases from modeled primary emission reductions using an ARB-approved version of the DNDC model.
- **Uncertainty:** Uncertainty in the baseline is based on the number of DNDC runs that a project developer chooses do. In the project scenario, ARB assigns a prescribed default value for the DNDC structural uncertainty.