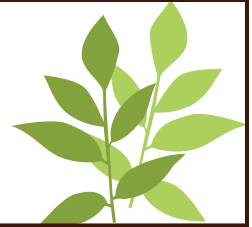




American Carbon Registry[®]
Trusted solutions for the carbon market



Voluntary Emission Reductions in Rice Management Systems

**Version 1.0
May 2013**



Voluntary Emission Reductions in Rice Management Systems

Version 1.0

Prepared by:



Terra Global Capital, LLC

With support from



Environmental Defense
Fund



California Rice Commission



Applied Geosolutions, LLC

May 2013

1	SOURCES	4
2	DEFINITIONS AND ACRONYMS	5
2.1	DEFINITIONS	5
2.2	ACRONYMS	6
3	SUMMARY DESCRIPTION OF THE METHODOLOGY	8
3.1	OPTIONS TO REDUCE GHG EMISSIONS IN RICE CULTIVATION	8
3.2	RICE-GROWING REGIONS.....	9
3.3	OVERVIEW OF METHODOLOGY	10
3.3.1	<i>Overview of Accounting Mechanics</i>	10
3.3.2	<i>Importance of Spatial Aggregation</i>	13
3.3.3	<i>Environmental Impact</i>	13
4	APPLICABILITY CONDITIONS	14
5	PROJECT BOUNDARY	15
5.1	GEOGRAPHIC BOUNDARY	15
5.2	GREENHOUSE GAS BOUNDARY	15
5.3	TEMPORAL BOUNDARY	18
6	PROCEDURE FOR DETERMINING THE BASELINE SCENARIO AND DEMONSTRATING ADDITIONALITY	20
6.1	DETERMINING WHETHER A COMMON PRACTICE BASELINE CAN BE USED	20
6.2	DETERMINING ADDITIONALITY	21
7	BASELINE EMISSIONS	23
7.1	DURATION AND STRUCTURE OF MODEL SIMULATIONS	23
7.2	IDENTIFYING CRITICAL VS. NON-CRITICAL MANAGEMENT PARAMETERS.....	24
7.3	MODEL PARAMETERIZATION.....	24
7.3.1	<i>Weather and Climate</i>	25
7.3.2	<i>Soil Data</i>	25
7.3.3	<i>Critical Management Parameters (only during Rice Growing Years)</i>	26
7.3.4	<i>Non-Critical Management Parameters</i>	27
7.3.5	<i>Using Dates in Baselines</i>	27
7.4	MODEL CALIBRATION AND MODEL VALIDATION FOR RICE GROWING SEASONS	28
7.4.1	<i>Regional Model Calibration and Model Validation and Calculation of Structural Uncertainty Deduction</i>	29
7.4.2	<i>Field-specific Model Calibration</i>	30
7.5	QUANTIFICATION OF BASELINE EMISSIONS.....	33
8	PROJECT EMISSIONS	34
8.1	DURATION AND STRUCTURE OF MODEL SIMULATIONS	34
8.2	MODEL PARAMETERIZATION.....	34
8.3	QUANTIFICATION OF PROJECT EMISSIONS	34

8.3.1	<i>Gross Project Emissions</i>	34
8.3.2	<i>Off-Field Emissions from Rice Straw (OFEF)</i>	35
8.3.3	<i>Emissions from Increases in Fertilization due to Baling (IFEFF)</i>	38
9	LEAKAGE	39
10	QUANTIFICATION OF NET GHG EMISSION REDUCTIONS AND/OR REMOVALS	40
10.1	UNCERTAINTY DEDUCTION	40
10.1.1	<i>Uncertainty in the Input Parameters</i>	40
10.1.2	<i>Structural Uncertainty</i>	41
10.1.3	<i>Combining the Sources of Uncertainty</i>	41
10.2	CALCULATION OF EMISSION REDUCTIONS	42
11	DATA AND PARAMETERS NOT MONITORED	43
12	MONITORING AND VERIFICATION	48
12.1	CHECK YIELD IMPACTS AND CALCULATE LEAKAGE.....	48
12.2	<i>EX-POST</i> MONITORING	50
12.3	FIELDS JOINING AND LEAVING THE PROJECT	51
12.4	PROJECT RENEWAL AND BASELINE UPDATE	51
12.5	VERIFICATION	53
12.5.1	<i>Levels of Verification: Desk Reviews and Field Visits</i>	53
12.5.2	<i>What must be done during an In-depth Audit?</i>	53
12.5.3	<i>How many and which fields must be visited in an in-depth audit?</i>	53
12.5.4	<i>Reducing the Burden of Field Visits by employing Industry Experts</i> ..	54
12.5.5	<i>Reducing the Burden of Field Visits by using Remote Sensing Data</i> .	54
12.5.6	<i>Timing of Verification</i>	55
12.5.7	<i>What happens if Requirements for Verification are not met?</i>	55
13	DATA AND PARAMETERS MONITORED	56
14	UNCERTAINTY QUANTIFICATION AND REQUIREMENTS FOR REGIONAL CALIBRATION MODULES	61
14.1	MODEL VALIDATION AND UNCERTAINTY QUANTIFICATION	61
14.1.1	<i>Overview</i>	61
14.1.2	<i>Verification of the lack of bias</i>	62
14.1.3	<i>Derivation of Uncertainty Deduction</i>	62
14.1.4	<i>Quantifying the standard deviation s and the correlation ρ</i>	65
14.2	REQUIREMENTS FOR REGIONAL CALIBRATION MODULES.....	66
15	REFERENCES	67

1 **1 Sources**

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

5 2 Definitions and Acronyms

6 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

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

8

9 3 Summary Description of the Methodology

10 3.1 Options to Reduce GHG Emissions in Rice Cultivation

11 Flooded rice fields are a source of atmospheric methane (CH₄). Flooding results in
12 anaerobic conditions in soils, which triggers anaerobic decomposition of organic
13 matter by methanogens, a class of soil bacteria. Methanogens produce CH₄ as the
14 product of the microbial decomposition of organic matter. Soon after the flooding of
15 rice fields, the oxygen in soil pores is depleted, and the process of anaerobic
16 decomposition of organic matter starts, leading to CH₄ emissions. The organic matter
17 used during anaerobic decomposition can originate from organic amendments, plant
18 residues or root exudates. The amount of CH₄ produced is proportional to the
19 duration of flooding (during the growing season and outside the growing season
20 during the winter months) and is impacted by the rice cultivar and the availability of
21 crop residues and organic matter.

22 This methodology uses the biogeochemical process model DNDC to quantify soil
23 carbon dynamics, N₂O and CH₄ emissions under the Baseline and Project scenarios.
24 Even though the DNDC model has been shown to be highly valid across a wide
25 range of activities and geographic areas in predicting both CH₄ and N₂O fluxes (Li,
26 2000; Pathak et al., 2005; Babu et al., 2006), this methodology only allows Project
27 Activities in geographic regions for which the DNDC model has been explicitly
28 calibrated with empirical data. This requirement is necessary because the
29 quantification of uncertainty around modeled CH₄ fluxes can only be done with local
30 and specific data consisting of empirical measurements of CH₄ fluxes². Instead of
31 requiring Project Proponents to demonstrate that the DNDC model is valid on a
32 project-by-project basis, this methodology divides model Calibration into two separate
33 steps: (1) a Regional Calibration and model Validation, which can be valid for a larger
34 area than just the project area, and (2) a field-specific Calibration, which must be
35 done on a field-by-field basis.

