Rice Cultivation Project Protocol

Reducing Methane Emissions from Rice Cultivation

WORKGROUP DRAFT

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Abbreviations and Acronyms

CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon dioxide
CRT	Climate Reserve Tonne
EPA	Environmental Protection Agency
GHG	Greenhouse gas
ISO	International Organization for Standardization
lb	Pound
MT	Metric ton (or tonne)
N_2O	Nitrous oxide
RC	Rice Cultivation
Reserve	Climate Action Reserve
SSRs	Sources, sinks, and reservoirs
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

The Climate Action Reserve (Reserve) Rice Cultivation Project Protocol (RCPP) provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with the implementation of rice cultivation practice changes that result with a decrease in methane emissions to the atmosphere.

The Climate Action Reserve is a national offsets program working to ensure integrity, transparency, and financial value in the U.S. carbon market. It does this by establishing regulatory-quality standards for the development, quantification and verification of GHG emissions reduction projects in North America; issuing carbon offset credits known as Climate Reserve Tonnes (CRT) generated from such projects; and tracking the transaction of credits over time in a transparent, publicly-accessible system. Adherence to the Reserve's high standards ensures that emission reductions associated with projects are real, permanent and additional, thereby instilling confidence in the environmental benefit, credibility and efficiency of the U.S. carbon market.

Project developers and aggregators that initiate Rice Cultivation (RC) projects use this document to register GHG reductions with the Reserve. The protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive annual, independent verification by ISO-accredited and Reserve-approved verification bodies. Guidance for verification bodies to verify reductions is provided in the Reserve Verification Program Manual and Section 8 of this protocol.

This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification and verification of GHG emission reductions associated with RC projects.

2 The GHG Reduction Project

2.1 Background

Methane (CH_4), a potent greenhouse gas (GHG), can be formed as a by-product of microbial respiration reactions that occur when organic materials decompose in the absence of oxygen (i.e. under anaerobic conditions). In the United States, rice is almost exclusively grown on flooded fields.[1] When fields are flooded during the rice cultivation process, oxygen retained in soil pores is rapidly depleted by aerobic decomposition of organic plant residues in the soil, and the soil environment becomes anaerobic. Organic matter continues to decompose under anaerobic conditions, resulting in formation of methane gas. While as much as 60 to 90 percent of the CH_4 produced by the anaerobic microbes is oxidized within the soil by aerobic microbes, remaining un-oxidized CH_4 is transported from the soil to the atmosphere via diffusive transport through the rice plants and the floodwaters.[1]

The quantity of methane emitted to the atmosphere at a given rice field over the course of a year will depend on numerous factors related primarily to the water management and plant residue management systems in place. Other contributing factors include fertilization practices (using organic vs. synthetic fertilizer), soil properties (type, temperature), rice variety, and other cultivation practices (i.e. tillage, seeding, and weeding practices).

According to the U.S. EPA, rice is currently cultivated in eight states (AR, CA, FL, LA, MS, MO, OK, TX), and rice cultivation is considered to be a relatively small source of CH_4 emissions in the U.S., with total 2009 emissions estimated to be 7.3 MMT CO_2e.[1] Nevertheless, opportunity exists to reduce the methane generated by rice cultivation through implementation of cultivation practice changes related to water and residue management. Management practice changes that decrease the amount of organic matter deposited in the soil, or decrease the amount of time a field is flooded, will typically reduce GHG emissions compared to baseline management practices.

Due to the complexities involved with accurately quantifying GHG emissions resulting from the biogeochemical interactions that occur in cropped rice field systems, this protocol relies on the application of the Denitrification – Decomposition (DNDC) biogeochemical process model for quantification of RC project and baseline GHG emissions to quantify associated emission reductions. Because of the significant geographic variability related to soil types, climate, and cultivation management practices, the DNDC model must be properly calibrated for the geographic area and for all relevant cultivation practices in order for the model to perform with an acceptable degree of certainty. Therefore, this protocol will apply only to the regions and practices for which the DNDC model has been explicitly validated with measured data. While this version of the RCPP is valid only in specified rice growing regions, the Reserve expects to periodically update the protocol to expand the geographic scope to include other U.S. rice growing regions as data and model calibration results become available. Currently, however, this protocol only applies to RC projects located in California's Sacramento Valley rice growing region.

[1] U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks.

Background on Rice Cultivation Techniques

In the US there are 3 dominant flooding systems for rice cultivation: continuous flood, pinpoint flood, and delayed flood.

- Continuous flood: In a continuous flood system fields are flooded prior to seeding. Once the flood is established, pre-germinated or sprouted seeds are sown (typically by aircraft) into a flooded field. These fields are then maintained in a flooded state until they are drained just before harvest.
- Pinpoint flood: In the pinpoint flood system, pre-germinated seeds are sown into floodwater. The field is drained after seeding for several days to allow the roots to establish or "peg" in the soil. This drain period varies based on soil conditions and weather, but typically lasts for 3-5 days to enable the roots to establish. During this drain period oxygen can permeate back into the soil. Once the rice seeds have pegged into the soil, the fields are re-flooded and maintained in flooded conditions until just before harvest.
- Delayed flood: In a delayed flood system fields are either dry seeded and irrigated for germination or water seeded using pre-germinated seeds that are sown directly into a flooded fields after which the fields are immediately drained. The fields are then kept drained for three to four weeks while the rice canopy is established. Once the canopy is established then the fields are flooded and remained flooded until the typical pre-harvest drain.

Producer's decisions regarding which seeding method to use are targeted at selecting the method that will result in proper seedling emergence and lead to a uniform canopy. Seeding methods depend on soil type, weather conditions, and producer preferences. Differences in seeding methods for rice production relate to (a) dry versus water seeded, (b) drill seeding versus broadcast and (c) use of stale seedbed or conventional seedbed.

- Water seeding: Water seeding describes sowing of dry or soaked seed into a flooded field. It is usually implemented for any or all of the following reasons: red rice control, wet planting season, planting efficiency and earlier crop maturity.
- Dry seeding: Dry seeding simply describes sowing seed into a dry seedbed by drilling or broadcasting. This method usually offers more flexibility in planting but may require more time to do so. This system is also weather dependent.

California Rice Cultivation Practices

In California's Sacramento Valley (CSV) rice growing region (see figure below), continuous flood is the dominant water management technique. Fields are flooded to a depth of 4-5 inches just prior to aerial seeding. While deeper flooding will further reduce weed pressures, it will also lead to poor stand establishment. Once the rice stand is established and the panicle initiation has occurred, many growers will increase the depth of the flood water to 8 inches. This helps with further weed control and protects the rice from cool nighttime temperatures that can lead to reduced yields. The timing of the draining the fields vary and can influence total yields. UCCE recommends growers drain their fields when the panicles are "fully tipped and golden". Occasionally, several weeks after seeding fields are drained for one day to apply herbicide for weed control. This drain is short lived and does not lead to drying of the soil surface and does not affect CH_4 emissions.

Continuous flooding and water seeded regime is used on over 96% of the acreage in California. A small fraction of the rice acreage is dry seeded in California. The flood for dry seeded rice starts approximately 25-30 days after seeding. During this period, fields are periodically irrigated to promote germination and stand establishment.

Rice straw can have a significant impact on greenhouse gas emissions. Timing of straw amendment/incorporation can impact greenhouse gas emissions by altering the timing and availability of substrate (dissolved organic carbon (DOC)) released from the fresh straw to methanogens. The timing of the residue incorporation relative to the flooding period will impact total methane production. Rice straw incorporation is currently the dominant management practice in California.

Burning of rice straw was the dominant management practice in CA until 1991. Following the 1991 Rice Straw Burning Reduction Act, burning of rice straw decreased dramatically on an annual basis. By the 2001 growing season burning of rice straw was permitted for disease control only with a cap of 25 percent of total rice acreage in the state burned annually. Currently, burning occurs on only 10-12 percent of rice acreage in California.[2] Some growers bale rice straw for off field uses. The current estimate of baling is 6-8% per year. This obviously fluctuates a bit with various straw markets. Baling does not remove all of the rice straw following harvest. Due to operational constraints and the market for straw, baling typically removes ~75% of rice straw, leaving the remaining straw on the field.

[2] Communication with Paul Buttner.

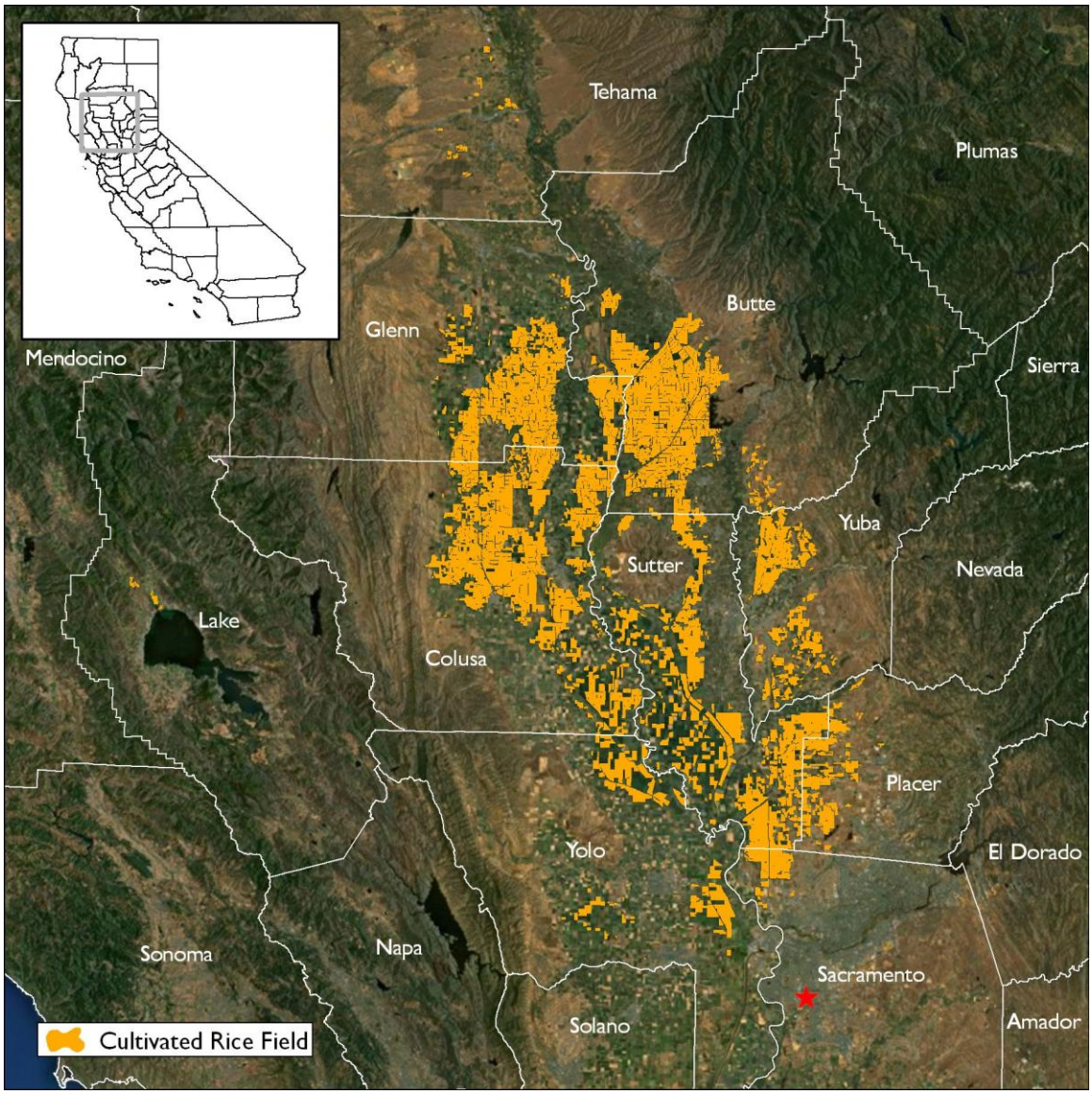


Figure 2.1. FIGURE NAME AND REFERENCE

2.2 Project Definition

For the purpose of this protocol, the GHG reduction project is defined as the adoption and maintenance of one or more of the approved rice cultivation management changes on an individual rice field, with at least five individual fields combined into a single project area. Boundaries for individual fields must be defined according to the requirements in Section 2.2.1

At least one approved rice cultivation management change must be implemented on each individual rice field in the project area. The project area does not need to be contiguous, and can encompass fields located on one farming operation, or distributed amongst different farms and/or producers. Project areas that encompass fields on multiple farming operations must submit to the Reserve as a 'Project Aggregate' according to the rules provided in Section 7.

