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Voluntary Emission Reductions in Rice Management Systems

Version 1.0
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A nonprofit enterprise of
WINROCK INTERNATIONAL

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1 Sources

- DNDC (i.e. DeNitrification-DeComposition) Model Version 9.4, available from http://www.dndc.sr.unh.edu/
- DNDC User Manual, available from http://www.dndc.sr.unh.edu/

2 Definitions and Acronyms

2.1 Definitions

Accuracy	The degree of closeness of repeated measurements under unchanged conditions to their true or actual value.
Baseline Scenario	A counterfactual scenario that forecasts the likely stream of emissions or removals to occur if the Project Proponent does not implement the project, i.e., the "business as usual" case.
Calibration	The process of tuning the coefficients of Model Parameters, of a process-based model such as DNDC, to observations.
Common Practice Baseline	The Baseline used for a Rice Field when the Project Activity implemented has an adoption rate below or equal to 5% within a Rice Growing Region.
Crediting Period	The finite length of time for which a GHG Project Plan is valid, and during which a project can generate offsets against its Baseline Scenario. The Baseline Scenario must be re-evaluated in order to renew the Crediting Period. The Crediting Period applies to the Project overall, rather than being Rice Field-specific. The start and end date of a Crediting Period are determined as described in 5.3.
Critical Management Parameter	A Model Parameter that is impacted by the Project Activities, either directly or indirectly.
Ex-ante	At validation of the GHG Project Plan; also refers to estimates made of GHG reductions prior to verification.
Ex-post	At verification; also refers to GHG reductions actually monitored and verified.
Field-Specific Baseline	The Baseline used for a Rice Field when the Project Activity implemented has an adoption rate greater than 5%, but less than 50%.
Flooded Field	A Rice Field that is completely inundated with water and no visible soil or mud.
GHG Project Plan	A document that describes the Project Activity, satisfies eligibility requirements, identifies sources and sinks of GHG emissions, establishes project boundaries, describes the Baseline Scenario, defines how GHG quantification will be done and what methodologies, assumptions and data will be used, and provides details on the project's monitoring, reporting and verification procedures. ACR requires every project to submit GHG Project Plan using an ACR-approved methodology.
GHG Project Plan Validation	The systematic, independent and documented process for the evaluation of a GHG Project Plan against applicable requirements of the ACR Standard, any relevant sector standard, and the applicable ACR-approved methodology.
Historical Period	The 20-year period used for model simulation to allow the DNDC model to attain equilibrium in certain critical variables for which empirical data is lacking. See 7.1.
Model Parameter	A data item that is supplied as input to a process-based model.
Model Validation	The process of evaluating calibrated model results using field-measured data and quantifying the residual (structural) uncertainty.
Non-Critical Management Parameter	A Model Parameter that is related to agricultural management but not impacted by Project Activities.
Parameterization	The selection of Model Parameters that a process-based model such as DNDC will use for simulation.

Precision	The degree to which repeated measurements under unchanged conditions show the same results.
Project	A group of Rice Fields on which Project Activities take place.
Project Activity	Change in agronomic management that leads to a reduction in GHG emissions in comparison to the baseline management and GHG emissions.
Regional Calibration	The specific steps required to Calibrate and Validate the DNDC model for a Rice Growing Region and specific Project Activities
Rice Field	A contiguous parcel of land with irrigation management that is homogeneous for the past five years and on that was cropped under rice semi-continuously (i.e., at least 2 out of 5 years). One Rice Field has one water inlet and one outlet and is usually separated into “checks” by berms inside of perimeter levees that delineate the field’s boundaries.
Rice Growing Region	A geographic region in which the climate and rice management practices are relatively homogeneous. There are four Rice Growing Regions in the United States: (1) Sacramento and San Joaquin Valley in California, (2) Mississippi River Delta mainly in Arkansas, but extending into Mississippi and Missouri, (3) Gulf Coast area in Texas, and (4) Gulf Coast area in Louisiana. A Rice Growing Region represents the geographical region that reflects the area over which one Calibration of the DNDC model remains valid.
Start Date	The start of the Vintage Year for the first Rice Field in the Project, as determined per 7.1.
Structural Uncertainty	The inherent uncertainty of process-based models that remains even if all input data were error-free.
Uncertainty Deduction	Deduction, accounting for both uncertainty in input parameters and model Structural Uncertainty, applied to the emission reductions calculated by DNDC to ensure that credited emission reductions remain conservative.
Validation/ Verification Body	A competent and independent person, persons or firm responsible for performing the validation and/or verification process. To conduct validation and verification the VVB must be ACR-approved and accredited by the American National Standards Institute (ANSI), or be a Designated Operational Entity approved under Clean Development Mechanism or Accredited Independent Entity approved under Joint Implementation.
Vintage Year	The time period of credit generation, determined by the interannual sequence of planted crops and the timing of harvest, spring tillage and fertilization as described in 5.3. The Vintage Year is not a calendar year and may be more or less than a year in duration.[1]

7 2.2 Acronyms

ACR	American Carbon Registry
AFOLU	Agriculture, Forestry and Other Land Use
ANR	Agriculture and Natural Resources
CARB	California Air Resources Board

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[1] Due to the dynamic nature of agriculture, it is impractical or impossible to define a Vintage Year between fixed dates. The current definition of Vintage Year is sufficiently strict to avoid double counting, and ensure that there is only one Vintage Year for every calendar year. While the start and end dates of a Vintage Year cannot be determined *Ex-ante*, they are fixed as a function of actual agricultural management decisions, so cannot be changed *Ex-post*.

CDM	Clean Development Mechanism
DANR	Department of Agriculture and Natural Resources
DNDC	DeNitrification and DeComposition model
EDF	Environmental Defense Fund
GHG	Greenhouse Gas
ha	hectare
NASS	National Agriculture Statistics Service
NRCS	Natural Resources Conservation Service of the U.S. Department of Agriculture
OFEF	Off-field Emission Factor
PBM	Process-based model
QA/QC	Quality Assurance and Quality Control
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
TDD	Thermal Degree Days
UCCE	University of California Cooperative Extension
UNFCCC	United Nations Framework Convention on Climate Change
VVB	Validation/Verification Body

3 Summary Description of the Methodology

3.1 Options to Reduce GHG Emissions in Rice Cultivation

Flooded rice fields are a source of atmospheric methane (CH_4). Flooding results in anaerobic conditions in soils, which triggers anaerobic decomposition of organic matter by methanogens, a class of soil bacteria. Methanogens produce CH_4 as the product of the microbial decomposition of organic matter. Soon after the flooding of rice fields, the oxygen in soil pores is depleted, and the process of anaerobic decomposition of organic matter starts, leading to CH_4 emissions. The organic matter used during anaerobic decomposition can originate from organic amendments, plant residues or root exudates. The amount of CH_4 produced is proportional to the duration of flooding (during the growing season and outside the growing season during the winter months) and is impacted by the rice cultivar and the availability of crop residues and organic matter.

This methodology uses the biogeochemical process model DNDC to quantify soil carbon dynamics, N_2O and CH_4 emissions under the Baseline and Project scenarios. Even though the DNDC model has been shown to be highly valid across a wide range of activities and geographic areas in predicting both CH_4 and N_2O fluxes (Li, 2000; Pathak et al., 2005; Babu et al., 2006), this methodology only allows Project Activities in geographic regions for which the DNDC model has been explicitly calibrated with empirical data. This requirement is necessary because the quantification of uncertainty around modeled CH_4 fluxes can only be done with local and specific data consisting of empirical measurements of CH_4 fluxes[2]. Instead of requiring Project Proponents to demonstrate that the DNDC model is valid on a project-by-project basis, this methodology divides model Calibration into two separate steps: (1) a Regional Calibration and model Validation, which can be valid for a larger area than just the project area, and (2) a field-specific Calibration, which must be done on a field-by-field basis.

During the Regional Calibration and model Validation, gas fluxes from a field close to the project area are used to fine-tune key Model Parameters and verify the model's ability to produce accurate results for a specific region and for specific Project Activities. During a Field-Specific Calibration, agricultural yields are used to calibrate the crop sub-model to ensure that crop biomass growth is simulated correctly.

In addition, this methodology contains provisions to develop Regional Calibration "modules" containing all the steps required for calibration for a specific region and

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[2] Note that empirical measurements of N_2O fluxes are not required since these are not the primary target of this methodology. Peer-reviewed literature indicates that the uncertainty around changes in N_2O fluxes due to the project activities is insignificant relative to the change in CH_4 fluxes (Li, 2000; Pathak et al., 2005; Babu et al., 2006). As a consequence, the prediction of changes in N_2O fluxes by the DNDC model are sufficient for GHG accounting purposes.

specific Project Activities. Approved simultaneously with this methodology was a Regional Calibration module for specified Project Activities in California. Other Regional Calibration modules may be approved in the future through ACR's public comment and peer review procedures. When an approved Regional Calibration module is available for the region a Project is located in and for the Project Activities under consideration, Project Proponents are allowed to skip the Regional Calibration step and use the Parameterization, model input variables, and structural Uncertainty Deduction contained in the Regional Calibration module. The existence of an appropriate module, therefore, greatly reduces the work that must be done to develop a Project.

3.2 Rice-Growing Regions

A Rice-Growing Region is a geographical region in which the climate and rice management practices are relatively homogeneous. A Rice Growing Region represents an area over which one calibration of the DNDC model remains valid. There are four major Rice Growing Regions in the United States: (1) Sacramento and San Joaquin Valleys in California, (2) Mississippi River Delta mainly in Arkansas, but extending into Mississippi and Missouri, (3) Gulf Coast area in Texas, and (4) Gulf Coast area in Louisiana.

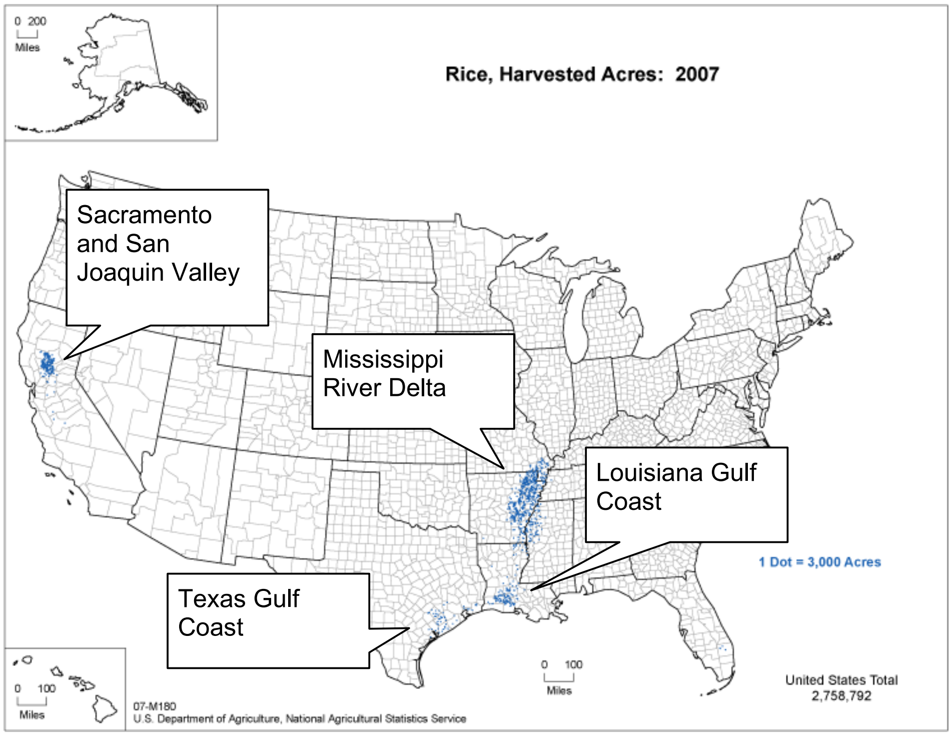

Figure 1. Map 07-M180 of the Agricultural Census of the USDA: Rice, Harvested Acres: 2007. Dot distribution map where each dot represents 3,000 acres of rice harvested in 2007. The largest concentrations of acres are in Arkansas and Louisiana. Available at http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/Field_Crops_Harvested/07-M180.asp

Within California, rice is grown in a very concentrated area; 95% of the rice produced in California is located within one 70x40 mile area. The management within this region is very homogeneous. Some small differences in water availability and temperature exist between the Sacramento and San Joaquin Valleys within California's Central Valley. However, the differences in water availability and temperature between the Sacramento and San Joaquin Valleys are adequately simulated by the DNDC model, as demonstrated by the correct simulation of seasonal weather patterns within the model validation sites. In addition, the number of rice growers in the San Joaquin Valley is small compared to the rice growers in the Sacramento Valley and does not justify a completely different reference region. Therefore, the rice growing region within California was selected as one single Rice Growing Region.

In the Mid-South, rice cropping occurs along the Mississippi River Delta as well as the Gulf Coast area in Texas and Louisiana. It is sensible to distinguish the Gulf Coast areas from the Mississippi River area due to differences in climate and rice management practices. In addition, ratoon cropping occurs mainly in Louisiana and less so in Texas. Therefore, the Louisiana Gulf Coast area is a separate Rice Growing Region from the Texas Gulf Coast area. Of these three regions, the Mississippi River delta is the largest and has the most diversity in it. However, extension specialists agree that the Mississippi River Delta area is sufficiently homogenous to be considered one Rice Growing Region. Note that since calculations of emission reductions still take into account the exact soil properties and management practices of a specific field, the variability of fields within one Rice Growing Region is still acknowledged.

3.3 Overview of Methodology

3.3.1 Overview of Accounting Mechanics

- The emission reductions from implementing Project Activities are calculated using the DNDC model separately for each field or stratum and for the Baseline and Project scenarios. The calculations must be done once before the start of the Project and included in the GHG Project Plan as an *ex ante* estimate of emission reductions, and must be redone after the Project Activities are complete to calculate the *ex post* actual emission reductions. An Uncertainty Deduction is applied to modeled emission reductions to account for model structural uncertainty and uncertainty in input parameters. The uncertainty deduction must be applied to each field individually (see Section 10.1.3).