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

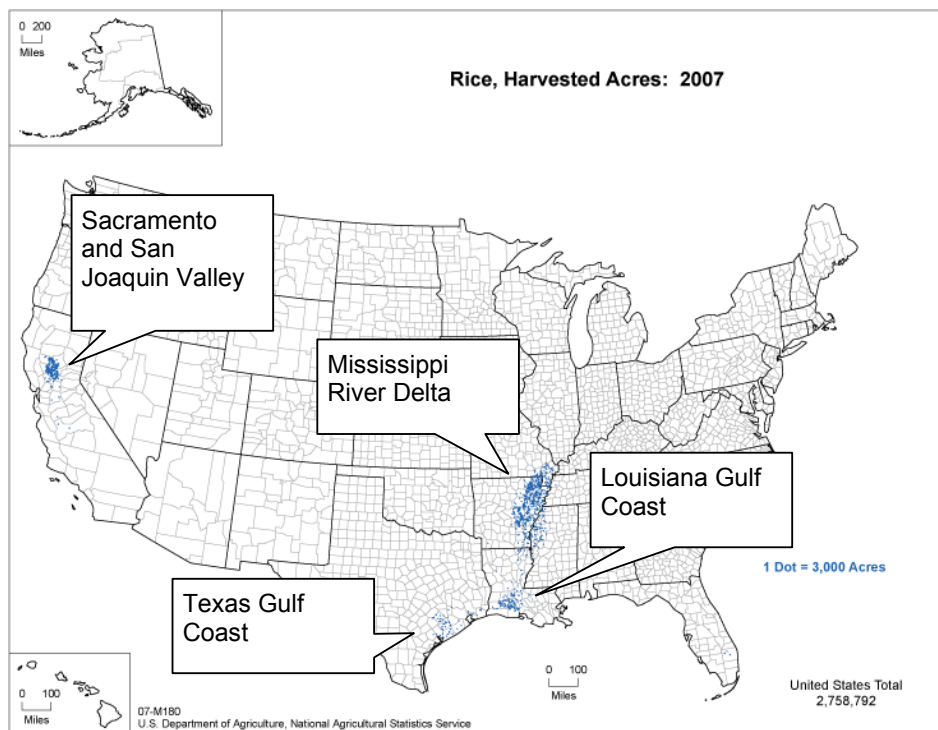
41 In addition, this methodology contains provisions to develop Regional Calibration
42 "modules" containing all the steps required for calibration for a specific region and

² Note that empirical measurements of N₂O fluxes are not required since these are not the primary target of this methodology. Peer-reviewed literature indicates that the uncertainty around changes in N₂O fluxes due to the project activities is insignificant relative to the change in CH₄ fluxes (Li, 2000; Pathak et al., 2005; Babu et al., 2006). As a consequence, the prediction of changes in N₂O fluxes by the DNDC model are sufficient for GHG accounting purposes.

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

53 3.2 Rice-Growing Regions

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



61

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

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

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

91 3.3 Overview of Methodology

92 3.3.1 Overview of Accounting Mechanics

- 93 • The emission reductions from implementing Project Activities are calculated
94 using the DNDC model separately for each field or stratum and for the
95 Baseline and Project scenarios. The calculations must be done once before
96 the start of the Project and included in the GHG Project Plan as an *ex ante*
97 estimate of emission reductions, and must be redone after the Project
98 Activities are complete to calculate the *ex post* actual emission reductions. An
99 Uncertainty Deduction is applied to modeled emission reductions to account
100 for model structural uncertainty and uncertainty in input parameters. The
101 uncertainty deduction must be applied to each field individually (see Section
102 10.1.3).
- 103 • Project Proponents must explicitly demonstrate that the DNDC model is
104 calibrated and must quantify the uncertainty around modeled emission
105 reductions for the proposed Project Activities and the geographic region of the
106 project. The methodology requires two different Calibration steps: (1) Regional

- 107 Calibration and Validation of the model using empirical gas flux data, and (2)
108 Field-Specific Calibration of the DNDC model's crop sub-model. Regional
109 Calibration is based on measured gas flux data from a field that is potentially
110 different than the Project fields and is, therefore, valid for a whole region. Field-
111 Specific Calibration uses the yield of an individual field and must be conducted
112 for each field separately. After the model has been Calibrated, the remaining
113 deviation between the modeled and measured results is used to calculate an
114 Uncertainty Deduction which, when applied to modeled emission reductions,
115 ensures that emission reductions remain conservative. The methodology
116 allows creating Regional Calibration modules as add-ons to this methodology.
- 117 • Emission reductions from changes in rice management in a given year are
118 permanent and cannot be reversed, regardless of future changes in
119 management. This methodology thus requires no buffer contribution or other
120 reversal risk mitigation mechanism.
 - 121 • The Baseline Scenario is determined by distinguishing Critical Management
122 Parameters – parameters that are directly or indirectly related to the Project
123 Activities – from Non-Critical Management Parameters – parameters that are
124 completely unrelated to the Project Activities. All Non-Critical Management
125 Parameters must remain the same between the Project and the Baseline
126 simulations; only the Critical Management Parameters are allowed to differ
127 between the Project and Baseline Scenario.
 - 128 • There are two options for setting the Baseline.
 - 129 ○ **Common Practice Baseline.** For proposed Project Activities that have
130 limited Baseline adoption, the management for the Baseline Scenario
131 must be set to the common practice across the industry. Specifically, a
132 Project that plans to implement a practice that has an adoption rate
133 below or equal to 5% within a Rice Growing Region can assume a
134 Baseline Scenario that reflects the management across the producers
135 that have not yet adopted the practice³.
 - 136 ○ **Field-Specific Baseline.** For Project Activities that have an adoption
137 rate greater than 5%, baseline emissions must (1) assume the same
138 sequence and frequency of whether Project Activities occurred (i.e.,
139 baling or not, dry seeding or not, etc.) as the five-year historical
140 sequence and frequency of Project Activity occurrence on each of the
141 individual Rice Fields, (2) obtain the Model Parameters (e.g., planting

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>

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

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

149 • In this methodology, Baselines are only partially fixed *Ex-ante*: only the values
150 of Critical Management Parameters are fixed *Ex-ante*. All Non-Critical
151 Management Parameters used for *Ex-post* calculations must reflect the actual
152 management and weather. This provision enables Project Proponents to
153 incorporate the impact of weather and management on CH₄ emissions and
154 growers' management decisions such as planting or harvesting dates. If
155 Baselines were entirely fixed *Ex-ante*, artificial emission reductions could be
156 generated due to extreme or outlying weather circumstances that are not
157 captured under the *Ex-ante* Baseline. To avoid the generation of such artificial
158 emission reductions, the Baseline must be recalculated *Ex-post* using the
159 actual historical weather information. Likewise, since certain management
160 decisions are dependent on weather (e.g., planting and harvesting dates), the
161 Baseline Scenario must be recalculated using the actual values of these
162 management decisions.

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

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

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

177 ○ Projects initiated using a Common Practice Baseline can renew their
178 Crediting Period after 5 years. However, if after 10 years, the Baseline
179 adoption rate is still less than 5%, the Crediting Period can no longer be

180 renewed. This limitation on Crediting Period renewal is based on the
181 view that if after 10 years the practice remains at <5% adoption, there
182 must be some other barrier to adoption and the reason for allowing
183 early adopters in the program (to prime the system and demonstrate
184 that a set of Project Activities can be successfully used) becomes less
185 persuasive. If after 10 years, the Baseline adoption rate is greater than
186 5% but smaller than 50%, the Crediting Period can be renewed.

187 *3.3.2 Importance of Spatial Aggregation*

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

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

201 *3.3.3 Environmental Impact*

202 Winter-flooded Rice Fields represent critical habitat for waterbirds (Day and Colwell
203 1998). Therefore, any reduction in winter flooding cannot be credited under this
204 methodology.

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

208 **4 Applicability Conditions**

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

- 210 1. The project area must include a minimum of five individual Rice Fields **or** 405
211 ha (1,000 acres)⁴. The fields can be distributed among different farmers/farms
212 or located on one farming operation.
- 213 2. The participating Rice Fields are located in a Rice Growing Region for which
214 the DNDC model has been successfully Calibrated for each of the proposed
215 Project Activities following Section 14.1⁵.
- 216 3. The Rice Fields included in the Project Area have been cropped under rice
217 under flooded conditions for at least two out of five years preceding the first
218 Project Activity on each field.
- 219 4. For each Rice Field, it is known whether the Project Activities were conducted
220 for each of the five years preceding the start of the Crediting Period during
221 which rice was grown. In addition, values for Model Parameters for each
222 individual Rice Fields are available for three out of the five years preceding the
223 start of the Crediting Period during which rice was grown⁶, unless rice was
224 grown only two out of the past five years, in which case two years of historical
225 data are sufficient.
- 226 5. The Project does not contain any soils with organic carbon content in the top
227 30 cm greater than 3%⁷.

⁴The 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 CH₄ and N₂O 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 N₂O 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.

228 **5 Project Boundary**

229 5.1 Geographic Boundary

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

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

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

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

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

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

261 5.2 Greenhouse Gas Boundary

262 Changing management practices potentially affects each of the three biogenic
263 greenhouse gases. The greenhouse gases included in and excluded from the Project

264 are shown in Table 1. It is allowed to include additional sources and gases in a
265 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 ₂ O	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 ₂ O	No	N ₂ O 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 ₂ O	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 ₂ O	No	N ₂ O 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 ₂ O	No	Due to the low N content of rice straw, N ₂ O 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

⁸*Dry-seeding*, as defined in Section 6 may increase N₂O 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 ₂ O	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..