Because nitrous oxide (N_2O) emissions are shown to be more variable with increased soil carbon content,[3] the project area cannot contain any soils with organic carbon content greater than 3% in the top 30cm of soil.[4]

At present, only practice changes described in Table 2.1 below are approved for project activity (by geographic scope).

Table 2.1. Definitions for Approved Project Activities

Approved RC Management Changes	Description	Geographic Scope
Dry seeding (DS)	A seeding method that involves sowing of dry seeds into dry or moist, non-puddled soil. Dry seeding can be performed by spreading seeds onto the soil surface and transferring soil on top of the seeds or by drilling seeds into a prepared seedbed, a practice known as "drill seeding."	CA
Post-harvest rice straw removal and baling (Baling)	After harvest, rice straw residue is traditionally left on agricultural fields and incorporated into soil, however; rice straw can be removed by baling. Baled straw can be sold even though the market is small. In California, Rice straw can be used for erosion control, animal bedding or as an alternative feed for cow and calf producers[5]	CA
Decreased frequency and/or duration of winter flooding (DWF)	For fields that use winter flooding as a preferred method for managing rice residue, the frequency of flooding a field (measured over a five year period) can be reduced. Similarly, the duration of each flood period may be reducible in any given year. Both activities would result with decreased overall winter flooded conditions.	CA

2.2.1 Defining Field Boundaries

For the purposes of this protocol, an individual rice field must be defined by the following criteria:

1. The defined field boundary must be under the direct management control of a single rice producer
2. The field management must be homogeneous across the entirety of the defined field boundary
3. The field must be calibrated and modeled independently of all other fields, using soil, RC management, and climate data inputs specific to the defined boundary

Soil input parameters necessary for DNDC model calibration and emissions modeling must be determined for each field through use of soil sampling, or use of the USDA NRCS SSURGO soil survey data.[6] See Section 6.1 for soil input data collection requirements.

[3] CITE SOURCE FOR N_20 EMISSIONS.
[4] The DNDC model has primarily been calibrated for soils with carbon contents smaller than this threshold.
[5] DANR, publication 8425.
[6] See http://soils.usda.gov/survey/geography/ssurgo/.

2.3 The Project Developer

The "project developer" is an entity that has an active account on the Reserve, submits a project for listing and registration with the Reserve, and is ultimately responsible for all project reporting and verification. Project developers may be rice growers, GHG project developers, aggregators, or other entities.

In all cases, the project developer must attest to the Reserve that they have exclusive claim to the GHG reductions resulting from the project. Each time a project is verified, the project developer must attest that no other entities are reporting or claiming (e.g. for voluntary reporting or regulatory compliance purposes) the GHG reductions caused by the project.[7] The Reserve will not issue CRTs for GHG reductions that are reported or claimed by entities other than the project developer.

Unless the project consists of at least 5 fields located on a single farming operation, the project must be submitted as a 'Project Aggregate' by a qualifying aggregator. In order to qualify as an aggregator, the entity submitting the project aggregate must meet the requirements specified in Appendix E.

Appendix E of the protocol defines the aggregation rules related to project ownership, submittal, calculation, reporting, and verification.

[7] This is done by signing the Reserve's Attestation of Title form, available at: http://www.climateactionreserve.org/how/projects/register/project-submittal-forms/

3 Eligibility Rules

Projects must fully satisfy the following eligibility rules in order to register with the Reserve. The criteria only apply to projects that meet the definition of a GHG reduction project (Section 2.2).

Eligibility Rule I:	Location	→	*California*
Eligibility Rule II:	Project Start Date	→	*Within six months prior to project submission**
Eligibility Rule III:	Anaerobic Baseline Conditions	→	*Demonstrate baseline flooded rice cultivation practice*
Eligibility Rule IV:	Additionality	→	*Meet performance standard*
		→	*Exceed regulatory requirements*
Eligibility Rule V:	Regulatory Compliance	→	*Compliance with all applicable laws*
Eligibility Rule VI:	Wildlife Habitat Protection	→	*Compliance with all habitat protection criteria*

* See Section 3.2 for additional information on project start date

3.1 Location

Only projects located in approved rice growing regions of the United States, or on U.S. tribal lands within an approved rice growing region, are eligible to register reductions with the Reserve under this protocol. Reductions from projects outside of the defined geographic region are not eligible to register with the Reserve at this time.

Currently, only the California rice growing region is approved under this protocol. Therefore, only RC projects located in California are eligible to register reductions with the Reserve.

3.2 Project Start Date

In order to produce accurate GHG emission modeling results, the DNDC model used for calculating GHG reductions must be run for each annual 'cultivation cycle.' For ease of modeling, a 'cultivation cycle' is defined as the period starting immediately after a rice harvest (in late summer or fall), and ending at the end of the next calendar year's harvest. Therefore, a complete cultivation cycle begins with post-harvest residue management over the fall and winter seasons, continues with field preparation, seeding, and cultivation, and culminates at the end of the rice crop harvest. A complete 'cultivation cycle' may be slightly greater or less than 365 days depending on planting/harvest dates etc.

The project start date for an RC project is defined as the first day of the 'cultivation cycle' during which one or more of the approved cultivation management practice changes is adopted on each of the fields comprising the project area. For project aggregates, all fields in the project area must have start dates beginning with the same cultivation cycle (e.g. all fields in the project area must have a start date in the late summer/early fall of the same calendar year).

Workgroup Questions: What are thoughts concerning how the start date should be defined for a project aggregate? It is simpler to require all fields in an aggregate to begin in the same year; however, this is more limiting for farmers and aggregators. Thoughts?

To be eligible, the project must be submitted to the Reserve no more than six months after the project start date, unless the project is submitted during the first 12 months following the date of adoption of this protocol by the Reserve board (the Effective Date).[8] For a period of 12 months from the Effective Date of this protocol (Version 1.0), projects with start dates no more than 24 months prior to the Effective Date of this protocol are eligible. Specifically, projects with start dates on or after December 7, 2009 are eligible to register with the Reserve if submitted by December 7, 2012. Projects with start dates prior to December 7, 2009 are not eligible under this protocol. Projects may always be submitted for listing by the Reserve prior to their start date.

3.3 Project Crediting Period

The crediting period for projects under this protocol is ten years. At the end of a project's first crediting period, project developers may apply for eligibility under a second crediting period. However, the Reserve will cease to issue CRTs for GHG reductions associated with adoption of any approved RC management practice changes if at any point in the future, the adopted project RC practice becomes legally required, as defined by the terms of the Legal Requirement Test (see Section 3.5.2**Error! Reference source not found.**). Thus, the Reserve will issue CRTs for GHG reductions quantified and verified according to this protocol for a maximum of two ten year crediting periods after the project start date, or until the project activity is required by law (based on the date that a legal mandate takes effect), whichever comes first. Section 3.5.1 describes requirements for qualifying for a second crediting period.

3.4 Anaerobic Baseline Conditions

Project developers must demonstrate that previous rice cultivation practices resulted with anaerobic conditions. This requirement is met by demonstrating that:

1. Each individual rice field included in the project area has been under continuous rice cultivation for five years preceding the start of the crediting period, with no more than one fallow season, and

2. Each individual rice field included in the project area is flooded for a period of at least 100 days during each growing season, and

3. Management records for each of the individual rice fields are available for each of the five years preceding the project start date. At a minimum, management records must include:
    - Annual rice yields
    - Planting and harvest dates
    - Flooding and draining dates
    - Fertilizer application dates and amounts

[8] Projects are considered submitted when the project developer has fully completed and filed the appropriate Project Submittal Form, available on the Reserve's website.

3.5 Additionality

The Reserve strives to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market.

Projects must satisfy the following tests to be considered additional:

1. The Performance Standard Test
2. The Legal Requirement Test

3.5.1 The Performance Standard Test

Projects pass the Performance Standard Test (PST) by meeting a performance threshold, i.e. a standard of performance applicable to all RC projects, established by this protocol.

For this protocol, the Reserve uses practice-based thresholds, which serve as "best practice standards" for management practices governing methane emissions from rice cultivation. By meeting the performance threshold for a specific management activity, a rice field demonstrates that cultivation management exceeds the regional common practice standard for methane emissions management. Each rice field participating in a project or project aggregate must pass the PST for each approved management change implemented on the field as part of the project activity.

The performance standard research, summarized in Appendix D, reviewed common water management, residue management, and other RC management practices in the approved rice growing regions.[9] Based on the performance standard analysis, the Reserve has developed Performance Standard Tests for each approved RC management practice change, as defined in Section 2.2. Table x below provides the PST for each approved RC management change.

Region	Approved RC Management Changes	Performance Standard Test	Justification
CA	Dry seeding (DS)	A rice field passes the PST by implementing dry seeding. Individual fields that employed dry seeding [at any point] in the past 5 years prior to the project start date are ineligible.	Research indicates that dry-seeding is currently practiced on less than 3% of the CA rice acreage.
	Post-harvest rice straw removal and baling (Baling)	A rice field passes the PST by implementing post-harvest rice straw 'baling.' Individual fields that employed bailing [at any point] in the past 5 years prior to the project start date are ineligible.	Research indicates that residue removal (baling) is currently practiced on less than 8% of the CA rice acreage.
	Decreased frequency and/or duration of winter flooding (DWF)	Individual fields that employed winter flooding for less than seven of the last ten years prior to the project start date are ineligible.	Research indicates that winter flooding practices are highly variable in CA, both regionally and temporally. Therefore it

[9] Based on the geographic limitations imposed by data availability, only management data from California rice cropping systems were sufficiently analyzed in the performance standard for this protocol. The Reserve plans to expand the geographic scope of this protocol to other U.S. regions based upon future data availability and successful peer-reviewed DNDC model validation results.

			is necessary to determine the baseline practice on a field-by-field basis (see Sec X). Increasing trends of winter flooding indicate that, once adopted as a preferred method, it is likely to remain so.

Although multiple fields are a submitted together under one project or project aggregate, each field must separately pass the PST in order to be eligible for each approved RC management practice change.

If a project developer wishes to apply for a second crediting period, the project must meet the eligibility requirements of the most current version of this protocol, including any updates to the PST.

Workgroup Questions/Feedback:

1. For winter flooding, this draft basically draws a threshold (somewhat arbitrary) that demonstrates that winter flooding must have been a 'preferred' practice for the project to be eligible. If a field passes this test, it is also necessary to model the baseline according to actual data for the field on frequency of flooding over the last 5 year history, as opposed to assuming winter flooding occurs every year in the baseline. Are both these requirements necessary? Does the trend noted above of continued use of winter flooding once it's adopted suggest a more lenient proxy could be used to assume winter flooding is the "preferred" practice? Please provide thoughts on winter flooding additionality tests. The reserve is pursuing additional data re: winter flooding to refine our analysis (see Appendix D).
2. Based on initial performance standard research, it would seem that the only other option for additional activities in CA is Mid-Season Drainage. Should we explore including this project activity? Based on current understanding, it is risky to attempt MSD in CA due to potential yield loss.
3. Any other cultivation management changes come to mind that we haven't included or discussed?

3.5.2 The Legal Requirement Test

All projects are subject to a Legal Requirement Test to ensure that the GHG reductions achieved by a project would not otherwise have occurred due to federal, state, or local regulations, or other legally binding mandates. An RC project passes the Legal Requirement Test when there are no laws, statutes, regulations, court orders, environmental mitigation agreements, permitting conditions, or other legally binding mandates (including conservation management plans and deed restrictions) that require the adoption or continued use of any approved rice cultivation management practices that are implemented on the project rice fields.

To satisfy the Legal Requirement Test, project developers must submit a signed Attestation of Voluntary Implementation form[10] prior to the commencement of verification activities each time the project is verified (see Section 8). In addition, the project's Monitoring Plan (Section 6) must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the Legal Requirement Test.

If a project developer wishes to apply for a second crediting period, the project must meet the eligibility requirements of the most current version of this protocol, including any updates to the Legal Requirement Test.

As of the Effective Date of this protocol, the Reserve could identify no existing federal, state or local regulations that obligate rice producers to adopt the rice cultivation management practices approved under this protocol. If any of the approved project activities of an eligible project later become legally required, emission reductions may be reported to the Reserve up until the date that the management practice is required by law to be adopted. If an RC project includes implementation of more than one of the approved rice cultivation management practices and only one of those practices later becomes legally required, emission reductions from that project activity may be reported to the Reserve up until the date it is required by law and the project may continue reporting emission reductions from the project activities that continue to be voluntary.

