Voluntary Emission Reductions in Rice Management Systems – Midsouth Module

Version 1.0

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1

1 Introduction

Rice is a major cropping system in five states of the Mid-South of the U.S (Figure 1). Of those five states, Arkansas is the largest rice-producing state in the United States, producing rice on approximately 1.2 million acres (486,000 hectares) in 2012.

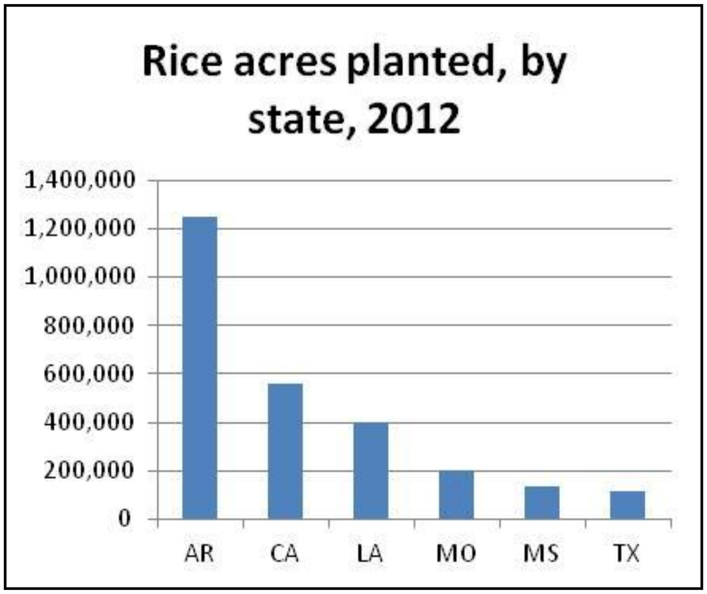

Figure 1. Acreage of rice planted in the U.S. by state.This module extends the existing and approved ACR methodology *Voluntary Emission Reductions in Rice Management Systems* (posted at http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emission-reductions-in-rice-management-systems) to work specifically for the Mississippi River Delta region, and the Louisiana Gulf Coast. This parent methodology includes procedures to quantify emission reductions from reduced methane production through changes in water and straw management practices. This module includes two practices that were also included in the California module of the parent methodology: straw removal after harvest, and early drainage at end of growing season. It also includes additional practices: intermittent flooding (alternate wetting and drying of rice fields during the growing season), and increasing water use efficiency and pumping efficiency (through converting ungraded fields to precision grade, precision grade to zero grade, or ungraded fields to zero grade; implementing side inlet/poly piping systems; switching to efficient diesel pumps and converting from diesel to electric pumps; and installation of soil moisture sensors to accurately control pumps and motors).

Reductions in nitrous oxide emissions from improved fertilizer practices and increasing fertilizer efficiency can be quantified, in addition to a reduction in methane production, using the approved ACR methodology “N_2O Emissions Reductions through Changes in Fertilizer Management.” (posted at http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management).

The outline of the module follows the steps as required in the parent methodology. This module must be used in conjunction with the parent methodology. All definitions and acronyms outlined in the parent methodology are relevant for this module.

The purpose of this module is to provide requirements and guidance for a Project Proponent using the ACR methodology *Voluntary Emission Reductions in Rice Management Systems* to design, implement and register a rice GHG offset project in the Midsouth U.S. Rice-Growing Regions covered in this module. The primary intended audiences are Project Proponents, Validation/Verification Bodies (VVBs), regulators, and other stakeholders. The authors expect that rice growers implementing the GHG mitigation practices eligible in this module will work with a Project Proponent, potentially serving as the aggregator of multiple rice growers, to use the methodology and prepare a GHG Project Plan.

The goal of the practices described in this module is to reduce GHG emissions in order to create marketable GHG offset credits. The included practices are included because they may decrease GHG emissions relative to the baseline scenario without, according to studies available to the authors, decreasing rice yield or milling quality. The goal is not to implement any practice that decreases yield or milling quality. We emphasize ACR is not making agronomic recommendations and all practices in this module are fully voluntary. If conditions in a particular year make it impossible to continue the practice, there is no penalty other than receiving no credits for the practice in that year.

2 Step 1. Definition of Included Project Activities

As a first step, it is important to unambiguously define project activities. While the definitions must be workable for growers and, therefore, be robust with respect to variations in weather, the definitions must also be sufficiently rigorous within the context of a carbon offset methodology, and verifiable by a Validation and Verification Body (VVB).

Table 1. Definitions of included project activities.

Included Project Activity	Definition
Straw Baling and Removal	After harvest, rice straw residue is often left on agricultural fields. However, rice straw can be removed from the field by baling. Baled straw can be sold, however the market is small and demand is limited. Rice straw can be used for erosion control, animal bedding, as an alternative feed for cow and calf producers (Nader et al., 2010), or for other purposes noted in 8.3.2 of the parent methodology "Voluntary Emission Reductions in Rice Management Systems" (posted at http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emission-reductions-in-rice-management-systems).

Included Project Activity	**Definition**
Early Drainage	Early Drainage is defined as terminating water applications and draining[1] a field at least 5 days earlier than the drainage date under conventional management ("Conventional Drainage Date").[2] Since there is not one single procedure to determine the Conventional Drainage Date that is used by all producers across all Rice Growing Regions, the procedure to set the Conventional Drainage Date as used by a specific participating grower shall be recorded in the GHG Project Plan and approved by a VVB. Under conventional management, the date on which no further irrigation water is applied to a field occurs at a fixed time following a plant growth stage. This module strongly encourages the use of the DD50 model or process-based rice models such as RicePSM or ORYZA. Specifically, the date on which no further irrigation water is applied is determined relative to the date of heading as prescribed by the DD50 crop growth simulation model. The use of the DD50 model or a process-based rice model rules out any subjectivity in determining a plant growth stage.[3]
Increased Water and/or Energy Use Efficiency	Increase water and/or energy use efficiency through practices including but not limited to: (1) conversion of ungraded fields to precision grade, precision grade to zero grade, or ungraded fields to zero grade, (2) improved pipe configuration (e.g., side inlet systems, poly piping/ poly tubing systems) which lead to more rapid flood establishment, (3) switching to more energy efficient combustion engines[4], (4) switching from pumps using combustion engines to electric pumps, (5) adopting soil moisture sensors that can reduce water consumption by allowing more precise tailoring of flooding and draining to the water needs of rice plants. Any technology or measure a grower can adopt that demonstrably increases water and/or energy use efficiency is eligible here, and will be demonstrated through a verified improvement in water use efficiency or reduction in diesel consumption. Note that simply implementing these changes and infrastructure does not automatically generate credits. The producer must demonstrably have increased

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[1] Draining is defined as the point in time at which a grower stops water applications to a non-flooded field and/or removes water (e.g., by pulling the boards) and stops water applications to a flooded field.
[2] This methodology does not endorse a specific procedure to set the Conventional Drainage Date or the early drainage date. 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.
[3] The Arkansas DD50 model is described at http://dd50.uaex.edu/dd50WebGuide.asp
[4] Older-generation diesel pumps are significantly less fuel-efficient than modern diesel pumps or electric pumps.