267

268 Project Proponents are allowed to use this methodology in combination with a
 269 separate methodology that credits reduced N₂O emissions from optimized fertilizer
 270 management⁹. When this methodology is used in conjunction with a fertilizer
 271 reduction methodology, only one GHG Project Plan shall be developed and the N₂O
 272 quantification shall occur based on the accounting procedures in the fertilizer
 273 reduction methodology. When the DNDC model is used for quantification in the
 274 fertilizer reduction methodology, only one simulation run for Baseline and project
 275 conditions shall be used that is used for both the fertilizer reduction methodology and
 276 this methodology.

277 5.3 Temporal Boundary

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

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

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

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

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>

296 growing season. A Crediting Period can be renewed following the rules in Section
297 12.4.

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

301 **6 Procedure for Determining the Baseline Scenario and Demonstrating** 302 **Additionality**

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

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

319 6.1 Determining whether a Common Practice Baseline can be used

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

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

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

340 the baseline adoption rate must be set as the average of at least 2 adoption
 341 rates in the 5 years preceding the Crediting Period.¹⁰
 342 • **Expert opinion.** If 3 independent experts assert that the baseline adoption
 343 rate of a given practice is less than or equal to 4% of the acres on which rice is
 344 grown within the Rice Growing Region, no survey has to be conducted, and
 345 projects using the practice must use a Common Practice Baseline. The
 346 independent experts must have at least 10 years of relevant experience in rice
 347 agronomy and must be associated with an academic institution, government
 348 institution, or must be a full-time certified crop advisor with experience in the
 349 Rice Growing Region. The validity of the independent experts shall be
 350 evaluated during validation of a GHG Project Plan by a third-party auditor.

351 6.2 Determining Additionality

352 An individual Project Activity that exceeds applicable legal/regulatory requirements¹¹,
 353 and for which the baseline adoption rate is less than or equal to 5% of all acres on
 354 which rice is grown within one Rice Growing Region, is automatically additional and
 355 no further additionality test must be conducted. Project Activities for which the
 356 baseline adoption rates is greater than 5% must explicitly demonstrate additionality
 357 using ACR's project-specific three-pronged test of additionality or a comparable ACR-
 358 approved additionality tool.¹² This demonstration needs to be conducted at project
 359 commencement and documented in the GHG Project Plan.

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

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

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/>.

370 or any other management aspect of rice cultivation, in the absence of
371 registration as an ACR Project Activity.
372 3. Discontinuing rice cultivation and converting the land to an alternative
373 agricultural use.

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

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

381 **7 Baseline Emissions**

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

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

401 **7.1 Duration and Structure of Model Simulations**

402 **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
<i>Historical Period</i>				<i>Crediting Period</i>	
Model Equilibration			Crop Yield Calibration	Period 1	Period 2

403

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

- 406 • The duration of a DNDC model simulation must be at least 20 years before the
 407 start of the Crediting Period so that the model can attain equilibrium in certain
 408 critical variables for which empirical data is lacking, such as the sizes and the
 409 quality of the different carbon pools, and the inorganic nitrogen contents of soil
 410 pore water. This period is referred to as the Historical Period. In case a Field
 411 Specific Baseline is used, the Model Parameters for the 20-year Historical
 412 Period must be set by repeating the frequency of historical occurrence of
 413 Project Activities during the last five years before the start of the Crediting
 414 Period four times, while using the management parameters of at least three
 415 out of five years before the start of the Crediting Period unless otherwise

- 416 noted. However, if rice was grown only two out of the past five years, two
417 years of historical data are sufficient to parameterize the DNDC model.
- 418 • The management parameters of at least three out of the last five years
419 preceding the Project Start Date, from the producer's own Rice Fields, must be
420 used to calibrate the modeled crop yields during the field-specific model
421 calibration step (see Section 7.4.2).
 - 422 • After the start of the Crediting Period, the model must be simulated in five-year
423 increments. The GHG Project Plan must include at least one five-year cycle
424 after the start of the Crediting Period.

425 7.2 Identifying Critical vs. Non-Critical Management Parameters

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

432 For example, if straw baling is a Project Activity, the residue left after harvest would
433 be a Critical Management Parameter; if dry seeding is a Project Activity, date of first
434 flood is a Critical Management Parameter. Sufficient attention must be paid to all
435 potential indirect impacts of the Project Activities on nutrient, weed, crop residue, and
436 flooding management. In the example of straw baling, the amount of nitrogen fertilizer
437 applied is a Critical Management Parameter as well because it is possible that
438 additional nitrogen fertilizer was applied to compensate for nutrient losses during
439 straw removal. This additional nitrogen fertilizer will potentially lead to an increase in
440 N₂O emissions, and must, therefore, be included as a Critical Management
441 Parameter. Note that the loss of other nutrients such as K will likely have to be
442 compensated as well by increasing the amount of K fertilizer; however, the GHG
443 emissions related to the increase in application rates for other nutrients are
444 considered insignificant. Project Proponents must present in the GHG Project Plan a
445 comprehensive list of the all Model Parameters and indicate which ones are critical
446 and which ones are not.

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

449 7.3 Model Parameterization

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

455 **7.3.1 Weather and Climate**

456 Weather significantly affects CH₄ emissions and hence the reduction in CH₄
 457 emissions due to alternative crop management. Variations in temperature not only
 458 directly affect CH₄ emissions; climate also affects annual CH₄ emissions since
 459 climate controls the length of the growing season: the exact planting date is
 460 dependent on the average temperature and rainfall in April-May and how many fields
 461 a farmer has. The harvesting date is dependent on the cumulative growing degree
 462 days since planting. Therefore, while *Ex-ante* baseline emissions must be calculated
 463 using five years of historical weather data preceding the start of the Crediting Period,
 464 *Ex-post* the Baseline must be re-calculated with the actual weather. The following
 465 requirements must be met:

- 466 • Daily climate data must come from a weather station that is located maximally
 467 50 miles away. If the Project is located in California, it is recommended to use
 468 weather data from the nearest CIMIS weather station
 469 (<http://www.cimis.water.ca.gov>).
- 470 • Weather data for the five years preceding the start of the Crediting Period must
 471 be collected. Weather data for the Historical Period must be set by repeating
 472 this five-year weather data set four times as described in 7.1. After the start of
 473 the Crediting Period, the same five-year weather data must be used and
 474 repeated, if necessary. As indicated before, *Ex-post*, actual weather data must
 475 be used for all emission calculations.
- 476 • Daily values of maximum temperature, minimum temperature, rainfall, and
 477 solar radiation must be collected and formatted according to the DNDC
 478 model's "Jday, MaxT, MinT, Rainfall, Radiation (MJ/m²/day)" format, which is
 479 the DNDC model's climate file mode 1.

480 **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

481

482 **7.3.2 Soil Data**

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

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

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

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

500 **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	-

501

502 7.3.3 Critical Management Parameters (only during Rice Growing Years)

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

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

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

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/>.

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

522 7.3.4 Non-Critical Management Parameters

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

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

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

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

542 7.3.5 Using Dates in Baselines

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

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

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

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

565 7.4 Model Calibration and Model Validation for Rice Growing Seasons

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

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

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

594 *7.4.1 Regional Model Calibration and Model Validation and Calculation of Structural*
595 *Uncertainty Deduction*

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

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

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

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

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

¹⁴ Soil Sci. Soc. Am. J. 72:331-342

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

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

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

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

643 The Structural Uncertainty deduction should then be calculated as:

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

644 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]

645 7.4.2 Field-specific Model Calibration

646 After the regional model calibration, it is required to conduct an additional field-
 647 specific Calibration for each Rice Field included in the Project. The field-specific
 648 Calibration tunes the crop sub-model of DNDC to the exact yields attained on each
 649 Rice Field. The field-specific Calibration shall always use yield data, but when the
 650 yield-based Calibration is insufficient to ensure that DNDC predicts the recorded

651 yields during at least three out of five years before the start of the project with a
 652 maximal relative Root Mean Squared Error (RMSE) of 10% of the observed means,
 653 the field-specific Calibration must also include additional crop data. However, if rice is
 654 grown only two out of the five years preceding the Project Start Date, yield data from
 655 these two years suffice to apply this test. These more general crop data include the
 656 default partitioning of carbon into different plant compartments, C/N ratio of the
 657 different plant compartments, and the thermal degree days required to reach maturity.