- Project Proponents must explicitly demonstrate that the DNDC model is calibrated and must quantify the uncertainty around modeled emission reductions for the proposed Project Activities and the geographic region of the project. The methodology requires two different Calibration steps: (1) Regional

Calibration and Validation of the model using empirical gas flux data, and (2) Field-Specific Calibration of the DNDC model's crop sub-model. Regional Calibration is based on measured gas flux data from a field that is potentially different than the Project fields and is, therefore, valid for a whole region. Field-Specific Calibration uses the yield of an individual field and must be conducted for each field separately. After the model has been Calibrated, the remaining deviation between the modeled and measured results is used to calculate an Uncertainty Deduction which, when applied to modeled emission reductions, ensures that emission reductions remain conservative. The methodology allows creating Regional Calibration modules as add-ons to this methodology.

- Emission reductions from changes in rice management in a given year are permanent and cannot be reversed, regardless of future changes in management. This methodology thus requires no buffer contribution or other reversal risk mitigation mechanism.

- The Baseline Scenario is determined by distinguishing Critical Management Parameters – parameters that are directly or indirectly related to the Project Activities – from Non-Critical Management Parameters – parameters that are completely unrelated to the Project Activities. All Non-Critical Management Parameters must remain the same between the Project and the Baseline simulations; only the Critical Management Parameters are allowed to differ between the Project and Baseline Scenario.

- There are two options for setting the Baseline.

    - **Common Practice Baseline.** For proposed Project Activities that have limited Baseline adoption, the management for the Baseline Scenario must be set to the common practice across the industry. Specifically, a Project that plans to implement a practice that has an adoption rate below or equal to 5% within a Rice Growing Region can assume a Baseline Scenario that reflects the management across the producers that have not yet adopted the practice[3].

    - **Field-Specific Baseline**. For Project Activities that have an adoption rate greater than 5%, baseline emissions must (1) assume the same sequence and frequency of whether Project Activities occurred (i.e., baling or not, dry seeding or not, etc.) as the five-year historical sequence and frequency of Project Activity occurrence on each of the individual Rice Fields, (2) obtain the Model Parameters (e.g., planting

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[3] The 5% threshold is identical to the VCS' level of activity penetration threshold of 5% in the Standardized Methods Requirements document, available at http://v-c-s.org/sites/v-c-s.org/files/VCS%20Guidance%2C%20Standardized%20Methods%2C%20v3.1.pdf

date, fertilization amounts, tillage, etc.) of at least three out of five years on each of the individual Rice Fields that participate, unless rice was grown in only two out of the past five years, and (3) obtain five-year historical weather information.

Note that for both the common-practice baseline case and field-specific baseline case, data on historical management is needed following Applicability Condition 4.

- In this methodology, Baselines are only partially fixed *Ex-ante*: only the values of Critical Management Parameters are fixed *Ex-ante*. All Non-Critical Management Parameters used for *Ex-post* calculations must reflect the actual management and weather. This provision enables Project Proponents to incorporate the impact of weather and management on CH_4 emissions and growers' management decisions such as planting or harvesting dates. If Baselines were entirely fixed *Ex-ante*, artificial emission reductions could be generated due to extreme or outlying weather circumstances that are not captured under the *Ex-ante* Baseline. To avoid the generation of such artificial emission reductions, the Baseline must be recalculated *Ex-post* using the actual historical weather information. Likewise, since certain management decisions are dependent on weather (e.g., planting and harvesting dates), the Baseline Scenario must be recalculated using the actual values of these management decisions.

- The standard project Crediting Period is 5 years. The Crediting Period can be renewed in increments of 5 years if the following conditions are met.

    - After 5 years, Projects using a Field-Specific Baseline must switch to a Common Practice Baseline. However, the Project's Crediting Period can only be renewed if the baseline adoption rate is less than or equal to 50%. The latter provision ensures that a Baseline is set based on common practice that represents the practice of a majority of the producers. Any practice for which the adoption is smaller than 50% cannot be considered common practice because less than half of the producers are implementing the practice.

    - After 10 years, Projects using a Field-Specific Baseline in the first 5 years of a Project can renew the Crediting Period indefinitely as long as the Common Practice Baseline adoption rate of the practice remains smaller than 50%.

    - Projects initiated using a Common Practice Baseline can renew their Crediting Period after 5 years. However, if after 10 years, the Baseline adoption rate is still less than 5%, the Crediting Period can no longer be renewed. This limitation on Crediting Period renewal is based on the view that if after 10 years the practice remains at <5% adoption, there must be some other barrier to adoption and the reason for allowing early adopters in the program (to prime the system and demonstrate that a set of Project Activities can be successfully used) becomes less persuasive. If after 10 years, the Baseline adoption rate is greater than 5% but smaller than 50%, the Crediting Period can be renewed.

3.3.2 Importance of Spatial Aggregation

Given the complexity of the calculations, it is most likely that many Rice Fields, potentially managed by different growers, will be combined within one GHG Project Plan through an aggregating entity. This aggregating entity will streamline monitoring requirements, third-party verification and other legal and financial requirements that must be put in place to generate carbon credits.

The methodology requires that the Project include a minimum of five individual Rice Fields **or** 405 ha (1,000 acres) to reduce structural uncertainty in model predictions. The methodology’s Uncertainty Deduction incentivizes further aggregation since the (relative) deduction will be smaller if more fields are combined within a Project. It is not necessary that Rice Fields within one spatial aggregate be of the same soil type since the methodology still requires stratification of all Rice Fields according to soil type, execution of DNDC simulations separately for each stratum within in a field, and quantification and reporting of GHG emissions for all fields individually.

3.3.3 Environmental Impact

Winter-flooded Rice Fields represent critical habitat for waterbirds (Day and Colwell 1998). Therefore, any reduction in winter flooding cannot be credited under this methodology.

If removing straw after harvest (i.e., baling) impacts waterbird food sources, methodology developers will reevaluate the methodology to ensure that significant negative impacts on food sources are mitigated.

4 Applicability Conditions

The following conditions must be met for this methodology to be used:

1. The project area must include a minimum of five individual Rice Fields **or** 405 ha (1,000 acres)[4]. The fields can be distributed among different farmers/farms or located on one farming operation.
2. The participating Rice Fields are located in a Rice Growing Region for which the DNDC model has been successfully Calibrated for each of the proposed Project Activities following Section 14.1[5].
3. The Rice Fields included in the Project Area have been cropped under rice under flooded conditions for at least two out of five years preceding the first Project Activity on each field.
4. For each Rice Field, it is known whether the Project Activities were conducted for each of the five years preceding the start of the Crediting Period during which rice was grown. In addition, values for Model Parameters for each individual Rice Fields are available for three out of the five years preceding the start of the Crediting Period during which rice was grown[6], unless rice was grown only two out of the past five years, in which case two years of historical data are sufficient.
5. The Project does not contain any soils with organic carbon content in the top 30 cm greater than 3%[7].

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[4] The methodology contains a minimal size and/or minimal number of Rice Fields due to concerns related to the structural uncertainty of a biogeochemical model. Fluxes of trace gases such as CH_4 and N_2O are notably spatially variable. Therefore, the (structural) uncertainty around modeled results decreases with increasing area (see Section 10.1.2).

[5] This requirement is necessary because the quantification of uncertainty around modeled results can only be done with local and specific data.

[6] Model Parameters must indicate rice variety and cultivar planted, yields, planting and harvesting dates, indicative flooding and draining dates throughout the year, yields, residue management and fertilization dates and amounts. Note that these data are confidential and do not have to be made publically available.

[7] N_2O emissions become more variable with increases in soil carbon content. To remain conservative and ensure that the biogeochemical model performs well, projects are limited to soils with carbon content less than 3%. The DNDC model has been calibrated primarily for soils with carbon contents smaller than this threshold.

5 Project Boundary

5.1 Geographic Boundary

The boundaries of one or more Rice Fields constitute the project boundary as the location where primary emission reductions are generated. Secondary emissions taking place outside of the project boundary are included in the carbon accounting of this methodology and covered in sections 8.3 and 9. The following requirements are needed related to geographic boundaries:

- A minimum of five Rice Fields **or** 405 ha (1,000 acres) must be included within the GHG Project Plan.
- The geographical coordinates of the boundaries of each Rice Field must be unambiguously defined and provided to the Validation/Verification Body (VVB) in .kml or shapefile format. Note that geographic coordinates shall remain confidential and do not have to be made publically available.
- This methodology allows for “Programmatic Aggregated Projects”, meaning that it is allowed to add new Rice Fields areas to an existing Project after the start of the Crediting Period as long as all the applicability criteria are met for each new Rice Field.

Large or heterogeneous fields must be stratified into homogeneous units or strata. Valid parameters that must be used to stratify the project area are:

- Common rice cultivation practices
- Biophysical conditions (soil type, climate, and water quality)
- Landscape type (sloping terrain, flood plains, etc.)
- Differences in legally binding requirements affecting the Project area

If the Project consists of parts that differ in one or more of the parameters listed above, and the emission reductions calculated for each of these different parts differ by more than 5% among each other, the different parts must be considered as separate strata. A description and justification of the stratification procedure must be included in the GHG Project Plan.

The Project Proponent is allowed to re-stratify Rice Fields after validation. Examples of reasons why re-stratification after validation occurs include: a Rice Field is split into two Rice Fields after validation; one side of a Rice Field has different characteristics than the other side that were not known at validation; or other reasons for re-stratification justified to the VVB.

5.2 Greenhouse Gas Boundary

Changing management practices potentially affects each of the three biogenic greenhouse gases. The greenhouse gases included in and excluded from the Project are shown in Table 1. It is allowed to include additional sources and gases in a Regional Calibration module.

266 **Table 1. Overview of included greenhouse gas sources.**

	Source	Gas	Included?	Justification/Explanation
Baseline Scenario	Soil microorganisms metabolizing soil C, root exudates, and soil mineral N	CO_2	Yes	Significant changes in CO_2 emissions due to Project Activities if straw is removed (baled) after harvest.
		CH_4	Yes	Significant Baseline emission source if Rice Fields are flooded.
		N_2O	Yes	Significant Baseline emission source if fertilizer is applied.
	Emissions from burning straw	CO_2	Yes	Significant emission if straw residues are burned
		CH_4	Yes	Significant emission if straw residues are burned.
		N_2O	No	N_2O emissions from burning residue are insignificant due to low N content of rice straw
Project Scenario	Soil microorganisms metabolizing soil C, root exudates, and soil mineral N	CO_2	Yes	Significant changes in CO_2 emissions due to Project Activities if straw is removed.
		CH_4	Yes	Significant emission source affected by Project Activities if flooding duration and periods are changed. Emissions from ruminants are potentially significant if feed is replaced by low-nitrogen rice straw.
		N_2O	Yes	Significant emission source affected by Project Activities if fertilizer amounts and dates are changed or seeding practices are altered[8]
	Emissions from burning straw	CO_2	Yes	Significant emission if straw residues are emitted
		CH_4	Yes	Significant emission if straw residues are emitted.
		N_2O	No	N_2O emissions from burning residue are insignificant due to low N content of rice straw
	Emissions from alternative uses of straw	CO_2	Yes	CO_2 emissions from decomposition of rice straw management are insignificant. However, fuel used to collect straw is potentially significant
		CH_4	Yes	Significant if rice straw decomposes anaerobically
		N_2O	No	Due to the low N content of rice straw, N_2O emissions during decomposition of rice straw are assumed insignificant.
	Increases in emissions related to production and transportation of N, P, and K fertilizer due to project activities	CO_2	Yes	Increases in emissions are only to be included if fertilization increases to replenish soil nutrients after straw removal (baling), and shall be omitted when no baling is done as a project activity.
		CH_4	Yes	Increases in emissions are only to be included if fertilization increases to replenish soil nutrients after straw removal (baling), and shall be omitted when no

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[8] *Dry-seeding*, as defined in Section 6 may increase N_2O emissions in the period right after seeding and before flooding, when the soil is kept moist and inorganic N from fertilizer is readily available.

				baling is done as a project activity..
		N_2O	Yes	Increases in emissions are only to be included if fertilization increases to replenish soil nutrients after straw removal (baling), and shall be omitted when no baling is done as a project activity..

Project Proponents are allowed to use this methodology in combination with a separate methodology that credits reduced N_2O emissions from optimized fertilizer management[9]. When this methodology is used in conjunction with a fertilizer reduction methodology, only one GHG Project Plan shall be developed and the N_2O quantification shall occur based on the accounting procedures in the fertilizer reduction methodology. When the DNDC model is used for quantification in the fertilizer reduction methodology, only one simulation run for Baseline and project conditions shall be used that is used for both the fertilizer reduction methodology and this methodology.

5.3 Temporal Boundary

Credits are calculated in increments that start and end at specific points during the growing season. Specifically:

- If **rice is grown continuously**, the Vintage Year shall start immediately after a harvest and end immediately after a subsequent harvest.
- When the **crop following the current year is not rice** (e.g., fallow, soy, etc.), the Vintage Year shall extend over the winter period and end at the time of spring tillage and/or fertilization to prepare planting of the following crop.
- When the **crop preceding the current year is not rice**, the Vintage Year shall start at the time of spring tillage and/or fertilization to prepare planting of the rice crop.

Because this methodology is specific to GHG emissions from rice production, no credits shall be generated for fallow seasons or during years where a crop other than rice is grown. In addition, farmers are allowed to remain in the Project without generating credits for one or more years if conditions are such that Project Activities cannot be implemented.

The Crediting Period includes five growing seasons and starts when the Vintage Year for the first Rice Field in the Project starts and ends when the Vintage Year for the last Rice Field in the Project ends, regardless of whether rice was grown in the last

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[9] Such as the methodology “N2O Emissions Reductions through Changes in Fertilizer Management” available at http://americancarbonregistry.org/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management

growing season. A Crediting Period can be renewed following the rules in Section 12.4.

The Crediting Period always applies to the Project overall rather than being field-specific. If fields are added after validation, they are subject to the Crediting Period end date of the Project they are joining.

6 Procedure for Determining the Baseline Scenario and Demonstrating Additionality

Determining the Baseline Scenario and demonstrating additionality shall occur for each Rice Field. For each of the Rice Fields included in the Project, Project Proponents must identify credible Baseline Scenarios describing what would have occurred on the field in absence of the Project Activities. The identified credible Baseline Scenarios must be limited to agricultural land uses. A conversion to non-agricultural land use is not allowed as a possible Baseline Scenario, and all areas that are likely to be converted to non-agricultural uses must be excluded from the Project.

There are two options for determining the Baseline Scenario. Projects that implement a Project Activity that has an adoption rate less than or equal to 5% of the rice acres in the Rice Growing Region where the Project is located must use a Common Practice Baseline and are automatically additional (provided the practice exceeds legal/regulatory requirements applicable on that Rice Field). Projects that implement a Project Activity with an adoption rate greater than 5% of the rice acres in the Project's Rice Growing Region must use a Field-Specific Baseline and must explicitly demonstrate additionality using the ACR three-prong test and associated tools.

