Wetland Implementation and Rice Cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and the Coast of California – Methodology for Quantifying Greenhouse Gas Emissions Reductions, Version 1.0 – PROJECT MODULES

Preface

The objective of this methodology is to describe quantification procedures for the reduction of greenhouse gas (GHG) emissions through conversion of land to wetlands and rice cultivation in the Sacramento-San Joaquin Delta, San Francisco Estuary and in coastal areas of California. The methodology has been written in a module format; Project Proponents can choose the applicable modules for their specific project and site. The Framework Module provides background and an over-arching description of the methodology requirements and modules. The remaining modules provide guidance for baseline and project scenario quantification, methods, modeling, calculation of uncertainty, and other quantification tools. Project Proponents should refer first to the Framework Module for applicability requirements and an outline of the specific modules necessary for their project type.

Contents

(PS-MW) Wetland Restoration and Rice Methodological Module - Estimation of project carbon stock changes and greenhouse gas emissions for managed wetlands 4
I. SCOPE, BACKGROUND, APPLICABILITY AND PARAMETERS 4
Scope 4
Applicability 4
Parameters 4
II. PROCEDURE 4
Step 1. Project Boundaries 5
Step 2. Stratification 5
Step 3. Monitoring Project Implementation 6
Step 4. Project GHG Emissions 6
Step 5. Project Carbon Stock Changes 6
Step 5. Estimation of Project Emission Reductions or Enhancement Removals 7
(PS -TW) Wetland Restoration and Rice Methodological Module - Estimation of Project Carbon Stock Changes and Greenhouse Gas Emissions for Tidal Wetlands with in the San Francisco Bay Estuary 9
I. SCOPE, APPLICABILITY AND PARAMETERS 9
Scope 9
Applicability 9
Parameters 9
II. PROCEDURE 10
Step 1. Project Boundaries 10
Step 2. Stratification 10
Step 3. Monitoring Project Implementation 11
Step 4. Project GHG Emissions 12
Step 5. Project Carbon Stock Changes 14
Step 6. Estimation of Project Emission Reductions and GHG Removals 14
(PS RC W/RC) Wetland Restoration and Rice Methodological Module - Estimation of project carbon stock changes and greenhouse gas emissions for rice cultivation 17
I. SCOPE, APPLICABILITY AND PARAMETERS 17
Scope 17
Applicability 17
Parameters 18
II. PROCEDURE 18
Step 1. Project Boundaries 18
Step 2. Stratification 18
Step 3. Monitoring Plan 19
Step 4. Project GHG Emissions 20
Step 5. Estimation and Monitoring of Project Carbon Stock Changes 20
Step 6. Estimation of Project Emission Reductions 21

Tables

Table 11. Factors and practices that can be used for stratification and their effects on GHG emissions and removals. 5
Table 12. Factors and practices that can be used for stratification and their effects on GHG emissions and removals. 19
Table 13. Annual nitrous oxide emissions estimates for varying soil organic carbon content and fertilizer application rates (0 and 71 lbs N per acre). 23

Figures

No table of figures entries found.

(PS-MW) Wetland Restoration and Rice Methodological Module - Estimation of project carbon stock changes and greenhouse gas emissions for managed wetlands

I. SCOPE, BACKGROUND, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating *ex-ante* and *ex-post* carbon stock enhancements and greenhouse gas (GHG) emissions related to managed non-tidal wetlands when the project activity includes hydrologic management, infrastructural modification, and plantings or natural plant regeneration. The module provides specific guidance for determining applicability, monitoring project implementation, stratification and estimating carbon stock changes and GHG emissions.

Applicability

This module is always mandatory when the project activity includes hydrologic management, infrastructural modification and plantings or natural plant regeneration for construction of managed non-tidal wetlands that occur in the Sacramento-San Joaquin Delta and San Francisco Estuary. Infrastructural modification includes drainage modification and earth moving. The baseline scenario for this project activity is limited to agriculture and seasonal wetlands on organic soils.

The following conditions must be met to apply this module.

- The project area must be on agricultural lands where crops are grown and/or animals are grazed in the Sacramento-San Joaquin Delta or seasonal wetlands in the Sacramento-San Joaquin Delta or San Francisco Estuary.
- The baseline is as defined for agricultural lands or seasonal wetlands.
- Baseline emissions are due to the oxidation of organic soils.
- The project activity is implementation of managed non-tidal wetlands.

Parameters

This module produces the following parameter.

Parameter	SI Unit	Description
$\Delta C_{actual\text{-}MW}$	Metric tons carbon dioxide equivalents ($t\ CO_2\text{-}e$)	Cumulative total of carbon stock changes and greenhouse gas emissions under the managed wetlands project scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{actual} in Equation 1	

II. PROCEDURE

Step 1. Project Boundaries

Information to delineate the project boundary may include:

- USGS topographic map or property parcel map where the project boundary is recorded for all areas of land. Provide the name of the project area (e.g., compartment number, allotment number
- Local name and a unique ID for each discrete parcel of land
- Aerial map (e.g. orthorectified aerial photography or georeferenced remote sensing images)
- Geographic coordinates for the project boundary, total land area, and land holder and user rights

A Geographic Information System shapefile which specifies project boundary locations and related information is required.