- 658 • **Step 1 – selecting the right parameter set for the variety used.** The
 659 specific rice variety used strongly impacts CH₄ emissions (Lindau et al., 1995).
 660 The crop parameters used must be appropriate for the rice variety used by the
 661 farmer. In addition, the “maximum biomass” parameter must be manually
 662 optimized until the actual cropping yield coincides with the cropping yield
 663 simulated by the DNDC model. Parameters for M-206 rice variety, based on
 664 calibration using field data from the Maxwell and Biggs study sites (Bossio et
 665 al. 1999, Fitzgerald et al. 2000 and Horwath et al., 2011, preliminary
 666 unpublished results), are given in Table 5 below. As more field data become
 667 available, model Calibration may improve, hence the parameters in Table 5
 668 may be updated in future versions of this methodology. In addition, crop
 669 parameterization values for other varieties will be published as an addendum
 670 to this methodology as they become available.

671 **Table 5. DNDC input parameters based on calibration data from two study sites, for the M-206 rice variety**
 672 **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

673
 674 Growers are allowed to change varieties after the Start Date as long as the
 675 new variety is well parameterized. If Project Activities did not impact the

676 decision to change the variety, variety shall be considered a Non-Critical
677 Management Parameter. However, if the variety change is the result of one of
678 the Project Activities, variety shall be considered a Critical Management
679 Parameter

680

681 • **Step 2 – tuning the “maximum biomass” parameter of the DNDC model.**

682 The “maximum biomass” parameter of the DNDC model must be manually
683 tuned using yield data so that DNDC predicts the recorded yields during at
684 least three out of five years before the start of the Project with a maximal
685 relative Root Mean Squared Error (RMSE) of 10% of the observed means.
686 However, if rice is grown only two out of the five years preceding the Project
687 Start Date, applying this test with two years of data suffices. If this is not
688 possible by adjusting the “maximum biomass” parameter, one or both of the
689 following options are to be followed until modeled yields are within a maximal
690 relative RMSE of 10% of observed means.

- 691 ○ If the “Crop” pane of the DNDC results (with title “Crop Yields and Heat-
692 Water-Nitrogen Stresses”) indicates that the modeled “Water demand”
693 value is greater than the “Water uptake” value during years with normal
694 weather, the value for “water demand, g water/g DM” in the “Crop” pane
695 of the Farming Practice Management dialog (equal to the
696 “Water_requirement” parameter in the .dnd file) must be reduced until
697 the “Water demand” is equal to the “Water uptake” value.
- 698 ○ Similarly, if the same pane indicates that the “Temperature demand”
699 value is greater than the value for “Thermal degree days for maturity”,
700 the “Thermal degree days for maturity” (equal to the “TDD” parameter in
701 the .dnd file) must be reduced until the “Temperature demand” is
702 smaller than or equal to the value of “Thermal degree days for maturity”.

703

- 704 • **Step 3 – Re-parameterization of crop if no sufficient correspondence is**
705 **achieved.** If sufficient correspondence was achieved during step 2, this step
706 shall be skipped. However, if no sufficient correspondence can be achieved by
707 following the procedure described above, Project Proponents must calibrate
708 the other crop parameters, including biomass allocation to roots, leaves/stems
709 and grain and the C/N ratio of roots, leaves/stems and grain using laboratory
710 measurements, scientific literature, and/or a cross-calibration with a more
711 sophisticated crop growth model such as the DD-50 model¹⁵. However, it is up
712 to the Project Proponents to execute a proper Calibration and provide all the
713 necessary justification to the third-party VVB. Because it is very challenging to
714 define rigorous criteria to calibrate each of the crop parameters and verify their

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

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

717 7.5 Quantification of Baseline Emissions

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

$$BE_{y,i} = \frac{44}{12} \cdot [CO_2 - C]_{baseline,y,i} + 310 \cdot \frac{44}{28} \cdot [N_2O - N]_{baseline,y,i} + 21 \cdot \frac{16}{12} \cdot [CH_4 - C]_{baseline,y,i} \quad [EQ 3]$$

721

722 Where:

$BE_{y,i}$	=	Baseline emissions in year y for individual Rice Field i [kg CO ₂ -eq ha ⁻¹ yr ⁻¹]
$[CO_2 - C]_{baseline,y,i}$	=	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]
$[N_2O - N]_{baseline,y,i}$	=	Baseline nitrous oxide flux rate in year y for individual Rice Field i as reported by DNDC [kg N ha ⁻¹]
$[CH_4 - C]_{baseline,y,i}$	=	Baseline CH ₄ flux rate in year y for individual Rice Field i as reported by DNDC [kg C ha ⁻¹]

723

724 Following ACR requirements, 21 and 310 are the Global Warming Potentials for
725 methane and nitrous oxide, respectively, as developed in the IPCC Second
726 Assessment Report and reported in Table 2.14 of the IPCC 4th Assessment Report of
727 Working Group 1, available at <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf>.
728

729 8 Project Emissions

730 Similarly to the Baseline emissions, Project emissions of CO₂, CH₄ and N₂O must be
 731 calculated using DNDC. For each individual Rice Field, a separate model simulation
 732 must be executed for the Project scenario and an appropriate input parameter file
 733 (“*.dnd”) must be available to the VVB.

734 8.1 Duration and Structure of Model Simulations

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

744 8.2 Model Parameterization

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

755 8.3 Quantification of Project Emissions

756 8.3.1 Gross Project Emissions

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

760

$$\begin{aligned}
 PE_{y,i} = & \frac{44}{12} \cdot [CO_2 - C]_{project,y,i} + 310 \cdot \frac{44}{28} \cdot [N_2O - N]_{project,y,i} & [EQ 4] \\
 & + 21 \cdot \frac{16}{12} \cdot [CH_4 - C]_{project,y,i}
 \end{aligned}$$

761

762 Where:

- $PE_{y,i}$ = Project emissions in year y for individual Rice Field i [kg CO₂-eq ha⁻¹ yr⁻¹]
- $[CO_2 - C]_{project,y,i}$ = 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]
- $[N_2O - N]_{project,y,i}$ = Project nitrous oxide flux rate in year y for individual Rice Field i as reported by DNDC [kg N ha⁻¹]
- $[CH_4 - C]_{project,y,i}$ = Project CH₄ flux rate in year y for individual Rice Field i as reported by DNDC [kg C ha⁻¹]

763 **8.3.2 Off-Field Emissions from Rice Straw (OFFEF)**

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

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

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

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

809

810 **Table 6. Emission factors for potential end-uses of removed straw (kg CO₂ equivalents per metric ton of**
 811 **dry straw).**

Potential end-use	Sources of (Avoided) Emissions	$OFEF_{y,i}$ [kg CO ₂ -eq t ⁻¹ dry straw]
Dairy replacement heifer feed	<i>avoiding post-harvest chopping and disking</i>	-50 ¹⁶
	<i>swathing, raking, baling</i>	20
	<i>increases in CH₄ emissions from enteric fermentation due to incorporating low-digestible rice straw in feed</i>	75 ¹⁷
	TOTAL	45
Beef cattle feed	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	<i>increases in CH₄ emissions from enteric fermentation due to incorporating low-digestible rice straw in feed</i>	75 ¹⁸

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 CH₄ 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 CH₄ of 55.65 MJ kg⁻¹ CH₄ (id.).

¹⁸ Assuming a calorific value of dry rice straw of 15 MJ kg⁻¹ (Pütün et al., 2004), an increase in the cattle CH₄ 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 CH₄ of 55.65 MJ kg⁻¹ CH₄ (id.).

Potential end-use	Sources of (Avoided) Emissions	$OFEF_{y,i}$ [kg CO ₂ -eq t ⁻¹ dry straw]
	TOTAL	45
Animal bedding	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	TOTAL	-30
Spread out on bare soils as erosion control	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	<i>roadsiding, storing, loading, transport</i>	60
	<i>spreading</i>	10 ¹⁹
	TOTAL	40
Stuffed in netted rolls to prevent soil loss	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	TOTAL	-30
Mushroom production	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	TOTAL	-30
Unused and accumulated in piles near the farm	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	<i>non-CO₂ emissions during the decomposition of the straw</i>	250 ²⁰
	TOTAL	220
Fiberboard manufacturing	<i>avoiding post-harvest chopping and disking</i>	-50
	<i>swathing, raking, baling</i>	20
	<i>non-CO₂ emissions during the manufacturing and life cycle of the fiberboard</i>	0 ²¹
	TOTAL	-30

812

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

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

²⁰ Using the average CH₄ Emission Factor for composting of 10 g CH₄ 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.