Included Project Activity	Definition
	water and/or energy use efficiency.
Intermittent Flooding	Cyclical wetting and drying of rice field during the growing season. During the dry-down phase, irrigation is ceased and the flood is allowed to subside naturally to the point where no standing water exists in the paddy. However, parts of the soil may still be saturated with water and contain some puddles of water.[5] If part of a field remains flooded, at this point, as generally occurs with precision-leveled or ungraded fields, only the portion of the field where no standing water is present may be included for this project activity. Hence, no credits for intermittent flooding will be generated for the part of the field that remains flooded. Intermittent flooding may encompass one or more wetting-drying cycles.[6]

Note that the project activities listed above may be combined with a reduction in N fertilization rate (e.g. from a typical N rate application rate of 150-180 lbs N/acre (168-202 kg/ha) to 125 lbs N/acre (140 kg/ha)). The accounting for a reduction in N fertilization rate, including how to set the business-as-usual fertilization practice, and how to quantify the GHG benefits from reducing N rate shall follow the approved ACR methodology “N_2O Emissions Reductions through Changes in Fertilizer Management”[7]. Specifically, only one set of DNDC runs (i.e., baseline and project scenarios) needs to be prepared according to the procedures of this module and the N_2O emission reduction methodology. It is allowed (but not necessary) to produce only one GHG Project Plan and verification that covers both methodologies, as long as all requirements of both methodologies are met and included in the GHG Project Plan(s).

In addition to the practices in the parent methodology “Voluntary Emission Reductions in Rice Management Systems”, this module also allows the generation of credits from reduced GHG emissions related to increased irrigation water-use efficiency or pump/well efficiency. Specifically, the practice “Increased Water and/or Energy Use Efficiency” includes two types of project activities: those that increase the efficiency of water distribution and thus reduce total water consumption without

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[5] The lack of standing water is insufficient to reduce methane emissions since saturated soils will still result in CH_4 emissions. Emission reductions will only be generated when the moisture content of a soil decreases below the saturation point. The DNDC model simulates the reduction of methane emissions after standing water has been removed and the soil dries down below the saturation point.

[6] Field trials have clearly indicated that this practice leads to methane emission reductions. In addition, the DNDC model is able to estimate the emission reductions conservatively. However, active research is on-going to better understand the exact circumstances under which the methane reductions are maximized. A drying out cycle potentially increases nitrous oxide emissions. This increase in nitrous oxide emissions will be simulated by the DNDC model and will be accounted for when following the standard accounting procedures. As more data becomes available from studies directly measuring N_2O fluxes under different fertilization and irrigation treatments, this flux data may be used to continually improve calibration and validation of the DNDC model.

[7] See http://americancarbonregistry.org/carbon-accounting/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management.

necessarily improving fuel efficiency per acre-inch of water pumped; and those that improve energy use efficiency and hence reduce energy consumption. Examples of practices that fall in either category are included in Table 2 below. Note this list merely serves as an example. The list is therefore non-exhaustive; other practices and technologies that enhance water and/or fuel efficiency may be used.

Table 2. Examples of practices under project activity Increased Water and/or Energy Use Efficiency.

Examples of practices that, if used properly, reduce irrigation water requirements of the rice cropping system but do not improve energy use efficiency of irrigation well (i.e., energy consumed per acre-inch of water pumped)
(1) Precision-leveling of field and/or conversion to zero grade, (2) Improved flood distribution (e.g., multiple- (side) inlet or similar system) which leads to more rapid flood establishment and improved control of rice flood that reduces over-pumping and increases rainfall capture, and (3) Adoption of flood depth and/or soil moisture sensors that can reduce water consumption by allowing more precise tailoring of irrigation to meet the water needs of rice plants.
Examples of practices that, if used properly, improve energy use efficiency of irrigation well but that do not reduce irrigation water requirements of the rice cropping system
(1) Switching from older or less efficient to newer or more efficient combustion engines, (2) Switching power units from internal combustion engines to electric motors. (3) Performing engine-well pump performance optimization procedures (e.g., maximizing flow rate (GPM) while minimizing engine RPM, and (4) Performing pump and well maintenance and repair (e.g., impeller maintenance/repair or screen maintenance/repair).

These practices may be implemented in combination – e.g. simultaneously installing plastic-tubing (poly piping and poly tubing) systems and more efficient combustion engines – which would reduce GHG emissions through both fewer acre-inches of water and lower GHG emissions per acre-inch pumped. The quantification of GHG emissions from energy use shall follow procedures outlined in Section 8 of this module.

3 Step 2. Rice Growing Regions

This module is applicable for the Mississippi River Delta (MRD) Rice Growing Region and the Louisiana Gulf Coast (LGC) Rice Growing Region, as defined in section 3.2 of the parent methodology "Voluntary Emission Reductions in Rice Management Systems". Within the MRD Rice Growing Region, Arkansas was found to have unique conditions requiring a specific uncertainty deduction. As of the date of drafting, insufficient data was available for calibration and validation of the DNDC model in the Texas Gulf Coast Rice-Growing Region, but this region may be added at a later date.

4 Step 3. Development of Performance Standard (Optional)

All of the Project Activities are completely voluntary because no legal requirements exist that mandate any of the included Project Activities. As a consequence, Project Activities will be in surplus to applicable regulations.

To evaluate the baseline adoption rate, the common management practices in relation to the proposed changes in management practices must be investigated. This can be done either by survey data or through expert opinion.

- **If Survey data or Remote Sensing data are used**. The adoption rate must be determined using a statistically valid survey or remote sensing analysis of producers within the Rice Growing Region where the Project is located. The survey must be designed to achieve a relative precision that is better than ±10% with 90% confidence. In addition, procedures must be in place to minimize digitization errors. It is acceptable that the survey ultimately has a smaller precision on the condition that the Project Proponent can demonstrate that this smaller precision was not impacted by systematic errors. The fields must be selected randomly over all the fields within the Rice Growing Region. The average of all available survey data (including those published in validated GHG Project Plans) must be used to calculate the baseline adoption rate. For initial validation, one adoption rate in the past 5 years suffices to set the baseline adoption rate. However, upon renewal of a project's Crediting Period, the baseline adoption rate must be set as the average of at least 2 adoption rates quantified at different time points or through different surveys in the 5 years preceding the Crediting Period.
- **If expert opinion is used**. If 3 independent experts assert that the baseline adoption rate of a given practice is less than or equal to 4% of the acres on which rice is grown within the Rice Growing Region, no survey has to be conducted, and projects using the practice must use a Common Practice Baseline (see Table 3). The independent experts must have at least 5 years of relevant experience in rice agronomy and must be associated with an academic institution, government institution, or must be a certified crop advisor with experience in the Rice Growing Region. The qualifications of the independent experts shall be evaluated during validation of a GHG Project Plan by the VVB.
- **Using adoption rates from already registered projects**. Project Proponents of a new project should review existing validated GHG Project Plans for rice project activities. If the adoption rate of the same practice the Project Proponent is implementing, in the same Rice Growing Region, has been analyzed and is included in a validated GHG Project Plan dated no more than 10 years prior to the date of GHG Project Plan submittal, Project Proponents may use this adoption rate and are not required to conduct their own adoption rate analysis. Note that:
    - If more than one validated GHG Project Plan has an adoption rate analysis for the same practice in the same Rice Growing Region, the average of the published adoption rates must be used.
    - In the case that a published validated GHG Project Plan(s) includes an adoption rate that is no longer representative of the adoption rate of the proposed practice in the Rice

Growing Region, due to a disruptive change in management, weather or other variables affecting adoption rates, the Project Proponent may exclude this GHG Project Plan(s) from the average on the condition that its exclusion can be duly justified to a VVB.