6.1 Determining whether a Common Practice Baseline can be used

An individual Project Activity for which the Baseline adoption rate is less than or equal to 5% of the rice acres within a Rice Growing Region must use a Common Practice Baseline. Note that a Project including multiple Rice Fields may have some fields on which the Common Practice Baseline is used and others on which a Field-Specific Baseline is used, depending on the Project Activities included. Note also that in the case of Rice Fields on which multiple Project Activities are implemented simultaneously (e.g. ACT2 dry seeding and ACT3 early drainage on the same Rice Field), the Baseline Scenario may be partly Common Practice (for activities with <5% adoption) and partly Field-Specific (for activities with >5% adoption)

There are two options to determine the Baseline adoption rate of a Project Activity: using survey data, or using expert opinion.

- **Survey data or Remote Sensing data**. The adoption rate may be determined using a statistically valid survey or remote sensing analysis of producers within the Rice Growing Region where the Project is located. The analysis must be set up so that a precision of 10% with 90% confidence is attained. The fields must be selected randomly over all the fields within the Rice Growing Region. The average of all available survey data (including those published in validated GHG Project Plans) must be used to calculate the baseline adoption rate. For initial validation, one adoption rate in the past 5 years suffices to set the baseline adoption rate. However, upon renewal of a project's Crediting Period, the baseline adoption rate must be set as the average of at least 2 adoption rates in the 5 years preceding the Crediting Period.[10]

- **Expert opinion**. If 3 independent experts assert that the baseline adoption rate of a given practice is less than or equal to 4% of the acres on which rice is grown within the Rice Growing Region, no survey has to be conducted, and projects using the practice must use a Common Practice Baseline. The independent experts must have at least 10 years of relevant experience in rice agronomy and must be associated with an academic institution, government institution, or must be a full-time certified crop advisor with experience in the Rice Growing Region. The validity of the independent experts shall be evaluated during validation of a GHG Project Plan by a third-party auditor.

6.2 Determining Additionality

An individual Project Activity that exceeds applicable legal/regulatory requirements[11], and for which the baseline adoption rate is less than or equal to 5% of all acres on which rice is grown within one Rice Growing Region, is automatically additional and no further additionality test must be conducted. Project Activities for which the baseline adoption rates is greater than 5% must explicitly demonstrate additionality using ACR's project-specific three-pronged test of additionality or a comparable ACR-approved additionality tool.[12] This demonstration needs to be conducted at project commencement and documented in the GHG Project Plan.

For the three-prong additionality test, Project Proponents shall demonstrate that the proposed change in management: 1) exceeds regulatory/legal requirements; 2) goes beyond common practice; and 3) overcomes at least one of three implementation barriers: institutional, financial or technical. The barrier analysis shall consider the likelihood of at least three potential Baseline Scenarios:

1. Rice cultivation with a continuation of the management before Project Start Date with respect to seeding procedure, straw management, pre-harvest drainage date, or any other management aspect of rice cultivation.
2. Rice cultivation with a change in management before Project Start Date with respect to seeding procedure, straw management, pre-harvest drainage date,

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[10] For example, an extension service publishes annual adoption rates of a specific practice. The five adoption rates of the five years before the project's crediting period renewal are 4%, 6%, 6%, 5%, and 3%; the average is 4.8% and a renewal of the crediting period is not allowed after the first renewal period.

[11] Specifically, the proposed Project Activity is not required by any law related to air quality, water quality, water discharge, nutrient management, safety, labor, endangered species and protection, or any other law in the jurisdiction to which the individual Rice Field belongs.

[12] Such as the "ACR Tool for Determining the Baseline and Assessing Additionality in REDD Project Activities" or the CDM Tool for the Demonstration and Assessment of Additionality at http://cdm.unfccc.int/methodologies/PAmethodologies/tools/.

or any other management aspect of rice cultivation, in the absence of registration as an ACR Project Activity.

3. Discontinuing rice cultivation and converting the land to an alternative agricultural use.

It must be demonstrated that scenario 1, rice cultivation with a continuation of the management before project Start Date, is the most likely baseline scenario by showing that it is more financially attractive than, or faces lower barriers than, all alternative scenarios.

Project Proponents only need to demonstrate additionality once for each Rice Field. The demonstration of additionality of a field added after validation shall be included in a monitoring report.

7 Baseline Emissions

Under this methodology, the calculation of GHG emissions under the Baseline and Project Scenarios must be evaluated using the version of the DNDC model posted at http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emission-reductions-in-rice-management-systems. It is possible that future updates of this methodology will include newer versions of the DNDC model and quantification procedures, reflecting advances in the science of predicting GHG emissions. For each individual Rice Field, a separate model run must be executed for the Baseline Scenario and an appropriate input parameter file ("*.dnd") must be available to the auditor.

There is a large body of evidence that demonstrates that the DNDC model can predict GHG emissions from rice systems under a range of different management conditions (planting, fertilization, straw management, winter flooding, etc) with Accuracy (*Li et al*., 2002; *Cai et al*., 2003; EDF, 2011), on the condition that the model is well calibrated for local conditions. This methodology specifies how the Model Parameters must be set so that the emissions calculated by DNDC are valid to be used to calculate credits. A detailed explanation on the meaning and impact of each of the Model Parameters and how to use DNDC is beyond the scope of this methodology. More practical information on how to use DNDC can be found in the DNDC User Manual, also available at http://www.dndc.sr.unh.edu/.

7.1 Duration and Structure of Model Simulations

Table 2. Schematic of the modeling period.

Year -20 to -15	Year -15 to -10	Year -10 to -5	Year -5 to 0	Year 0 to 5	Year 5 to 10
Historical Period				*Crediting Period*	
Model Equilibration			Crop Yield Calibration	Period 1	Period 2

Table 2 indicates the structure of a DNDC modeling simulation. The following is required:

- The duration of a DNDC model simulation must be at least 20 years before the start of the Crediting Period so that the model can attain equilibrium in certain critical variables for which empirical data is lacking, such as the sizes and the quality of the different carbon pools, and the inorganic nitrogen contents of soil pore water. This period is referred to as the Historical Period. In case a Field Specific Baseline is used, the Model Parameters for the 20-year Historical Period must be set by repeating the frequency of historical occurrence of Project Activities during the last five years before the start of the Crediting Period four times, while using the management parameters of at least three out of five years before the start of the Crediting Period unless otherwise noted. However, if rice was grown only two out of the past five years, two years of historical data are sufficient to parameterize the DNDC model.

- The management parameters of at least three out of the last five years preceding the Project Start Date, from the producer's own Rice Fields, must be used to calibrate the modeled crop yields during the field-specific model calibration step (see Section 7.4.2).
- After the start of the Crediting Period, the model must be simulated in five-year increments. The GHG Project Plan must include at least one five-year cycle after the start of the Crediting Period.

7.2 Identifying Critical vs. Non-Critical Management Parameters

For each Project Activity, all Model Parameters shall be divided into Critical Management Parameters and Non-Critical Management Parameters. Critical Management Parameters are Model Parameters for the DNDC model that are directly or indirectly impacted by the Project Activities. Non-Critical Management Parameters are Model Parameters related to agricultural management but not impacted by Project Activities.

For example, if straw baling is a Project Activity, the residue left after harvest would be a Critical Management Parameter; if dry seeding is a Project Activity, date of first flood is a Critical Management Parameter. Sufficient attention must be paid to all potential indirect impacts of the Project Activities on nutrient, weed, crop residue, and flooding management. In the example of straw baling, the amount of nitrogen fertilizer applied is a Critical Management Parameter as well because it is possible that additional nitrogen fertilizer was applied to compensate for nutrient losses during straw removal. This additional nitrogen fertilizer will potentially lead to an increase in N_2O emissions, and must, therefore, be included as a Critical Management Parameter. Note that the loss of other nutrients such as K will likely have to be compensated as well by increasing the amount of K fertilizer; however, the GHG emissions related to the increase in application rates for other nutrients are considered insignificant. Project Proponents must present in the GHG Project Plan a comprehensive list of the all Model Parameters and indicate which ones are critical and which ones are not.

If a pre-approved Regional Calibration module is used, Project Proponents shall use the identification of Critical Management Parameters presented in the module.

7.3 Model Parameterization

Parameterization of a process-based model is the step of selecting Model Parameters that the model will use for simulation. For DNDC parameters include: soil conditions (organic matter, texture, pH, porosity, wilting point, bulk density, etc.), weather (temperature, precipitation, wind speed, solar radiation, etc.), and agricultural management (planting and harvest dates, tillage, fertilizer use, irrigation, etc.).

7.3.1 Weather and Climate

Weather significantly affects CH_4 emissions and hence the reduction in CH_4 emissions due to alternative crop management. Variations in temperature not only directly affect CH_4 emissions; climate also affects annual CH_4 emissions since climate controls the length of the growing season: the exact planting date is dependent on the average temperature and rainfall in April-May and how many fields a farmer has. The harvesting date is dependent on the cumulative growing degree days since planting. Therefore, while *Ex-ante* baseline emissions must be calculated using five years of historical weather data preceding the start of the Crediting Period, *Ex-post* the Baseline must be re-calculated with the actual weather. The following requirements must be met:

- Daily climate data must come from a weather station that is located maximally 50 miles away. If the Project is located in California, it is recommended to use weather data from the nearest CIMIS weather station (http://wwwcimis.water.ca.gov).
- Weather data for the five years preceding the start of the Crediting Period must be collected. Weather data for the Historical Period must be set by repeating this five-year weather data set four times as described in 7.1. After the start of the Crediting Period, the same five-year weather data must be used and repeated, if necessary. As indicated before, *Ex-post*, actual weather data must be used for all emission calculations.
- Daily values of maximum temperature, minimum temperature, rainfall, and solar radiation must be collected and formatted according to the DNDC model's "Jday, MaxT, MinT, Rainfall, Radiation ($MJ/m^2/day$)" format, which is the DNDC model's climate file mode 1.

Table 3. Input parameters related to weather.

Input Parameters	Unit
Jday (Julian day)	Day of year
MaxT (Maximum temperature)	°C
MinT (minimum temperature)	°C
Rainfall	$mm\ day^{-1}$
Radiation	$MJ\ m^{-2}\ day^{-1}$

7.3.2 Soil Data

For each of the Rice Fields in the Project, it is recommended that soil texture, organic carbon content, bulk density and soil pH are empirically measured and the measurements used to parameterize the relevant input Model Parameters. At least 3 samples shall be taken for each agricultural field and measured separately. Averages and standard errors of the measurement shall be used in subsequent calculations. Official soil laboratory statements must be included with the GHG Project Plan.

If no empirical measure values for soil texture, organic carbon content, bulk density and soil pH are available, it is allowed to use values queried by SSURGO, or STATSGO if no SSURGO data are available.[13]

The standard values from DNDC for field capacity, wilting point and hydraulic conductivity for the closest clay content as the one that was measured (or taken from SSURGO or STATSGO) shall be used.

The value for the initial concentration of NO_3^- and NH_4^+ in the soil surface must be set to 0.5 and 0.05 mg N/kg, respectively, which are appropriate initial values commonly used during DNDC model simulations. Since model simulations start at least 20 years prior to the start of the Crediting Period, concentrations of NO_3^- and NH_4^+ in the surface soil will eventually equilibrate.

Table 4. Input parameters related to soil data.

Input Parameters	Unit
Clay content	$kg\ kg^{-1}$ soil
Sand content	$kg\ kg^{-1}$ soil
Organic carbon content	$kg\ kg^{-1}$ soil
Bulk Density	$g\ cm^{-3}$
pH	-

7.3.3 Critical Management Parameters (only during Rice Growing Years)

The baseline scenario for Rice Fields that use a Field Specific Baseline is set so that the Baseline follows the same sequence of Project Activity Practices on that field as the management during the 5-year period before the project start. The Critical Management Parameters of the Baseline are set to the values of the management during at least three out of five years preceding the Project Start Date until the next baseline update. However, if rice is only grown two out of the five years preceding the Project Start Date, two years of historical data are sufficient.

Rice Fields that use a Common Practice Baseline must set the Critical Management Parameters based on actual management from at least 5 fields on which the common practice management is done. In addition, the management data shall be reviewed by at least 3 independent peer reviewers such as farm advisors, extension agents or academic scientists. Contact information of the three peer reviewers shall be provided to the VVB.

Values for the Critical Management Parameters shall be fixed *Ex-ante* and used for all *Ex-post* calculations of the Baseline. Critical Management Parameters are not allowed to change until the Baseline is updated. In case new Rice Fields are added,

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[13] SSURGO is the Soil Survey Geographic Database of the USDA - Natural Resources Conservation Service (NRCS). See http://soils.usda.gov/survey/geography/ssurgo/. STATSGO is NRCS's U.S. General Soil Map. See http://soils.usda.gov/survey/geography/statsgo/.

the values of the Critical Management Parameters of the existing Project shall remain fixed. Historical data collected throughout multiple years must be used consecutively cycled through during the Baseline period.

7.3.4 Non-Critical Management Parameters

All Non-Critical Management Parameters must be set based on information from the last 5 years preceding the Start Date (either from the fields themselves in case of a Field Specific Baseline, or from areas as explained in 7.3.3 in case of a Common Practice Baseline) for *Ex-ante* calculations. However, for *Ex-post* calculation of emission reductions, the values of Non-Critical Management Parameters shall be set to actual values monitored during the period being reported and verified.

Thus Non-Critical Management Parameters are not fixed *Ex-ante* and must be identical between the Project and Baseline Scenarios in both the *Ex-ante* and *Ex-post* calculations.

Straw burning events must be scheduled in the Baseline Scenario as they occur according to surveys and historical data. Straw burning during the Crediting Period must follow all relevant regulations in the jurisdiction in which the Project is located.

All management during years in which no rice is grown (i.e. fields are fallow, or another crop is grown) shall be considered non-critical. As explained in section 5.3, no credits shall be generated during these years but the fields are allowed to remain in the Project without generating credits. Crediting can only start and end at one specific time during every year, i.e. the start and end of the Vintage Year, as specified in 5.3. During fallow seasons or years where no rice is grown, the DNDC model shall be parameterized on a best-effort basis.