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

820

821 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 [-]

822

823 **8.3.3 Emissions from Increases in Fertilization due to Baling (IFEF)**

824 Removing rice straw from a Rice Field removes a significant amount of nutrients. This
 825 nutrient removal must be compensated by increasing fertilization. This increase in
 826 fertilization is associated with an increase in GHG emissions from fertilizer production
 827 and fertilizer transportation. Emissions from fertilizer transportation are assumed to
 828 be negligible, but emissions from fertilizer production are not. The average nutrient
 829 content of rice straw is 0.77% N, 0.10% P and 1.74% K (ANR, 2010), and GHG
 830 emissions from fertilizer production are 4 kg CO₂-eq (kg N)⁻¹, 1.6 kg CO₂-eq (kg P)⁻¹,
 831 0.71 kg CO₂-eq (kg K)⁻¹ (coefficients taken from the GREET model as published in
 832 Chalmers and Walden, 2009). As a consequence, the emissions related to the
 833 increase in fertilization per metric ton of rice straw removed are 1000*(0.0077*4 +
 834 0.001*1.6 + 0.0174 * 0.71) = 44.7 kg CO₂-eq (t dry straw)⁻¹.

835 This factor is referred to as *IFEF* (Increased Fertilizer Emission Factor) in section
 836 10.2. In that section, it is explained that *IFEF* shall be multiplied by $CRH_{y,i}$, the crop
 837 residue harvested in year y for individual Rice Field i as defined in Section 8.3.2 to
 838 quantify the emissions from increases in fertilization due to baling.

839

840 **9 Leakage**

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

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

843 Where:

$E_{leakage,t,i}$ = Ex-ante emissions from leakage in year t for individual Rice
Field i [tCO₂-eq yr⁻¹]

844

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

848 10 Quantification of Net GHG Emission Reductions and/or Removals

849 10.1 Uncertainty Deduction

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

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

863 10.1.1 Uncertainty in the Input Parameters

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

870 **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%

871

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).

872 A multivariate lognormal distribution must be used to sample parameters for the
 873 Monte Carlo analysis²³. At least 1000 (n) different draws out of this multivariate
 874 lognormal distribution for both the Baseline Scenario and the Project Scenario and
 875 subsequent model simulations must be executed. For each of the n draws of the
 876 distribution, one emission reduction is calculated by subtracting the Baseline
 877 emissions from the Project emissions. Calculate the relative input uncertainty factor
 878 for field i , $u_{input,i}$, as the value corresponding to the 10% quantile for the distribution
 879 of n emission reduction values divided by the mean of the n emission reduction
 880 values.

881 10.1.2 Structural Uncertainty

882 Structural Uncertainty can be quantified by comparing modeled gas fluxes with
 883 empirical gas fluxes. The Structural Uncertainty around the size of the emission
 884 reductions of a project that combines multiple individual Rice Fields will decrease with
 885 increasing number of individual Rice Fields included. For example, Olander and Malin
 886 (2010) demonstrate that the RMSE decreases from 9 kg N-N₂O ha⁻¹ for an individual
 887 Rice Field to 1.8 kg N-N₂O ha⁻¹ if 10 Rice Fields are combined within one Project.
 888 The methodology requires a minimum of five Rice Fields or 405 ha (1,000 acres) be
 889 included within the Project, and requires estimating a Structural Uncertainty factor by
 890 comparing modeled with measured CH₄ emissions. Procedures to calculate this
 891 factor are included in 7.4.1.

892 10.1.3 Combining the Sources of Uncertainty

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

895

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

896

897 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].

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 CO₂-eq ha⁻¹]
 $BE_{y,i}$ = Baseline emissions in year y for individual Rice Field i [kg CO₂-eq ha⁻¹]
 $u_{input,i}$ = Relative input uncertainty factor [-]

898

899 As per ACR requirements, no Uncertainty Deduction is required if the half-width of the
 900 resulting combined confidence interval is within 10% of the mean at 90% confidence.

901 Hence, if $u_i \geq 0.9$, no Uncertainty Deduction is to be applied and a value of $u_i = 1$
 902 shall be assumed in all subsequent calculations. However, if $u_i < 0.9$, the Uncertainty
 903 Deduction factor u_i must be applied as is.

904 10.2 Calculation of Emission Reductions

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

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

906

907 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 CO₂-eq t⁻¹ dry straw]
 $IFEF$ = Increased Fertilizer Emission Factor [kg CO₂-eq t⁻¹ dry straw]

908

909 **11 Data and Parameters Not Monitored**

Data Unit / Parameter:	Soil_Texture
Data unit:	-
Description:	<p>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).</p>
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:	

910

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:	

911

912

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:	

913

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:	

914

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.

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,

915

	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.

916

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.

917

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.

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

918

	(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:	

919

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:	

920

Data Unit / Parameter:	$\epsilon_{rice, rice}$
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.

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:	<p>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 include²⁴:</p> <ul style="list-style-type: none"> • 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

922

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

923 **12 Monitoring and Verification**

924 12.1 Check Yield Impacts and Calculate Leakage

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

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

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

936

$$y_{norm_{t,i}} = \frac{y_{t,i}}{y_{county_t}} \quad \text{[EQ 9]}$$

937

$$s_i = stdev(y_{norm_{t,i}}) \quad \text{[EQ 10]}$$

938

$$\overline{y_{norm_i}} = mean(y_{norm_{t,i}}) \quad \text{[EQ 11]}$$

939

940 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 [$Mg\ ha^{-1}$]

941

942 Normalize the sum of the historical yields for all the Rice Fields included in the
 943 Project by dividing the yield sum by the county mean for that specific year and

944 for the aggregated rice crop in units of “yield, measured in lbs / acre” obtained
 945 from the USDA NASS (<http://quickstats.nass.usda.gov>).

946
 947 Verify the distribution of $y_{norm_{t,i}}$ values. Most likely, these will be log-
 948 normally distributed. Apply the appropriate statistical transformation to
 949 y_{norm_t} to obtain a normal distribution before taking standard deviation and
 950 means.

951
 952 (2) Calculate the “minimum yield threshold” below which normalized yields are
 953 significantly smaller than the county mean:

954

$$y_{min_i} = \overline{y_{norm_{t,i}}} - t(0.10, n - 1) \cdot s_i \quad [EQ 12]$$

955

956 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 [$Mg\ ha^{-1}$]

957

958 (3) For every year of the Crediting Period, calculate y_{norm_t} and compare this
 959 value to y_{min} . If $y_{norm_{t_0}}$ is smaller than y_{min} , yields were significantly
 960 smaller than under pre-Project conditions, even normalized for inter-annual
 961 differences. In this case, the theoretical yield that could have been attained
 962 without Project Activities, i.e. the Baseline yield, is:

$$y_{baseline_{t,i}} = \overline{y_{norm_{t,i}}} \cdot y_{county_t} \quad [EQ 13]$$

963

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

$$y_{baseline_{t,i}} - y_{t,i} \quad [EQ 14]$$

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

$$\frac{BE_{t,i}}{y_baseline_{t,i}} \quad [EQ\ 15]$$

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

$$E_{leakage,t,i} = \varepsilon_{rice,rice} \cdot (y_baseline_{t,i} - y_{t,i}) \cdot \frac{BE_{t,i}}{y_baseline_{t,i}} \quad [EQ\ 16]$$

967

968 Where:

- $E_{leakage,t,i}$ = Emissions from leakage in year t for individual Rice Field i [tCO₂-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 [tCO₂-eq yr⁻¹]

969

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

973 12.2 *Ex-post* Monitoring

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

- 976 • Planting preparation description and date
- 977 • Planting date
- 978 • Fertilization amounts and dates
- 979 • Flooding start and duration throughout the year
- 980 • Harvesting date
- 981 • Post-harvesting description and dates

982 12.3 Fields Joining and Leaving the Project

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

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

994 12.4 Project Renewal and Baseline Update

995 Per the *ACR Standard*, the duration of the Crediting Period equals the period of
996 baseline validity, which is five years under this methodology. The Crediting Period for
997 a Project (or Rice Field within a Project) using a Common Practice Baseline can be
998 renewed at the end of a 5-year Crediting Period for another five years. However, if 10
999 years after the start of the first Crediting Period, the Baseline adoption rate of the
1000 Project Activity in the Rice Growing Region is still less than 5%, the Crediting Period
1001 can no longer be renewed.²⁵ If after 10 years the adoption rate of the Project Activity
1002 in the Rice Growing Region is greater than 5%, the Crediting Period can be renewed.