As rice project activities are registered, ACR may publish subsequent versions of this methodology that include the baseline adoption rates for particular practices and Rice Growing Regions, along with the length of time for which these adoption rates may be used before a new adoption rate analysis is required.

Based on discussions with industry experts, the following baseline adoption rates are estimated.

Table 3. Adoption rates of included project actions.

Project Action	Description of adoption and/or adoption rate
Straw Baling and Removal	• Expert 1: ≤1% in Mississippi. • Expert 2: <4% for Arkansas • Expert 3: <4% in Arkansas • Expert 4: 1-2% in Arkansas • Expert 5: very low; generally no interest expressed to NRCS by rice growers in Arkansas ***Therefore the adoption of straw baling and removal is less than 5%, and can use Common Practice Baseline.***
Early Drainage	• Expert 1: ≤4% of rice flood is intentionally drained early in Mississippi. • Expert 2: <4% for Arkansas • Expert 3: <4% in Arkansas • Expert 4: 1-2% in Arkansas • Expert 5: <4% in Arkansas ***Therefore the adoption of early drainage is less than 5%, and can use Common Practice Baseline.***
Increased Water and/or Energy Use Efficiency	**(1) conversion of ungraded fields to precision grade, precision grade to zero grade, or ungraded fields to zero grade.** • Expert 1: Based on a variety of surveys, ≥ 70% of the rice acres in Mississippi are precision-leveled, meaning that ≤30% of rice is grown in contoured fields. • Expert 2: 6% of acres in Arkansas are zero grade; precision grade plus zero grade represents about 50% of acres.[8] • Expert 3: Up to 25% are precision leveled or zero grade in AR. Many fields that are "put to grade" soon require re-leveling.

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[8] Wilson, C. E., S. K. Runsick, and R. Mazzanti. 2008. Trends in Arkansas Rice Production. In R.J. Norman et al. editors, B.R. Wells, Rice Research Studies 2008. Arkansas Agricultural Experiment Station, Division of Agriculture. Research Series 571. Fayetteville, Arkansas. ISSN: 1931-3764. pp 13-23.

Project Action	Description of adoption and/or adoption rate
	• Expert 4: Approximately 5% of acres are zero grade. Precision grade plus zero grade may be 40%. • Expert 5: 5% or less of acres are zero grade. Over the past five years, NRCS has paid for leveling of approximately 70,000 acres, of which approximately half zero grade and half precision graded. ***Therefore increased water and/or energy use efficiency by the conversion of ungraded fields to precision grade, precision grade to zero grade, or ungraded fields to zero grade is greater than 5%, and must use a Field-Specific Baseline.*** **(2) improved pipe configuration** • Expert 1: 20% of rice acres are using poly tubing in Mississippi. • Expert 2: use of poly piping is perhaps 15-20% of acres in Arkansas. Higher in northeast Arkansas than other parts of the state. • Expert 3: use of poly piping seems to be decreasing in Arkansas based on most recent surveys. • Expert 4: use of poly piping is relatively low – greater than 5% of acres, but less than 30%, in Arkansas. ***Therefore increased water and/or energy use efficiency by improving pipe configuration is greater than 5%, and must use a Field-Specific Baseline.*** **(3) switching to more energy efficient combustion engines** • Expert 1: most diesel pumps are kept in service a long time, due to capital costs, so replacement rate is low in Mississippi. • Expert 2: less than 4%. • Expert 3: less than 4%. • Expert 4: there are about 30,000 diesel engines in Arkansas rice fields, which are being converted at less than 1% per year. Definitely less than 4% have been converted. Diesel engine upgrades, switch to electric, and pump automation technologies combined have an estimated adoption level around 1%. ***Therefore increased water and/or energy use efficiency by switching to more energy efficient combustion engines is less than 5%, and can use Common Practice Baseline.*** **(4) switching from pumps using combustion engines to electric pumps** • Expert 1: in Mississippi switch is generally attractive, but rate of adoption is low, partly due to limited access to 3-phase power. • Expert 2: less than 4%. • Expert 3: less than 4%. • Expert 4: there are about 30,000 diesel engines in Arkansas rice fields,

Project Action	Description of adoption and/or adoption rate
	which are being converted at less than 1% per year. Definitely less than 4% have been converted. Diesel engine upgrades, switch to electric, and pump automation technologies combined have an estimated adoption level around 1%. ***Therefore increased water and/or energy use efficiency by switching from pumps using combustion engines to electric pumps is less than 5%, and can use Common Practice Baseline.*** **(5) adopting soil moisture sensors** • Expert 1: very low adoption rates in Mississippi. • Expert 2: very low adoption rates, really just an experimental technology. Less than 4% in Arkansas. • Expert 3: near zero adoption in Arkansas. • Expert 4: very low adoption, way below 4% in Arkansas. ***Therefore increased water and/or energy use efficiency by adopting soil moisture sensors is less than 5%, and can use Common Practice Baseline.***
Intermittent flooding during growing season	• Expert 1: ≤4% of rice flood is intentionally managed using intermittent flooding in Mississippi. • Expert 2: <4% for Arkansas. • Expert 3: 0% in Arkansas. • Expert 4: <4% in Arkansas. ***Therefore the adoption of intermittent flooding during the growing season is less than 5%, and can use Common Practice Baseline.***

5 Step 4. Identification of Critical and Non-Critical Management Parameters

Refer to the parent methodology “Voluntary Emission Reductions in Rice Management Systems” for a full definition and explanation of the purpose of Critical and Non-Critical Management Parameters. In short, critical management parameters are model parameters that are impacted by the project activities, either directly or indirectly. Only parameters that are indicated to be critical in Table 3 may differ between the baseline and project scenarios.

Table 4. Enumeration of Critical (C) and Non-critical (NC) parameters for each of the included project activities.