7.3.5 Using Dates in Baselines

Planting and harvesting dates vary from one year to the next, depending on the weather. Therefore, it is necessary to adapt the Baseline Scenario given the actual weather. Every date used in Baseline determination shall be relative to either the planting date or harvesting date. For example, dates of fertilization could be set at 1 week before planting for the pre-plant fertilizer and at the day of planting for starter fertilizer. Similarly, dates of draining a field by stopping pumping and/or pulling the boards could be set at 2 weeks before harvest, and the date for straw incorporation could be set 2 weeks after harvesting.

For Projects that use a Common Practice Baseline, dates that are Critical Management Parameters, i.e. dates that are different between the Project and Baseline Scenarios, shall be set relative to the planting and harvesting dates of producers employing common practice.

Dates that are not Critical Management Parameters, i.e., dates that are equal in the Project and Baseline Scenarios, shall be set relative to the actual planting and harvesting dates of the specific field.

For example, the planting date for dry seeding is different than when water seeding is used. Assume dry seeding has 4% adoption in the Rice Growing Region. Projects using a Common Practice Baseline that include dry seeding shall use the planting date used by 96% of producers during the Vintage Year. In contrast the planting date for fields on which baling occurs will be similar to fields where no baling occurs; in such cases the actual planting date for the Rice Field would be used to set the Baseline.

7.4 Model Calibration and Model Validation for Rice Growing Seasons

Calibration of a process-based model such as DNDC is the process of tuning the coefficients of Model Parameters to observations. For example, setting the maximum yield or C/N values of roots, leaves and stems of a particular crop is Calibration. The Calibration process can be applied to both internal and external parameters. However, Calibration of the internal Model Parameters is done only in model development by the developer while tuning of the external Parameters is done in a Regional Calibration Module and by the Project Proponent (see below).

Model Validation is the process of evaluating a calibrated model's results using field-measured data and quantifying the residual (structural) uncertainty. Model Validation requires independent measurements (measurements that were not used in calibration of internal parameters) for comparison with model estimates.

Two different Calibration steps must be conducted: a Regional Model Calibration and validation, in which the use of the DNDC model in a similar area as the Project is demonstrated, and a field-specific model calibration, in which field-specific yields are used to tune the maximal yield parameter in DNDC. Because credits can only be generated during rice growing periods, the calibration and model validation steps only have to be conducted for periods where rice is grown. Even though it is optimal to collect the calibration and model validation data from the Project Rice Fields, this is not strictly necessary; however yield data must come from the Rice Fields themselves (see 7.4.2). The Regional Model Calibration is representative for the whole Rice Growing Region and can be used for many Rice Fields and projects, while the field-specific calibration must be repeated for each different Rice Field. By distinguishing the two levels of Calibration, the effort to calibrate multiple Projects is greatly reduced with only a minimal reduction in representativeness of the calibration and model validation data. This distinction is justified as the management, climate, and general soil types remain similar across a region, while cropping yields are potentially very field-specific. However, whenever possible, both methane flux and yield data shall be collected from the Project area.

7.4.1 Regional Model Calibration and Model Validation and Calculation of Structural Uncertainty Deduction

During the Regional Model Calibration and Model Validation, measured methane fluxes from the Project area itself or a field within the same Rice Growing Region as the participating Rice Field must be used to calibrate the DNDC model. The methodology does not prescribe a specific procedure for calibration. Rather, the methodology requires Project Proponents to present in the GHG Project Plan values for each of the Model Parameters of the DNDC model and a set of at least eight observations of modeled results vs. measured fluxes. Project Proponents are allowed to skip this step if an appropriate pre-approved Regional Calibration Module is available.

Methane fluxes must be calculated from the rate of change in chamber concentration, chamber volume, and soil surface area as described in Hutchinson and Mosier (1981) and Rochette (2008)[14]. Methane fluxes shall be derived using standards and procedures used in the peer-reviewed literature, and must be measured in a laboratory that uses standard operating procedures available for review by the VVB if requested. At least one full year of measurements must be included. In addition it is recommended that:

- The chamber methane concentrations be measured using established analytical techniques such as Gas Chromatography, a Tunable Diode Laser or other laser-based equipment.
- The detection limit of the analytical equipment be minimally 20 μl l^{-1} (ppbv).
- The analytical equipment be calibrated by a trained professional to manufacturer specifications to achieve a precision that is smaller than 5% before each measurement.
- Methane fluxes be measured at least twice a week during periods with rainfall and around draining and wetting events (“critical periods”); every two weeks during non-critical periods of the growing season; and at least every 6 weeks outside of the rice growing season.
- Two or 3 years of measurements be included.

Annual emissions must be calculated by interpolating daily emissions between sampling days using linear interpolation, which is a broadly accepted mechanism in the scientific peer-reviewed literature (Hutchinson and Mosier, 1981).

Using the pairs of modeled results vs. measured methane fluxes, it must be explicitly tested that the model calibration strategy is unbiased. The lack of bias must be tested by following the procedures outlined in section 14.1.2.

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[14] Soil Sci. Soc. Am. J. 72:331-342

The remaining uncertainty between modeled and measured values is a conservative estimate of the Structural Uncertainty of using the DNDC model within the Rice Growing Region. The Structural Uncertainty is related to the inherent uncertainty of process-based models that remains even if all input data were error-free. A deduction for the Structural Uncertainty must be calculated based on the residuals between modeled results and measured gas fluxes using the procedures in this section. By applying this deduction, it can be ensured that simulated emission reductions will remain conservative at a confidence level of 90%. The full derivation of the uncertainty deduction is included in section 14.1.

Assume m pairs of $\left(Y_{field}(i), Y_{model}(i)\right)$ pairs of annual fluxes of field measurements and simulated results.

Calculate the standard deviation of the difference of the field measurements and simulated results:

$$s = \mathrm{stdev}\left(Y_{field,i} - Y_{model,i}\right) \qquad \text{[EQ 1]}$$

The Structural Uncertainty deduction should then be calculated as:

$$u_{struct} = s\sqrt{2n(1-\rho)} \cdot t_{inv}(0.90, k) \qquad \text{[EQ 2]}$$

Where:

u_{struct} = Absolute deduction for structural uncertainty for the whole Project Area [kg CO_2-eq]
s = Standard deviation of the residuals between modeled and measured values
$Y_{field,i}$ = Field measurement of experiment i
$Y_{model,i}$ = Simulated flux of experiment i
u_{struct} = Structural uncertainty factor
ρ = Correlation between Project residuals and Baseline residuals
t_{inv} = Inverse of the cumulative t-distribution with a specific confidence and degrees of freedom
k = Number of pairs of modeled and measured values used for model verification.
n = Size of Project Area [ha]

7.4.2 Field-specific Model Calibration

After the regional model calibration, it is required to conduct an additional field-specific Calibration for each Rice Field included in the Project. The field-specific Calibration tunes the crop sub-model of DNDC to the exact yields attained on each Rice Field. The field-specific Calibration shall always use yield data, but when the yield-based Calibration is insufficient to ensure that DNDC predicts the recorded yields during at least three out of five years before the start of the project with a maximal relative Root Mean Squared Error (RMSE) of 10% of the observed means, the field-specific Calibration must also include additional crop data. However, if rice is grown only two out of the five years preceding the Project Start Date, yield data from these two years suffice to apply this test. These more general crop data include the default partitioning of carbon into different plant compartments, C/N ratio of the different plant compartments, and the thermal degree days required to reach maturity.

- **Step 1 – selecting the right parameter set for the variety used.** The specific rice variety used strongly impacts CH_4 emissions (Lindau et al., 1995). The crop parameters used must be appropriate for the rice variety used by the farmer. In addition, the “maximum biomass” parameter must be manually optimized until the actual cropping yield coincides with the cropping yield simulated by the DNDC model. Parameters for M-206 rice variety, based on calibration using field data from the Maxwell and Biggs study sites (Bossio et al. 1999, Fitzgerald et al. 2000 and Horwath et al., 2011, preliminary unpublished results), are given in Table 5 below. As more field data become available, model Calibration may improve, hence the parameters in Table 5 may be updated in future versions of this methodology. In addition, crop parameterization values for other varieties will be published as an addendum to this methodology as they become available.

Table 5. DNDC input parameters based on calibration data from two study sites, for the M-206 rice variety commonly grown in California.

DNDC Input parameter	M-206
Rate_reproductive	0.044
Rate_vegetative	0.015
Psn_efficiency	0.4
Psn_maximum	47
Initial_biomass	12.5
Cover_crop	0
Perennial_crop	0
Grain_fraction	0.6
Shoot_fraction	0.3
Root_fraction	0.1
Grain_CN	30
Shoot_CN	65
Root_CN	65
TDD	3000
Water_requirement	508
Optimum_temp	25
Max_LAI	6
N_fixation	1.05
Vascularity	1

Growers are allowed to change varieties after the Start Date as long as the new variety is well parameterized. If Project Activities did not impact the decision to change the variety, variety shall be considered a Non-Critical Management Parameter. However, if the variety change is the result of one of the Project Activities, variety shall be considered a Critical Management Parameter

- **Step 2 – tuning the "maximum biomass" parameter of the DNDC model**. The "maximum biomass" parameter of the DNDC model must be manually tuned using yield data so that DNDC predicts the recorded yields during at least three out of five years before the start of the Project with a maximal relative Root Mean Squared Error (RMSE) of 10% of the observed means. However, if rice is grown only two out of the five years preceding the Project Start Date, applying this test with two years of data suffices. If this is not possible by adjusting the "maximum biomass" parameter, one or both of the following options are to be followed until modeled yields are within a maximal relative RMSE of 10% of observed means.
    - If the "Crop" pane of the DNDC results (with title "Crop Yields and Heat-Water-Nitrogen Stresses") indicates that the modeled "Water demand" value is greater than the "Water uptake" value during years with normal weather, the value for "water demand, g water/g DM" in the "Crop" pane of the Farming Practice Management dialog (equal to the "Water_requirement" parameter in the .dnd file) must be reduced until the "Water demand" is equal to the "Water uptake" value.
    - Similarly, if the same pane indicates that the "Temperature demand" value is greater than the value for "Thermal degree days for maturity", the "Thermal degree days for maturity" (equal to the "TDD" parameter in the .dnd file) must be reduced until the "Temperature demand" is smaller than or equal to the value of "Thermal degree days for maturity".

- **Step 3 – Re-parameterization of crop if no sufficient correspondence is achieved.** If sufficient correspondence was achieved during step 2, this step shall be skipped. However, if no sufficient correspondence can be achieved by following the procedure described above, Project Proponents must calibrate the other crop parameters, including biomass allocation to roots, leaves/stems and grain and the C/N ratio of roots, leaves/stems and grain using laboratory measurements, scientific literature, and/or a cross-calibration with a more sophisticated crop growth model such as the DD-50 model[15]. However, it is up to the Project Proponents to execute a proper Calibration and provide all the necessary justification to the third-party VVB. Because it is very challenging to define rigorous criteria to calibrate each of the crop parameters and verify their

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[15] The Missouri Rice Degree Day 50 (DD-50) model is available at http://agebb.missouri.edu/rice/ricemodel.htm

impact on simulation results, a third-party VVB may request that the new calibration be reviewed by an independent expert.

7.5 Quantification of Baseline Emissions

Separate model simulations of the Baseline Scenario must be conducted for each of the individual Rice Fields. The Project Proponent shall then look up the annual values for “Flux rates” from the “Greenhouse gas” page of the DNDC results.

$$BE_{y,i} = \frac{44}{12} \cdot [CO2 - C]_{baseline,y,i} + 310 \cdot \frac{44}{28} \cdot [N2O - N]_{baseline,y,i} + 21 \cdot \frac{16}{12} \cdot [CH4 - C]_{baseline,y,i} \quad \text{[EQ 3]}$$

Where:

$BE_{y,i}$ = Baseline emissions in year y for individual Rice Field i [kg CO_2-eq ha^{-1} yr^{-1}]

$[CO2 - C]_{baseline,y,i}$ = Baseline carbon dioxide flux rate from changes in SOC content in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]

$[N2O - N]_{baseline,y,i}$ = Baseline nitrous oxide flux rate in year y for individual Rice Field i as reported by DNDC [kg N ha^{-1}]

$[CH4 - C]_{baseline,y,i}$ = Baseline CH_4 flux rate in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]

Following ACR requirements, 21 and 310 are the Global Warming Potentials for methane and nitrous oxide, respectively, as developed in the IPCC Second Assessment Report and reported in Table 2.14 of the IPCC 4th Assessment Report of Working Group 1, available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf.

8 Project Emissions

Similarly to the Baseline emissions, Project emissions of CO_2, CH_4 and N_2O must be calculated using DNDC. For each individual Rice Field, a separate model simulation must be executed for the Project scenario and an appropriate input parameter file ("*.dnd") must be available to the VVB.

8.1 Duration and Structure of Model Simulations

All Critical and Non-Critical Management Parameters for the Historical Period for the Project scenario simulations must be identical to the Model Parameters for the Historical Period for the Baseline Scenario, except for Projects that are using a Common Practice Baseline. Projects that are using a Common Practice Baseline shall use their historical field-specific management for the Historical Period for the *Ex-ante* Project scenario simulation. After the start of the Crediting Period, only the Critical Management Parameters are allowed to be different between the Baseline and Project scenarios. Actual, monitored values of Critical and Non-Critical Management Parameters are used for *Ex-post* calculations.

8.2 Model Parameterization

The Parameterization of weather and soil input parameters for model simulations of Project emissions shall be similar to the Parameterization of input parameter values for model simulations of the Baseline. In addition, all values for Non-Critical Management Parameters, identified in Section 7.2, shall be the same between the Baseline and Project simulations. Only the values of Critical Management Parameters are allowed to be different between the Baseline and Project simulations. For *Ex-ante* calculations, values for the Critical Management Parameters under the Project scenario must be set based on expert opinion. For *Ex-post* calculations, values for the Critical Management Parameters must be set using farming records and empirical data of the Project Activities actually implemented.