Step 2. Stratification

In the GHG Project Plan, Project Proponents shall present an *ex-ante* stratification of the project area or justify the absence of stratification. Stratification for *ex-ante* estimations shall be based on the Project Management Plan. Table 11 provides typical factors and practices that can be used for stratification.

Table 1. Factors and practices that can be used for stratification and their effects on GHG emissions and removals.

Stratification Factor or Practice	Description	Potential GHG Effect
Wetland management practices	Depth of water and land surface elevation	Depth of water affects GHG removal and emissions and vegetation
Wetland management practices	Flow through or limited or zero outflow	May affect CH_4 emissions
Wetland vegetation	Variation in species	May affect GHG removals
Wetland vegetation	Planted seedlings, seeded, colonize or natural recruitment	Affects time required for vegetative cover, CH_4 emissions and GHG removal.
Wetland vegetation	Open water areas	Minimal GHG removal, GHG emissions
Wetland spatial variability	Location relative water circulation	May affect GHG removals and GHG emissions
Wetland age		May affect GHG removal rates
Soil chemical composition – soil organic matter content	For baseline conditions	Soil organic matter is key determinant of baseline GHG emissions on organic soils
Soil hydrology	Depth to groundwater, oxidation-reduction conditions	Depth to groundwater is an important determinant of baseline GHG emissions on organic soils
Agricultural land use	Crops or seasonal wetlands	Affects baseline GHG emissions and removals

Step 3. Monitoring Project Implementation

As described in Methodology Framework (MF-W/R), Project Proponents shall include a single monitoring plan in the Project Plan that includes description of baseline and project monitoring and estimation of carbon stock changes. Information shall be provided in the monitoring plan (as part of the GHG Project Plan), to document that:

a. The geographic position of the project boundary is recorded for all areas of land;
b. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded, and archived;
c. Commonly accepted principles of wetland management are implemented;
d. Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management are applied;
e. Use or adaptation of relevant practices already applied in managed wetland monitoring, or available from published relevant materials are implemented;
f. The monitoring plan, together with a record of implemented practices and monitoring during the project, shall be available for validation and verification.

Step 4. Project GHG Emissions

Greenhouse-gas emissions shall be estimated using methodology described in the Methods Module (MM-W/R). The Methods Module (MM-W/RC) provides the appropriate methods for measuring and estimating emissions for project and baseline activities. The methods listed in the MM-W/R module may be used alone or in tandem with the other methods listed for estimating project GHG emissions. Emissions can be estimated using appropriate peer-reviewed proxy measurements or estimates for similar situations in which case the environmental setting for the estimates shall be detailed. Also, there shall be an in-depth demonstration of conservatism and applicability. Biogeochemical models documented in the peer-reviewed literature that are calibrated and validated for the project area and demonstrably similar project conditions can be used for estimating GHG emissions.

Parameter estimates shall be based on measured data or existing published data where appropriate and can be demonstrated as applicable. If different values for a parameter used in models or calculations are equally plausible, a value that does not lead to over-estimation of net GHG emission reductions must be selected and its use documented. If project activities include moving sediments, fossil fuel combustion emissions must be quantified during project activities using methods described in module E-FFC if determined to be significant using module T-SIG. An *Ex-Ante* estimate shall be made of fuel consumption based on projected fuel usage.

Step 5. Project Carbon Stock Changes

Methods are described in the Methods Module (MM-W/R) for calculating above- and below-ground biomass and soil organic carbon stock changes. Acceptable methods include eddy covariance and soil coring. For use of the mean in estimating carbon stock changes, the 90% statistical confidence interval (CI) for estimated values of carbon stock changes can be no more than +/-10% of the mean estimated amount of the combined carbon stock change across all strata[1].

A 5-year monitoring and reporting frequency is considered adequate for the determination of changes in soil carbon stocks. Specifically, coring for measurements of carbon stock changes can be conducted every five years after project inception and placement of feldspar markers. If eddy covariance measurements are used to estimate carbon stock changes, continual monitoring shall occur from project inception unless another method is selected (such as a calibrated biogeochemical modeling). Project Proponents shall demonstrate that the spatial and temporal monitoring frequency adequately reflects reported and credited changes. Peer-reviewed biogeochemical models developed and calibrated for project conditions shall be used to simulate project carbon stock changes and GHG emissions at 5-year intervals.

Pertinent concepts and assumptions

1. Above- and below-ground biomass of wetland vegetation and litter contribute to the soil organic carbon (SOC) pool in wetlands.
2. Net increases in the SOC pool as the result of biomass contributions shall be estimated using methods described in the Methods Module (MM-W/R).
3. Project Proponents shall not double count carbon stock changes in above- and below-ground biomass and the SOC pool.

Step 5. Estimation of Project Emission Reductions or Enhancement Removals

The actual net GHG removals by sinks shall be estimated using the equations in this section. When applying these equations for the *ex-ante* calculation of actual net GHG removals by sinks, Project Proponents shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of monitoring activities. Project Proponents should retain a conservative approach in making these estimates.

$$\Delta C_{ACTUAL\_MW} = \Delta C_p - \Delta GHG_p - \mathrm{E}_{\mathrm{FFC},i,t} \tag{8}$$

where:

ΔC_{ACTUAL_MW} is the cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e);

ΔGHG_p is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e); and

$\mathrm{E}_{\mathrm{FFC},i,t}$ is the cumulative total emission from fossil fuel combustion in stratum *i* (t CO_2-e).[2]

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[1] For calculating pooled confidence interval of carbon pools across strata, see equations in Barry D. Shiver, *Sampling Techniques for Forest Resource Inventory* (John Wiley & Sons, Inc., 1996).