Input Management Parameter	Project Activity			
	ACT1	ACT2	ACT3	ACT4
	Straw Baling	Early Drainage	Increased Water and/or Energy Use Efficiency	Intermittent Flooding
Harvesting date	NC	C	NC	NC
Fraction of residues left after harvest	C	NC	NC	NC
Crop residue management (tillage) date(s)[9]	C	NC	NC	NC
Crop residue management (tillage) method[10]	C	NC	NC	NC
Crop residue burning date	C	NC	NC	NC
Frequency of winter flooding	C[11]	NC	NC	NC
Start of the winter flooding period (if any)	C	NC	NC	NC
End of the winter flooding period (if any)	C	NC	NC	NC
Spring fertilization amount	C	NC	NC	C
Spring fertilization date	C	NC	NC	NC
Spring fertilization type	C	NC	NC	NC
Spring fertilization application method	C	NC	NC	NC
Pre-plant field preparation (tillage) date	NC	NC	NC	NC
Pre-plant field preparation (tillage) method	C	NC	NC	NC
Planting date	NC	NC	NC	NC
Initial Flooding date and flooding/draining dates during the growing season for intermittent flooding	NC	C	NC	C
Fertilization amount during growing season	NC	NC	NC	C
Fertilization date during growing season or alternatively, plant growth stage at which fertilization is applied.	NC	NC	NC	C
Fertilization type during growing season	C	NC	NC	C
Fertilization application method during growing season	NC	NC	NC	NC
Draining date	NC	C	NC	NC
Fuel/Energy efficiency of pumping system	NC	NC	C	NC
Water pumped	NC	NC	C/NC[12]	C

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[9] In case there are multiple tillage events for crop residue management, specify the start date and end date and the number of passes. Similar for pre-plant field preparation tillage events.

[10] Describe equipment used, whether no-tillage or clean till were used etc.

[11] Remaining residue in a field will result in field being wet longer. This, in turn, may impact the decision of whether a field is winter flooded or not.

6 Step 5. Demonstration that the DNDC Model Simulates Fluxes in an Unbiased Way

Future updates to model calibration/validation and the associated uncertainty equations will be published in ACR's 'DNDC structural uncertainty deduction factors' addendum. The most updated uncertainty deduction factors for a given Rice Growing Region, as published in this addendum, are required to be used at the time of GHG Project Plan Validation.

With the exception of Arkansas, values of measured and modeled fluxes and a demonstration that the **DNDC model simulates fluxes in an unbiased way** according to the procedures in section 14.1.2 of the parent methodology, as well as a table of uncertainty deduction factors as deduced using the procedures in this section. It was found that the Arkansas model does not pass the Two One Sided T (TOST) test for being unbiased. Procedures at the end of this section describe the statistical approach used for deriving the uncertainty deduction for when the model is biased, that allow Arkansas fields to be included under the this module.

Sixteen different annual fluxes of C emissions were measured for a number of different management scenarios in the Mississippi River Delta (MRD) and 40 in the Louisiana Gulf Coast (LGC). The same management scenarios were modeled using the DNDC model. These scenarios represent the Project Activities. Results from this exercise are summarized in Table 5. Further details can be found in EDF (2011).

Table 5. Modeled and measured C fluxes from field trials in the Mississippi River Delta (MRD) and the Louisiana Gulf Coast (LGC).

Observation nr.	Site	Treatment	Year	Modeled [kg C ha^{-1} yr^{-1}]	Measured [kg C ha^{-1} yr^{-1}]
Mississippi River Delta (MRD)					
1	Stuttgart, AR[1]	Continuous flooding	2012	157.51	138.27
2	Stuttgart, AR[1]	AWD	2012	3.63	6.66
3	Stuttgart, AR[1]	0 kg N/ha	2011	25.81	27.36
4	Stuttgart, AR[1]	112 kg N/ha	2011	92.47	55.81
5	Stuttgart, AR[1]	168 kg N/ha	2011	124.22	61.60
6	Stuttgart, AR[1]	224 kg N/ha	2011	147.27	53.14
7	Stuttgart, AR[1]	Variety: CLX	2012	144.1	74.94
8	Stuttgart, AR[1]	Variety: FRA	2012	107.54	107.47
9	Stuttgart, AR[1]	Variety: JUP	2012	81.94	95.73
10	Stuttgart, AR[1]	Variety: SAB	2012	79.48	105.62
11	Stuttgart, AR[2]	Rice-Rice Flood	2013	177.81	194.53
12	Stuttgart, AR[2]	Rice-Soy Flood	2013	171.99	133.24
13	Stuttgart, AR[2]	Rice-Soy AWD 60	2013	63.91	6.01
14	Stuttgart, AR[2]	Rice-Rice AWD 60	2013	59.45	17.49
15	Stuttgart, AR[2]	Rice-Rice AWD40	2013	37.55	18.41

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[12] The water pumped parameter is critical when water use efficiency is changed. If only the fuel use of the pumping system is changed without changing the water use efficiency, this parameter is non-critical.

Observation nr.	Site	Treatment	Year	Modeled [kg C ha^{-1} yr^{-1}]	Measured [kg C ha^{-1} yr^{-1}]
16	Stuttgart, AR[2]	Rice-Soy AWD 40	2013	36.99	7.63
Louisiana Gulf Coast (LGC)					
1	Lindau, LA[3]	Control	1989	4.1	0.1
2	Lindau, LA[3]	KNO3	1989	4.0	0.0
3	Lindau, LA[3]	Urea	1989	4.1	0.3
4	Lindau, LA[4]	Urea_000 kg N	1990	332.7	431.5
5	Lindau, LA[4]	Urea_100 kg N	1990	372.3	362.5
6	Lindau, LA[4]	Urea_200 kg N	1990	354.3	314.9
7	Lindau, LA[4]	Urea_300 kg N	1990	351.5	220.4
8	Lindau, LA[5]	1-urea with plants	1991	852.0	916.4
9	Lindau, LA[5]	2-urea without plants	1991	23.1	45.7
10	Lindau, LA[5]	3-unfertilized plants	1991	476.7	475.9
11	Lindau, LA[5]	4-urea with plants + rice straw	1991	1,604.8	1,921.9
12	Lindau, LA[6]	urea	1991	481.1	354.3
13	Lindau, LA[6]	urea + DCD	1991	481.1	294.3
14	Lindau, LA[6]	urea + ECC	1991	481.1	222.0
15	Lindau, LA[6]	urea + Na2SO4 rate I	1991	473.6	244.4
16	Lindau, LA[6]	urea + Na2SO4 rate II	1991	453.7	231.9
17	Lindau, LA[7]	ammonium sulfate	1991	473.6	297.2
18	Lindau, LA[7]	ammonium sulfate_high	1992	456.9	343.1
19	Lindau, LA[7]	ammonium sulfate_low	1992	465.3	267.6
20	Lindau, LA[7]	control	1992	183.2	209.5
21	Lindau, LA[7]	potassium nitrate_high	1992	373.9	318.3
22	Lindau, LA[7]	potassium nitrate_low	1992	313.1	285.5
23	Lindau, LA[7]	urea_high	1992	371.9	774.8
24	Lindau, LA[7]	urea_low	1992	376.5	381.3
25	Lindau, LA[8]	$CaSO_4$ = 1000kg	1992	630.3	434.4
26	Lindau, LA[8]	$CaSO_4$ = 2000kg	1992	494.8	318.7
27	Lindau, LA[8]	$CaSO_4$ = 0000kg	1992	783.1	589.6
28	Lindau, LA[9]	bengal	1993	645.1	540.9
29	Lindau, LA[9]	cypress	1993	645.1	570.8
30	Lindau, LA[9]	lacassine	1993	962.7	725.2
31	Lindau, LA[9]	mars	1993	962.7	954.8
32	Lindau, LA[9]	maybelle	1993	962.7	865.5
33	Lindau, LA[9]	tebonnet	1993	1,045.6	1,166.8
34	Lindau, LA[10]	control	1996	455.1	585.6
35	Lindau, LA[10]	g-1	1996	218.4	267.5
36	Lindau, LA[10]	g-2	1996	218.4	262.3
37	Lindau, LA[10]	g-3	1996	218.4	203.9
38	Lindau, LA[10]	pg-1	1996	218.4	314.1
39	Lindau, LA[10]	pg-2	1996	218.4	321.1
40	Lindau, LA[10]	pg-3	1996	218.4	297.1