8.3 Quantification of Project Emissions

8.3.1 Gross Project Emissions

Similarly to the Baseline simulations, the DNDC model must be run separately for each of the individual Rice Fields. The annual Project emissions correspond to the annual values for "Flux Rates" from the "Greenhouse gas" page of the DNDC results.

$$PE_{y,i} = \frac{44}{12} \cdot [CO2 - C]_{project,y,i} + 310 \cdot \frac{44}{28} \cdot [N2O - N]_{project,y,i} + 21 \cdot \frac{16}{12} \cdot [CH4 - C]_{project,y,i} \qquad \text{[EQ 4]}$$

Where:

$PE_{y,i}$ = Project emissions in year y for individual Rice Field i [kg CO_2-eq ha^{-1} yr^{-1}]

$[CO2-C]_{project,y,i}$ = Project carbon dioxide flux rate from changes in SOC content in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]

$[N2O-N]_{project,y,i}$ = Project nitrous oxide flux rate in year y for individual Rice Field i as reported by DNDC [kg N ha^{-1}]

$[CH4-C]_{project,y,i}$ = Project CH_4 flux rate in year y for individual Rice Field i as reported by DNDC [kg C ha^{-1}]

8.3.2 Off-Field Emissions from Rice Straw ($OFEF$)

In the case of Projects implementing ACT1, the end uses for rice straw must be explicitly identified so that any potential increase in emissions due to the removal and subsequent end use of rice straw can be accounted for. Project Proponents shall either use the default emission factors in Table 6, or use their own emission calculations on the condition it can be demonstrated that the reported emissions are conservative (Summers and Williams, 2001).

Baling rice straw potentially increases emissions during swathing, raking or baling operations, but will reduce emissions related to the avoidance of post-harvest chopping and disking. In addition, depending on the end-use of the baled straw, additional off-field emissions potentially occur. Table 6 contains the net emissions for the following end-uses that were identified in ANR (2010):

- **Dairy replacement heifer feed.** Wheat straw is traditionally used in heifer feed. Rice straw can be used if it is cut to the right length (ANR, 2010). Quality of the straw (crude protein content, moisture content, etc.) must meet minimal standards before it can be used. It is possible that there are some effects on enteric fermentation by feeding lower quality straw. Only emissions from increased enteric fermentation due to the lower straw quality must be accounted for.
- **Beef cattle feed**. Rice straw is used by beef cattle operations as a dry matter supplement to pasture feeding during fall and winter (ANR, 2010). Cattle ranchers spread the large bales out on the range in fall and allow the cattle to feed on the bales. Quality of the straw (crude protein content, moisture content, etc.) must meet minimal standards before it can be used. It is possible that there are some effects on enteric fermentation by feeding lower quality straw.
- **Animal bedding**. Application of straw to soil at dairies and feedlots as a way to help preserve and dry the soil is a well-established, longstanding use of rice

straw. The decomposition of the straw is considered aerobic for the purposes of this methodology.

- **Spread out on bare soils as erosion control**. Rice straw is valuable for erosion control since it is produced in an aquatic environment and does not pose a risk of introducing upland weeds, unlike wheat or barley straw. When used for erosion control, rice straw will decompose aerobically.
- **Stuffed in netted rolls to prevent soil loss**. Rice straw is also used in construction areas to protect bare soil surfaces from soil loss. Netted rolls stuffed with rice straw are placed at the edge of the construction site to trap soil on the site.
- **Mushroom production.** Rice straw is an effective substrate for mushroom production. Wheat straw is the primary substrate used for mushroom production (CARB, 1995). Therefore, no increase in emissions from anaerobic decomposition from replacing wheat straw by rice straw is expected.
- **Use in fiberboard manufacturing.** Rice straw may be used for fiberboard manufacturing, in which case emissions from post-harvest chopping and disking will be avoided, but the increased emissions from swathing, raking or baling operations must be accounted for.

Table 6. Emission factors for potential end-uses of removed straw (kg CO_2 equivalents per metric ton of dry straw).

Potential end-use	Sources of (Avoided) Emissions	$OFEF_{y,i}$ [kg CO_2-eq t^{-1} dry straw]
Dairy replacement heifer feed	*avoiding post-harvest chopping and disking*	*-50*[16]
	swathing, raking, baling	*20*
	increases in CH_4 emissions from enteric fermentation due to incorporating low-digestible rice straw in feed	*75*[17]
	TOTAL	**45**
Beef cattle feed	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	increases in CH_4 emissions from enteric fermentation due to incorporating low-digestible rice straw in feed	*75*[18]

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[16] Salas, Li, and Sumner (2010). Final report for project "Creating and Quantifying Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers and the Environment"

[17] Assuming a calorific value of dry rice straw of 15 MJ kg^{-1} (Pütün et al., 2004), an increase in the cattle CH_4 conversion factor due to switching to low-digestible food of 1% (2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol. 4), and an energy content of CH_4 of 55.65 MJ kg^{-1} CH_4 (id.).

[18] Assuming a calorific value of dry rice straw of 15 MJ kg^{-1} (Pütün et al., 2004), an increase in the cattle CH_4 conversion factor due to switching to low-digestible food of 1% (2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol. 4), and an energy content of CH_4 of 55.65 MJ kg^{-1} CH_4 (id.).

Potential end-use	Sources of (Avoided) Emissions	$OFEF_{y,i}$ [kg CO_2-eq t^{-1} dry straw]
	TOTAL	**45**
Animal bedding	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	TOTAL	**-30**
Spread out on bare soils as erosion control	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	roadsiding, storing, loading, transport	*60*
	spreading	*10*[19]
	TOTAL	**40**
Stuffed in netted rolls to prevent soil loss	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	TOTAL	**-30**
Mushroom production	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	TOTAL	**-30**
Unused and accumulated in piles near the farm	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	non-CO_2 emissions during the decomposition of the straw	*250*[20]
	TOTAL	**220**
Fiberboard manufacturing	*avoiding post-harvest chopping and disking*	*-50*
	swathing, raking, baling	*20*
	non-CO_2 emissions during the manufacturing and life cycle of the fiberboard	*0*[21]
	TOTAL	**-30**

This factor is referred to as $OFEF$ (Off-field Emission Factor) in section 10.2 and is relative to $CRH_{y,i}$ the amount of Crop Residue harvested in year y for individual Rice Field i, in units of t dry straw ha^{-1}. The crop residue harvested, shall be either measured directly during harvesting of the rice straw, following the monitoring requirements for parameter $CRH_{y,i}$ in Section 13, or shall be calculated based on DNDC's estimate of the crop residue produced. In the latter case, the crop residue harvested shall be calculated as follows:

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[19] Assumed to be similar to emissions from post-harvest chopping and disking.

[20] Using the average CH_4 Emission Factor for composting of 10 g CH_4 kg^{-1} waste (2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol. 5, Table 4.1)

[21] Rice straw replaces wood products for manufacturing of fiberboard. Avoidance of harvesting and transport of wood products provides likely net-positive GHG benefits.

$$CRH_{y,i} = \frac{1}{0.4} \cdot \frac{1}{1000} \cdot CRP_{y,i} \cdot f_{RH,y,i} \qquad \text{[EQ 5]}$$

Where:

$CRH_{y,i}$ = Crop residue harvested in year y for individual Rice Field i [t dry matter ha^{-1}]

0.4 = Average carbon content of rice straw [kg C kg^{-1} dry matter]

1000 = Conversion factor from kg to t.

$CRP_{y,i}$ = Carbon in crop residue produced in year y for individual Rice Field i [kg C ha-1 yr-1]

$f_{RH,y,i}$ = Fraction of residue left after harvest for field i and year y, monitored following the procedures in Section 13 [-]

8.3.3 Emissions from Increases in Fertilization due to Baling ($IFEF$)

Removing rice straw from a Rice Field removes a significant amount of nutrients. This nutrient removal must be compensated by increasing fertilization. This increase in fertilization is associated with an increase in GHG emissions from fertilizer production and fertilizer transportation. Emissions from fertilizer transportation are assumed to be negligible, but emissions from fertilizer production are not. The average nutrient content of rice straw is 0.77% N, 0.10% P and 1.74% K (ANR, 2010), and GHG emissions from fertilizer production are 4 kg CO_2-eq (kg N)$^{-1}$, 1.6 kg CO_2-eq (kg P)$^{-1}$, 0.71 kg CO_2-eq (kg K)$^{-1}$ (coefficients taken from the GREET model as published in Chalmers and Walden, 2009). As a consequence, the emissions related to the increase in fertilization per metric ton of rice straw removed are 1000*(0.0077*4 + 0.001*1.6 + 0.0174 * 0.71) = 44.7 kg CO_2-eq (t dry straw)$^{-1}$.

This factor is referred to as $IFEF$ (Increased Fertilizer Emission Factor) in section 10.2. In that section, it is explained that $IFEF$ shall be multiplied by $CRH_{y,i}$, the crop residue harvested in year y for individual Rice Field i as defined in Section 8.3.2 to quantify the emissions from increases in fertilization due to baling.

9 Leakage

For *Ex-ante* calculations, it shall be assumed that leakage is negligible since the impact of Project Activities on yields must be minimal per applicability conditions.

$$E_{leakage,t,i} = 0 \qquad \text{[EQ 6]}$$

Where:

$E_{leakage,t,i}$ = Ex-ante emissions from leakage in year t for individual Rice Field i [tCO_2-eq yr^{-1}]

However, for *Ex-post* calculations, the impact of Project Activities on yields and potential leakage shall be calculated using actual yields according to the procedures in Section 12.1.

10 Quantification of Net GHG Emission Reductions and/or Removals

10.1 Uncertainty Deduction

As this methodology relies on a biogeochemical model to quantify GHG fluxes, the sources of uncertainty related to using models must be considered. The total uncertainty of any process-based model (PBM) such as DNDC is usually split into two sources of uncertainty: (1) uncertainty of input data and (2) Structural Uncertainty. The Structural Uncertainty is related to the inherent uncertainty of PBMs that remains even if all input data were error-free; the uncertainty of input data is related to the impact of errors in the input data on simulated results. The distinction is important since the Structural Uncertainty is inherent to the model and cannot be reduced unless the model is improved, while the uncertainty in input data can be controlled by users of a PBM, e.g. by expanding the number of samples on which input data is based.

This section explains how to calculate, combine, and apply deductions for these two sources of uncertainty.

10.1.1 Uncertainty in the Input Parameters

Uncertainty due to variability in the input parameters can be captured using a Monte-Carlo analysis, and can be calculated using the built-in tools in the DNDC model. Table 7 indicates which parameters must be included in the uncertainty analysis dependent on the source of the data as either from soil laboratory measurements or GIS databases such as STATSGO or SSURGO. If no data is available to empirically quantify the variability, the following distribution parameters must be assumed:

Table 7. Distribution parameters for input parameters to execute a Monte Carlo analysis.

Parameter	Value when using actual soil measurements	Value when using SSURGO or STATSGO data[22]
Distribution of Clay content	Log-Normal	Log-Normal
Distribution of Organic carbon content	Log-Normal	Log-Normal
Distribution of Bulk Density	Log-Normal	Log-Normal
Coefficient of Variation (CV) Clay content	actual CV	10%
Coefficient of Variation of Organic carbon content	actual CV	10%
Coefficient of Variation of Bulk Density	actual CV	10%
Correlation between clay content and organic carbon	actual correlation	10%
Correlation between clay content and bulk density	actual correlation	-50%
Correlation between organic carbon and bulk density	actual correlation	-60%

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[22] Default values are based on a landscape-scale analysis of SSURGO data across rice growing regions in the U.S. (Salas et al., unpublished).

A multivariate lognormal distribution must be used to sample parameters for the Monte Carlo analysis[23]. At least 1000 (n) different draws out of this multivariate lognormal distribution for both the Baseline Scenario and the Project Scenario and subsequent model simulations must be executed. For each of the n draws of the distribution, one emission reduction is calculated by subtracting the Baseline emissions from the Project emissions. Calculate the relative input uncertainty factor for field i, $u_{input,i}$, as the value corresponding to the 10% quantile for the distribution of n emission reduction values divided by the mean of the n emission reduction values.

10.1.2 Structural Uncertainty

Structural Uncertainty can be quantified by comparing modeled gas fluxes with empirical gas fluxes. The Structural Uncertainty around the size of the emission reductions of a project that combines multiple individual Rice Fields will decrease with increasing number of individual Rice Fields included. For example, Olander and Malin (2010) demonstrate that the RMSE decreases from 9 kg N-N_2O ha^{-1} for an individual Rice Field to 1.8 kg N-N_2O ha^{-1} if 10 Rice Fields are combined within one Project. The methodology requires a minimum of five Rice Fields or 405 ha (1,000 acres) be included within the Project, and requires estimating a Structural Uncertainty factor by comparing modeled with measured CH_4 emissions. Procedures to calculate this factor are included in 7.4.1.

10.1.3 Combining the Sources of Uncertainty

Since the two sources of uncertainty are uncorrelated, one can sum the variance related to uncertainties to get the combined uncertainty.

$$u_i = \frac{u_{struct}}{\sum_{i=1}^{nrFields} A_i\left(PE_{y,i} - BE_{y,i}\right)} + u_{input,i} \qquad \text{[EQ 7]}$$

Where:

u_i = Uncertainty Deduction factor for individual Rice Field i [-]

u_{struct} = Absolute deduction for structural uncertainty for the whole Project Area [kg CO_2-eq]

$nrFields$ = Number of individual Rice Fields included in the Project area

A_i = Size of individual Rice Field i [ha].

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[23] For example, using the `rlnorm` function of the `R` package (http://rss.acs.unt.edu/Rdoc/library/compositions/html/rlnorm.html).

$PE_{y,i}$ = Project emissions in year y for individual Rice Field i [kg CO_2-eq ha^{-1}]

$BE_{y,i}$ = Baseline emissions in year y for individual Rice Field i [kg CO_2-eq ha^{-1}]

$u_{input,i}$ = Relative input uncertainty factor [-]

As per ACR requirements, no Uncertainty Deduction is required if the half-width of the resulting combined confidence interval is within 10% of the mean at 90% confidence. Hence, if $u_i \geq 0.9$, no Uncertainty Deduction is to be applied and a value of $u_i = 1$ shall be assumed in all subsequent calculations. However, if $u_i < 0.9$, the Uncertainty Deduction factor u_i must be applied as is.