[2] Include in equation if project activities include moving sediment and fossil fuel combustion emissions have been determined to be significant using module T-SIG.

Note: In this module, Equation 8 is used to estimate actual cumulative net GHG removals for the period of time elapsed since the last verification period.

PARAMETERS ORIGINATING IN OTHER MODULES

Parameter	ΔC_p
Units	Metric tons carbon dioxide equivalents (t CO_2-e)
Used in Equation	8
Description	Cumulative total of carbon stock changes under the project scenario up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	ΔGHG_p
Units	t CO_2-e
Used in Equation	8
Description	Cumulative total of GHG emissions as a result of implementation of the project activity up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	$E_{FFC,i,t}$
Units	t CO_2-e
Used in Equation	8
Description	Cumulative total emission from fossil fuel combustion in stratum *i*
Module	E-FCC
Comment	Relevant information shall be included in the GHG Project Plan

(PS -TW) Wetland Restoration and Rice Methodological Module - Estimation of Project Carbon Stock Changes and Greenhouse Gas Emissions for Tidal Wetlands with in the San Francisco Bay Estuary

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module provides guidance for estimating *ex-ante* and *ex-post* carbon stock enhancement and greenhouse gas (GHG) emissions related to tidal wetlands construction and restoration in the San Francisco Estuary. The module provides specific guidance for determining applicability, monitoring project implementation, stratification and estimating carbon stock changes and GHG emissions.

Applicability

This module is always mandatory for use with tidal wetlands when the project activity includes hydrologic management and infrastructural modification with plantings, natural plant recruitment, or seeding. Tidal wetland restoration includes tidal marshes and Eelgrass meadows in the San Francisco Estuary. Hydrologic management and infrastructural modification activities include levee breaching and construction, earth moving, levee construction and other activities related to re-introducing tidal action and application of dredged material. The following conditions must be met to apply this module.

- The project activity is restoration of tidal wetlands where the baseline scenario is seasonal wetlands or open water in the San Francisco Estuary;
- This module is not applicable where application of nitrogen fertilizer(s) such as chemical fertilizer or manure, occurs in the project area during the project period.

Parameters

This module produces the following parameter.

Parameter	**SI Unit**	**Description**
ΔC_{actual_TW}	Metric tons carbon dioxide equivalents (t CO_2-e)	Cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario.
Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{actual} in Equation 1	

II. PROCEDURE

Step 1. Project Boundaries

Guidance for definition of geographic and temporal boundaries is provided in the Framework Module (WR-MF). The Project Proponent must provide a detailed description of the geographic boundaries for project activities. Note that the project activities may occur on more than one discrete area of land, but each area must meet the project eligibility requirements.

Step 2. Stratification

Strata shall be delineated using spatial data (e.g. maps, GIS, classified imagery). Strata must be spatially discrete and stratum areas must be known. Areas of individual strata must sum to the total project area. For estimation of *ex-ante* carbon stocks, strata should be defined based on parameters that affect GHG sequestration or emissions and/or that are key variables for the methods used to measure changes in carbon stocks. Potential strata criteria are as follows.

a. Wetland elevation
b. Vegetation type and species, such as eelgrass meadows
c. Age class
d. Water quality (e.g. salinity, nutrient inputs, distance from source, etc.). See discussion below for relevance to methane (CH_4) emissions
e. Hydrology (e.g. wetland water depth, depth of eelgrass meadow)
f. Soil type (e.g. organic or mineral soils)

Tidal wetlands may also be stratified according to salinity with relevance for CH_4 emissions. It is generally understood that wetlands exposed to high concentrations of sulfate (an anion present in seawater) emit CH_4 at relatively low rates due to low rates of CH_4 production. The presence of sulfate in tidal marsh soils allows sulfate-reducing bacteria to outcompete methanogens for energy sources, consequently inhibiting CH_4 production[3]. However, sulfate can be reduced to sulfide in marsh soils and thus the inhibitory effect of marine-derived saline water can be affected by site-specific conditions that allow CH_4 production to persist if sulfate availability is limited by diffusion or oxidation-reduction conditions[4]. Moreover, temporal and spatial variation in sources and sinks for sulfate and CH_4 can create conditions where both processes can coexist[5]. Therefore, estimates of CH_4 emissions and corresponding stratification may require direct measurements or conservative estimates as described in Step 4 below.