1003 A Crediting Period for a Project using either a Field-Specific or Common Practice
1004 Baseline can be renewed until the adoption rate of the Project Activity in the Rice
1005 Growing Region is greater than 50%. The latter provision is included to ensure that a
1006 Baseline is set based on common practice that represents the practice of a majority
1007 of the producers. Any practice for which the adoption is smaller than 50% cannot be
1008 considered common practice because less than half of the producers are
1009 implementing the practice.

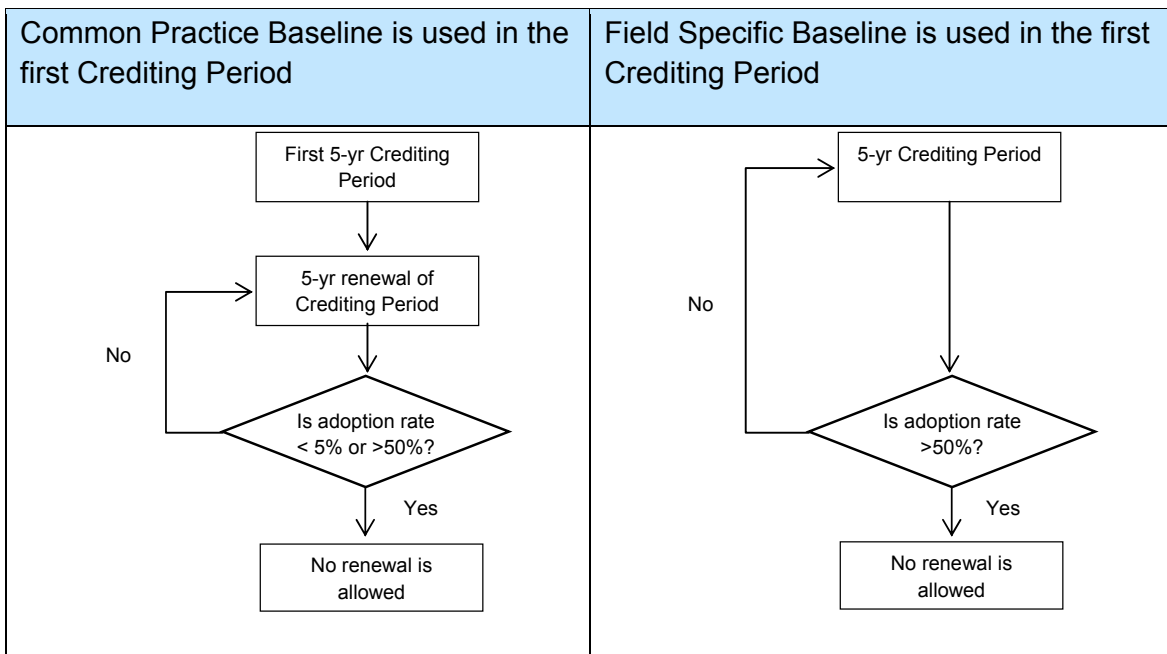
1010 At every renewal of a Project's Crediting Period, Project Proponents shall calculate
1011 the adoption rate of the Project Activity so that the requirements above can be
1012 verified. The procedures in Section 6.1 must be used to calculate the adoption rate of
1013 the practice. The flowchart in Figure 2 can be used to determine the renewal
1014 eligibility.

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.

1015 Rice Fields using a Field-Specific Baseline in the first Crediting Period must switch to
 1016 a Common Practice Baseline when the Project Crediting Period is renewed as
 1017 indicated in Table 8. Rice Fields using a Common Practice Baseline in the first
 1018 Crediting Period must continue using a Common Practice Baseline.

1019 For Common Practice Baselines, the Baseline values of the Critical Management
 1020 Parameters shall not be older than five years before the start of the current Crediting
 1021 Period according to the procedures in Section 7 for determining Common Practice
 1022 Baselines.

1023 Note that the Crediting Period is project-specific and not field-specific. If a Rice Field
 1024 joins in the third year of the Crediting Period, it joins the Crediting Period of the
 1025 overall Project rather than beginning its own 5-year Crediting Period. If this field is
 1026 using a Field Specific Baseline, it must switch to a Common Practice Baseline upon
 1027 renewal of the overall Project Crediting Period at year 5, similar to the other fields in
 1028 the Project.



1029 Figure 2. Flow chart of renewal of a Crediting Period.

1030 **Table 8. The use of Field Specific and Common Practice Baselines for Projects starting with either a Field**
 1031 **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.

1032

1033 12.5 Verification

1034 *12.5.1 Levels of Verification: Desk Reviews and Field Visits*

1035 At a verification event, a VVB shall review that all required monitoring parameters are
 1036 available for every Rice Field (“completeness audit”) in a desk review based on the
 1037 data provided in a monitoring report. In addition to the completeness audit, the VVB
 1038 shall check a random selection of fields using a more in-depth audit in which the
 1039 values of specific parameters are verified during a field visit (“in-depth audit”) and the
 1040 DNDC simulations are checked. The use of remote sensing techniques and local
 1041 experts can reduce or even eliminate field visits.

1042 Rice Fields on which Project Activities were conducted before this methodology was
 1043 adopted by ACR are exempt from undergoing an in-depth audit.

1044 *12.5.2 What must be done during an In-depth Audit?*

1045 During an in-depth audit, two aspects shall be verified: (1) whether a Project Activity
 1046 occurred or not, e.g. whether a field was baled or not, and (2) whether the Model
 1047 Parameters that are indicated as Critical Management Parameters in the
 1048 methodology for the Project Activities on a specific Rice Field are within an expected
 1049 (or verifiable) range. The procedures to verify that the value of each Critical
 1050 Management Parameter is within the verifiable range are specified in the description
 1051 of each parameter in section 13.

1052 *12.5.3 How many and which fields must be visited in an in-depth audit?*

- 1053 • For every year of the Crediting Period being verified, at least 20% of the Rice
 1054 Fields generating credits during that year or 2 Rice Fields, whichever is
 1055 greater, shall be selected for verification. Note that this does not imply that a
 1056 verification audit has to occur every year of the Crediting Period; practices and
 1057 parameters of multiple years may be verified during one single audit.

- 1058 • For every year of the Crediting Period being verified, the Rice Fields that are to
 1059 be visited shall be selected at random from the Rice Fields generating credits
 1060 during that year of the Crediting Period. Each field shall only be visited at most
 1061 one time within one year, but a Rice Field may potentially be visited multiple
 1062 times during different years.

1063 *12.5.4 Reducing the Burden of Field Visits by employing Industry Experts*

1064 The methodology allows for aggregators, project developers, extension agents, or
 1065 other industry experts to eliminate the need of a VVB themselves to conduct a field
 1066 visit on the conditions that (1) the VVB has selected the fields to be visited at random
 1067 and (2) the selection of the fields is only communicated with the growers after the
 1068 Project Activities have been implemented and (3) the information provided by the
 1069 expert follows the parameter-specific description in Section 13. Section 13 describes
 1070 which evidence can eliminate a field visit and focuses on how the risk for tampering
 1071 can be eliminated. For example, a VVB may request a geo-tagged photograph of a
 1072 specific field after baling. The photograph must be taken by a GPS-enabled camera
 1073 and shall be automatically uploaded to an account to which the VVB has full access,
 1074 so that the metadata cannot be tampered with.

1075 *12.5.5 Reducing the Burden of Field Visits by using Remote Sensing Data*

1076 The Project Proponent is allowed to employ remote sensing to replace a field visit for
 1077 Project Activities or Model Parameters that can be observed using remote sensing
 1078 with sufficient accuracy. The Project Activities or Model Parameters that may be
 1079 verified using remote sensing instead of a field visit are described in the parameter
 1080 list in section 13. However, evaluating the presence or absence a Project Activity
 1081 using remote sensing must have an Accuracy of at least 90% as evaluated on a held-
 1082 out sample. If the Accuracy is less than 90%, remote sensing procedures shall not be
 1083 used to replace the field visit.

1084

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.

1085

1086 *12.5.6 Timing of Verification*

1087 It is the nature of agriculture that Project Activities can only be observed at discrete
 1088 points during the growing season. Therefore, the timing of field visits shall follow the
 1089 growing calendar. As the timing of the growing calendar depends on the weather, a
 1090 VVB shall be in close contact with the Project Proponents to ensure the window of
 1091 verification shall not be missed.

1092 **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

1093

1094 *12.5.7 What happens if Requirements for Verification are not met?*

1095 As indicated above, during an in-depth parameter audit, it shall be verified (1)
 1096 whether a practice occurred and (2) whether the values of the Critical Management
 1097 Parameters are within a verifiable range as specified in the description of each
 1098 parameter in Section 13.