10.2 Calculation of Emission Reductions

The GHG emission reductions for year y (ER_y) are calculated as:

$$ER_y = \sum_{i=1}^{nrFields} A_i\left[u_i\left(PE_{y,i} - BE_{y,i}\right) - CRH_{y,i}\left(OFEF_{y,i} + IFEF\right)\right] - E_{leakage,i} \qquad \text{[EQ 8]}$$

Where:

ER_y = GHG emissions reductions and/or removals in year y

$nrFields$ = Number of individual Rice Fields included in the Project area

A_i = Size of individual Rice Field i [ha].

u_i = Uncertainty Deduction factor for individual Rice Field i

$PE_{y,i}$ = Project emissions in year y for individual Rice Field i

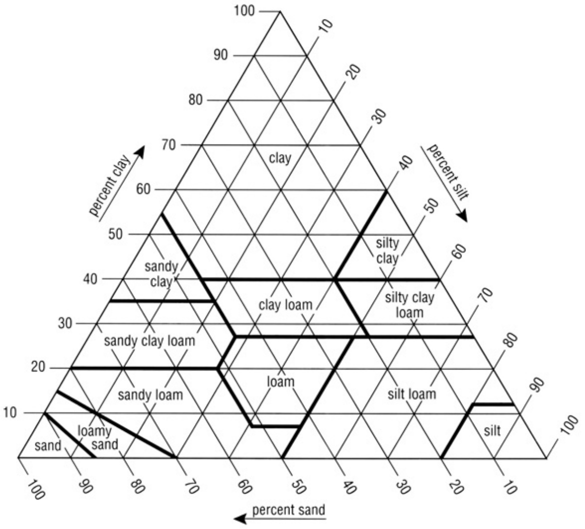
$BE_{y,i}$ = Baseline emissions in year y for individual Rice Field i

$CRH_{y,i}$ = Crop Residue harvested in year y for individual Rice Field i defined in Section 8.3.2 [t dry straw ha^{-1}]

$OFEF_{y,i}$ = Off-Field Emission Factor in year y for individual Rice Field i [kg CO_2-eq t^{-1} dry straw]

$IFEF$ = Increased Fertilizer Emission Factor [kg CO_2-eq t^{-1} dry straw]

11 Data and Parameters Not Monitored

Data Unit / Parameter:	Soil_Texture
Data unit:	-
Description:	Soil texture class determined by percent contents of clay, sand and silt particles. Common texture classes are – sand, loamy sand, sandy loam, silt loam, loam, sandy clay loam, silty clay loam, clay loam, sandy clay, silty clay, clay and organic soil. The texture class is determined from the content of soil particles. The soil triangle below shows the percentage of clay, silt and sand in basic soil texture class (except for organic soil). 
Source of data:	Soil laboratory statements, peer-reviewed literature, or GIS databases such as SSURGO. The STATSGO database shall only be used if no SSURGO data are available.
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	Soil_pH
Data unit:	-
Description:	pH of top soil. A measure of the acidity or alkalinity of soil. The range of pH for most soils is from 4 to 10 in logarithmic scale.
Source of data:	Soil laboratory statements, peer-reviewed literature, or GIS databases such as SSURGO. The STATSGO database shall only be used if no SSURGO data are available.
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	SOC_at_Surface
Data unit:	kg C kg^{-1}
Description:	Content of total soil organic carbon (SOC), excluding litter and visible plant debris.
Source of data:	Soil laboratory statements, peer-reviewed literature, or GIS databases such as SSURGO. The STATSGO database shall only be used if no SSURGO data are available.
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

912

Data Unit / Parameter:	Clay_fraction
Data unit:	Fraction ranging from 0 to 1.
Description:	Fraction of clay in the top horizon
Source of data:	Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer reviewed literature, analysis carried out by the Project Proponents at certified soil laboratories, or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	Soil laboratory statements, peer-reviewed literature, GIS databases such as SSURGO. The STATSGO database shall only be used if no SSURGO data are available.
Any comment:	

913

Data Unit / Parameter:	Field_capacity
Data unit:	Fraction ranging from 0 to 1.
Description:	Water-filled porosity of soil (WFPS) at soil field capacity.
Source of data:	Established procedures shall be followed to measure field capacity as detailed in Head (1992) and NRCS (2004). Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer-reviewed literature, analysis carried out by the Project Proponents at certified soil laboratories, or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	If uncertainty is present in the data unit/parameter or the parameter is only known within a certain range, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the input parameters.
Any comment:	When soil texture is selected, a default field capacity value will be given although it can be modified by users.

914

Data Unit / Parameter:	Wilting_point
Data unit:	Fraction ranging from 0 to 1.
Description:	Water-field porosity at soil wilting point.
Source of data:	Established procedures shall be followed to measure wilting point as detailed in Head (1992) and NRCS (2004). Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer reviewed literature,

	or analysis carried out by the Project Proponents at certified soil laboratories, or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	If uncertainty is present in the data unit/parameter or the parameter is only known within a certain range, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the input parameters.
Any comment:	When soil texture is selected, a default wilting point will be given although it can be modified by users.

915

Data Unit / Parameter:	Hydro_conductivity
Data unit:	m hr^{-1}
Description:	Saturated hydraulic conductivity
Source of data:	Established procedures shall be followed to measure saturated hydraulic conductivity as detailed in Head (1992) and NRCS (2004). Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer reviewed literature, or analysis carried out by the Project Proponents at certified soil laboratories, or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	If uncertainty is present in the data unit/parameter or the parameter is only known within a certain range, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the input parameters.
Any comment:	When soil texture is selected, a default value will be used although it can be modified by users.

916

Data Unit / Parameter:	Soil_porosity
Data unit:	Fraction ranging from 0 to 1.
Description:	Soil porosity.
Source of data:	Established procedures shall be followed to measure porosity as detailed in Head (1992) and NRCS (2004). Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer reviewed literature, or analysis carried out by the Project Proponents at certified soil laboratories, or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	If uncertainty is present in the data unit/parameter or the parameter is only known within a certain range, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the input parameters.
Any comment:	When soil texture is selected, a default value will be used although it can be modified by users.

917

Data Unit / Parameter:	SOC_profile_A
Data unit:	kg C kg^{-1}
Description:	Content of total soil organic carbon (SOC in soil profile A)
Source of data:	Established procedures shall be followed to measure soil organic carbon as detailed in Head (1992) and NRCS

	(2004). Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer reviewed literature, measurement carried out by the Project Proponents, or analysis carried out by the Project Proponents at certified soil laboratory(ies) , or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	If uncertainty is present in the data unit/parameter or the parameter is only known within a certain range, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the input parameters.
Any comment:	

918

Data Unit / Parameter:	SOC_profile_B
Data unit:	kg C kg^{-1}
Description:	Content of total soil organic carbon (SOC) in soil profile B)
Source of data:	Established procedures shall be followed to measure soil organic carbon as detailed in Head (1992) and NRCS (2004). Soil laboratory statements from Government agency, recent (i.e. less than 10 year old) peer reviewed literature, measurement carried out by the Project Proponents, or analysis carried out by the Project Proponents at certified soil laboratory(ies), or a typical range in values according to the soil texture class.
Justification of choice of data or description of measurement methods and procedures applied:	If uncertainty is present in the data unit/parameter or the parameter is only known within a certain range, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the input parameters.
Any comment:	

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Data Unit / Parameter:	$\varepsilon_{rice,rice}$
Data unit:	[-]
Description:	Own-price crop acreage elasticity for rice cropping. [-]
Source of data:	Using econometric analysis available in scientific papers, such as Lee and Kennedy (2008). In the latter publication, a value of 0.3567 is indicated. A default factor of 0.6 is to be used if no scientific publications are available.
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Estimates from econometric analysis are often uncertain. Therefore, a conservative choice of the own-price crop acreage elasticity must be selected.

920

Data Unit / Parameter:	Average flood-up and draining duration
Data unit:	days
Description:	**Flood up duration**: average time it takes to flood a field between the start of flooding and complete coverage of the soil with water. **Drainage duration**: average time it takes to drain a field by either pulling the boards or stopping pumping until all

	standing water has left the field. Note that at this stage, some water may remain in puddles, but no more water will be flowing into the ditch.
Source of data:	Farmer experience, remote sensing procedures.
Description of measurement methods and procedures to be applied:	
QA/QC procedures to be applied:	
Verification requirements:	
Any comment:	The flood-up and drainage duration depends on the geometry of a field, the length of the draining ditches, the number of boards, whether the boards are pulled when draining or the water is subsiding naturally through infiltration and the flow rate of the pumps.

921

Data Unit / Parameter:	Conventional Drainage Date determination
Data unit:	Narrative
Description:	Methodology to set the conventional, i.e., baseline, drainage date for a specific field
Source of data:	Producer or crop advisor
Description of measurement methods and procedures to be applied:	A reasonably workable description of how the drainage date has been set either historically on a specific field if no Common Practice Baseline is used or following common practice in case a Common Practice Baseline is used. Examples of procedures how a conventional Drainage Date are set include[24]: • Fixed number of days after a specific crop growth stage is reached (e.g. 50% heading, or R7). It must be described how it is determined that a specific crop growth stage is reached (i.e., through crop advisor, by producer, detailed description of phenological or morphological indicators that a crop growth stage is reached, etc.). • Fixed number of days relative to a growth stage simulated by the DD50 model (Counce et al., 2009) available through extension agents.
QA/QC procedures to be applied:	
Verification requirements:	Cross-checked with independent crop advisors or extension agents.
Any comment:	Interview with producer or crop advisor if contact information is provided

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[24] Note that the examples are given for illustration purposes only. They are no recommendations or endorsements from the authors of this methodology. Producers are advised to use the judgment of extension staff or other experts to determine a drainage date that is appropriate for their specific circumstances

12 Monitoring and Verification

12.1 Check Yield Impacts and Calculate Leakage

If the Project Activities lead to a statistically significant decrease in the rice yield totaled over all participating Rice Fields, compared to the available yields of at least three of the five years before the Project Start Date, credits must be discounted according to the procedures this section. This deduction is necessary to account for potential market leakage effects. Yields are normalized against seasonal variations in yields using yield statistics obtained by the NASS or NRCS.

Use the following procedure to conduct this test and calculate any potential leakage:

(1) For yields that are available during at least three out of the five years t before t_0 – unless rice is grown two out of the past five years, in which case two years of yield data suffice (“historical yields”), normalize the yield and calculate the standard deviation and mean of the normalized yields as follows:

$$y\_norm_{t,i} = \frac{y_{t,i}}{y\_county_t} \qquad \text{[EQ 9]}$$

$$s_i = stdev(y\_norm_{t,i}) \qquad \text{[EQ 10]}$$

$$\overline{y\_norm_i} = mean(y\_norm_{t,i}) \qquad \text{[EQ 11]}$$

Where:

$y\_norm_{t,i}$ = Normalized yield at time t for individual Rice Field i [Mg ha^{-1}]

$y_{t,i}$ = Actual yield at time t for individual Rice Field i [Mg ha^{-1}]

y_county_t = Average yield of the county at time t for individual Rice Field i [Mg ha^{-1}]

s_i = Standard deviation of the historical normalized yields for individual Rice Field i [Mg ha^{-1}]

$\overline{y\_norm_i}$ = Average of the historical normalized yields for individual Rice Field i [Mg ha^{-1}]

Normalize the sum of the historical yields for all the Rice Fields included in the Project by dividing the yield sum by the county mean for that specific year and for the aggregated rice crop in units of “yield, measured in lbs / acre” obtained from the USDA NASS (http://quickstats.nass.usda.gov).

Verify the distribution of $y\_norm_{t,i}$ values. Most likely, these will be log-normally distributed. Apply the appropriate statistical transformation to y_norm_t to obtain a normal distribution before taking standard deviation and means.

(2) Calculate the “minimum yield threshold" below which normalized yields are significantly smaller than the county mean:

$$y\_min_i = \overline{y\_norm_{t,i}} - t(0.10, n-1) \cdot s_i \qquad \text{[EQ 12]}$$

Where:

y_min_i = Minimum yield threshold for individual Rice Field i

$\overline{y\_norm_{t,i}}$ = Average of the historical normalized yields for individual Rice Field i [Mg ha^{-1}]

$t(0.10, n-1)$ = t-distribution value with 90% confidence (for a one-tailed test) and $n-1$ degrees of freedom [-]

n = Number of historical years used in the normalization

s_i = Standard deviation of the historical normalized yields for individual Rice Field i [Mg ha^{-1}]

(3) For every year of the Crediting Period, calculate y_norm_t and compare this value to y_min. If $y\_norm_{t_0}$ is smaller than y_min, yields were significantly smaller than under pre-Project conditions, even normalized for inter-annual differences. In this case, the theoretical yield that could have been attained without Project Activities, i.e. the Baseline yield, is:

$$y\_baseline_{t,i} = \overline{y\_norm_{t,i}} \cdot y\_county_t \qquad \text{[EQ 13]}$$

The decrease in yield caused by Project Activities is, therefore:

$$y\_baseline_{t,i} - y_{t,i} \qquad \text{[EQ 14]}$$

The intensity of greenhouse gas emissions, expressed per unit yield is:

$$\frac{BE_{t,i}}{y\_baseline_{t,i}} \qquad \text{[EQ 15]}$$

Finally, the potential leakage caused by a decrease in yield is:

$$E_{leakage,t,i} = \varepsilon_{rice,rice} \cdot \left(y\_baseline_{t,i} - y_{t,i}\right) \cdot \frac{BE_{t,i}}{y\_baseline_{t,i}} \qquad \text{[EQ 16]}$$

Where:

$E_{leakage,t,i}$ = Emissions from leakage in year t for individual Rice Field i [tCO_2-eq yr^{-1}]

$\varepsilon_{rice,rice}$ = Own-price elasticity for rice cropping. [-]

$y\_baseline_{t,i}$ = Baseline yield at time t for individual Rice Field i, the (theoretical) yield that could have been attained without Project Activities

$\overline{y\_norm_{t,i}}$ = Average of the historical normalized yields for individual Rice Field i [Mg ha^{-1}]

y_county_t = Average yield of the county at time t [Mg ha^{-1}]

$y_{t,i}$ = Actual yield at time t for individual Rice Field i [Mg ha^{-1}]

$BE_{t,i}$ = Baseline emissions in year y for individual Rice Field i [tCO_2-eq yr^{-1}]

In this calculation, it is assumed that the GHG intensity of rice production where the leakage occurs is similar to the Baseline GHG intensity on the Project Rice Fields, and that the cross-price crop acreage elasticity can be conservatively omitted.

12.2 *Ex-post* Monitoring

The following management data must be collected by the farmer after the Project Start Date:

- Planting preparation description and date
- Planting date
- Fertilization amounts and dates
- Flooding start and duration throughout the year
- Harvesting date
- Post-harvesting description and dates

12.3 Fields Joining and Leaving the Project

The Project Proponent is allowed to add and remove Rice Fields from the Project during the Crediting Period. The fields can either leave permanently or temporarily. For example, if weather conditions are not conducive to implementing dry seeding, a Rice Field can temporarily leave the Project for that year and rejoin the next year. No credits are issued during that year. The start of the Crediting Period shall always be counted from the first field joining the Project.