Established strata may be merged if reasons for their establishment have disappeared or have proven

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[3] Poffenbarger, Hanna J. Needelman, Brian A. & Megonigal, J. Patrick, 2011, Salinity Influence on Methane Emissions from Tidal Marshes, Wetlands, 31:831-842.
[4] E.g. Megonigal JP, Hines ME, Visscher PT (2004) Anaerobic metabolism: linkages to trace gases and aerobic processes. In: Schlesinger WH (ed.) Biogeochemistry. Elsevier-Pergamon, Oxford, pp 317–424.
Weston NB, Vile MA, Neubauer SC, Velinsky DJ (2011) Accelerated microbial organic matter mineralization following salt-water intrusion into tidal freshwater marsh soils. Biogeochemistry 102:135–151.
[5] Callaway, John C., Borgnis, Evyan L. Turner, R. Eugene & Milan, Charles S., 2012, Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands, Estuaries and Coasts, (2012) 35:1163–1181.

irrelevant to key variables for estimating net GHG emission reductions or removals. In the GHG Project Plan, Project Proponents shall present an *ex-ante* stratification of the project area or justify the absence of stratification. Stratification for *ex-ante* estimations shall be based on the Project Management Plan. Aerial or satellite imagery used to delineate strata shall be verified in the field. The *ex-ante* defined number and boundaries of the strata may change during the crediting period (*ex-post*). The *ex-post* stratification shall be updated if natural or anthropogenic impacts or other factors add variability to the carbon stock changes or emissions of the project area.

Eelgrass Meadows

Seagrasses which include Eelgrass (*Zostera marinas)* are among the planet's most effective natural ecosystems for sequestering (capturing and storing) carbon However, there is limited data and quantifying and modelling the GHG removal capacity is critical for successfully managing Eelgrass ecosystems to maintain their substantial abatement potential[6]. Given the tendency of eelgrasses to respond differently under different light and depth regimes, projects may differentiate between eelgrass meadow sections that occur at different depths given discrete - or relatively abrupt - bathymetric and substrate changes. For Eelgrass meadow restoration projects in areas with existing Eelgrass meadows, Project Proponents must quantify the percentage of natural meadow expansion that can be attributed to the restoration effort. Existing meadows are not eligible for inclusion in calculations of project emissions, even in cases where the restored meadow influences carbon emission rates in existing meadows.

New beds that result from natural expansion must be contiguous with restored meadow plots to be included in project accounting unless Project Proponents can demonstrate that non-contiguous meadow patches originated from restored meadow seeds. This may be done through genetic testing or estimated as a percentage of new meadow in non-contiguous plots observed no less than four years after the project start date[7]. This percentage must not exceed the proportion of restored meadow area relative to the total Eelgrass meadow areal extent and Project Proponents must demonstrate the feasibility of current-borne seed dispersal from the restored meadow. In cases where a restored meadow coalesces with an existing meadow(s), Project Proponents must delineate the line at which the two meadows joined. Project proponents may use either aerial observations showing meadow extent or direct field observations.

Step 3. Monitoring Project Implementation

As described in Methodology Framework (WR-MF), Project Proponents shall include a single monitoring plan in the Project Plan that includes description of baseline and project monitoring and estimation of carbon stock changes and emissions. Information shall be provided in the monitoring plan (as part of the GHG Project Plan), to document that:

a. The geographic position of the project boundary is recorded for all areas of land;

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[6] P.I. Macreadie, M.E. Baird, S.M. Trevathan-Tackett, A.W.D. Larkum, P.J. Ralph, 2014, Quantifying and modelling the carbon sequestration capacity of seagrass meadows – A critical assessment, Marine Pollution Bulletin, 82, 430 - 439.

[7] McGlathery, KL, LK Reynolds, LW Cole, RJ Orth, SR Marion, A. Schwarzchild. 2012. Recovery trajectories during state change from bare sediment to eelgrass dominance. *Marine Ecology Progress Series* 448: 209-221.

b. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded, and archived;
c. Commonly accepted principles of wetland management are implemented;
d. Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management are applied;
e. Use or adaptation of relevant practices already applied in managed wetland monitoring, or available from published relevant materials are implemented;
f. The monitoring plan, together with a record of implemented practices and monitoring during the project, shall be available for validation and verification.

Step 4. Project GHG Emissions

Greenhouse-gas emissions shall be estimated using methodology described in the Methods Module (MM-W/R) which provides the appropriate methods for measuring and estimating emissions for project and baseline activities (use Baseline Modules BL OW W or BL SW W). The methods listed the Methods Module may be used alone or in tandem with the other methods listed. For emissions measurements for tidal wetland project activities, chamber and eddy covariance methods are appropriate. The Methods Module provides guidance, and quality assurance and control precautions and recommendations for chamber and eddy covariance techniques. Emissions can be estimated using appropriate proxy measurements or estimates for similar situations documented in the peer-reviewed literature. In this case, the environmental setting for the estimates shall be detailed. Also, there shall be a comprehensive demonstration of conservatism and applicability.

As discussed above, CH_4 fluxes are generally influenced by salinity that can affect stratification. Methane emissions can be measured using methods described in the Methods Module. These methods can be used to directly determine and characterize the spatial and temporal variability resultant from topography, temperature, vegetation and water levels. Alternatively, a conservative estimate of CH_4 emissions requires measurement in the stratum where emissions are likely to be the largest. That is, chamber or eddy covariance measurements shall be conducted at times and places in which CH_4 emissions are expected to be the highest based on expert judgment, datasets or literature. These are likely to be wettest strata that support emergent vegetation, but may include stagnant pools of water. If eddy flux towers are used for the conservative approach, they will be placed so that the footprint lies in the stratum with the highest CH_4 emissions for 50% of the time.