3.5.2.1State and Local-Level Water Conservation Mandates

Though the Reserve could identify no existing regulations that explicitly require the approved RC management practices, some states and/or local irrigation or water management districts may seasonally mandate water conservation measures that, in turn, may indirectly require reductions in winter flooding, an approved RC management practice.

In the state of California, for example, the state's Water Board can enact Water Rights Standard Permit Term 91 ("Term 91") in years of particularly high water-stress, as a means of maintaining good water quality and limiting the salinity in the Sacramento-San Joaquin River Delta. When enacted, "Term 91" curtails water diversion to permittees with junior (i.e. lower priority) water rights, which effectively prevents rice producers from flooding their fields due to a legal mandate. The State Water Board is required to advise permittees of potential imminent curtailment of diversion as far in advance as practicable, as well as notify permittees again upon finding that no water will be available for diversion.[11] It is worth noting that even the threat that Term 91 may be enacted in a given year will often result in less rice growers flooding their fields that year, Term 91 will only be considered a legal requirement when actually enacted by the State Water Board.

[10] Form available at http://www.climateactionreserve.org/how/projects/register/project-submittal-forms/.
[11] NEED LINK TO LEGISLATION HERE.

Workgroup Question:

Are there any other relevant water conservation mandates? Other legal actions that irrigation districts can take?

Which option (below) seems more practicable?

In years where Term 91, or an analogous local water conservation mandate, is in effect, emission reductions generated by reduced winter flooding in the affected locale, will not be eligible.

OR

In years where Term 91, or an analogous local water conservation mandate, is in effect, the legal requirement to limit winter flooding must be included in the baseline.

3.6 Regulatory Compliance

As a final eligibility requirement, project developers must attest that the project is in material compliance with all applicable laws relevant to the project activity (e.g. air, water quality, water discharge, nutrient management, safety, labor, endangered species protection, etc.) prior to verification activities commencing each time a project is verified. Project developers are required to disclose in writing to the verifier any and all instances of material non-compliance of the project with any law. If a verifier finds that a project is in a state of recurrent non-compliance or non-compliance that is the result of negligence or intent, then CRTs will not be issued for GHG reductions that occurred during the period of non-compliance. Non-compliance solely due to administrative or reporting issues, or due to “acts of nature,” will not affect CRT crediting.

3.6.1 California Rice Straw Burning Regulation

In California, rice producers are required to comply with the Connelly-Areias-Chandler Rice Straw Burning Reduction Act of 1991 and the subsequent regulations of the Conditional Rice Straw Burn Permit Program, which limit the amount of rice straw residue producers may burn in any given year, as part of the state’s strategy to comply with National Ambient Air Quality Standards. The 1991 Act required that rice straw burning in the Sacramento Valley be reduced by 75 percent over a ten-year period, starting in 1992. Since September 2001, the Conditional Rice Straw Burn Permit Program has limited rice producers to burning rice straw in fields only when the presence of significant levels of disease can be satisfactorily demonstrated to the local air pollution control officer (APCO) and conditional rice straw burning permits are issued[12]. When project developers in California sign the Attestation of Regulatory Compliance, they are attesting that they are also in compliance with this regulation and that they have secured the appropriate “Conditional Rice Straw Burn Permits” from the Air Resources Board or other appropriate agency.

[12] Since 2001, the Conditional Rice Straw Burn Permit Program allows for burning to occur on a maximum of 25% of each grower’s planted rice acreage or 125,000 total acres in the Sacramento Valley Air Basin, whichever is lesser. However, due to the fact because disease must also be present for a burn to occur, the presence of disease is typically the limiting factor, as opposed to the maximum burn area of 25%. Regulations establishing the Conditional Rice Straw Burning Program can be found in the California Code of Regulations, Title 17, § 80156. More information can be found on the California Air Resources Board webpage at: http://www.arb.ca.gov/smp/rice/condburn/condburn.htm

Wherever rice straw burning occurs, the project developer must demonstrate that the amount of burning was within legal limits, if legal limits exist, as is the case in California, and that all necessary permits have been secured.

Burning of rice straw is assumed to be an activity that would have occurred occasionally under business as usual as a pest management strategy. As such, whenever burning occurs, project input parameters to the model (see Section 5) should be adjusted, to reflect the correct percentage of rice straw burned in both the baseline and the project. Additionally, it should be noted that rice straw burning is not an approved project activity; though an increase in rice straw burning may reduce methane emissions, it is not an eligible activity under this protocol, even in cases when an increase in rice burning may be permissible by law.

A notable component of California's Conditional Rice Straw Burn Permit Program is the possibility to generate and trade Rice Straw Emission Reduction Credits (ERCs) within certain air quality management districts (e.g. Butte County, Placer County). These ERCs are associated with the reductions of criteria pollutant emissions (e.g. VOCs, NOx, SOx, CO, PM10, PM2.5) from rice burning, as opposed to greenhouse gas (GHG) reductions, and can be used for compliance purposes under the respective district's implementation of Clean Air Act Regulations. Whether or not ERCs have been generated for a rice field within the Project will not directly affect the Project's additionality. However, rice producers participating in the ERC program are typically required to sign deed restrictions prohibiting rice straw burning and are placed on a restricted burn list managed by the local air district. When such a deed restriction exists, it will be considered a legal requirement and must be modeled in the baseline scenario.

3.6.2 Regulations on Special-Status Species

Regulations exist at the Federal, State, and Local levels to protect threatened and endangered species (i.e. "special-status species") of wildlife and their habitats. These regulations include the federal and many state-level Endangered Species Acts and the Migratory Bird Treaty Act. As a component of the federal Endangered Species Act, the US Fish and Wildlife works with private landowners to develop Habitat Conservation Plans (HCPs) and Safe Harbor Agreements (SHAs).[13] When in effect on a rice field within the Project Area, an HCP or SHA should be considered a legally binding mandate, which must be considered in the verifier's evaluation of Regulatory Compliance.

[13] Brief explanation on HCP and SHA needed here.

Workgroup Questions:

- Do you know of any circumstances where there are HCPs or SHAs in place governing rice fields? Seems possible for "newer" rice fields which were converted from their natural state since the 1982 amendments to the ESA?
- Do you know of any circumstances where an HCP (or SHA) was required for changing rice cultivation management practices (specifically, reduced flooding)?
    - More background: The ESA makes it unlawful for a person to "take" or "harm" a listed animal without a permit. Through regulations, the term "harm" is defined as "an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering."
    - We are wondering if reduced winter flooding would ever be considered "habitat modification," as the Reserve wants to further evaluate whether it is possible that FWS require an HCP for the Project. Suggested contacts/resources on this is appreciated.

3.7 Wildlife Habitat Conservation

Ongoing human development and expansion of lands used for agriculture has resulted in the extensive loss and degradation of wetlands worldwide, with more than half of U.S. wetlands drained over the past two centuries alone.[14] In California's Central Valley, the loss of wetlands is even more extensive, with 95% of the originally existing wetlands converted from their natural state. [15]

As native wetland habitats have been increasingly degraded, wetland-dependent species have adapted to using flooded rice lands as a substitute for their native habitat. For example, 7 million waterfowl and several hundred thousand shorebirds are supported by California rice lands annually.[16] Wetland-dependent species have come to rely on rice fields due largely to the fact that management practices for rice cultivation can result in flooding of rice lands for up to eight months of the year, mimicking natural wetland conditions and providing surrogate habitat for foraging, breeding, and in the case of migratory birds, wintering.

Though a wide range of species can be observed in each of the U.S. rice growing regions, it should be noted that more species data are available for California's Central Valley than for other U.S. rice-growing regions. Over 230 species have been identified in California rice lands, alone, including waterfowl (e.g. ducks), shorebirds, wading birds, raptors, reptiles, amphibians, and small mammals.[17] Notably, 31 special-status species, such as the federally endangered Giant Garter Snake have also been identified in California rice lands.

In the U.S., rice lands are considered a leading example of integrating agricultural and natural resource management, with USDA recently honoring the USA Rice Federation with the first national "Legacy of Conservation" award in 2011.

[14] Revenga et al. 2000.
[15] Petrie et al (DU report).
[16] Petrie et al (DU report).
[17] Sterling et al.

The Reserve's Program Manual explains that generally "projects must have no negative social, economic or environmental consequences and ideally should result in benefits beyond climate change mitigation." Further, the policy encourages individual protocols, where relevant, to allow for reporting of measures taken to avoid negative impacts or enhance wildlife habitat.

As the adoption of reduced winter flooding under this protocol may have the effect of reducing the surrogate habitat of wildlife species, options for mitigating the effects on wildlife must be considered

Project developers must implement the following "Wildlife Habitat Conservation Criteria (WHCCs)" throughout the duration of the project, demonstrating compliance at each verification. If a Project, or specific field within a project, operates outside of compliance of the established WHCCs, that portion of the project is ineligible to generate CRTs during that period when that portion of the project was outside of WHCCs.

3.7.1 Wildlife Habitat Conservation Criteria (WHCCs)

Workgroup Questions:

The following are options for mitigating the impact of reduced winter flooding on water birds and other wildlife. Do you believe these options will successfully mitigate that effect? Are these options practical for the rice grower? Are any mitigating options missing? Should the Reserve require 1 or 2 out of a larger pool of options?

Mitigation Options (source of the mitigation option noted in parentheses)

- Limit the total reduction of area under winter flooding to no more than 10% reduction from baseline (VCS methodology)
- Limit the reduced duration of winter flooding to no more than a 2 month reduction between planting and harvest (VCS methodology)
    - NOTE: the VCS methodology requires both conditions are met.
- Rotational reduction in flooding (rotating which fields are not flooded, with an effort to distribute the flooded/non-flooded fields in a random patchwork)
- Flood individual fields immediately after harvest, instead of waiting to flood all fields once the entire harvest is complete (CalRice Pilot)
- Varying water depths across all rice fields (ranging from 1 to 10 inches), to benefit a wider variety of species (CalRice Pilot / component of NRCS Practice Standard)
    - [NOTE: Cal Rice Pilot article doesn't give a number. The range of 1-10 in. is from the NRCS Practice Standard 646's two ranges, targeting waterfowl (6-10 in.) and shorebirds (1-4 in.). A range of 2-6 in would be closer to the ideal range from Elphick and Oring article]
- Flatten berms between rice field checks and reduce vegetation (CalRice Pilot)
- Develop natural habitat areas/corridors on the edges of farm fields to attract more wildlife (CalRice Pilot / component of NRCS Practice Standard)
- Directly require project developers to implement components of relevant NRCS practice standards for a certain portion of rice lands
    - E.g. NRCS 646 – Shallow Water Development and Management;
    - NRCS 644 – Wetland Wildlife Habitat Management
- Require site-specific annual or bi-annual bird sampling/census, with a bird count in the baseline (pre-project) as well.
    - Possibility to set up guidelines for rice grower/aggregator self-assessment?
    - Practicality/cost of contracting an expert bi-annually?
    - At what threshold does the project become ineligible or necessitate the other mitigation options? (assuming no mitigation required up to a certain point)

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that must be assessed by project developers in order to determine the net change in emissions caused by a RC project.[18] The GHG Assessment Boundary encompasses all the GHG sources, sinks, and reservoirs that may be significantly affected by project activities, including sources of methane and nitrous oxide emissions from the soil, biological CO_2 emissions and soil carbon sinks, and fossil fuel combustion GHG emissions. For accounting purposes, the sources, sinks, and reservoirs included in the GHG Assessment Boundary are organized according to whether they are predominantly associated with an RC project's "primary effect" (i.e. the RC project's intended GHG reduction, or its "secondary effects" (i.e. unintended changes in carbon stocks, N_2O emissions, or other GHG emissions).[19] Secondary effects may include increases in mobile combustion CO_2 emissions associated with site preparation, as well as increased GHG emissions caused by the shifting of cultivation activities from the project area to other agricultural lands (often referred to as "leakage").Projects are required to account for all SSRs that are included in the GHG Assessment Boundary regardless of whether the particular SSR is designated as a "primary" or "secondary" effect.

Table 4.1 provides a comprehensive list of the GHG sources, sinks, and reservoirs (SSRs) that may be affected by an RC project, and indicates which SSRs must be included in the GHG Assessment Boundary.