However, credits can only be issued if at least 5 fields **or** 405 ha (1,000 acres) are in the Project at the time of verification. If less than 5 fields **or** 405 ha remain in the Project, no credits shall be issued that verification event. However, the Project Proponent may include new fields in the Project and postpone the issuance of credits for all Rice Fields until at least 5 fields **or** 405 ha are available again.

12.4 Project Renewal and Baseline Update

Per the *ACR Standard*, the duration of the Crediting Period equals the period of baseline validity, which is five years under this methodology. The Crediting Period for a Project (or Rice Field within a Project) using a Common Practice Baseline can be renewed at the end of a 5-year Crediting Period for another five years. However, if 10 years after the start of the first Crediting Period, the Baseline adoption rate of the Project Activity in the Rice Growing Region is still less than 5%, the Crediting Period can no longer be renewed.[25] If after 10 years the adoption rate of the Project Activity in the Rice Growing Region is greater than 5%, the Crediting Period can be renewed.

A Crediting Period for a Project using either a Field-Specific or Common Practice Baseline can be renewed until the adoption rate of the Project Activity in the Rice Growing Region is greater than 50%. The latter provision is included to ensure that a Baseline is set based on common practice that represents the practice of a majority of the producers. Any practice for which the adoption is smaller than 50% cannot be considered common practice because less than half of the producers are implementing the practice.

At every renewal of a Project's Crediting Period, Project Proponents shall calculate the adoption rate of the Project Activity so that the requirements above can be verified. The procedures in Section 6.1 must be used to calculate the adoption rate of the practice. The flowchart in Figure 2 can be used to determine the renewal eligibility.

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[25] This limitation on Crediting Period renewal for Projects using Common Practice Baselines is based on the belief that if after 10 years the Project Activity remains at <5% adoption, there must be a different barrier to adoption and the reasons for allowing a Common Practice Baseline in the program (i.e., to prime the system and demonstrate that a set of project activities can be successfully used) become obsolete.

Rice Fields using a Field-Specific Baseline in the first Crediting Period must switch to a Common Practice Baseline when the Project Crediting Period is renewed as indicated in Table 8. Rice Fields using a Common Practice Baseline in the first Crediting Period must continue using a Common Practice Baseline.

For Common Practice Baselines, the Baseline values of the Critical Management Parameters shall not be older than five years before the start of the current Crediting Period according to the procedures in Section 7 for determining Common Practice Baselines.

Note that the Crediting Period is project-specific and not field-specific. If a Rice Field joins in the third year of the Crediting Period, it joins the Crediting Period of the overall Project rather than beginning its own 5-year Crediting Period. If this field is using a Field Specific Baseline, it must switch to a Common Practice Baseline upon renewal of the overall Project Crediting Period at year 5, similar to the other fields in the Project.

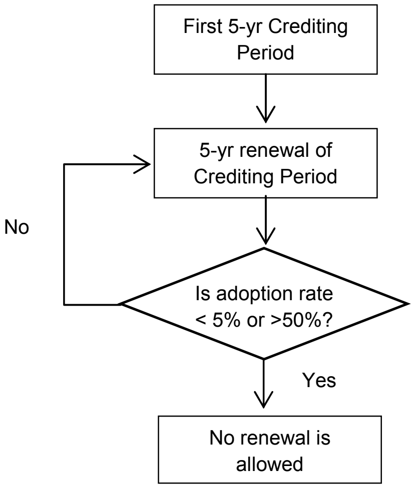
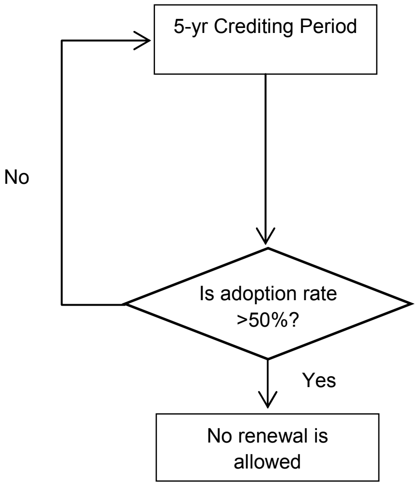
Common Practice Baseline is used in the first Crediting Period	Field Specific Baseline is used in the first Crediting Period
	

Figure 2. Flow chart of renewal of a Crediting Period.

Table 8. The use of Field Specific and Common Practice Baselines for Projects starting with either a Field Specific or Common Practice Baseline.

Period	**-5 to 0**	**0 to 5**	**5 to 10**	**10 to 15**	**Etc.**
Procedure for projects starting with a Field Specific Baselines		Based on conditions on the Rice Field itself from year -5 to 0	Based on common practice in Rice Growing Region from year 0 to 5	Based on common practice in Rice Growing Region from year 5 to 10	Etc.
Procedure for Projects starting with a Common Practice Baselines		Based on common practice in Rice Growing Region from year -5 to 0	Based on common practice in Rice Growing Region from year 0 to 5	Based on common practice in Rice Growing Region from year 5 to 10	Etc.

12.5 Verification

12.5.1 Levels of Verification: Desk Reviews and Field Visits

At a verification event, a VVB shall review that all required monitoring parameters are available for every Rice Field (“completeness audit”) in a desk review based on the data provided in a monitoring report. In addition to the completeness audit, the VVB shall check a random selection of fields using a more in-depth audit in which the values of specific parameters are verified during a field visit (“in-depth audit”) and the DNDC simulations are checked. The use of remote sensing techniques and local experts can reduce or even eliminate field visits.

Rice Fields on which Project Activities were conducted before this methodology was adopted by ACR are exempt from undergoing an in-depth audit.

12.5.2 What must be done during an In-depth Audit?

During an in-depth audit, two aspects shall be verified: (1) whether a Project Activity occurred or not, e.g. whether a field was baled or not, and (2) whether the Model Parameters that are indicated as Critical Management Parameters in the methodology for the Project Activities on a specific Rice Field are within an expected (or verifiable) range. The procedures to verify that the value of each Critical Management Parameter is within the verifiable range are specified in the description of each parameter in section 13.

12.5.3 How many and which fields must be visited in an in-depth audit?

- For every year of the Crediting Period being verified, at least 20% of the Rice Fields generating credits during that year or 2 Rice Fields, whichever is greater, shall be selected for verification. Note that this does not imply that a verification audit has to occur every year of the Crediting Period; practices and parameters of multiple years may be verified during one single audit.

- For every year of the Crediting Period being verified, the Rice Fields that are to be visited shall be selected at random from the Rice Fields generating credits during that year of the Crediting Period. Each field shall only be visited at most one time within one year, but a Rice Field may potentially be visited multiple times during different years.

12.5.4 Reducing the Burden of Field Visits by employing Industry Experts

The methodology allows for aggregators, project developers, extension agents, or other industry experts to eliminate the need of a VVB themselves to conduct a field visit on the conditions that (1) the VVB has selected the fields to be visited at random and (2) the selection of the fields is only communicated with the growers after the Project Activities have been implemented and (3) the information provided by the expert follows the parameter-specific description in Section 13. Section 13 describes which evidence can eliminate a field visit and focuses on how the risk for tampering can be eliminated. For example, a VVB may request a geo-tagged photograph of a specific field after baling. The photograph must be taken by a GPS-enabled camera and shall be automatically uploaded to an account to which the VVB has full access, so that the metadata cannot be tampered with.

12.5.5 Reducing the Burden of Field Visits by using Remote Sensing Data

The Project Proponent is allowed to employ remote sensing to replace a field visit for Project Activities or Model Parameters that can be observed using remote sensing with sufficient accuracy. The Project Activities or Model Parameters that may be verified using remote sensing instead of a field visit are described in the parameter list in section 13. However, evaluating the presence or absence a Project Activity using remote sensing must have an Accuracy of at least 90% as evaluated on a held-out sample. If the Accuracy is less than 90%, remote sensing procedures shall not be used to replace the field visit.

Box 1. Example of using remote sensing to replace field visit

Imagery from the MODIS satellite can be used to verify dry seeding practices. Specifically, if the green signal – which is related to the planting date – is picked up before the water signal – which indicates flooding – one can be certain that dry seeding occurred.

For example, on one Rice Field, it is found that the planting signal occurs well before the flooding signal with 95% Accuracy. As a consequence, this field does not have to be visited. On another Rice Field, the imagery is unclear and only a very weak planting signal is present before the flooding signal, yielding an Accuracy of only 75%. In this case, remote sensing cannot replace a field visit, and the Rice Field must be visited.

12.5.6 Timing of Verification

It is the nature of agriculture that Project Activities can only be observed at discrete points during the growing season. Therefore, the timing of field visits shall follow the growing calendar. As the timing of the growing calendar depends on the weather, a VVB shall be in close contact with the Project Proponents to ensure the window of verification shall not be missed.

Table 9. Illustrative timing of verification field visits.

Project Action	Window during which practice can be verified
Removal of straw after harvest (e.g., by baling)	October
Dry seeding	May
Early drainage	August-September

12.5.7 What happens if Requirements for Verification are not met?

As indicated above, during an in-depth parameter audit, it shall be verified (1) whether a practice occurred and (2) whether the values of the Critical Management Parameters are within a verifiable range as specified in the description of each parameter in Section 13.

If, during an in-depth parameter audit, it cannot be verified whether a Project Activity occurred on a specific Rice Field, the Rice Field shall be removed from credit calculations for that year. If more than 5 fields or 405 ha (1,000 acres) remain in the Project, credits can be generated. If less than 5 fields or 405 ha remain in the Project, no credits are to be issued that year. However, the Project Proponent is allowed to include new Rice Fields in the Project and postpone the issuance of credits for all fields until 5 fields or 405 ha are available. If for more than two fields belonging to the same grower, the VVB cannot verify whether a practice occurred, all Rice Fields for this grower shall undergo an in-depth parameter audit.

If, during an in-depth parameter audit, the Critical Management Parameters are not found to be within the verifiable range, the fields do not automatically become ineligible. The problematic Critical Management Parameter shall be included in a Monte Carlo analysis after specifying an expected range to quantify the uncertainty due to variability in the Model Parameters.

13 Data and Parameters Monitored

Data Unit / Parameter:	Climate Data
Data unit:	DNDC climate data file
Description:	Daily meteorological data files(s) in the plain text (i.e., ASCII) format for each year. Data files are written in format readable in the DNDC model.
Source of data:	Weather station data
Description of measurement methods and procedures to be applied:	If the project area is located in California, it is recommended to use weather data from the nearest CIMIS weather station (http://wwwcimis.water.ca.gov). National Climate Data Center (www.ncdc.noaa.gov/oa/ndcd.html) is another source of climatic data that can be used.
Frequency of monitoring/recording:	Daily
QA/QC procedures to be applied:	Daily climate data must come from a weather station that is located maximally 50 miles away.
Verification requirements:	Source of the data shall be provided to the VVB so that the data can be independently retrieved by the VVB and compared to the data submitted at verification.
Any comment:	See user manual of the DNDC model for guidance on format of files.

Data Unit / Parameter:	Plant_time
Data unit:	-
Description:	Planting month and day. A number from 1 – 12 for month; and a number from 1 to 31 for day.
Source of data:	Agricultural statistical records, farmer records, or remote sensing procedures.
Description of measurement methods and procedures to be applied:	If uncertainty is present in the data unit/parameter, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the Model Parameters.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Verification requirements:	Geo-tagged picture within 3 weeks after planting date indicated in Monitoring Report OR date of first green signal assessed using remote sensing data occurring within 4 weeks after planting date indicated in Monitoring Report
Any comment:	

Data Unit / Parameter:	Harvest_time
Data unit:	-
Description:	Harvesting month and day. A number from 1 – 12 for month; and a number from 1 to 31 for day.
Source of data:	Agricultural statistical records, farmer records, or remote sensing procedures.
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	If uncertainty is present in the data unit/parameter, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the Model Parameters.
Verification requirements:	Geo-tagged picture within 3 weeks after harvesting OR date-stamped receipt from the mill occurring within 2 weeks after the harvest date indicated in the Monitoring Report OR any other receipt or contractual information indicating the harvesting date
Any comment:	

1116

Data Unit / Parameter:	Yield
Data unit:	t DM ha^{-1}
Description:	Crop productivity (i.e. rice productivity for rice) in the growing season
Source of data:	Agricultural statistical records or farmer records.
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually or per growing season.
QA/QC procedures to be applied:	
Verification requirements:	Signed affidavit of farmer OR interview with farmer by VVB OR date-stamped receipt from the mill indicating yield OR yield information on any other contract
Any comment:	

1117

Data Unit / Parameter:	Tilling Date/Period and Method
Data unit:	Date and -
Description:	Date of tilling event. In case multiple tillage events are done throughout a period (e.g., for post-harvest straw residue management), it suffices to provide the dates of the first and last tillage events. Tilling method is to be provided as one of the following four methods: a. No-till (i.e., only mulching) (0 cm) b. Plowing slightly (5 cm) c. Plowing with disk or chisel (10 cm) d. Deep plowing (30 cm)
Source of data:	Agricultural statistical records or farmer records.

Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Verification requirements:	Signed affidavit of farmer OR interview with farmer by VVB
Any comment:	All tillage operations must be included, whether they occur during the fall or springtime.

1118

Data Unit / Parameter:	Fertilizer Date, Amount and Composition
Data unit:	Date, kg N ha^{-1}
Description:	Date of fertilizer application, amount of fertilizer applied and chemical composition of fertilizer
Source of data:	Agricultural statistical records or farmer records.
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Verification requirements:	Signed affidavit of farmer OR interview with farmer by VVB
Any comment:	

1119

Data Unit / Parameter:	$CRH_{y,i}$ the amount of Crop Residue harvested in year y for individual Rice Field i (optional – see comment below)
Data unit:	t dry straw ha^{-1}
Description:	The amount of dry Crop Residue harvested and removed from the field through baling or any other means in year y for individual Rice Field i
Source of data:	Field measurement.
Description of measurement methods and procedures to be applied:	Measure directly during baling or harvesting of the straw. Make sure to correct for any residual moisture content of the straw
Frequency of monitoring/recording:	Annually, any time baling occurs as part of a project activity
QA/QC procedures to be applied:	
Verification requirements:	Logging of baling equipment OR notes, contract, or agreement from or with baler or end-user of rice straw OR interview with baler or end-user of straw if contact information is provided
Any comment:	The $CRH_{y,i}$ parameter is not required to be monitored on the condition that $f_{RH,y,i}$ is provided. Specifically, crop residues can either be measured directly, as specified in this parameter, or may be calculated using equation [EQ 5]. In the latter case, $f_{RH,y,i}$ must be monitored or provided.