162

[1] Pittelkow et al, 2013,Yield-scaled global warming potential of annual nitrous oxide and methane emissions from continuously flooded rice in response to nitrogen input Agriculture, Ecosystems & Environment, Volume 177, 1 September 2013, Pages 10-20.

[2] University of California, Davis and University of Arkansas, in preparation

[3] Lindau, CW, W.H. Patrick, R.D. Delaune and K.R. Reddy. 1990. Rate of accumulation and emission of N2, N2O and CH4 from a flooded rice soil. Plant and Soil 129: 269-276.

[4] Lindau, CW, PK Bollich, PD Delaune, WH Patrick, and VJ Law. 1991. Effect of urea fertilizer and environmental factors on CH 4 emissions from a Louisiana, USA rice field. Plant and Soil 136: 195-203.

[5] Lindau, CW and PK Bollich. 1993. Methane Emissions from Louisiana first and ratoon crop rice. Soil Science, 156, p42-47.

[6] Lindau, CW, PK Bollich, RD Delaune, AR Mosier, and KF Bronson. 1993. Methane mitigation in flooded Louisiana rice fields. Biology and Fertility of Soils, 15: 174-178.

[7] Lindau, CW. 1994. Methane Emissions from Louisiana Rice Fields Amended with Nitrogen Fertilizers. Soil Biology and Biochemistry, 26 (3): 353-359.

[8] Lindau, CW, DP Alford, PK Bollich, and SD Linscombe. 1994. Inhibition of methane evolution by calcium sulfate addition to flooded rice. Plant and Soil 158: 299-301.

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Table 6. Basic statistics for the calibration and validation set for the Louisiana Gulf Coast (LGC)

Parameter	LGC
Slope of regression through origin (mean ± standard error)	0.9534 +/- 0.0384
P-value for slope > 1.1	0.0003
P-value for slope < 0.9	0.0865
s (kgCO$_2$-eq/ ha)	2442.3
ρ	0.745
k	40
n	Project Area size in ha
$t_{inv}(0.90, k)$	1.303077

Table 6 indicates that the LGC Rice Growing Region passed the Two One Sided T (TOST) test. The slope of regression for the MRD Rice Growing Region was found to be 0.7749 +/- 0.1089, which does not pass the TOST test, showing bias in the model. The main reason is that given the current measurements and calibration, the model is over-estimating emissions to a minor but statistically significant extent. SectionStep 5. Demonstration that the DNDC Model Simulates Fluxes in an Unbiased Way 6.1 includes more on a correction factor to eliminate the impact of bias for the MRD Rice Growing Region, specifically for the state of Arkansas.

Table 7 summarizes the results of structural uncertainty deduction calculation. This methodology requires that a minimum of five fields or 405 ha (1,000 acres) be included. This minimum of 5 required fields corresponds to an uncertainty deduction of 113 kg CO_2-eq per year and per hectare for the LGC Rice Growing Region.

Table 7. Structural uncertainty deduction factors for projects in the Louisiana Gulf Coast (LGC) Rice Growing Region.

Project Area size (n) [ha]	**Structural Uncertainty deduction per ha [kg CO_2-eq ha^{-1} yr^{-1}]**	**u_{struct} [kg CO_2-eq yr^{-1}]**
405 (minimum)	113	45,780
500	102	50,867
750	83	62,299
1,000	72	71,937
2,500	45	113,742
5,000	32	160,856
10,000	23	227,485

6.1 Arkansas Derivation of Uncertainty Deduction in the Presence of Model Bias

It is the intent that this section will be incorporated as an addendum to the parent methodology Voluntary Emission Reductions in Rice Management Systems. Despite this omission in the parent methodology if a bias is found, as was found in Arkansas, this tool maybe used.

In the parent methodology, the model was assumed to be unbiased with normal residuals (see Section 14.1.3 of parent methodology). The variance of the residuals does not depend on whether the situation being modeled is a baseline or project scenario. Thus,

$$\mathrm{PE_{model}} = \mathrm{PE_{meas}}\varepsilon_1, \varepsilon_1, \sim \mathrm{N}\ (0, \sigma^2\ )$$

$$\mathrm{BE_{model}} = \mathrm{PE_{meas}}\varepsilon_2, \varepsilon_2, \sim \mathrm{N}\ (0, \sigma^2\ )$$

Unfortunately, it will sometimes occur that the model cannot be demonstrated to be unbiased using a TOST equivalence testing approach (see Section 14.1.2 of parent methodology). Thus, it is necessary to introduce a slope and/or intercept to describe the relationship between modeled and measured emissions. Specifically,

$$\mathrm{PE_{model}} = \beta_0 + \beta_1\mathrm{PE_{meas}} + \varepsilon_1, \varepsilon_1, \sim \mathrm{N}\ (0, \sigma^2\ )$$

$$\mathrm{PE_{model}} = \beta_0 + \beta_1\mathrm{BE_{meas}} + \varepsilon_2, \varepsilon_2, \sim \mathrm{N}\ (0, \sigma_a^2)$$

where β_0 and β_1 are parameters to be estimated from the data. Equivalently, we can write

$$\mathrm{PE_{meas}} = \gamma_0 + \gamma_1\ \mathrm{PE_{model}} + \varepsilon_1, \varepsilon_1, \sim \mathrm{N}\ (0, \sigma^2\ )$$

$$\mathrm{BE_{meas}} = \gamma_0 + \gamma_1\ \mathrm{BE_{model}} + \varepsilon_2, \varepsilon_2, \sim \mathrm{N}\ (0, \sigma^2\ )$$

where $\gamma_0 = -\beta_0/\beta_1, \gamma_1 = -1/\beta_1$, and $\sigma^2\ =\ \sigma_a^2/\beta_1^2$. It is the latter form that we will actually use to estimate the structural uncertainty deduction. As before, our interest is in the quantity

$\mathrm{DER_{model}} - \mathrm{DER_{measure}}$, i.e.