Table 4.1. Description of All Sources, Sinks, and Reservoirs

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Justification/Explanation
Primary Effect Sources, Sinks, and Reservoirs					
1. *Soil Dynamics*	Soil dynamics refer to the biogeochemical interactions occurring in the soil that produce emissions of carbon dioxide(biogenic), methane , nitrous oxide, and changes in soil carbon stocks. GHG flux rates are dependent on water management (including during seeding and after harvest), residue management, fertilizer application, and other site-specific variables.	CO_2	I	DNDC	Changes in soil carbon stocks resulting from project activity may be significant. Decreases in carbon stocks must be accounted for.
		CH_4	I	DNDC	The primary effect of an RC project is reduction in methane emissions from soil due to reduced flooding and/or reduced organic residues available for decomposition.
		N_2O	I	DNDC	A Significant source affected by project activities if fertilizer application amounts and/or dates are changed, or seeding practice is altered.
Secondary Effect Sources, Sinks, and Reservoirs					
2. *Water Pumps*	Indirect fossil fuel emissions from transport of water onto fields	CO_2	E	N/A	Excluded, as project activity is very likely to reduce the quantity of water used during the cultivation process as compared to baseline management.

[18] The definition and assessment of sources, sinks, and reservoirs (SSRs) is consistent with ISO 14064-2 guidance.
[19] The terms "Primary Effect" and "Secondary Effect" come from WRI/WBCSD, 2005. *The Greenhouse Gas Protocol for Project Accounting*, World Resources Institute, Washington, DC. Available at http://www.ghgprotocol.org.

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Justification/Explanation
		CH_4	E	N/A	Excluded, as this emission source is assumed to be very small.
		N_2O	E	N/A	Excluded, as this emission source is assumed to be very small.
3. *Cultivation Equipment*	Fossil fuel emissions from equipment used for field preparation, seeding, fertilizer/pesticide/herbicide application, and harvest.	CO_2	I	Emission Factors	Emission may be significant if management is altered. Increased emissions due to project activity must be accounted for.
		CH_4	E	N/A	Excluded, as this emission source is assumed to be very small.
		N_2O	E	N/A	Excluded, as this emission source is assumed to be very small.
4. *Crop Residue Baling*	Fossil fuel emissions from baling and transportation of baled rice straw for offsite use/management	CO_2	I	Included in Baling Emission Factors	Emission may be significant if residue management is altered. Increased emissions due to project activity must be accounted for.
		CH_4	E	N/A	Excluded, as this emission source is assumed to be very small.
		N_2O	E	N/A	Excluded, as this emission source is assumed to be very small.
5. *Crop Residue Management*	Fugitive emissions from aerobic or semi-anaerobic rice straw management (on or off-site).	CO_2	E	N/A	Biogenic emissions are excluded.
		CH_4	I	Emission Factors	May be a significant source of fugitive methane emissions, depending on management/use of rice straw.
		N_2O	E	N/A	Due to low N content of rice straw, changes in N_2O emissions from alternative rice straw management are likely insignificant.
6. *GHG Emissions from Shifted Production (Leakage)*	If project activity results with a statistically significant decrease in yield, rice production and associated GHG emissions may be shifted outside the project area.	CO_2	I	**?**	If rice yield totaled over all participating fields are found to have statistically decreased due to project activity, the associated GHG emissions from shifted rice production must be estimated.
		CH_4	I	**?**	
		N_2O	I	**?**	

5 Quantifying GHG Emission Reductions

The primary impact of an RC project is a reduction in methane emissions due to either i) a decrease in duration of flooded conditions (switching to dry seeding and/or decreasing frequency/duration of winter flooding), or ii) a decrease in the availability of degradable organic matter in the soil (residue baling). While there is directional certainty (i.e. it is highly likely that project cultivation changes will reduce methane emissions compared to the baseline scenario), the magnitude of reductions is highly variable and dependent on numerous other parameters related to field-scale management techniques, soil characteristics, and climatic conditions. In order to accurately quantify the baseline and project methane emissions, and ensure that changes in related but secondary emissions of nitrous oxide and changes in soil carbon stocks are properly accounted for, this protocol relies on the application of the DNDC model for quantification of the primary and secondary effect SSR-1 defined in Section 4. Detailed requirements for accurate and consistent application of the DNDC model are provided in Section 5.1 below.

In addition to SSR-1, RC projects may result with unintended project increases to GHG emission from other secondary SSRs. Section 5.2 provides requirements for calculating those secondary GHG emissions resulting from the project activity.

Total emission reductions from an entire RC project area equals the combined modeled primary emission reductions from SSR-1 for all fields in the project boundary, minus the increase in emissions from all other SSRs due to the project activity. Equation 5.1 below provides the emission reduction calculation

For fields that include reduced frequency of winter flooding as a component of the project activity, emission reductions are determined based on a full five year reporting period. Each field adopting decreased frequency of winter flooding must demonstrate, ex-post, that the frequency of winter flooding was decreased over the five year reporting period compared to the five year project-specific baseline frequency. Only upon successful verification of the entire 5 year period will CRTs for reduced winter flooding be issued. Projects with a required five year reporting period must follow the reporting and verification schedule set in Section 7.5. All fields that are not altering the winter flooding frequency compared to the baseline scenario can elect to have annual reporting periods. Reporting periods shorter than one full cultivation cycle are not allowed under this protocol.

Equation 5.1. Calculating GHG Emission Reductions

$$ER = SDER - SE$$

Where,			Units
ER	=	The total emission reductions from the project area for the reporting period.	$MTCO_2e$
SDER	=	The total modeled GHG emission reductions from soil dynamics (SSR-1) from the entire project area during the reporting period, as calculated in Section 5.1).	$MTCO_2e$
SE	=	The total Secondary Effect GHG emissions caused by project activity during the reporting period for the entire project area (as calculated in Section 5.2).	$MTCO_2e$

5.1 Modeling Primary Emission Reductions with the DNDC Model

For the purposes of this protocol, the modeling of GHG emissions from soil dynamics under baseline and project scenarios must be performed using an approved version of the DNDC model.[20] A separate model run must be performed for each individual rice field that is incorporated in the project area.

The methodology described in Section 5.1 incentivizes aggregation of multiple rice fields into a single project area by recognizing that structural model uncertainty, which is quantified by comparing modeled gas fluxes to actual measured gas fluxes across multiple modeling runs, decreases with increasing number of independent model runs performed. Therefore, the uncertainty adjustment factors (presented in Section 5.1.7 and derived in Appendix C) that must be applied to the modeled emission reduction results are inversely proportional to the number of fields (and thus the number of independent model runs) included in the project area.

Section 5.1.1 through Section 5.1.8 provides the quantification approach for determining the total primary modeled emission reductions for each rice field.

5.1.1 Parameterizing the DNDC Model

To model emission reductions from RC management changes for an individual rice field, the DNDC model must be properly parameterized with appropriate field-level data related to soil characteristics, climatic drivers, water and residue management, and other related parameters. For each field, a separate model run is performed using an appropriate input parameter file ("*.dnd") for both the 'baseline' scenario and the 'project' scenario. The difference between the two emissions estimates (after accounting for both input uncertainty and model structural uncertainty) is the total emission reductions achieved from the project activity at the field. The modeling runs are performed for each 'cultivation cycle' of the reporting period to get net reductions for the field over the reporting period.

For convenience, model inputs are classified into two categories: critical inputs, and non-critical inputs. The critical inputs are those that relate to the management parameters that are being changed as a result of the project (i.e. seeding practices, residue management practices, and/or winter flooding practices). The critical inputs to the DNDC model are the only parameters that will vary when modeling baseline and. project emissions to determine the GHG reductions related to the field's management change. All other inputs that are used to parameterize the model are referred to hereafter as 'non-critical' inputs.

Refer to Table 6.1 in Section 6 for a list and description of all DNDC input parameters.

5.1.1.1Determining the Baseline Scenario 'Critical Inputs'

To 'set' a baseline scenario for a field, it is necessary to assign values to each of the critical inputs related to the baseline water, residue, seeding, and fertilizer management. These critical inputs make up what is referred to as the 'baseline scenario' for each field. Once the baseline critical inputs are set, they must remain unchanged for the entirety of the crediting period (representing the baseline management scenario). The baseline scenario must represent the historical field management practices related to seeding practices, residue management practices, and winter flooding practices.

[20] All approved versions of the DNDC model will be available on the Reserve's website.

The following critical inputs must be set for each rice field included in the project area using field-level management records going back a full 5 years (5 cultivation cycles) prior to the project start date.

Table 5.1. Determining Critical Inputs

Baseline Practice	Critical Input
Seeding	Dates of flooding relative to the planting date
	Dates of all fertilization events relative to planting date (both pre-flood and top-dressed after flooding)
Residue Management	Proportion of straw removed after harvest (0 if no straw removed)
	Quantity of additional fertilizer used to account for nutrient losses following straw removal
Winter Flooding	Frequency of winter flooding during 5 year period
	Start date of each winter flooding event
	End Date of each winter flooding event

Workgroup Questions:

1. In the VCS protocol, the baseline is set for 5 years, and then re-assessed after 5 years. Reserve protocols typically allow for reductions from baseline to be earned for 10 years before baseline is re-assessed. Is rice management more variable than other sectors? Should we use a 5 year crediting period and require a re-assessment of baseline after 5 years?
2. We will provide more detail in setting input values, suggestions for doing so are welcome.

5.1.1.2Non-Critical Input Parameters

Non-critical inputs are those that, while necessary for an accurate calculation, are not directly related to project activities. All non-critical inputs should be based on actual field-level data (unless otherwise specified), and must be the same when modeling baseline vs. project emissions for a specific cultivation cycle.

Climate Parameters

Seasonal weather can significantly affect methane emissions and, hence, the reduction in methane emissions due to alternative crop management. Weather during the cultivation cycle will impact decisions made regarding the planting and harvesting dates, and therefore impacts the length of the growing season. The following requirements for determining climate parameter inputs for each cultivation cycle calculation must be met:

- Daily climate data must come from a weather station that is located maximally 20 miles away. If the project area is located in California, it is recommended to use weather data from the nearest CIMIS weather station (http://wwwcimis.water.ca.gov).
- Weather data for the five years preceding the start of the crediting period must be collected. Weather data for the historic period (see Section 5.1.2) must be set by repeating this five-year weather data set. After the start of the crediting period, actual weather data must be used for all emission calculations.

- Daily values of maximum temperature, minimum temperature, rainfall, and solar radiation must be collected and formatted according to DNDC's climate file mode 1 format (Table below).

Table 5.2. Climate Parameters

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}

Non-Critical Management Parameters

All non-critical management parameters must be set based on actual data for each cultivation cycle calculation. As with all other non-critical inputs, the values for the following management parameters must be identical in the baseline and project model run for each cultivation cycle during the crediting period. All of the following variables must be collected for each cultivation cycle during the crediting period:

Table 5.3. Non-Critical Management Parameters

Input Parameters	Unit
Date of pre-planting field preparation	Date
Planting date	Date
Fertilization amounts and dates, and type of fertilizer used	Lbs per acre, date, type (e.g., nitrate, ammonium, or urea)
Dates and duration of flooding during growing season	Dates, number of days
Rice Straw Fraction Burned	Fraction of total (by area or weight)
Harvesting date	Date
Date and description post-harvest operations	Date and description (mowing, mulching, residue incorporation, etc.)

Soil Data

Some Soil parameters affect methane emissions to a significant extent. Therefore, for each of the individual rice fields, values for the following inputs must be obtained either from the USDA NRCS SSURGO data set, or based on soil measurements:

- Clay Content
- Bulk Density
- Soil pH
- Soil Organic Carbon (SOC) at Surface Soil
- Soil Texture

If using soil measurements, data may not be older than 10 years prior to the time the project is submitted to the Reserve. Official soil laboratory statements must be available during the verification process. See Section 6 for more guidance on determining soil inputs.

5.1.2 Historical Modeling Run and Crop Yield Calibration

The DNDC model must be run for at least 20 years before the start of the crediting period so that the model can attain equilibrium in certain critical variables for which empirical data is lacking, such as the sizes and the quality of the different carbon pools, and the inorganic nitrogen contents of soil pore water. This period is referred to as the historical period. The input parameters for the 20-year historical period must be set by repeating all parameters from the five years before the start of the crediting period four times, unless otherwise noted.

The last five years of the historical period must be used to calibrate the modeled crop yields crop yields (see discussion below). Table 5.2 provides the schematic for the modeling period for each field.