Where a default factor approach is used based on salinity, the salinity average or low value shall be measured in shallow pore water or soil salinity within 30 cm of land surface using acceptable technology or analytical determination of total dissolved solids. Sulfate concentrations shall also be determined when salinity is measured using standard analytical methods at a certified laboratory. The salinity average shall be calculated from measurements during periods of peak CH_4 emissions. When the number of measurements is fewer than monthly for one year, the minimum salinity value shall be used. The salinity of the floodwater source may be used as a proxy for salinity in pore water provided there is regular hydrologic exchange between the source and the wetland (i.e. the source floods the wetland at least on 20% of the time during high tides).

The default factor[8] may be used with caution (see exceptions below) where the salinity average or salinity minimum is greater than 18 parts per thousand. Thus the estimated default CH_4 flux:

$$fGHG_{TW,i} = 0.0045 \text{ t } CH_4 \text{ acre}^{-1} \text{ yr}^{-1} \qquad (9)$$

Where

$fGHG_{TW,i}$ is the annual rate of CH_4 emissions (t CO_2-e) from the project area in stratum i.

The default factor shall not be used where oxidation-reduction conditions or sulfate concentrations are such that CH_4 production may not be inhibited. For example, Winfrey and Ward[9] demonstrated greatly increased CH_4 pore-water concentrations with decreasing sulfate to chloride ratios in intertidal sediments below 0.01. Morris and Riley[10] reported a sulfate chloride ratio of 0.14 +/- 0.00023 for the world's oceans.

Specific applicability conditions follow for the use of the default factor:

1. The default factor shall not be used when sulfate/chloride ratios are less 0.01;
2. In intertidal areas where there are likely sulfate to chloride ratios near or below 0.01, CH_4 fluxes shall be measured using methods described in the Methods Module (MM-R/C);
3. Methane flux measurements shall be used to characterize the spatial and temporal variability caused by topography, temperature, vegetation and water levels or conservatively estimated based on direct measurements taken at times and places in which CH_4 emissions are expected to be the highest based on expert judgment, datasets or literature

Project proponents may also estimate GHG emissions using locally calibrated and peer-reviewed biogeochemical models as per guidance in the biogeochemical modeling Methods Module and the Framework Module (WR-MF). Proponents shall provide transparent calculations for the parameters or data used for modeling during the crediting period. Parameter estimates shall be based on measured data or existing published data where appropriate and can be demonstrated as applicable. In addition, Project Proponents must be conservative in estimating parameters. If different values for a parameter used in models or calculations are equally plausible, a value that does not lead to over-estimation of net GHG emission reductions must be selected and its use documented. Emissions of N_2O may be conservatively set to zero for Eelgrass meadows.

If project activities include moving sediments, fossil fuel combustion emissions must be quantified during project activities using methods described in module E-FFC if determined to be significant using module T-SIG. An *Ex-Ante* estimate shall be made of fuel consumption based on projected fuel usage.

[8] Poffenbarger, Hanna J. Needelman, Brian A. & Megonigal, J. Patrick, 2011, Salinity Influence on Methane Emissions from Tidal Marshes, Wetlands, 31:831-842.
[9] Winfrey, M.R. and Ward, D.M., 1983, Substrates for Sulfate Reduction and Methane Production in Intertidal Sediments, Applied and Environmental Microbiology, January, 193-199.
[10] Morris, A.W. and Riley, J.P., 1966, The bromide/chorinity and sulphate/chlorinity ratio in sea water, Deep Sea Research and Oceanographic Abstracts, August, 699 – 705.

Step 5. Project Carbon Stock Changes

Methods are described in the Methods Module (MM-R/C) for calculating above- and belowground biomass and soil organic carbon stock changes. Acceptable methods for estimating soil carbon stock changes include eddy covariance and soil coring as described in the Methods Module (MM-R/C). For use of the mean value or replicate measurements in time and space in estimating carbon stock changes, guidance in the uncertainty (X-UNC) and framework (WR-MF) modules .

A 5-year monitoring and reporting interval is considered adequate for the determination of changes in soil carbon stocks. Specifically, coring for measurements of carbon stock changes shall be conducted every five years after project inception and placement of feldspar markers or sediment pins where opening of the project area would wash feldspar markers away due to tidal influence. Sediment pins are pounded into the ground to refusal and sediment accretion is measured against the pin's height[11].

If eddy covariance measurements are used to estimate carbon stock changes, continual monitoring shall occur from project inception until such time as biogeochemical models can effectively predict carbon stock changes. As per guidance in the Methods Module aqueous carbon fluxes shall be accounted for when eddy covariance methods are used for estimating soil carbon stock changes. Project Proponents shall demonstrate that the spatial and temporal monitoring frequency adequately reflects reported and credited changes. Biogeochemical models developed and calibrated for project conditions shall be used to simulate cumulative project carbon stock changes and GHG emissions at 5-year intervals.

Pertinent concepts and assumptions

1. Above- and belowground biomass of wetland vegetation and litter contribute to the soil organic carbon (SOC) pool in wetlands. Measurement of these biomass contributions to the wetland can only be used as inputs for biogeochemical models and will not be double counted with changes in the SOC pool for estimating carbon sequestration.
2. Net increases in the SOC pool as the result of biomass contributions shall be estimated using methods described in the Methods Module (MM-W/R).
3. Project Proponents using non-project specific values must demonstrate use of conservative estimates.