$$(\mathrm{BE_{model}} - \mathrm{PE_{model}}) - (\mathrm{BE_{measure}} - \mathrm{PE_{measure}})$$

$$= (\mathrm{BE_{model}} - \mathrm{PE_{model}}) - [(\gamma_0 + \gamma_1\ \ \mathrm{BE_{model}} = \varepsilon_2)\text{-(}\ (\gamma_0 + \gamma_1\ \mathrm{PE} + \varepsilon_1)]$$

$$=(1-\gamma_1)(\mathrm{BE_{model}} - \mathrm{PE_{model}})\ +\varepsilon$$

with $\varepsilon \sim N(0{,}2\sigma^2\ (1-\rho))$. We can estimate σ^2 as the variance of the residuals of measured on modeled values for the field sites, and ρ as the correlation of the residuals between project-baseline pairs. Where the model is estimated based on k pairs of modeled and measured values, and n hectares of fields are included in the project, then following the rationale of the parent methodology, constructing an approximate 1-sided 90% confidence limit for $\mathrm{DER_{model}} - \mathrm{DER_{measure}}$, i.e. yields an uncertainty deduction of

$$u_{struct} = n(1-\gamma_1)(E[\mathrm{BE_{model}} - \mathrm{PE_{model}}]) =\ \mathrm{s}\sqrt{2\mathrm{n}(1-\rho)}\ t_{inv}\ (0.90, k-2)$$

where the expectation in the left hand term indicates the average modeled net emissions reduction on a per hectare basis, and s is the empirical standard deviation of the regression residuals. The degrees of freedom in the inverse of the cumulative t distribution is $k-2$, because there are 2 estimated parameters in the regression (versus 0 in the original derivation, where the slope was assumed to be 1 and the intercept was assumed to be 0). The left hand term in the equation adjusts the original modeled net emissions reduction for the systematic departure of the model from a 1:1 line. This term will be positive when the model tends to over-predict measured emissions, and can be negative if the model tends to under-predict measured emissions on average. The second term, which is always positive, provides the adjustment for the variability in predictions around the typical model performance. The better the model is at predicting measured emissions, following adjustment by a linear calibration, the smaller the second term will be.

6.1.1 Illustration Using Arkansas Data

The calculation of a structural uncertainty deduction for a biased model is implemented using data on methane emissions from rice production in Stuttgart, Arkansas. Sixteen individual treatments have been simulated, and there are 16 baseline-project pairings in the data shown in Table 5.

Regression of the measured emissions on the modeled emissions yields $\gamma_0 = -6.6810$ and $\gamma_1 = -0.8245$. Irrespective of the confidence limits, this value of the slope indicates the model would fail the TOST equivalence test. The standard deviation of the residuals is $\mathrm{s} = 25.7525$.

Matching baseline-project pairs and calculating the correlation coefficient, we obtain $\rho = -0.1468$. This correlation is not significantly different from zero, so we could be forgiven for treating the residuals as uncorrelated, but we retain the correlation coefficient for the sake of illustration. We now have the information needed to calculate a generic uncertainty deduction equation for an arbitrary bundled project with *n* hectares:

$$u_{struct} = 0.1755n(E[\mathrm{BE_{model}} - \mathrm{PE_{model}}]) + 52.4583\sqrt{\mathrm{n}}$$

Note that the quantity $n(E[\mathrm{BE_{model}} - \mathrm{PE_{model}}])$ is just the total modeled net emissions reduction for the project (in kg, not kg/ha). The first term in the structural uncertainty is positive because measured emissions tend to be less than modeled emissions, on average. The second term, which is guaranteed to be positive, increases with the square root of the project area. Note, however, that on a per-hectare basis, the bias-adjusted uncertainty deduction is just a constant fraction of the average net emissions reduction per hectare, plus a variability term that diminishes as a fraction of the total deduction as the number of hectares bundled in the project grows large.

7 Template .dnd Input Files

The following table is a template .dnd input file with an indication of fixed default values or if values must be added by Project Proponents.

The template .dnd file may change during the course of validation, as more model calibration and validation data is included in the analysis and the model is further fine-tuned to eliminate bias in the MRD.

Table 8. Template dnd input file for the Mississippi River Delta (MRD) and the Louisiana Gulf Coast (LGC)

		Selection procedure for value	
Line	**DND Parameter**	**MRD**	**LGC**
1	Input_Parameters:		
2	--		
3	Site_data:		
4	Simulated_Year:	Provide number of years being simulated	
5	Latitude:	Use latitude of project area	
6	Daily_Record:	0	
7	--		
8	Climate_data:		
9	Climate_Data_Type:	User defined (1,2 or 4)	
10	NO3NH4_in_Rainfall	1	
11	NO3_of_Atmosphere	0.06	
12	BaseCO2_of_Atmosphere	397	
13	Climate_file_count		
14		Provide path to climate file	
15	Climate_file_mode	1	

Line	DND Parameter	Selection procedure for value	
		MRD	LGC
16	CO2_increase_rate	0	
17	---------------------------------------		
18	Soil_data:		
19	Soil_Texture	Provide result of empirical soil measurements	
20	Landuse_Type	2	
21	Density	Provide result of empirical soil measurements	
22	Soil_pH	Provide result of empirical soil measurements	
23	SOC_at_Surface	Provide result of empirical soil measurements	
24	Clay_fraction	Provide result of empirical soil measurements	
25	BypassFlow	0	
26	Litter_SOC	0.02	
27	Humads_SOC	0.4	
28	Humus_SOC	0.58	
29	Soil_NO3(-)(mg N/kg)	0.5	
30	Soil_NH4(+)(mg N/kg)	0.05	
31	Soil_PassiveCN	500	
32	Lateral_influx_index	1	
33	Field_capacity	Provide result of empirical soil measurements	
34	Wilting_point	Provide result of empirical soil measurements	
35	Hydro_conductivity	Provide result of empirical soil measurements	
36	Soil_porosity	Provide result of empirical soil measurements	
37	SOC_profile_A	0.2	
38	SOC_profile_B	2	
39	DC_litter_factor	1	
40	DC_humads_factor	1	
41	DC_humus_factor	1	
42	Humad_CN	10	
43	Humus_CN	10	
44	Soil_PassiveC	0	
45	Soil_microbial_index	1	
46	Highest_WT_depth	9.99	
47	Depth_WRL_m	0.3	
48	Slope	0	
	Salinity	0	
49	SCS_curve_use	0	
50	---------------------------------------		
51	Crop_data:		
52	Rotation_Number	Provide count of rotations	
	REPEAT FROM 20 YEARS BEFORE START OF CREDITING PERIOD UNTIL 10 YEARS AFTER START		