Table 5.4. Schematic of Modeling Period

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

Source: Figure adapted from Proposed VCS Methodology: Calculating Emission Reductions in Rice Management Systems.

After the start of the crediting period, the model must be run in 5-year increments. The project document must include at least one 5-year cycle after the start of the crediting period.

Crop Model Calibration

Proper parameterization of soil physical conditions (which drive soil moisture dynamics) and crop simulation plays a crucial role in modeling C and N biogeochemistry and N_2O emissions. Through transpiration and N uptake as well as depositing litter into soil, plant growth regulates soil water, C and N regimes, which in turn determine a series of biogeochemical reactions impacting N_2O emissions. Users shall calibrate the DNDC crop model for cropping systems to be included in the project. Figure 1 outlines the steps for crop calibration. In DNDC, crops are defined by the following parameters:

- ***Maximum biomass (kg C/ha)***: The maximum biomass productions for grain, leaves+stems (non-harvest above ground biomass), and roots under optimum growing conditions (namely, maximum biomass assuming no N, water or growing degree day limitations). The unit is kg C/ha (1 kg dry matter contains 0.4 kg C). Maximum yield values will be used for step 2 in figure 1 below.
- ***Biomass fraction***: The grain, leaves+stem, and root fractions of total biomass at maturity.
- ***Biomass C/N ratio***: Ratio of C/N for grain, leaves+stems, and roots at maturity.
- ***Total N demand (kg N/ha)***: Amount of the total N demanded by the crop to reach the maximum production.
- ***Thermal degree days (°C)***: Cumulative air temperature from seeding till maturity of the crop.
- ***Water demand (g water/g dry matter***): Amount of water needed for the crop to produce a unit of dry matter of biomass.
- ***N fixation index***: The default number is 1 for non-legume crops. For legume crops, the N fixation index is equal to the ratio (total N content in the plant)/(plant N taken from soil).

Default values for these parameters for rice are provided with DNDC and can be found in the C:\DNDC\Library\Lib_crop directory. This parameterization is sufficient in most circumstances as long as the "maximum biomass" parameter is manually in the model. More specifically, the "maximum biomass" parameter of the DNDC model must be manually tuned so that DNDC predicts the recorded yields during the five years before the start of the project as good as possible with a maximal relative RMSE of 10% of the observed means.

However, project developers must demonstrate that DNDC has been properly calibrated using actual site conditions. At least 5 years of observed crop yields should be used for maximum grain yield (kg C/ha), biomass fraction (% grain and % leaf and stem), and biomass C:N ratio for grain, leaves and stem, and roots. The steps for crop calibration are outlined below and shown in Figure 5.1.

To carry out the crop calibration process, the user must use the following steps for the single year with the maximum observed rice yield:

1. **Adjust maximum biomass parameter**:
    a. Enter observed maximum biomass and fraction for grain, leaf and stem and root[21];
    b. Provide more than adequate fertilization (*i.e.* apply much more fertilizer than necessary or use the auto-fertilization option in DNDC);
    c. Provide more than adequate irrigation (*i.e.* use the irrigation index mode and set the index to 1);
    d. Run the year (or rotation) with the actual local climate/soil conditions;
    e. Check the modeled grain yield – the difference between the modeled and observed grain yield should be less than 10%:
        i. If the difference is greater than 10% and the modeled grain yield is less than the actual yield, increase the maximum biomass parameter;
        ii. If the difference is greater than 10% and the modeled grain yield is greater than the actual yield, decrease the maximum biomass parameter.
2. **Adjust accumulative thermal degree days (TDD)**: Check the modeled maturity date – this can be found in the "Day_FieldCrop.csv" file[22]: the last column of this file, "GrainC", shows daily grain weight (kgC/ha); the maturity date can be inferred by checking the last day where there is an increase in grain weight (*i.e.* the first day where the grain weight levels off):
    a. If the modeled maturity date is later than the harvest date, you will need to reduce the TDD value;
    b. If the modeled maturity date is earlier than the harvest date, you will need to increase the TDD value.
3. **Adjust water requirement**: Change irrigation practices back to actual management practices while maintaining the high fertilizer application rate and run the model again:
    a. If the modeled yield/biomass is lower than observed yield/biomass, decrease the water requirement value;

[21] Biomass fraction and C:N ratios are typically constant for a cultivar, so if this data is not available for the farm to be modeled, the information can usually be acquired from the local university extension.
[22] This file will only be available in the site results if the "record daily results" option is selected on the climate tab of the DNDC GUI.

b. If the modeled yield/biomass is higher than observed yield/biomass, increase the water requirement value.

A flow-chart in Figure 5.1 illustrates this calibration process.

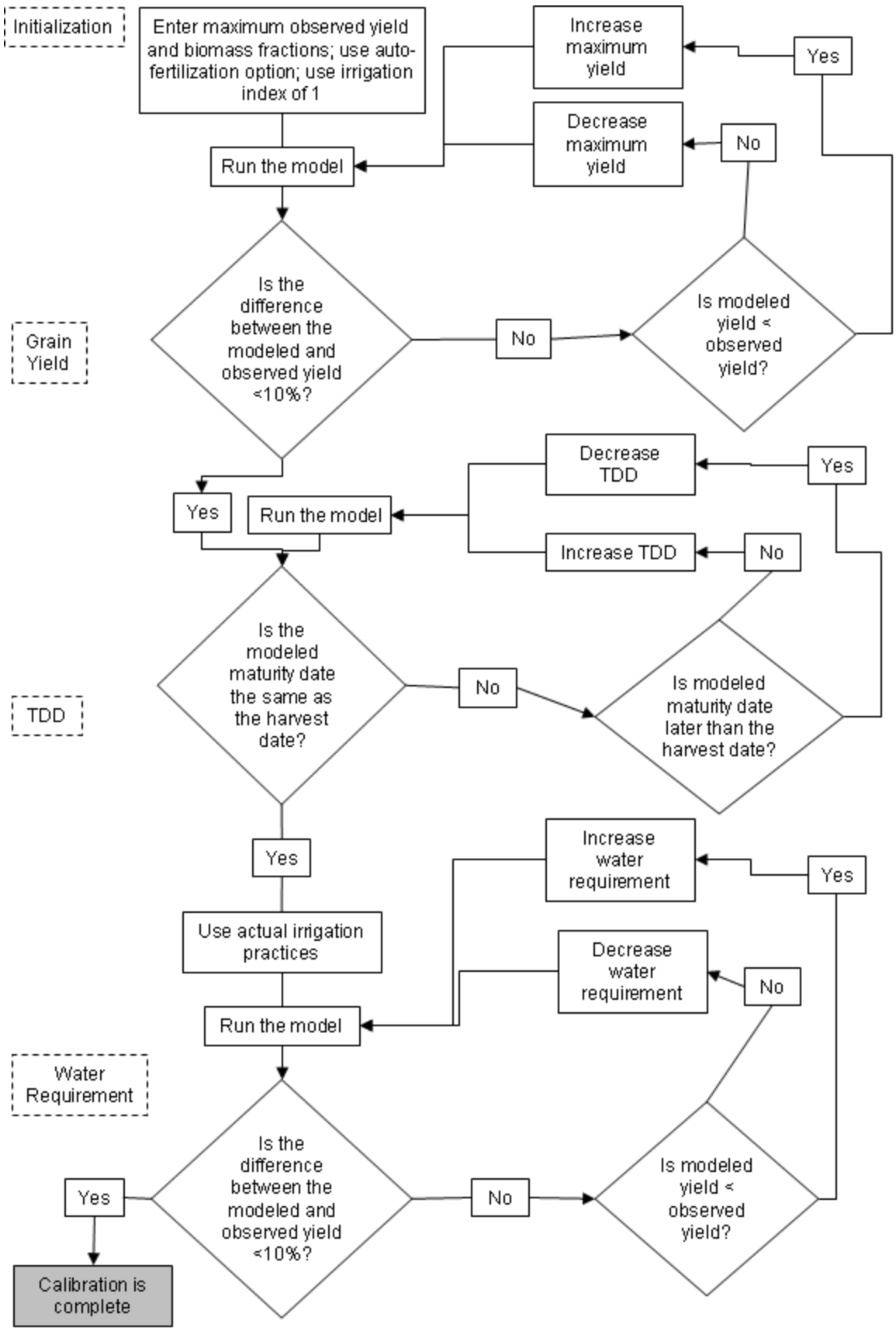

Initialization
Enter maximum observed yield and biomass fractions; use auto-fertilization option; use irrigation index of 1
Run the model
Increase maximum yield
Decrease maximum yield
Yes
No
Grain Yield
Is the difference between the modeled and observed yield <10%?
No
Is modeled yield < observed yield?
Yes
Run the model
Decrease TDD
Increase TDD
Yes
No
TDD
Is the modeled maturity date the same as the harvest date?
No
Is modeled maturity date later than the harvest date?
Yes
Use actual irrigation practices
Run the model
Increase water requirement
Decrease water requirement
Yes
No
Water Requirement
Is the difference between the modeled and observed yield <10%?
No
Is modeled yield < observed yield?
Yes
Calibration is complete

Figure 5.1. Flowchart for Calibrating DNDC Model

Workgroup Question:

1. Should this section on calibrating the DNDC model be moved to an appendix, or does it work well as is?

5.1.3 Accounting for Input Uncertainty using Monte Carlo Simulations

Soil physical and chemical properties have a significant impact on N_2O production, consumption and emissions. Project Proponents have the choice of estimating soil conditions based on field samples or soil surveys. If field measurements are used, then the target precision level for each soil parameter shall be +/-10% of the mean at a 90% confidence level. The distribution of the field values shall be assumed to be normally distributed.

If NRCS SSURGO soil survey data[23] are used for setting soil parameters, then default uncertainty estimates shall be set based on uncertainty estimates and probability distribution functions (PDF) listed in Table Y. For each stratum, the mean value shall be calculated as the area-weighted sum of the representative values for all compartments with the SSURGO MUKEY[24].

Table Y. Source Selected from http://www.abdn.ac.uk/modelling/cost627/Questionnaire.htm

Parameter	PDF	Uncertainty
Bulk density	Log-normal	0.1 g/cm^3
Clay content	Log-normal	+/- 10%
SOC	Log-normal	+/- 20%
pH	Normal	+/- 1 pH unit

A selection of 2,000 soil parameter (SOC, pH, clay fraction and bulk density) combinations shall be compiled for the Monte Carlo DNDC model runs (see Sections 5.1.4 and 5.1.5 below). The selection soil parameter combination will be random selection for each parameter based on the PDF and uncertainty estimates (derived from field measurements). From the Monte Carlo runs, project proponents will calculate the uncertainty deduction for input uncertainty as the half-width of the 90% confidence interval.

5.1.4 Modeling Field Level Baseline Emissions

The baseline ($GHG_{BSL\ i,j}$) GHG emissions for each field *i* will be determined by performing a Monte Carlo simulation with 2000 DNDC simulations.

Based on the uncertainty of input soil parameters quantified in section 5.1.3, DNDC will be run through a Monte Carlo analysis for baseline emission calculations. The duration of each Monte Carlo run should be the same as the duration of the reporting period. The Monte Carlo runs will be accomplished by running DNDC in batch mode with each entry in the batch file list a separate Monte Carlo run (see DNDC user's guide about running in batch mode).

Once the Monte Carlo runs are complete, results are recorded in a CSV file. The name of the file is the site name as entered into DNDC. From the CSV file extract the N_2O and CH_4 emissions and change in SOC content for Monte Carlo run *j* in each field *i*.

[23] See http://soils.usda.gov/survey/geography/ssurgo/.
[24] Polygon GIS layers are linked to attribute tables via an attribute called MUKEY.