Step 6. Estimation of Project Emission Reductions and GHG Removals

Equations and methods for project emissions and carbon stock changes are provided in the Methods Module (MM-R/C. The Framework Module provides equations for calculating net carbon stock change. The project carbon stock change shall be estimated using the equations in this section. In applying these equations *ex-ante*, Project Proponents shall provide estimates before the start of the crediting period and monitoring activities. Project Proponents shall utilize a conservative approach in making these estimates. The net carbon stock change when using soil coring is estimated as follows.

$$\Delta C_{actual\_TW} = \Delta C_p - \Delta GHG_p - E_{FFC} \quad (10)$$

[11] US Geological Survey. 2012. Sediment pin standard operating procedures. Unpublished protocols. USGS, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA. http://www.tidalmarshmonitoring.org/pdf/USGS-WERC-Sediment-Pin-SOP.pdf

where:

ΔC_{actual_TW} is the cumulative total of carbon stock changes and greenhouse gas emissions (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e);

ΔGHG_p is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e); and

E_{FFC} is the cumulative emissions of fossil fuels (t CO_2-e).

Where allochthonous soil organic carbon (soil organic carbon originating outside the project boundary and being deposited in the project area) accumulates on the project site in the project scenario, the following procedure is provided for a compensation factor, D_{cf}.

$$D_{cf} = \Delta C_{p\ i} \times (\%C_{alloch} / 100) \quad (11)$$

where:

D_{cf} is the deduction to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e);

$\%C_{alloch}$ is the percentage of carbon stock derived from allochthonous soil organic carbon (%); and

i is the stratum within the project boundary (1,2,3,…M).

D_{cf} may be conservatively set to zero for the baseline.

PARAMETERS ORIGINATING IN OTHER MODULES

Parameter	ΔC_p
Units	Metric tons carbon dioxide equivalents (t CO_2-e)
Used in Equation	10
Description	Cumulative total of carbon stock changes under the project scenario up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	ΔGHG_p
Units	t CO_2-e
Used in Equation	10
Description	Cumulative total of GHG emissions as a result of implementation of the project activity up to time *t*
Module	Methods Module (MM-W/R)

Comment	Relevant information shall be included in the GHG Project Plan

(PS RC W/RC) Wetland Restoration and Rice Methodological Module - Estimation of project carbon stock changes and greenhouse gas emissions for rice cultivation

I. SCOPE, APPLICABILITY AND PARAMETERS

Scope

This module provides methods for estimating *ex-ante* and *ex-post* carbon stock enhancement greenhouse gas (GHG) emissions related to rice cultivation (RC) when the project activity includes hydrologic management and infrastructural modification on subsided lands in the Sacramento-San Joaquin Delta. The module provides specific guidance for determining applicability, monitoring project implementation, stratification and estimating carbon stock changes and GHG emissions.

Applicability

This module is always mandatory when the project activity includes rice cultivation on organic and highly organic mineral soils in the Sacramento-San Joaquin Delta. The module is applicable for estimating project GHG emissions and carbon-stock changes for project areas planned for rice cultivation where drained agriculture is the baseline activity as discussed in the agricultural Baseline Module (BL-Ag). The rice cultivation project activity includes a combination of hydrologic management changes with planting and infrastructural modification. Infrastructural modification includes drainage modification and earth moving.

The following conditions must be met to apply this module.

- The project area must be on agricultural lands where crops are grown and/or animals are grazed in the Sacramento-San Joaquin Delta or seasonal wetlands in the Sacramento-San Joaquin Delta.
- The baseline is as defined for agricultural lands. Baseline emissions are due to the oxidation of organic soils.
- The project activity is rice cultivation on subsided lands where there are organic soils.
- Rice shall remain flooded during the growing season at depths ranging from not less than 4 inches up to 1 foot.
- Straw burning and removal are not allowed.
- Baseline drained agricultural activities as described in the agricultural Baseline Module (BL-Ag) shall be in place during 5 years prior to beginning rice cultivation.

Parameters

This module produces the following parameters:

Parameter	SI Unit	Description
ΔC_{actual_RC}	Metric tons carbon dioxide equivalents (t CO_2-e)	Cumulative total carbon stock changes and greenhouse gas emissions under the project scenario.

Comment	The notation for this parameter in the Framework Module is expressed in its generic form as ΔC_{actual} in Equation 1

II. PROCEDURE

Step 1. Project Boundaries

The geographic boundaries of a rice project are fixed *ex-ante*. Guidance for definition of geographic and temporal boundaries is provided in the Framework Module (WR-MF). The Project Proponent must provide a detailed description of the geographic boundaries for project activities. Note that the project activities may occur on more than one discrete area of land, but each area must meet the project eligibility requirements.

Step 2. Stratification

If the project activity area is not homogeneous (and where applicable), proponents shall implement stratification to improve the accuracy and precision of carbon stock estimates. For estimation of *ex-ante* carbon stocks, strata should be defined based on parameters that affect GHG removal or emissions and/or that are key variables for the methods used to measure changes in carbon stocks. The key factors affecting GHG emissions are fertilization and soil organic carbon concentrations. Potential strata criteria are described in Table 12.

Table 2. Factors and practices that can be used for stratification and their effects on GHG emissions and removals.