Line	DND Parameter	Selection procedure for value	
		MRD	**LGC**
	CREDITING PERIOD:		
53	Rotation_ID	Provide index of rotation	
54	Totalyear	Provide count of simulation years within rotation	
55	Years_Of_A_Cycle		
56	YearID_of_a_cycle	Provide index of year	
57	Crop_total_Number	1	
58	Crop_ID	1	
59	Crop_Type	20	
60	Plant_time	Provide exact date, for example 5 1	
61	Harvest_time	Provide exact date, for example 9 11	
62	Year_of_harvest	1	
63	Ground_Residue	Set to 1 if no baling is applied, otherwise 0.25 or empirical measurement	
64	Yield	Provide monitored yield	
65	Leaf_fraction	0.22	0.27
66	Leaf_CN	85	
67	Psn_efficiency	0	
68	Psn_maximum	0	
69	Initial_biomass	0	
70	Cover_crop	0	
71	Perennial_crop	0	
72	Grain_fraction	0.48	0.41
73	Stem_fraction	0.23	0.27
74	Root_fraction	0.07	0.05
75	Grain_CN	45	
76	Stem_CN	85	
77	Root_CN	85	
78	TDD	Provided through crop calibration. Initial value is 3000.	
79	Water_requirement	508	
80	Optimum_temp	22	20
81	N_fixation	1.05	
82	Vascularity	1	
83	Tillage_number	Provide count of tillage events	
	REPEAT FOR ALL TILLAGE EVENTS:		
84	Tillage_ID	Provide index of tillage event	
85	Month/Day/method	Provide exact date and method, for example 4 23 3	
	(end of tillage event enumeration)		
94	Fertil_number	Provide count of fertilization events	
	REPEAT FOR EACH FERTILIZATION EVENT:		
95	fertilization_ID	Provide index of fertilization event	

Line	DND Parameter	Selection procedure for value	
		MRD	LGC
96	Month/Day/method	Provide exact date and method, for example 4 30 1	
97	Depth	0.2	
98	Nitrate	Provide exact amount based on fertilizer	
99	AmmBic	Provide exact amount based on fertilizer	
100	Urea	Provide exact amount based on fertilizer	
101	Anh	Provide exact amount based on fertilizer	
102	NH4NO3	Provide exact amount based on fertilizer	
103	NH42SO4	Provide exact amount based on fertilizer	
104	NH4HPO4	Provide exact amount based on fertilizer	
105	Release_rate	1	
106	Inhibitor_efficiency	0	
107	Inhibitor_duration	0	
108	Urease_efficiency	0	
109	Urease_duration	0	
	(end of fertilization event enumeration)		
141	Manure_number	0	
142	Plastic_film	0	
143	Ventilation	0	
144	Flood_number	1	
145	FloodWaterN	1	
146	Water_control	0	
147	Leak_rate	0	
	REPEAT FOR EACH FLOODING EVENT:		
150	Flooding_ID	1	
151	Flood_Month/Day	Provide exact date, for example 1 1	
152	Drain_Month/Day	Provide exact date, for example 1 31	
153	Water_N	0	
154	Shallow_flood	0	
	Water_gather	1	
	WT_file	None	
	Empirical_parameters	0.00000 0.00000 0.00000 0.00000 0.00000 0.00000	
	(end of flooding event enumeration)		
168	Irrigation_number	Needed for dry seeding scenario	
169	Irrigation_type	0 Provide type based on actual irrigation system	
170	Irrigation_Index	0	
171	Grazing_number	0	
172	Cut_number	0	
	(end of crediting year enumeration)		
435	Crop_model_approach	0	

8 Quantification of GHG Emissions from Energy Use

This section indicates how to quantify GHG emissions from energy use. The calculation of energy use is only necessary for practices that change the water use efficiency and/or the energy use, which is practice 3, "Increased Water and/or Energy Use Efficiency" and practice 4, "Intermittent Flooding." As the DNDC model does not include any components related to energy or fuel use, these emission reductions must be calculated using the equations in this section and added to the emission reductions calculated by the DNDC model as specified in the parent methodology.

If the project activity reduces GHG emissions in whole or in part by improving water use efficiency (reducing water pumped but does not reduce fuel/energy consumption per acre-inch pumped), then:

- **Baseline Water Pumped** shall be calculated based on the average typical water volume actively pumped on a specific field during the growing season, before the implementation of water use efficiency measures. Water pumped shall be measured using either flow rates and pumping durations, or standard water usage reported in refereed peer-reviewed literature or engineering handbooks. The Baseline Water Pumped value shall be cross-checked using multiple sources of data such as multiple pumping stations, handbooks, or literature sources and any discrepancies in the magnitude of the water usage shall be justified. In case historical water usage is used, data from multiple years shall be used, so that the baseline represents typical water pumped in both wet and dry years (since less water will need to be pumped in years with more rain during growing season). The onus is on the Project Proponent to justify the Baseline Water Pumped to the VVB with reasonable assurance. However, it must be recognized that strict procedures to verify the Baseline Water Pumped without any ambiguity cannot be defined.
- **Project Water Pumped** shall be monitored during the growing season.

If the project activity reduces GHG emissions in whole or in part by improving energy use efficiency (reducing fuel consumption and thus GHG emissions per acre-inch pumped), then:

- To determine the **Baseline Energy Use**, it is recommended to either use records of energy and/or fuel use from the past 5 years before conversion, or to run an energy/fuel consumption test on the old pump before it is removed. If no historical records of fuel or energy use efficiency from the field itself are available, fuel and/or energy use efficiency from a nearby field or regional pumping stations with similar pumping systems may be used. Finally, if no historical records are available on the field itself or on nearby fields, fuel efficiency may be estimated using standard factors relative to the volume of water pumped on the condition that it can be demonstrated that the factor is (1) applicable and (2) conservative. Acceptable sources for standard factors are engineering handbooks, university extension services, scientific literature, and the pump manufacturer's guidance and manuals. One way of demonstrating the conservative nature of standard factors is to use partial historical records.
- **Project Energy Use** shall be monitored during the growing season and shall be calculated based on the equations below.

Baseline and project emissions from fuel and energy use shall be calculated using the following equation, and added to the baseline and project emissions ([EQ 3] and [EQ 4], respectively) in the parent methodology “Voluntary Emission Reductions in Rice Management Systems”. Equation [EQ 3] with the Emissions from Fuel and Energy added is included below. Equation [EQ 4] shall be adjusted similarly.

$$BE_{y,i} = \frac{44}{12} \cdot [CO2]_{baseline,y,i} + 310 \cdot \frac{44}{28} \cdot [N2O]_{baseline,y,i} + 21 \cdot \frac{16}{12} \cdot [CH4]_{baseline,y,i} + E_{fe}$$

$$E_{fe} = EF_{fuel} \cdot Ef_{pump,fuel} \cdot V_{water,fuel} + EF_{elec} \cdot Ef_{pump,elec} \cdot V_{water,elec} \qquad \text{[EQ 3]}$$

Where:

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

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

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

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

E_{fe} = Emissions from fuel and energy [tCO_2-eq yr^{-1}]

EF_{fuel} = Stationary Combustion Emission Factors [tCO_2-eq per gallon of diesel]. Obtain from the EPA’s Emission Factors for Greenhouse Gas Inventories, available at http://www.epa.gov/climateleadership/guidance/ghg-emissions.html. Note the units of these EPA emission factors vary and care should be taken to convert appropriately: e.g., if the emission factor is reported in kg CO_2 per gallon, divide by 1,000 to convert to tCO_2-eq per gallon. Ignore the small CH_4 and N_2O emissions from diesel combustion and use only the CO_2 emission factor.