			Units
$N_2O_{BSLj,i}$	=	Annual baseline N_2O emissions from rice field *i* from Monte Carlo run *j*	kg N_2O-N.ha^{-1}
$CH_{4,\ BSLj,i}$	=	Annual baseline CH_4 emissions from rice field *i* from Monte Carlo run *j*	kg CH_4-C. ha^{-1}
$SOC_{BSLj,i,j,i}$	=	Annual baseline change in soil organic carbon content from rice field *i* from Monte Carlo run *j*	kg dSOC-C

Calculate total average greenhouse gas emissions in metric tons (t) CO_2-e.ha^{-1} for field *i* for all Monte Carlo runs as follows:

$$GHG_{BSL,j,i} = N2O_{BSL,j,i} * \frac{44}{28} * GWP_{N2O} + CH4_{BSL,j,i} * \frac{16}{12} * GWP_{CH4} + SOC_{BSL,j,i} * \frac{44}{12} \quad \textbf{(1)}$$

$$GHG_{BSL\_i} = \frac{\sum_{j=1}^{N} \left(GHG_{BSL,j,i} \right)}{n} \quad \textbf{(2)}$$

Where,			Units
$GHG_{BSL\_,i}$	=	Greenhouse gas emissions for field *i* as a result of management activities within the project boundary in the baseline	t CO_2-e.ha^{-1}
j	=	*1, 2, 3 … N* Monte Carlo runs	
i	=	1, 2, 3 …*M* fields	

5.1.5 Modeling Field Level Project Emissions

The project ($GHG_{P,i,j}$) GHG emissions in each field *i* for each Monte Carlo run *j* will be determined by running DNDC. Based on the uncertainty of input soil parameters quantified in Section 5.1.3, DNDC will be run through a Monte Carlo analysis for both baseline and project emission calculations. The duration of each Monte Carlo run should be the same as the duration of the project. The Monte Carlo runs will be accomplished by running DNDC in batch mode with each entry in the batch file list a separate Monte Carlo run (see DNDC user's guide about running in batch mode).

Once the Monte Carlo runs are complete, results are recorded in a CSV file. The name of the file is the site name as entered into DNDC. From the CSV file extract the N_2O and CH_4 emissions and change in SOC content for Monte Carlo run *j* in each field *i*.

			Units
$N_2O_{Pj,i}$	=	Annual project N_2O emissions from rice field *i* from Monte Carlo run *j*	kg N_2O-N.ha^{-1}
$CH_{4,P,j,i}$	=	Annual project CH_4 emissions from rice field *i* from Monte Carlo run *j*	kg CH_4-C. ha^{-1}
$SOC_{P,j,i}$	=	Annual project change in soil organic carbon content from rice field *i* from Monte Carlo run *j*	kg NH_3-N.ha^{-1} + NO_X-N.ha^{-1} volatilized

Calculate total average greenhouse gas emissions in metric tons (t) CO_2-e.ha^{-1} for field *i* for all Monte Carlo runs as follows:

$$GHG_{P,j,i} = N2O_{P,j,i} * \frac{44}{28} * GWP_{N2O} + CH4_{P,j,i} * \frac{16}{12} * GWP_{CH4} + SOC_{P,j,i} * \frac{44}{12} \quad \textbf{(3)}$$

$$GHG_{P\_i} = \frac{\sum_{j=1}^{N} \left(GHG_{P,j,i} \right)}{n} \quad \textbf{(4)}$$

Where, Units

GHG_{P_i}	=	Greenhouse gas emissions for field *i* as a result of management activities within the project boundary in the project	t CO_2-e.ha^{-1}
j	=	*1, 2, 3 … N* Monte Carlo runs	
i	=	1, 2, 3 …*M* fields	

5.1.6 Input Uncertainty Adjustments

The model uncertainty ($\mu_{inputs,i}$) for greenhouse gas emissions due to uncertainty in soil inputs parameters for field *i* shall be calculated as the half-width of the 90% confidence interval of the modeled reductions, where the modeled reductions for each Monte Carlo run *j* is calculated as:

$\mu_{inputs,i}$ = half-width of 90% CI of distribution of $\left(GHG_{BSL\_i,j} - GHG_{P\_i,j} \right)$ expressed as a percent of the mean GHG emission reduction of field *i.*

The deductions for input uncertainty are applied at the field level.

5.1.7 Structural Uncertainty Adjustments

Inherent in biogeochemical models, like DNDC, are uncertainties due to imperfect science in the models. This uncertainty is often referred as model structural uncertainty. Model structural uncertainty is quantified by comparing model estimates of greenhouse gases with measured emission estimates. The measured data are assumed to have no uncertainty (although it is well known that measurements can have large sources of uncertainties). This section describes the approach for adjusting for model structural uncertainty to insure conservativeness in estimates of project emission reductions.

5.1.7.1 Basic Assumptions Underlying Uncertainty Deductions

- The structural error induced by a biogeochemical model such as DNDC is multiplicative, not additional:

  $$Y_{field,i} = Y_{model,i} \cdot \varepsilon_i$$

  The multiplicative nature of the deviation between modeled and measured results originates from increasing deviations with increasing modeled values. This assumption is generally valid when moderate changes to input data lead to moderate changes in the results of the biogeochemical model and no sudden non-linear changes exist. Under the applicability conditions of the methodology, the DNDC model will react linearly to moderate changes in input data.
- No bias exists between measured and modeled results, so that $(Y_{field}) = (Y_{model})$. In addition, the error ε is log-normally distributed, $\varepsilon \sim \ln \mathcal{N}(0, \sigma)$. The DNDC model has

been shown to predict greenhouse fluxes without bias, when correctly calibrated. This methodology specifies how model inputs can be set so that the model is calibrated correctly. It must be explicitly tested that the model calibration strategy does not lead to bias.

- Model results of an alternative treatment are 100% correlated with the model results of the baseline treatment:
  $Y_{field,project} = k \cdot Y_{field,baseline}$

Where k is dependent on all factors that were not impacted by the project. In other words, changes in emissions due to weather or other non-critical variables are similar between project and baseline scenarios, apart from a linear constant.

5.1.7.2 Procedure to Calculate the Structural Uncertainty Deduction Factor

Since the structural error is multiplicative, the residual of the log-transformed field and measured results is normally distributed:

$$[\ln(Y]_{field})[-\ln(Y]_{model}) \sim \mathcal{N}(0, \sigma)$$

Assume that n is the number of $[(Y]_{field,i}, Y_{model,i})$ pairs, σ can be estimated as:

$$s = stdev([\ln(Y]_{field,i})[-\ln(Y]_{model,i}))$$

Since σ is not known, traditional statistical theory dictates that confidence and prediction intervals need to be estimated based on the student t-distribution with n degrees of freedom. We are interested in the effect of taking averages of individual fields on the decrease in the uncertainty. However, since the sum of different student t-distribution does not have an easy analytical form, we will assume that the error σ is normally distributed. In this case, the 95%-confidence prediction interval becomes:

$$[-s \cdot \phi(0.025); +s \cdot \phi(0.975)]$$

In case one is looking at the average of m field measurements, the 95%-confidence prediction interval around the m measurements becomes:

$$\left[\frac{-s}{\sqrt{m}} \cdot \phi(0.025); \frac{+s}{\sqrt{m}} \cdot \phi(0.975)\right]$$

The discounting factor u_{struct} must be set so that, with 95% confidence:

$$u_{struct} \cdot (Y_{model,alternative} - Y_{model,baseline}) < Y_{field,alternative} - Y_{field,baseline}$$

Using assumption 2, this comparison can be simplified as following

$$u_{struct} \cdot Y_{model,baseline} \cdot (1-k) < Y_{field,baseline} \cdot (1-k)$$
$$u_{struct} \cdot Y_{model,baseline} < Y_{field,baseline}$$

After taking a logarithm and rearranging:

$$\ln[(u]_{struct}) < \ln(Y_{field,baseline}) - \ln(Y_{model,baseline})$$

The discounting factor for structural uncertainty is therefore:

$$u_{struct} = e^{\frac{-s}{\sqrt{m}} \cdot \phi(0.025)}$$

5.1.7.3 Derivation of Structural Uncertainty Deduction for California Projects

Nine different annual fluxes of CH_4 emissions were measured for a number of different management scenarios. The same practices were modeled using the DNDC model. These scenarios represent the variety of management practices that is covered by this methodology. Results from this exercise are summarized in Table 5.5. Further details can be found in EDF (2011).

Table 5.5. Modeled and Measured CH_4 Fluxes from Field Trials in California

Seeding	Tillage	Winter Flooding	Residue	Modeled kg CH_4-C ha^{-1}	Measured
Water	Conv	Yes	incorporation	121	130
Water	Conv	Yes	burn	56	52
Water	Conv	No	incorporation	68	75
Water	Conv	Yes	incorporation	166	273
Water	Conv	Yes	burn	56	57
Water	Conv	Yes	incorporation	71	165
Water	Conv	?	?	465	354
Water	Stale seedbed (essentially no-till prior to plant)	WS SSB	?	417	390
Dry		DS	?	254	229

Source: Data Reproduced with Permission from EDF (2011).

The average of the natural logarithm of the deviations between measured and modeled fluxes is 0.112; the standard deviation is 0.346.Using the equation above, the appropriate discounting factors can be calculated, therefore, as following:

$$u_{struct}(m) = e^{\frac{-0.346}{\sqrt{m}} \cdot 1.96}$$

Error! Reference source not found.5.6 summarizes the results of this equation. This methodology requires that a minimum of five fields (or 1000 acres) be included. This minimum of 5 required fields corresponds to an uncertainty deduction of 26%. In conclusion, the maximal structural uncertainty deduction is 26%.

Table 5.6. Structural Uncertainty Deduction Factors for Projects within California

Number of fields (m)	u_{struct}	Eligibility
1	51%	Not eligible
2	62%	
3	68%	
4	71%	
5	74%	
6	76%	Eligible
7	77%	
8	79%	
9	80%	
10	81%	
15	84%	
25	87%	
0	91%	
100	93%	
1000	98%	

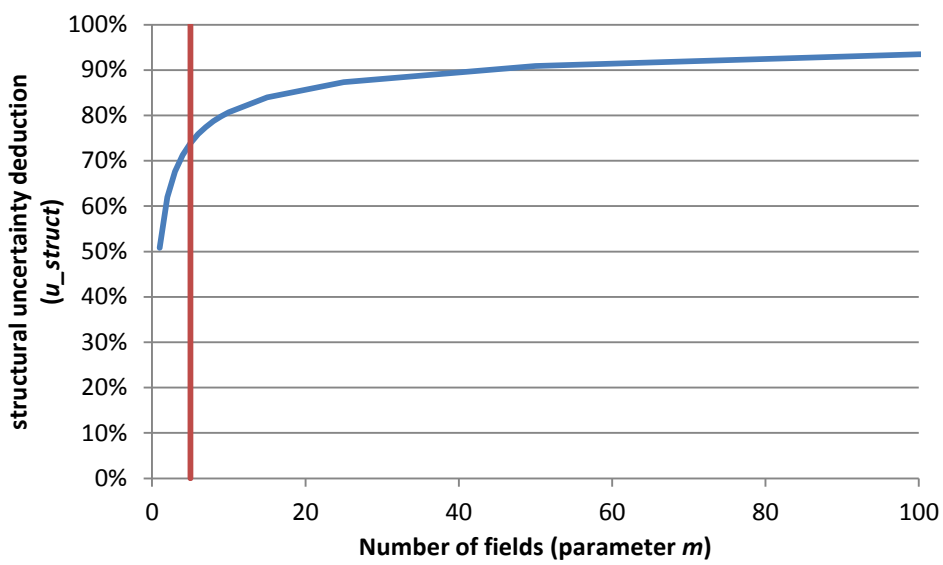


Figure 5.2. Model Structural Uncertainty

5.1.8 Calculation of GHG Emission Reductions for

The total primary effect greenhouse gas emission reductions (tCO_2eq) for a project area are calculated as:

$$MPER = \mu_{struct} * \sum_{i=1}^{m} \mu_{inputs\_i} * (GHG_{BSL,i} - GHG_{P,i})$$

Where,

MPER	=	Modeled primary effect GHG emissions reductions over the project area
m	=	Number of individual rice fields included in the project area
$\mu_{inputs,i}$	=	Accuracy deduction factor for individual rice field *i* due to input uncertainties (% reduction for each field)
GHG_{P_i}	=	Project emissions in year *y* for individual rice field *i*
GHG_{BSL_i}	=	Baseline emissions in year *y* for individual rice field *i*
μ_{struct}	=	Accuracy deduction from model structural uncertainty (% reduction)

Workgroup Feedback:

We are continuing to explore options for improving the input uncertainty and structural uncertainty adjustments, please read through Appendix C for a better understanding. It is our goal to focus on improving the description of the DNDC modeling methodology to improve usability. Please provide feedback regarding improvements that can be made to enhance the 'usability' and make the DNDC modeling methodology easier to understand.

5.2 Quantifying Secondary Effects

Secondary effect GHG emissions are unintentional changes in GHG emissions from the secondary SSRs within the GHG Assessment Boundary. Secondary effect emissions may increase, decrease, or go unchanged as a result of the project activity. If emissions from secondary SSRs increase as a result of the project, these emissions must be subtracted from the total modeled primary emission reductions (as specified in Equation 5.1) for each reporting period on an *ex-post* basis.