Stratification Factor or Practice	Description	Potential GHG Effect
Rice water- management practices	Depth of water	Depth of water affects GHG removal and emissions and vegetation
Rice water management practices	Flow through or limited or zero outflow	May affect GHG emissions
Rice cultivar	Time for maturity varies among cultivars	Affects length of growing season which affects GHG removals and emissions
Soil chemical composition – soil organic matter content	For baseline conditions	Soil organic matter is key determinant of baseline GHG emissions on organic soils
Soil hydrology	Depth to groundwater, oxidation-reduction conditions	Depth to groundwater is an important determinant of baseline GHG emissions on organic soils
Agricultural land use	Baseline crops or seasonal wetlands	Affects baseline GHG emissions and removals
Fertilization rates and timing	Optimum fertilization rates vary for different organic matter[12].	Nitrous oxide emissions affected by rates and timing[13].

In the GHG Project Plan, the Project Proponents shall present an *ex-ante* stratification of the project area or justify the absence of stratification. Stratification for *ex-ante* estimations shall be based on the Project Management Plan. Aerial photography or satellite imagery used to delineate strata shall be verified in the field. The *ex-ante* defined number and boundaries of the strata may change during the crediting period (*ex-post*). The *ex-post* stratification shall be updated if natural or anthropogenic impacts or other factors add variability to the growth pattern or emissions of the project area.

Step 3. Monitoring Plan

As described in the Methodology Framework, Project Proponents shall include a single monitoring plan in the Project Plan that includes a description of baseline and project monitoring and estimation of carbon stock changes. Information shall be provided in the monitoring plan (as part of the Project Plan), to establish that:

a. The geographic position of the project boundary is recorded for all areas of land;
b. The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded, and archived;
c. Commonly accepted principles of rice cultivation for minimizing GHG emissions in the Delta are

[12] Matthew B. Espe, Emilie Kirk, Chris van Kessel, William H. Horwath, and Bruce A. Linquist, 2015, Indigenous nitrogen supply of rice is predicted by soil organic carbon, Soil Sci. Soc. Am. J, doi:10.2136/sssaj2014.08.0328.
[13] Ye, R. and Horwath, W.R., 2014 Influence of variable soil C on CH_4 and N_2O emissions from rice fields 2013-2014. Presentation at UC Davis.

implemented as described in the Appendix;

d. Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for field data collection and data management are implemented;
e. The monitoring plan, together with a record of implemented practices and monitoring during the project, shall be available for validation and verification.

Step 4. Project GHG Emissions

GHG emissions shall be estimated using the methodology described in this section and the Methods Module (MM-W/R) which provides the appropriate methods for measuring and estimating emissions for project and baseline activities. The methods listed in the Methods Module may be used alone or in tandem with the other methods listed. For emissions measurements for rice cultivation project activities, chamber and eddy covariance methods are appropriate. Monitoring shall occur during the entire calendar year. Emissions can be estimated using appropriate proxy measurements or estimates for similar situations if proxy measurements are used, the environmental setting relevance and scientific validity shall be detailed. Also, there shall be a demonstration of conservatism. Peer-reviewed biogeochemical models that are calibrated and validated for the project area and demonstrably similar project conditions can be used for estimating GHG emissions.

Project Proponents shall provide transparent calculations or estimates for the parameters that are monitored or used for calculations or modeling during the crediting period. These estimates shall be based on measured data or existing published data where appropriate. In addition, Project Proponents shall apply the principle of conservativeness. If different values for a parameter are equally plausible, a value that does not lead to demonstrable overestimation of net GHG emission reductions must be selected. If project activities include moving sediments, fossil fuel combustion emissions must be quantified during project activities using methods described in module E-FFC if determined to be significant using the T-SIG tool. An *Ex-Ante* estimate shall be made of fuel consumption based on projected fuel usage.

Step 5. Estimation and Monitoring of Project Carbon Stock Changes

Methods can be found in the Methods Module (MM-W/R) for calculating above-and belowground biomass and soil organic carbon stock changes. Acceptable monitoring methods include eddy covariance, remote sensing techniques and biogeochemical models. If eddy covariance techniques are used, the carbon of the harvested biomass must be accounted for as described in the Methods Module. The 90% statistical confidence interval (CI) for estimated values of carbon stock changes can be no more than +/-10% of the mean estimated amount of the combined carbon stock change across all strata[14]. If the Project Proponents cannot meet the targeted +/-10% of the mean at 90% confidence, then the reportable amount for calculation of offsets shall be adjusted as per the Framework Module (W/R-FM) A 5-year monitoring and reporting frequency is considered adequate for the determination of changes in soil carbon stocks. The Project Proponents shall demonstrate that the spatial and temporal monitoring frequency adequately reflects and supports reported and credited changes.

[14] For calculating pooled confidence interval of carbon pools across strata, see equations in Barry D. Shiver, *Sampling Techniques for Forest Resource Inventory* (John Wiley & Sons, Inc., 1996).