1120

Data Unit / Parameter:	$f_{RH,y,i}$, fraction of residue left after harvest (optional – see

	comment below)
Data unit:	Fraction
Description:	A fraction of the above-ground crop residue left as stubble in the field after harvest for field i and year y.
Source of data:	Field measurement.
Description of measurement methods and procedures to be applied:	Measure either directly, or estimate using the cutter height used during harvesting using the relationship between cutter height and straw yield in Summers et al. (2001): [straw yield - % of maximum] = -2.95 * [cutter height - in] + 94.8 For example, if the cutter height was set to 4 in, the straw yield as a % of maximum is 83%, and the percentage left after harvest is 17%.
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Verification requirements:	Geotagged picture of stubble height OR contract with baler or end-user indicating end use of straw OR interview with baler or end-user of straw if contact information is provided
Any comment:	This parameter is not to be monitored or provided when $CRH_{y,i}$ is monitored. A default fraction of 0.10 for $f_{RH,y,i}$ may be used.

Data Unit / Parameter:	Flooding and Draining Dates
Data unit:	Date (month and day)
Description:	Start and end dates for flooding and draining in Rice Fields. Dates shall be given in month and day combination. If start and end dates fall in different years, then year must also be provided.
Source of data:	Agricultural statistical records, farmer records, or remote sensing procedures.
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	If uncertainty is present in the data unit/parameter, this data unit/parameter must be included in the Monte Carlo procedure to quantify the uncertainty due to variability in the Model Parameters.
Verification requirements:	Geotagged pictures taken of field or pulled boards within one week of date provided in Monitoring Report OR remote sensing imagery within 2 weeks of dates provided in Monitoring Report OR observations from farm advisers OR records, observations, or interviews with the water districts confirming that no more water was required within 1 week of the date provided in the Monitoring Report
Any comment:	

Data Unit / Parameter:	End use of baled straw
Data unit:	-
Description:	The end use for rice straw. Select from the following: a. Dairy replacement heifer feed b. Beef cattle feed c. Animal bedding d. Spread out on bare soils as erosion control e. Stuffed in netted rolls to prevent soil loss f. Mushroom production g. Fiberboard manufacturing h. None of the above. Describe end-use
Source of data:	Farmer records
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Verification requirements:	Contact information of baler or end-user of straw shall be provided so that baler or end-user of straw can be contacted to verify end-use of straw.
Any comment:	

1123

Data Unit / Parameter:	Date of straw burning event
Data unit:	Date
Description:	The date of a burned event used for post-harvest straw management
Source of data:	Farmer records
Description of measurement methods and procedures to be applied:	
Frequency of monitoring/recording:	Annually
QA/QC procedures to be applied:	
Verification requirements:	
Any comment:	

1124

14 Uncertainty Quantification and Requirements for Regional Calibration Modules

14.1 Model Validation and Uncertainty Quantification

The DNDC model must be successfully calibrated and validated for each of the proposed Project Activities before it can be used in carbon accounting. Procedures to do so are contained in this section. It is up to the Project Proponents to justify to the VVB the boundaries of the area for which the DNDC model has been calibrated by demonstrating the homogeneity of the area in terms of Project Activities, rice cultivars planted, and soil types. Empirical gas flux data are required for at least five individual Rice Fields located in the same Rice Growing Region as the Project.

14.1.1 Overview

The Structural Uncertainty deduction u_{struct} is a deduction that is applied to the gross emission reductions to compensate for the Structural Uncertainty of model simulations. This deduction is calculated beforehand using values of pairs of measured emissions and simulated emissions. The measurements must take place in the Rice Growing Region where the Project is located. Therefore, it is possible to calculate the Structural Uncertainty deduction for a Rice Growing Region beforehand and apply the same factor on emission reductions for any Rice Field in the Rice Growing Region. The Structural Uncertainty deduction will also decrease with the number of fields included in the Project, since errors in one field can be compensated by errors in a different field. As a consequence, the more fields participating in the Project, the smaller the resulting error on the emission reductions summed over all fields, and the smaller the Structural Uncertainty deduction.

The Structural Uncertainty deduction is mathematically defined such that, after application of the deduction to the direct emission reductions, the following inequality holds in 90% of the outcomes, i.e., with 90% confidence:

$$\mathrm{DERs} < BE_{meas} - PE_{meas}$$

An outcome should be interpreted in the frequentist sense of the word, in which measurements are seen as samples drawn out of a greater population, and each outcome is a set of samples drawn out of the greater population.

The structural uncertainty factor, a negative value, must be added to the gross difference between project and baseline emissions:

$$\mathrm{DERs} = u_{struct} + (BE_{meas} - PE_{meas})$$

Where:

DERs = Direct Emission Reductions
u_{struct} = Structural uncertainty factor
$PE_{model}(i\ )$ = Model results for Project emissions

$BE_{model}(i)$ = Model results for Baseline emissions
$PE_{meas}(i)$ = Field results for Project emissions
$BE_{meas}(i)$ = Field results for Baseline emissions

14.1.2 Verification of the lack of bias

The derivation of the Structural Uncertainty deduction assumes that no bias exists between measured and modeled results, or that $\mathrm{E}(Y_{meas}) = \mathrm{E}(Y_{model})$. The DNDC model has been shown to predict GHG fluxes without bias, when correctly calibrated. This methodology specifies how model inputs can be set so that the model is calibrated correctly. It must still be explicitly tested that the model calibration strategy does not lead to bias by comparing modeled and measured emissions. A classical paired t-test is suboptimal since the goal is not to demonstrate a significant difference between modeled and measured values using a set confidence, but rather the lack of a difference. In such a case, Two One-Sided Tests (TOST) equivalence testing is superior. For equivalence tests, a tolerable deviation between measured and modeled results must be defined. We set this tolerable deviation to the statistical convention of 10%. In practice, a regression must be executed between measured and modeled values, and it must be ensured that the slope is not smaller than 0.90 with 90% confidence, as well as not greater than 1.1 with 90% confidence.

14.1.3 Derivation of Uncertainty Deduction

The structural error induced by a biogeochemical model is assumed to be additive. The relation between modeled and actual emissions is therefore as follows:

$$Y_{model,i} = Y_{field,i} + \varepsilon_i \text{ with } \varepsilon \sim \mathcal{N}(0, \sigma^2)$$

If the model is unbiased, the following error model can be assumed for the project and baseline emissions:

$$PE_{model} = PE_{meas} + \varepsilon_1 \text{ with } \varepsilon_1 \sim \mathcal{N}(0, \sigma^2)$$

$$BE_{model} = BE_{meas} + \varepsilon_2 \text{ with } \varepsilon_2 \sim \mathcal{N}(0, \sigma^2)$$

A correlation between the Project and Baseline residuals potentially exists:

$$\rho = \mathrm{corr}(\varepsilon_1, \varepsilon_2)$$

Where:

$PE_{model}(i)$ = Model results for Project emissions
$BE_{model}(i)$ = Model results for Baseline emissions
$PE_{meas}(i)$ = Field results for Project emissions
$BE_{meas}(i)$ = Field results for Baseline emissions
ε_1 Error term for Project emissions
ε_2 Error term for Baseline emissions
σ Standard deviation of the residuals between modeled and measured values
ρ Correlation between Project residuals and Baseline residuals

The direct emission reductions are the difference between Project and Baseline emissions:

$$DER_{model} = BE_{model} - PE_{model}$$

$$DER_{meas} = BE_{meas} - PE_{meas}$$

Where:

DER_{model} = Direct emission reductions based on modeled emissions
DER_{meas} = Direct emission reductions based on measured emissions

After it has been shown that the DNDC model is unbiased following the procedures in Section 14.1.2, the average of the difference between $DER_{model} - DER_{meas}$ is 0. The variance of this difference is:

$$\begin{aligned}\mathrm{Var}(DER_{model} - DER_{meas}) &= \mathrm{Var}(\varepsilon_1) + \mathrm{Var}(\varepsilon_2) - 2\mathrm{Cov}(\varepsilon_1, \varepsilon_2) \\ &= \sigma^2 + \sigma^2 - 2\sigma^2\rho \\ &= 2\sigma^2(1-\rho)\end{aligned}$$

In practice, experimental Rice Fields on which fluxes are measured are much smaller than production Rice Fields managed by commercial producers. Often, experimental rice fields can be as small as 10-25 m^2 up to about 1 ha. Since the relative uncertainty decreases with increasing plot size, the uncertainty as quantified on experimental plots must be adjusted for the greater size of the project area relative to the size of an experimental plot. Let n denote the number of times the total project size is greater than a typical experimental plot. Assuming a greater size of experimental plots will lead to greater uncertainty deductions. Therefore, to remain conservative and for simplicity, we have set the size of an experimental plot to the upper bound of the range of sizes of experimental plots, 1 ha. Therefore, n is simply equal to the project area in ha. Hence, the variance of the sum of the emission reductions across a Project Area of size n is:

$$\begin{aligned}\mathrm{Var}\left(\sum_{i=1}^{n} DER_{model,i} - DER_{meas,i}\right) &= n\cdot\mathrm{Var}(\varepsilon_1) + n\cdot\mathrm{Var}(\varepsilon_2) - 2n\cdot\mathrm{Cov}(\varepsilon_1, \varepsilon_2)\\ &= n\sigma^2 + n\sigma^2 - 2n\sigma^2\rho\\ &= 2n\sigma^2(1-\rho)\end{aligned}$$

If s is the standard deviation of the model residuals based on a limited set of k calibration values, the one-sided 90% confidence interval around the average of the sum of the differences $DER_{model} - DER_{meas}$ is:

$$DER_{model} - DER_{meas} < s\sqrt{2n(1-\rho)} \cdot t_{inv}(0.90, k)$$

This equation enables to define the absolute deduction for structural uncertainty u_{struct} .

$$u_{struct} = \sqrt{2n(1-\rho)} \cdot t_{inv}(0.90, k)$$

Where:

u_{struct} = Absolute deduction for structural uncertainty for the whole Project Area [kg CO_2-eq]

s = Standard deviation of the residuals between modeled and measured values

ρ = Correlation between Project residuals and Baseline residuals

t_{inv} = Inverse of the cumulative t-distribution with a specific confidence and degrees of freedom

k = Number of pairs of modeled and measured values used for model verification.

n = Size of Project Area [ha]

In other words, subtracting u_{struct} from DER_{model}, average modeled emission reductions are smaller than average measured emission reductions with 90% confidence:

$$DER_{model} - u_{struct} < DER_{model}$$

14.1.4 Quantifying the standard deviation s and the correlation ρ

The calculation of u_{struct} is critically dependent on the standard deviation of the residuals s and the correlation between the residuals of the Project emissions and the residuals of the Baseline emissions ρ.

If k pairs of $[Y_{meas}(i), Y_{model}(i)]$ are available, the quantity s can be calculated as the standard deviation of the difference between $Y_{meas}(i)$ and $Y_{model}(i)$. The quantity ρ can be estimated by dividing the measurements in Baseline cases, $BE_{meas}(i)$ and Project cases, $PE_{meas}(i)$. Using conventional terminology, the Baseline would be the control or conventional treatment. Subsequently, pairs of measured and modeled emission reductions $DER_{meas}(i)$ and $DER_{model}(i)$ can be calculated as the difference between $PE_{meas}(i)$ and $BE_{meas}(i)$, and $PE_{model}(i)$ and $BE_{model}(i)$, respectively. Calculate ρ as the correlation coefficient between $DER_{meas}(i)$ and $DER_{model}(i)$. Smaller correlation coefficients will result in greater uncertainty deductions. Therefore, it is good practice to calculate a set of correlation coefficients through leave-one-out jackknifing and set the correlation coefficient to the low range of this set of values.

In most cases, only a very limited set of values will be available. For the standard deviation of the residuals, using a student-t distribution instead of a normal distribution will compensate for the potential bias introduced by a limited number of values. In addition, this methodology requires the standard deviation s to be calculated based on at least 8 pairs of measured and simulated annual emissions that have been measured over at least 2 growing seasons.

If a set of daily fluxes are available, the quantities s and ρ can be calculated with more accuracy based on daily values of these quantities as:

$$s_{annual} = 365 \cdot s_{daily}$$

$$\rho_{annual} = \rho_{daily}$$

Note that measurements aggregated over any other time period than daily can be used to estimate ρ. This methodology requires to use at least 50 measurements of daily measured and modeled methane fluxes to calculate ρ.

It is likely that new and improved measurements become available after the Project Start Date. Therefore, it is allowed to recalculate s_{annual}, ρ_{annual} leading to a potential decrease in u_{struct} at a verification event after the Start Date of the Project using the additional and/or improved measurements.

14.2 Requirements for Regional Calibration Modules

This methodology can be expanded using modules in which the regional calibration and model validation step is executed for specific Project Activities and additional Rice Growing Regions. If a Regional Calibration Module is available, Project Proponents are allowed to skip the regional calibration and model validation step on the condition that the Structural Uncertainty deduction included in the module is used, as well as the template input file to the DNDC model.

New Regional Calibration Modules must contain the following elements:

1. **Step 1.** Exact and unambiguous **definition of Project Activities**. The definitions must be workable for growers and sufficiently rigorous for carbon methodologies. Definitions must be robust with respect to variations in weather.
2. **Step 2.** Selection of one of the four Rice Growing Regions in the U.S. (see Section 3.2) for which the Regional Calibration Module is valid.
3. **Step 3. Development of performance standard (optional).** For each of the Project Activities defined in step 1, and for the full Rice Growing Region defined in step 2, the Regional Calibration Module can include an analysis of the adoption rate and the additionality following the procedures in Section 6.
4. **Step 4. Identification of Critical and Non Critical Management Parameters.** This shall follow the procedure defined in Section 7.2.
5. **Step 5.** Values of measured and modeled fluxes and a demonstration that the **DNDC model simulates fluxes in an unbiased way** according to the procedures in section 7.4.1, as well as a table of Structural Uncertainty deductions as deduced using the procedures in this section.
6. **Step 6. A template .dnd input file** with each of the DNDC Model Parameters, and how they must be parameterized (default value, lookup table, historical records, field measurements, etc.)

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