As shown in Equation 5.2 the total secondary effect GHG emissions are equal to:

- Increased carbon dioxide emissions from mobile and stationary combustion of fossil fuels by farm equipment used for field preparation, seeding, cultivation (SSR 3), plus
- Carbon dioxide emissions from transport and processing of rice straw residues (SSR 4), and methane emissions from aerobic or semi-anaerobic treatment/use of baled rice straw residue (SSR 5), plus
- Emissions of methane and carbon dioxide due to shifted rice production outside the project boundary (SSR 6)

Equation 5.2. Total Secondary Effect Emissions from Project Activity for Each Field

$$SE = \sum_{fields} SE_{FF,f} + SE_{RM,f} + SE_{PS,f}$$

Where,			Units
$SE_{FF,f}$	=	The total secondary effect GHG emissions from increased fossil fuel combustion for field 'f', as calculated in Section 5.2.1	$MTCO_2e$
$SE_{RM,f}$	=	The total secondary effect GHG emissions from alternative residue management for field 'f', as calculated in Section 5.2.2	$MTCO_2e$
$SE_{PS,f}$	=	The total secondary effect GHG emission from production shifting outside of the project boundary, as calculated in Section 5.2.3	$MTCO_2e$

5.2.1 Project Emissions from On-Site Fossil Fuel Combustion (SSR 3)

On-Site Stationary Combustion

Included in the GHG Assessment Boundary are secondary carbon dioxide emissions resulting from increased fossil fuel combustion for on-site equipment used for performing RC management activities related to seeding, fertilizer application, harvesting, rice straw management etc.

If the project management changes require new equipment or an increase in the operational hours for existing equipment, the CO_2 emissions from the increased fossil fuel combustion shall be calculated per Equation 5.3 below.

Equation 5.3. Project Carbon Dioxide Emissions from Fossil Fuel and Grid Electricity

$$PE_{CO_2} = \sum_m PE_{CO_2,FF} + PE_{CO_2,GE}$$

Where,			Units
$PE_{CO2,FF}$	=	The total carbon dioxide emissions from the destruction of fossil fuel during the reporting period	$MTCO_2$
$PE_{CO2,GE}$	=	The total indirect carbon dioxide emissions from the consumption of electricity from the grid during the reporting period	$MTCO_2$

$$PE_{CO_2,FF} = \frac{\sum_i \left(FF_{PR,i} * EF_{FF,i} \right)}{1000}$$

Where,			Units
$FF_{PR,I}$	=	Total increase in fossil fuel consumed by on-site combustion during the reporting period, by fuel type i	Volume Fossil Fuel
$EF_{FF,i}$	=	Fuel specific emission factor, reference from Appendix B	$kgCO_2$ / Volume Fossil Fuel
1000	=	Kilograms per tonne	$kgCO_2/tCO_2$

5.2.2 Project Emissions from Rice Straw Residue Management/Use

Project emissions from rice straw management consist of CH_4 produced from anaerobic or semi-anaerobic decay of the rice straw, and fossil fuel emissions that are used for swathing, raking, and baling of the rice straw. Depending on the end-use of the rice straw, the magnitude of the emissions will vary, but may be significant. If rice straw is unused and accumulates in piles on or near the farm, anaerobic decay will produce emissions that are quite significant, potentially outweighing the GHG benefits of baling the rice straw.

For calculating the emissions from rice straw management and/or use, emission factors were developed for the following identified end-uses:[25]

- **Dairy replacement heifer feed.** Wheat straw is traditionally used in heifer feed. Rice straw can be used if it is cut to the right length (ANR, 2010). Quality of the straw (crude protein content, moisture content, etc.) must meet minimal standards before it can be used. There may be a significant effect on enteric fermentation from replacing wheat straw by rice straw due to feeding animals lower quality straw.

- **Beef cattle feed.** Rice straw is used by beef cattle operations as a dry matter supplement to pasture feeding during fall and winter (ANR, 2010). Cattle ranchers spread the large bales out on the range in fall and allow the cattle to feed on the bales. Quality of the straw (crude protein content, moisture content,…) must meet minimal standards before it can be used. There may be some effects on enteric fermentation by

[25] End-uses referenced from ANR, 2010.

feeding lower quality straw. Increased emissions from enteric fermentation, baling, handling and transportation must be accounted for.

- **Animal bedding.** Application of straw to soil at dairies and feedlots as a way to help preserve and dry the soil is a well-established, longstanding use of rice straw. The decomposition of the straw will be assumed to be mostly aerobic. Only emissions related to baling, handling and transportation must be accounted for.

- **Spread out on bare soils as erosion control.** Rice straw is particularly valuable for erosion control since it is produced in an aquatic environment and does not pose a risk of introducing upland weeds, unlike wheat or barley straw. When used for erosion control, rice straw will decompose aerobically. Only emissions related to baling, handling and transportation must be accounted for.

- **Stuffed in netted rolls to prevent soil loss.** Rice straw is also used in construction areas to protect bare soil surfaces from soil loss. Netted rolls stuffed with rice straw are placed at the edge of the construction site to trap soil on the site. Decomposition of the rice straw may be partially anaerobic. Emissions related to anaerobic decomposition, baling, handling and transportation must be accounted for.

- **Mushroom production.** Rice straw is an effective substrate for mushroom production. Wheat straw is the primary substrate used for mushroom production (CARB, 1995). Therefore, no increase in emissions from anaerobic decomposition by replacing wheat straw by rice straw is expected. Emissions related to anaerobic decomposition, baling, handling and transportation must be accounted for.

Projects must use Equation 5.4 to calculate the project CH_4 emissions from the end use of all baled rice straw. Projects must use the emission factor in Table A.1 in Appendix A corresponding to the appropriate end use or uses documented by the project developer.

Equation 5.4. Emissions from Rice Straw End-Use

$$SE_{RM,f} = \sum_{U} \left[W_{RS,U} \times EF_{U} \right]$$

Where,			Units
$W_{RS,U}$	=	The total weight of rice straw in dry tons with end use 'U'	Dry ton
EF_u	=	The emission factor from Table A.1 in Appendix A for end use 'U'	$MTCO_2e$ / dry ton of straw

5.2.3 GHG Emissions from the Shift of Rice Production Outside of Project Boundaries (Leakage)

If rice yields are decreased as a direct result of project activity, it must be assumed that the decrease in rice production result with a net increase in production elsewhere outside the

project boundary. The emissions associated with this shift in production must be estimated if project related yield losses are statistically significant.

[Methodology Under Development]

6 Project Monitoring

The Reserve requires a Monitoring Plan to be established for all monitoring and reporting activities associated with the project. The Monitoring Plan will serve as the basis for verifiers to confirm that the monitoring and reporting requirements in this section and Section 7 have been and will continue to be met, and that consistent, rigorous monitoring and record-keeping is ongoing at the project site. The Monitoring Plan must cover all aspects of monitoring and reporting contained in this protocol and must specify how data for all relevant parameters in Table 6.1 (below) will be collected and recorded.

At a minimum the Monitoring Plan shall stipulate the frequency of data acquisition; a record keeping plan (see Section 7.3 for minimum record keeping requirements); the frequency of sampling activities; and the role of individuals performing each specific monitoring and sampling activity. The Monitoring Plan should include QA/QC provisions to ensure that data acquisition is carried out consistently and with precision.

Finally, the Monitoring Plan must include procedures that the project developer will follow to ascertain and demonstrate that the project at all times passes the Legal Requirement Test, the Regulatory Compliance Test, and the Habitat Conservation Test (Section 3.5.2, 3.6, and 3.7 respectively).

Project developers are responsible for monitoring the performance of the project and ensuring that the operation of all project-related equipment is consistent with the manufacturer's recommendations.

6.1 Determining Soil Input Data

The modeling unit for DNDC in this protocol is an individual field. Users of this protocol have the choice to either collect their own soil measurements following the NRCS guidelines[26], or use the NRCS SSURGO soil survey. If the NRCS SSURGO soil database is used, then project developers must calculate the soil parameters for each project field on an area weighted basis. The figure below illustrates this concept for a rice field in Yolo County.

[26] Need reference to NRCS guidelines…WG Help?

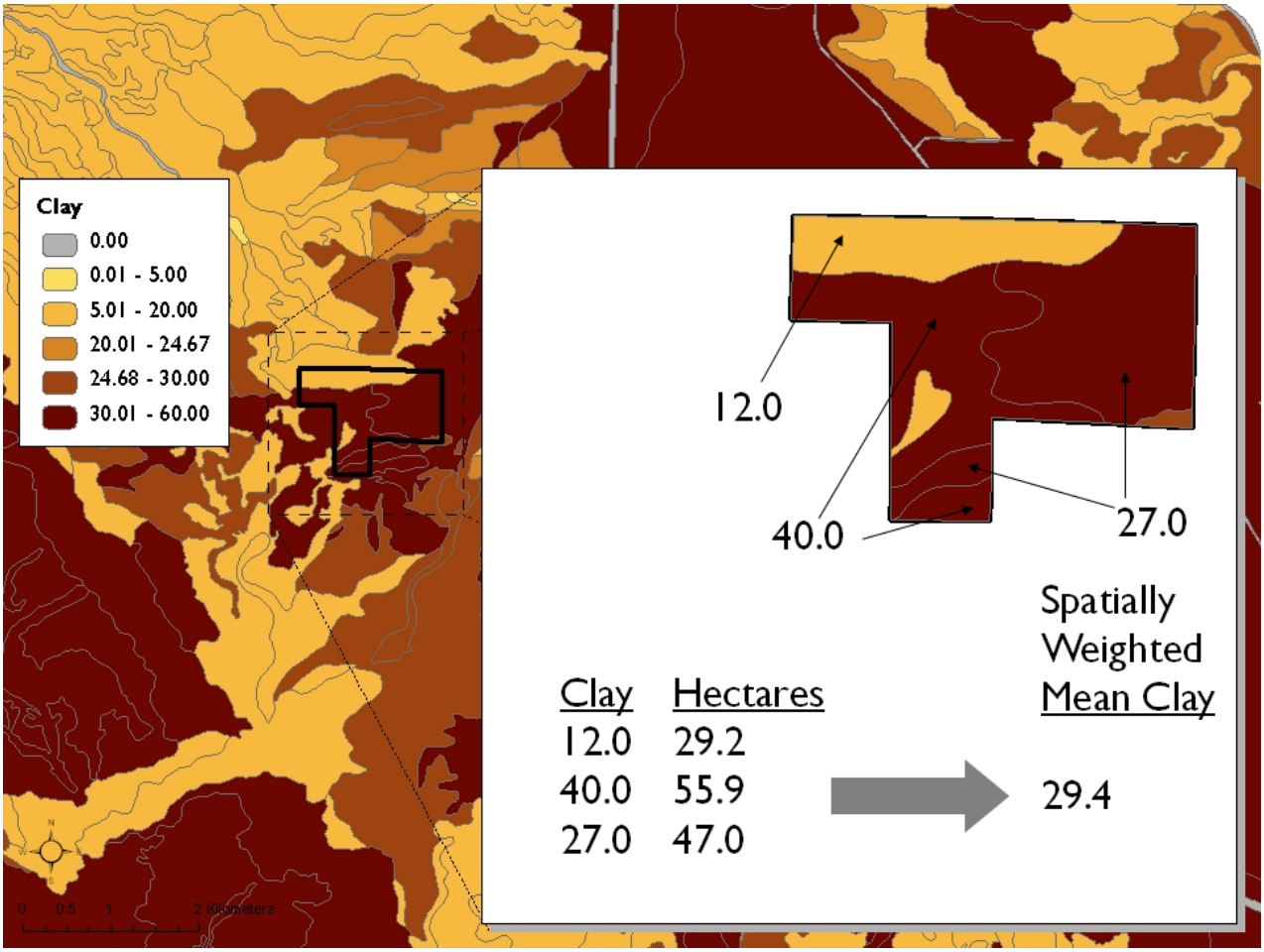


Figure 6.1. FIGURE NAME AND REFERENCE

6.2 Ongoing Management Data

The following management data must be collected and retained for each field for each cultivation cycle during the reporting period:

- Planting preparation description and date
- Planting date
- Fertilization amounts and dates
- Flooding start dates and drainage dates (during the growing season, and during post-harvest period)
- Harvesting date
- Post-harvesting description and dates
- Quantity of rice straw removed
- End use of rice straw

6.3 Monitoring Parameters

Prescribed monitoring parameters necessary to calculate baseline and project emissions are provided in Table 6.1.