1099 If, during an in-depth parameter audit, it cannot be verified whether a Project Activity
 1100 occurred on a specific Rice Field, the Rice Field shall be removed from credit
 1101 calculations for that year. If more than 5 fields or 405 ha (1,000 acres) remain in the
 1102 Project, credits can be generated. If less than 5 fields or 405 ha remain in the Project,
 1103 no credits are to be issued that year. However, the Project Proponent is allowed to
 1104 include new Rice Fields in the Project and postpone the issuance of credits for all
 1105 fields until 5 fields or 405 ha are available. If for more than two fields belonging to the
 1106 same grower, the VVB cannot verify whether a practice occurred, all Rice Fields for
 1107 this grower shall undergo an in-depth parameter audit.

1108 If, during an in-depth parameter audit, the Critical Management Parameters are not
 1109 found to be within the verifiable range, the fields do not automatically become
 1110 ineligible. The problematic Critical Management Parameter shall be included in a
 1111 Monte Carlo analysis after specifying an expected range to quantify the uncertainty
 1112 due to variability in the Model Parameters.

1113 **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://www.cimis.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.

1114

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:	

1115

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: <ul style="list-style-type: none"> 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.

1118

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.

1119

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:	

1120

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.

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>i</i> and year <i>y</i> .
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.

1121

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:	

1122

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

1125 **14 Uncertainty Quantification and Requirements for Regional Calibration**
 1126 **Modules**

1127 14.1 Model Validation and Uncertainty Quantification

1128 The DNDC model must be successfully calibrated and validated for each of the
 1129 proposed Project Activities before it can be used in carbon accounting. Procedures to
 1130 do so are contained in this section. It is up to the Project Proponents to justify to the
 1131 VVB the boundaries of the area for which the DNDC model has been calibrated by
 1132 demonstrating the homogeneity of the area in terms of Project Activities, rice cultivars
 1133 planted, and soil types. Empirical gas flux data are required for at least five individual
 1134 Rice Fields located in the same Rice Growing Region as the Project.

1135 *14.1.1 Overview*

1136 The Structural Uncertainty deduction u_{struct} is a deduction that is applied to the gross
 1137 emission reductions to compensate for the Structural Uncertainty of model
 1138 simulations. This deduction is calculated beforehand using values of pairs of
 1139 measured emissions and simulated emissions. The measurements must take place in
 1140 the Rice Growing Region where the Project is located. Therefore, it is possible to
 1141 calculate the Structural Uncertainty deduction for a Rice Growing Region beforehand
 1142 and apply the same factor on emission reductions for any Rice Field in the Rice
 1143 Growing Region. The Structural Uncertainty deduction will also decrease with the
 1144 number of fields included in the Project, since errors in one field can be compensated
 1145 by errors in a different field. As a consequence, the more fields participating in the
 1146 Project, the smaller the resulting error on the emission reductions summed over all
 1147 fields, and the smaller the Structural Uncertainty deduction.

1148 The Structural Uncertainty deduction is mathematically defined such that, after
 1149 application of the deduction to the direct emission reductions, the following inequality
 1150 holds in 90% of the outcomes, i.e., with 90% confidence:

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

1151 An outcome should be interpreted in the frequentist sense of the word, in which
 1152 measurements are seen as samples drawn out of a greater population, and each
 1153 outcome is a set of samples drawn out of the greater population.

1154 The structural uncertainty factor, a negative value, must be added to the gross
 1155 difference between project and baseline emissions:

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

1156 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

1157

1158 *14.1.2 Verification of the lack of bias*

1159 The derivation of the Structural Uncertainty deduction assumes that no bias exists
 1160 between measured and modeled results, or that $E(Y_{meas}) = E(Y_{model})$. The DNDC
 1161 model has been shown to predict GHG fluxes without bias, when correctly calibrated.
 1162 This methodology specifies how model inputs can be set so that the model is
 1163 calibrated correctly. It must still be explicitly tested that the model calibration strategy
 1164 does not lead to bias by comparing modeled and measured emissions. A classical
 1165 paired t-test is suboptimal since the goal is not to demonstrate a significant difference
 1166 between modeled and measured values using a set confidence, but rather the lack of
 1167 a difference. In such a case, Two One-Sided Tests (TOST) equivalence testing is
 1168 superior. For equivalence tests, a tolerable deviation between measured and
 1169 modeled results must be defined. We set this tolerable deviation to the statistical
 1170 convention of 10%. In practice, a regression must be executed between measured
 1171 and modeled values, and it must be ensured that the slope is not smaller than 0.90
 1172 with 90% confidence, as well as not greater than 1.1 with 90% confidence.

1173 *14.1.3 Derivation of Uncertainty Deduction*

1174 The structural error induced by a biogeochemical model is assumed to be additive.
 1175 The relation between modeled and actual emissions is therefore as follows:

1176

$$1177 \quad Y_{model,i} = Y_{field,i} + \varepsilon_i \text{ with } \varepsilon \sim \mathcal{N}(0, \sigma^2)$$

1178

1179 If the model is unbiased, the following error model can be assumed for the project
 1180 and baseline emissions:

1181

$$1182 \quad PE_{model} = PE_{meas} + \varepsilon_1 \text{ with } \varepsilon_1 \sim \mathcal{N}(0, \sigma^2)$$

$$1183 \quad BE_{model} = BE_{meas} + \varepsilon_2 \text{ with } \varepsilon_2 \sim \mathcal{N}(0, \sigma^2)$$

1184 A correlation between the Project and Baseline residuals potentially exists:

1185

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

1186 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

1187

1188 The direct emission reductions are the difference between Project and Baseline
1189 emissions:

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

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

1190

1191 Where:

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

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

1192

1193 After it has been shown that the DNDC model is unbiased following the procedures in
1194 Section 14.1.2, the average of the difference between $DER_{model} - DER_{meas}$ is 0. The
1195 variance of this difference is:

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

1196

1197 In practice, experimental Rice Fields on which fluxes are measured are much smaller
1198 than production Rice Fields managed by commercial producers. Often, experimental
1199 rice fields can be as small as 10-25 m² up to about 1 ha. Since the relative
1200 uncertainty decreases with increasing plot size, the uncertainty as quantified on
1201 experimental plots must be adjusted for the greater size of the project area relative to
1202 the size of an experimental plot. Let n denote the number of times the total project

1203 size is greater than a typical experimental plot. Assuming a greater size of
 1204 experimental plots will lead to greater uncertainty deductions. Therefore, to remain
 1205 conservative and for simplicity, we have set the size of an experimental plot to the
 1206 upper bound of the range of sizes of experimental plots, 1 ha. Therefore, n is simply
 1207 equal to the project area in ha. Hence, the variance of the sum of the emission
 1208 reductions across a Project Area of size n is:

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

1209

1210 If s is the standard deviation of the model residuals based on a limited set of k
 1211 calibration values, the one-sided 90% confidence interval around the average of the
 1212 sum of the differences $DER_{model} - DER_{meas}$ is:

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

1213 This equation enables to define the absolute deduction for structural uncertainty
 1214 u_{struct} .

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

1215 Where:

- u_{struct} = Absolute deduction for structural uncertainty for the whole Project Area [kg CO₂-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]

1216

1217 In other words, subtracting u_{struct} from DER_{model} , average modeled emission
 1218 reductions are smaller than average measured emission reductions with 90%
 1219 confidence:

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

1220 *14.1.4 Quantifying the standard deviation s and the correlation ρ*

1221 The calculation of u_{struct} is critically dependent on the standard deviation of the
1222 residuals s and the correlation between the residuals of the Project emissions and the
1223 residuals of the Baseline emissions ρ .

1224 If k pairs of $[Y_{meas}(i), Y_{model}(i)]$ are available, the quantity s can be calculated as the
1225 standard deviation of the difference between $Y_{meas}(i)$ and $Y_{model}(i)$. The quantity ρ
1226 can be estimated by dividing the measurements in Baseline cases, $BE_{meas}(i)$ and
1227 Project cases, $PE_{meas}(i)$. Using conventional terminology, the Baseline would be the
1228 control or conventional treatment. Subsequently, pairs of measured and modeled
1229 emission reductions $DER_{meas}(i)$ and $DER_{model}(i)$ can be calculated as the difference
1230 between $PE_{meas}(i)$ and $BE_{meas}(i)$, and $PE_{model}(i)$ and $BE_{model}(i)$, respectively.
1231 Calculate ρ as the correlation coefficient between $DER_{meas}(i)$ and $DER_{model}(i)$.
1232 Smaller correlation coefficients will result in greater uncertainty deductions.
1233 Therefore, it is good practice to calculate a set of correlation coefficients through
1234 leave-one-out jackknifing and set the correlation coefficient to the low range of this
1235 set of values.