$Ef_{pump,fuel}$ = Efficiency of fuel pump [acre-inch of water per Gallon of diesel]

$V_{water,fuel}$ = Annual water volume pumped by fuel pump [acre-inch of water per year]

EF_{elec} = Emission factor of electrical pump [tCO_2-eq per MWh]. Use latest eGRID data by eGRID sub-region available from http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html. At the time of writing, the latest eGRID data was eGRID2012 -- year 2009. Alternatively, regional factors obtained from local utility company may be used. Note that no unit conversion factors are included here as utility companies report Emission Factors in different units. Project Proponents shall convert units appropriately; e.g. for eGRID electricity emission factors, presented in lb CO_2/MWh, divide by 2,204.6 to convert lbs CO_2 to metric tons.

$Ef_{pump,elec}$ = Efficiency of electrical pump [acre-inch of water per MWh]

$V_{water,elec}$ = Annual water volume pumped by electricity pump [acre-inch of water per year]

9 Data and Parameters Not Monitored

These data and parameters are in addition to the data and parameters that are already specified in the parent methodology “Voluntary Emission Reductions in Rice Management Systems”.

Data Unit / Parameter:	Baseline Fuel and/or Energy Efficiency
Data unit:	tCO_2-eq per gallon of water
Description:	Fuel efficiency of combustion engine connected to pump before switching to an increased-efficiency pumping system. Fuel efficiency shall be expressed as GHG emissions in metric tons CO_2 equivalent (tCO_2-eq) relative to the volume of water pumped.
Source of data:	Select from following (only select lower options when higher options are not available) a) Records of energy and/or fuel use from the past 5 years before conversion to determine the baseline energy and/or fuel use for given volumes of water b) Energy/fuel consumption test on the old pump before it is removed together with field-specific water use or the time the pump is switched on c) Fuel and/or energy efficiency from a nearby field or regional pumping stations with similar pumping systems, or typical fuel efficiency values included in peer-review articles, reports, or other appropriate sources. d) Standardized efficiency factors included in refereed peer-review articles, reports, or other appropriate sources. For options (c) and (d), it must be demonstrated that the approach is both applicable and conservative. Fuel (diesel) use shall be converted into tCO_2-eq using Equation (2) in the approved CDM tool "Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities". However, values of the Stationary Combustion Emission Factors in kg CO_2 per gallon shall not be obtained from the CDM tool, but rather from the EPA's Emission Factors for Greenhouse Gas Inventories, available at http://www.epa.gov/climateleadership/guidance/ghg-emissions.html
Description of measurement methods and procedures to be applied:	If one pump serves multiple fields, the proportion of water received by each field served by the pump shall be estimated and used to separate the baseline fuel efficiency among the fields served by one pump.
QA/QC procedures to be applied:	
Verification requirements:	Source of the data shall be provided to the Validation/Verification Body (VVB) so that the data can be independently retrieved by the VVB and compared to the data submitted at verification. If available, geotagged and date-stamped pictures of fuel and/or water meters.
Any comment:	The baseline fuel/energy use efficiency needs to be provided only on fields on which increased water use efficiency and/or increased fuel use efficiency interventions are planned.

300

Data Unit / Parameter:	Baseline Water Pumped
Data unit:	Gallons per year, or acre-inches per year
Description:	Total water pumped on a specific field during the growing season, before the implementation of any water use efficiency measures. This water volume shall only include water that is actively pumped and shall exclude, therefore, any water coming from precipitation.
Source of data:	The actual water pumped shall be estimated using either measured flow rates and pumping durations, or standard water usage reported in refereed peer-reviewed literature or engineering handbooks.
Description of measurement methods and procedures to be applied:	
QA/QC procedures to be applied:	The proposed Baseline Water Pumped value shall be cross-checked using multiple sources of data and any discrepancies in the magnitude of the water usage shall be justified. In case historical water usage is used, data from multiple years shall be used. The onus is on the Project Proponent to justify the Baseline Water Pumped to the VVB with reasonable assurance. However, it must be recognized that strict procedures to verify the Baseline Water Pumped without any ambiguity cannot be defined.
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:	The Baseline Water Pumped needs to be provided only on fields on which increased water use efficiency interventions are planned.

Data Unit / Parameter:	Conventional drainage date determination
Data unit:	Narrative
Description:	Methodology to set the conventional, i.e., baseline, drainage date for a specific field
Source of data:	Producer or crop advisor
Description of measurement methods and procedures to be applied:	A reasonably workable description of how the drainage date has been set either historically on a specific field if no Common Practice Baseline is used, or following common practice in case a Common Practice Baseline is used. Select from the following options: • 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. • Conventional drain date as determined in a process-based rice model such as RicePSM or ORYZA.
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

302

10 Additional Data and Parameters Monitored

Data Unit / Parameter:	Actual Fuel and/or Energy Efficiency
Data unit:	tCO_2-eq per gallon of water
Description:	Fuel/Energy efficiency of increased-efficiency pumping system. Fuel/Energy efficiency shall be expressed as GHG emissions in metric tons CO_2 equivalent (tCO_2-eq) relative to the volume of water pumped in Gallons.
Source of data:	The actual fuel efficiency shall be calculated based on either: a) Annual records of energy and/or fuel use as well as water pumped during that period; or b) Energy/fuel consumption test on the increased-efficiency pumping system.
Frequency	At least every 5 years
Description of measurement methods and procedures to be applied:	If one pump serves multiple fields, the proportion of water received by each field served by the pump shall be estimated and used to separate the baseline fuel efficiency among the fields served by one pump.
QA/QC procedures to be applied:	
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. If available, geotagged and date-stamped pictures of fuel, energy and/or water meters.
Any comment:	The actual fuel/energy use efficiency needs to be monitored only on fields where increased fuel use efficiency interventions are conducted.

Data Unit / Parameter:	Actual Water Pumped
Data unit:	Gallons per year
Description:	Total water pumped on a specific field during the growing season.
Source of data:	The actual water pumped shall be recorded on a specific field using a water flow meter. In the event one pump serves multiple fields, only some of which are enrolled in the Project, a flowmeter must be used on the field(s) enrolled in the Project.
Frequency	Annually
Description of measurement methods and procedures to be applied:	
QA/QC procedures to be applied:	
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. If available, geotagged and date-stamped pictures of water meters shall be taken.
Any comment:	The actual water pumped needs to be monitored only on fields on which increased water use efficiency and/or increased fuel use efficiency interventions are conducted.

Data Unit / Parameter:	Conventional Drainage Date
Data unit:	Date
Description:	Conventional drainage date when no early drainage is (or would have been) employed
Source of data:	Producer or crop advisor
Description of measurement methods and procedures to be applied:	The conventional drainage date must be set using the “Conventional drainage date determination” methodology included in the GHG project plan.
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

11 References

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