Pertinent concepts and assumptions

1. Above-and belowground biomass of rice vegetation and litter contribute to the soil organic carbon (SOC) pool. As discussed in the Methods Modules, monitoring of biomass and soil organic carbon stock changes shall not be used to double count GHG removal or carbon sequestration.
2. The mass of carbon in the harvested grain shall be counted in the carbon stock change estimates. The mass of carbon in the seed may also be counted.
3. Net increases and/or avoided losses in the soil-organic-carbon pool as the result of rice cultivation shall be estimated using methods described in the Methods Module (MM-W/R).
4. Emissions shall be measured in the field under project conditions or may be quantified by an acceptable proxy, reference sample plots, or field monitoring of similar sites, using approved local or national parameters, peer-reviewed biogeochemical models or peer-reviewed literature.
5. Project Proponents using non-project specific values must use conservative estimates and demonstrate applicability.

Step 6. Estimation of Project Emission Reductions

This section describes calculation of $\Delta C_{Actual\text{-}RC}$ (cumulative total of the carbon stock changes and GHG emissions under the project scenario in tons CO_2-e). The actual net GHG removals by sinks shall be estimated using the equations in this section. When applying these equations for the *ex-ante* calculation of actual net GHG removals by sinks, Project Proponents shall provide estimates of the values of those parameters that are not available before the start of the crediting period and commencement of monitoring activities. Project Proponents should retain a conservative approach in making these estimates.

The net carbon stock change is estimated using the following general equation.

$$\Delta C_{actual\_RC} = \Delta C_p - \Delta GHG_p - E_{FFC} \qquad (12)$$

where:

ΔC_{ACTUAL_RC} is the cumulative total of carbon stock changes and greenhouse gas emissions under the project scenario (t CO_2-e);

ΔC_p is the cumulative total of carbon stock changes under the project scenario (t CO_2-e) (MM-W/R);

ΔGHG_p is the cumulative total of GHG emissions as a result of implementation of the project activity (t CO_2-e) (MM-W/R); and

E_{FFC} is the cumulative total emission from fossil fuel combustion in stratum *i* (t CO_2-e).[15]

[15] Only include in equation if project activities include moving sediment and fossil fuel combustion emissions have been determined to be significant using module T-SIG.

Equations for project emissions and carbon stock changes are provided in the Methods Module (MM-W/R). In applying these equations *ex-ante*, Project Proponents shall provide estimates before the start of the crediting period and monitoring activities using peer-reviewed literature or biogeochemical models calibrated for project soil, climate and hydrologic conditions. Project Proponents should retain a conservative approach in making these estimates.

Table 13 can be used to estimate the N_2O emissions for rice cultivation for varying soil organic carbon content and fertilization rates in the Sacramento-San Joaquin Delta. Where fertilization rates are intermediate between 0 and 71 pounds N/acre, the project proponent can either conservatively use the high emissions estimate or estimate an emissions rate as a proportion of the rate for 71 pounds N per acre. For example for 5% soil carbon and a fertilization rate of 35 pounds N per acre, a project proponent may estimate the annual nitrous oxide emission rate at 0.25 t CO_2-e per acre (0.25 = 0.34 – ((0.34 - 0.16)/ (71/35))).

Table 3. Annual nitrous oxide emissions estimates for varying soil organic carbon content and fertilizer application rates (0 and 71 lbs. N per acre)[16].

Rate: 71 lbs. N per acre

Soil carbon content (%)	Annual N_2O emission (t CO_2-e/acre-year)	Standard error
5	0.34	0.03
6	0.28	0.02
7	0.22	0.02
8	0.15	0.01
9	0.09	0.01
10	0.03	0.02
11	0.04	0.03
12	0.05	0.04
13	0.07	0.05
14	0.08	0.06
15	0.09	0.06
16	0.10	0.07
17	0.11	0.08
18	0.13	0.09
19	0.14	0.05
20	0.15	0.05
21	0.11	0.04
22	0.07	0.02
23	0.02	0.01
24	-0.02	0.01
25	-0.06	0.11

[16] Ye, R. and Horwath, W.R., 2014. Influence of variable soil C on CH_4 and N_2O emissions from rice fields 2013-2014. Presentation at UC Davis.

Rate: 0 lbs. N per acre

Soil carbon content (%)	Annual N_2O emission (t CO_2-e/acre-year)	Standard error
5	0.16	0.09
6	0.13	0.08
7	0.11	0.06
8	0.08	0.05
9	0.06	0.03
10	0.03	0.02
11	0.04	0.02
12	0.04	0.02
13	0.05	0.03
14	0.05	0.03
15	0.06	0.03
16	0.07	0.04
17	0.07	0.04
18	0.08	0.04
19	0.08	0.05
20	0.09	0.04
21	0.07	0.03
22	0.05	0.02
23	0.04	0.02
24	0.02	0.01
25	0.00	0.04

PARAMETERS ORIGINATING IN OTHER MODULES

Parameter	ΔC_p
Units	Metric tons carbon dioxide equivalents (t CO_2-e)
Used in Equation	12
Description	Cumulative total of carbon stock changes under the project scenario up to time *t*
Module	Methods Module (MM-W/R)
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	ΔGHG_{RC}
Units	t CO_2-e
Used in Equation	12
Description	Cumulative total of GHG emissions as a result of implementation of the project activity up to time *t*
Module	MM-W/R
Comment	Relevant information shall be included in the GHG Project Plan

Parameter	E_{FFC}
Units	t CO_2-e
Used in Equation	12
Description	Cumulative total emission from fossil fuel combustion in stratum *i*
Module	E-FCC
Comment	Relevant information shall be included in the GHG Project Plan