1236 In most cases, only a very limited set of values will be available. For the standard
1237 deviation of the residuals, using a student-t distribution instead of a normal
1238 distribution will compensate for the potential bias introduced by a limited number of
1239 values. In addition, this methodology requires the standard deviation s to be
1240 calculated based on at least 8 pairs of measured and simulated annual emissions
1241 that have been measured over at least 2 growing seasons.

1242 If a set of daily fluxes are available, the quantities s and ρ can be calculated with
1243 more accuracy based on daily values of these quantities as:

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

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

1244 Note that measurements aggregated over any other time period than daily can be
1245 used to estimate ρ . This methodology requires to use at least 50 measurements of
1246 daily measured and modeled methane fluxes to calculate ρ .

1247 It is likely that new and improved measurements become available after the Project
1248 Start Date. Therefore, it is allowed to recalculate s_{annual} , ρ_{annual} leading to a potential
1249 decrease in u_{struct} at a verification event after the Start Date of the Project using the
1250 additional and/or improved measurements.

1251 14.2 Requirements for Regional Calibration Modules

1252 This methodology can be expanded using modules in which the regional calibration
1253 and model validation step is executed for specific Project Activities and additional
1254 Rice Growing Regions. If a Regional Calibration Module is available, Project
1255 Proponents are allowed to skip the regional calibration and model validation step on
1256 the condition that the Structural Uncertainty deduction included in the module is used,
1257 as well as the template input file to the DNDC model.

1258 New Regional Calibration Modules must contain the following elements:

- 1259 1. **Step 1. Exact and unambiguous definition of Project Activities.** The
1260 definitions must be workable for growers and sufficiently rigorous for carbon
1261 methodologies. Definitions must be robust with respect to variations in
1262 weather.
- 1263 2. **Step 2. Selection of one of the four Rice Growing Regions in the U.S. (see**
1264 **Section 3.2) for which the Regional Calibration Module is valid.**
- 1265 3. **Step 3. Development of performance standard (optional).** For each of the
1266 Project Activities defined in step 1, and for the full Rice Growing Region
1267 defined in step 2, the Regional Calibration Module can include an analysis of
1268 the adoption rate and the additionality following the procedures in Section 6.
- 1269 4. **Step 4. Identification of Critical and Non Critical Management**
1270 **Parameters.** This shall follow the procedure defined in Section 7.2.
- 1271 5. **Step 5.** Values of measured and modeled fluxes and a demonstration that the
1272 **DNDC model simulates fluxes in an unbiased way** according to the
1273 procedures in section 7.4.1, as well as a table of Structural Uncertainty
1274 deductions as deduced using the procedures in this section.
- 1275 6. **Step 6. A template .dnd input file** with each of the DNDC Model Parameters,
1276 and how they must be parameterized (default value, lookup table, historical
1277 records, field measurements, etc.)

1278 **15 References**

- 1279 Agriculture and Natural Resources (ANR) of the University of California 2010. Rice
1280 Producers' Guide to Marketing Rice Straw. ANR Publication 8425.
- 1281 Babu, Y.J., Li, C., Frolking, S., Nayak, D.R., Adhya, T.K., 2006. Field validation of
1282 DNDC model for methane and nitrous oxide emissions from rice-based production
1283 systems of India. *Nutrient Cycling in Agroecosystems* 74, 157–174.
- 1284 Cai, Z., Sawamoto, S., Li, C., Kang, G., Boonjawat, J., Mosier, A., and R. Wassmann
1285 (2003) Field validation of the DNDC model for greenhouse gas emissions in East
1286 Asian cropping systems. *Global Biogeochem. Cycles* 17(4),
1287 doi:10.1029/2003GB002046.
- 1288 California Air Resources Board (CARB), Department of Food and Agriculture, et al.,
1289 1995. Report of the Advisory Committee on Alternatives to Rice Straw Burning.
- 1290 California Rice Commission. 2009. Environmental and conservation balance sheet for
1291 the California rice industry. Available online at
1292 [http://calrice.thewebhounds.com/Environment/Balance+Sheet/Chapter+4+-](http://calrice.thewebhounds.com/Environment/Balance+Sheet/Chapter+4+-+Air+Quality.htm)
1293 [+Air+Quality.htm](http://calrice.thewebhounds.com/Environment/Balance+Sheet/Chapter+4+-+Air+Quality.htm)
- 1294 Chalmers and Walden, 2009. The Impact of Expanding Biofuel Production on GHG
1295 emissions. White paper #1: Accessing and interpreting existing data. Winrock.
1296 Available at
1297 [http://www.globalbioenergy.org/uploads/media/0904_Winrock_International_-](http://www.globalbioenergy.org/uploads/media/0904_Winrock_International_-_White_paper_1_GHG_implications_biofuel.pdf)
1298 [_White_paper_1_GHG_implications_biofuel.pdf](http://www.globalbioenergy.org/uploads/media/0904_Winrock_International_-_White_paper_1_GHG_implications_biofuel.pdf)
- 1299 Colwell and Taft, 2000. Waterbird communities in managed wetlands of varying
1300 depths. *The International Journal of Waterbird Biology*. 23: 45-55.
- 1301 Day, J.H. Colewell, M.A. 1998. Waterbird communities in rice fields subjected to
1302 different post-harvest treatments. *Colonial waterbirds* 21:185-197.
- 1303 Elphick, C.S., Oring, L.W. 2003. Conservation implications of flooding rice fields on
1304 winter waterbird communities. *Agriculture, Ecosystems and Environment* 94:17-
1305 29.
- 1306 Environmental Defense Fund (EDF) 2011. Final report for NRCS project 69-3A75-7-
1307 87. Creating and Quantifying Carbon Credits from Voluntary Practices on Rice
1308 Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers
1309 and the Environment.
- 1310 Head (2006). Manual of soil laboratory testing 3rd edition. Vol. 1: Soil classification
1311 and compaction tests. CRC Press.

- 1312 Li, C., 2000. Modeling trace gas emissions from agricultural ecosystems. *Nutrient*
1313 *Cycling in Agroecosystems* 58, 259–276.
- 1314 Li, C., J Qiu, S. Frolking, X. Xiao, W. Salas, B. Moore III, S. Boles, Y. Huang, and R.
1315 Sass, 2002. Reduced methane emissions from large-scale changes in water
1316 management in China’s rice paddies during 1980-2000, *Geophysical Research*
1317 *Letters*, 29(20), doi:10.1029/2002GL015370, 2002.
- 1318 Lindau CW, Bollich PK, DeLaune RD. 1995. Effect of rice variety on methane
1319 emission from Louisiana rice. *Agriculture Ecosystems and Environment* 54:109-
1320 114.
- 1321 Natural Resources Conservation Service [NRCS]. 2004. Soil Survey Laboratory
1322 Methods Manual. Soil Survey Laboratory Investigations Report No. 42. Available
1323 online at <http://soils.usda.gov/technical/lmm/>
- 1324 Pathak, H., Li, C., Wassmann, R., 2005. Greenhouse gas emissions from Indian rice
1325 fields: calibration and upscaling using the DNDC model. *Biogeosciences* 2, 113–
1326 123.
- 1327 Petrie, Mark, and Kevin Petrik. —Assessing Waterbird Benefits from Water Use in
1328 California Ricelands. Ducks Unlimited. May 2010.
1329 <http://www.calrice.org/pdf/DucksUnlimited.pdf>
- 1330 Pütün A.E., Apaydına, E., and Pütün, E. 2004. Rice straw as a bio-oil source via
1331 pyrolysis and steam pyrolysis. *Energy* 29: 12-15.
- 1332 Summer, M.D. and Williams, J. 2001. Developing engineering data on rice straw for
1333 improvement of harvesting, handling, and utilization. *Proceedings: Rice Straw*
1334 *Management Update*. UCCE. Yuba
- 1335 Sumner, Daniel A., and Henrich Brunke. —The Economic Contributions of the
1336 California Rice Industry. California Rice Commission. September 2003.
1337 <http://www.calrice.org/Economics/Economic+Contributions.htm>
- 1338 USDA National Agricultural Statistics Service - California Field Office. California
1339 Agricultural Statistics: 2011 Crop Year. Available at
1340 <http://www.cdfa.ca.gov/statistics/ or www.nass.usda.gov/ca.>