Table 6.1. Rice Cultivation Project Monitoring Parameters

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
General Project Parameters						
	Regulations	Project developer attestation of compliance with regulatory requirements relating to the rice cultivation project	Environmental regulations	n/a	Each verification cycle	Information used to: 1) To demonstrate ability to meet the Legal Requirement Test – where regulation would require the diversion of MSW food waste from landfills. 2) To demonstrate compliance with associated environmental rules, e.g. criteria pollutant wastewater discharge, etc.
DNDC Input Parameters						
	Climate	GPS location of Field	decimal ^{o}	m	once	
		Atmospheric background NH_3 concentration	µg N/m^3	l	n/a	
		Atmospheric background CO_2 concentration	ppm	l	n/a	
		N concentration in rainfall	mg N/l or ppm	l	annual	Source: NADP
	Soils**	Daily meteorology		m	daily	Source: Nearest CIMIS station
		Land-use type	type	m	once	
		Clay content	0-1	m/l	once	Source: measured or SSURGO
		Bulk density	g/cm^3	m/l	once	Source: measured or SSURGO
		Soil pH	value	m/l	once	Source: measured or SSURGO
		SOC at surface soil	kg C/kg	m/l	once	Source: measured or SSURGO
		Soil texture	type	l	once	Source: measured or SSURGO
		Slope	%	m	once	
		Depth of water retention layer	cm	m	once	Default: 30cm
		High groundwater table	cm	m	once	Default: 9.9 meters
		Field capacity	0-1	c	once	DNDC calculates based on soil texture
		Wilting point	0-1	c	once	DNDC calculates based on soil texture
	Rice Cropping	Planting date	date	m	annual	Famer's records
		Harvest date	date	m	annual	Famer's records

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
		C/N ratio of the grain	ratio	m/l	Once per variety	Can use default dnd file values
		C/N ratio of the leaf + stem tissue	ratio	m/l	Once per variety	Can use default dnd file values
		C/N ratio of the root tissue	ratio	m/l	Once per variety	Can use default dnd file values
		Fraction of leaves & stem left in field after harvest	0-1	m	annual	Farmer's records
	Rice Flooding	Maximum yield	kg dry matter/ha	m	annual	Farmer's records
		Date of flood up for growing season	date	o	annual	Farmer's records
		Date of drain for crop harvest	date	o	annual	Farmer's records
		Date of flood up for winter flooding (if applicable)	date	o	annual	Farmer's records
	Tillage system	Date of drain for winter flooding (if applicable)	date	o	annual	Farmer's records
		Number of tillage events	number	o	annual	Farmer's records
		Date of tillage events	date	o	annual	Farmer's records
	N Fertilizer	Depth of tillage events	6 depths†	o	annual	Farmer's records
		Number of fertilizer applications	number	o	annual	Farmer's records
		Date of each fertilizer application	date	o	annual	Farmer's records
		Application method	surface / injection	o	annual	Farmer's records
		Type of fertilizer	type*	o	annual	Farmer's records
		Fertilizer application rate	kg N/ha	o	annual	Farmer's records
		Time-release fertilizer	# days for full release	o	annual	Farmer's records
	Organic Fertilizer	Nitrification inhibitors		o	annual	Farmer's records
		Number of organic applications per year	number	o	annual	Farmer's records
		Date of application	date	o	annual	Farmer's records
		Type of organic amendment	type	o	annual	Farmer's records
		Application rate	kg C/ha	o	annual	Farmer's records
	Irrigation System	Amendment C/N ratio	ratio	o	annual	Farmer's records
		Number of irrigation events	number	o	annual	Farmer's records
		Date of irrigation events		o	annual	Farmer's records
		Irrigation type	3 types‡	o	annual	Farmer's records
		Irrigation	mm	o	annual	Farmer's records

Eq. #	Parameter	Description	Data Unit	Calculated (c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
		application rate				

†0, 5, 10, 20, 30, 50 cm
**DNDC accepts seven types of fertilizers: Urea, Anhydrous Ammonia, Ammonium Nitrate, Nitrate, Ammonium Bicarbonate, Ammonium Sulfate and Ammonium Phosphate.*
‡Flood, sprinkler or surface drip tape
***Soil parameters for DNDC are for the properties of the top layer of the soil profile. If not measured, then look up values from NRCS SSURGO database is required.*

7 Aggregation and Reporting Guidelines

This section provides requirements and guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers. Project developers must submit verified emission reduction reports to the Reserve annually at a minimum.

7.1 Project Aggregation Guidelines

Because of the necessity to aggregate multiple rice fields into a single project area to minimize DNDC model structural uncertainty, the Reserve has developed rules and procedures under which multiple individual rice fields of independent ownership/management control must be aggregated. While the goal of aggregation is primarily to reduce model uncertainty, the Reserve also recognizes that field aggregation will likely help to alleviate transaction costs associated with implementation, verification, and registration of RC projects. Allowing smaller projects to register as part of a group, or "aggregate," can help reduce costs by enabling economies of scale and supporting the marketing of offset credits at volume. Through aggregation, the Reserve expects that RC projects will be viable to a larger percentage of rice producers. Detailed aggregation guidelines are provided in Appendix E of this protocol. Below is a summary of the aggregation approach.

The approach to aggregation works as follows:

- Unless an RC project area consists of at least 5 contiguous, individual rice fields under the sole management control of a single rice producer, all rice fields must be submitted as a project aggregate by a qualified aggregation entity.
- Aggregators must manage project aggregate submittal, sign attestation documents, select verification bodies, coordinate verification schedules, and maintain a Reserve account to which CRTs[27] will be issued upon completion of verification for each project aggregate.
- Because of the complexities involved with project calculations, aggregators will likely be the party responsible for engaging in project development, collection of historical data and ongoing data collection, data management, and DNDC modeling. The scope of aggregator services is up to negotiation between each field owner/manager and must be reflected in the contracts between all parties.

Workgroup Questions:

1. Are fields allowed to enter/leave aggregates at will, or must they commit to a minimum five year period? Leaving an aggregate mid-way through a reporting period will cause much complexity
2. Verification schedules are typically set for other Reserve protocols so that every site has to have annual verification with site visit. Should we allow for less than annual site visits to each field? Do verification activities need to occur every year during a 5 year reporting period?

Please provide thoughts on overall aggregator/farmer structure with regards to submittal, DNDC calculations, data sampling/monitoring, verification, CRT issuance etc.

[27] A CRT (Climate Reserve Tonne) is a credit issued by the Reserve for verified GHG reductions. One CRT represents one metric ton (tonne) of carbon dioxide equivalent (CO_2e) reductions or removals.

7.2 Project Submittal Documentation

For each project area, project developers/aggregators must provide the following documentation to the Reserve in order to register a RC project.

- Project Submittal form (for each project area)
- Signed Attestation of Title form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of Voluntary Implementation form
- Verification Report
- Verification Opinion

Project developers/aggregators must provide the following documentation each reporting period in order for the Reserve to issue CRTs for quantified GHG reductions.

- Verification Report
- Verification Opinion
- Signed Attestation of Title form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of Voluntary Implementation form

At a minimum, the above project documentation will be available to the public via the Reserve's online registry. Further disclosure and other documentation may be made available on a voluntary basis through the Reserve. Project submittal forms can be found at http://www.climateactionreserve.org/how/projects/register/project-submittal-forms/.

7.3 Record Keeping

For purposes of independent verification and historical documentation, project developers/aggregators are required to keep all information outlined in this protocol for a period of 10 years after the information is generated or 7 years after the last verification. This information will not be publicly available, but may be requested by the verifier or the Reserve.

System information the project developer should retain includes:

- All data inputs for the calculation of the project emission reductions, including all required sampled data
- Copies of all permits, Notices of Violations (NOVs), and any relevant administrative or legal consent orders dating back at least 3 years prior to the project start date
- Executed Attestation of Title forms, Attestation of Regulatory Compliance forms and Attestation of Voluntary Implementation forms
- On-site fossil fuel use records
- Results of CO_2e annual reduction calculations
- Initial and annual verification records and results
- All maintenance records relevant to the farm equipment and monitoring equipment

7.4 Reporting Period & Verification Cycle

Project developers must report GHG reductions resulting from project activities during each reporting period. The reporting period cannot span less than one full cultivation cycle. Projects or project aggregates that include reduced frequency of winter flooding as a project activity must have a reporting period of be 5 years. Projects and project aggregates must be verified annually

for 1 year reporting periods, or once every 5 years for 5 year reporting periods. Project aggregates must follow additional reporting and verification requirements provided in Section 7.1.

Because a single cultivation cycle spans two years (from fall of one year to late summer of the next), the project must assign each cultivation cycle a single 'vintage' for reporting purposes. For reporting reductions to the Reserve, the calendar year in which the rice crop is harvested represents the vintage year for the cultivation cycle. For instance, all GHG reductions from a cycle beginning in fall 2012 and ending with harvest in late summer 2013 shall be assigned as 2013 'vintage' when reporting reductions to the Reserve.

8 Verification Guidance

[UNDER DEVELOPMENT]

9 Glossary of Terms

[UNDER DEVELOPMENT]

Accredited verifier	A verification firm approved by the Climate Action Reserve to provide verification services for project developers.
Additionality	Organic waste management practices that are above and beyond business-as-usual operation, exceed the baseline characterization, and are not mandated by regulation.
Anaerobic	Pertaining to or caused by the absence of oxygen.
Anthropogenic emissions	GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e. fossil fuel destruction, de-forestation, etc.).
Biogenic CO_2 emissions	CO_2 emissions resulting from the destruction and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the Carbon Cycle, as opposed to anthropogenic emissions.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Direct emissions	Greenhouse gas emissions from sources that are owned or controlled by the reporting entity.
Effective Date	The date of adoption of this protocol by the Reserve board: expected in June 2011.
Emission factor (EF)	A unique value for determining an amount of a greenhouse gas emitted for a given quantity of activity data (e.g. metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Fossil fuel	A fuel, such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
GHG reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.

GHG source	A physical unit or process that releases GHG into the atmosphere.
Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Metric ton (MT) or “tonne”	A common international measurement for the quantity of GHG emissions, equivalent to about 2204.6 pounds or 1.1 short tons.
Methane (CH_4)	A potent GHG with a GWP of 21, consisting of a single carbon atom and four hydrogen atoms.
MMBtu	One million British thermal units.
Mobile combustion	Emissions from the transportation of materials, products, waste, and employees resulting from the combustion of fuels in company owned or controlled mobile combustion sources (e.g. cars, trucks, tractors, dozers, etc.).
Project baseline	A business as usual GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	An entity that undertakes a GHG project.
Stationary combustion source	A stationary source of emissions from the production of electricity, heat, or steam, resulting from combustion of fuels in boilers, furnaces, turbines, kilns, and other facility equipment.
Verification	The process used to ensure that a given participant’s greenhouse gas emissions or emission reductions have met the minimum quality standard and complied with the Reserve’s procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A Reserve approved firm that is able to render a verification opinion and provide verification services for operators subject to reporting under this protocol.

10 References

[A LIST OF REFERENCE WILL BE DISTRIBUTED TO THE WORKGROUP PRIOR TO THE WORKGROUP MEETING]

Appendix A Parameter Look-Up Tables

Workgroup Question:

1. The DNDC model uses input files that we often refer to as “dnd” files. These are simple text files that list the input parameters for a DNDC run. These files are edited and saved through a GUI interface for DNDC. Should we provide default template dnd files for all of the allowable management practices as part of the methodology?

Appendix B DNDC Model Users Guide

This will focus on using DNDC for quantifying changes in GHG emissions through a change in management practices. Users can also refer to the DNDC Users Guide that is available for download.

Appendix C Summary of DNDC Model Calibration and Uncertainty Analysis

Workgroup Discussion:

Summary of the plan for proper quantification of DNDC model uncertainty:

In the main text, the approach follows the VCS methodology which is based solely on the California validation (9 points). We are in the process of obtaining additional data for CA and should have more validation points in CA by mid-to-late summer. The section below this comment box shows the results of previous rice validation studies and includes a total of 99 validation points. These validations were done on a wide range of rice areas, including India, China, SE Asia, Texas and US. The advantage of this large validation set is we can ask questions regarding how well the model estimates changes in emissions from changes in management. We can also develop accuracy metrics based on biophysical drivers (e.g. soil conditions – so we may be able to quantify model performance based on soil texture and OM classes).

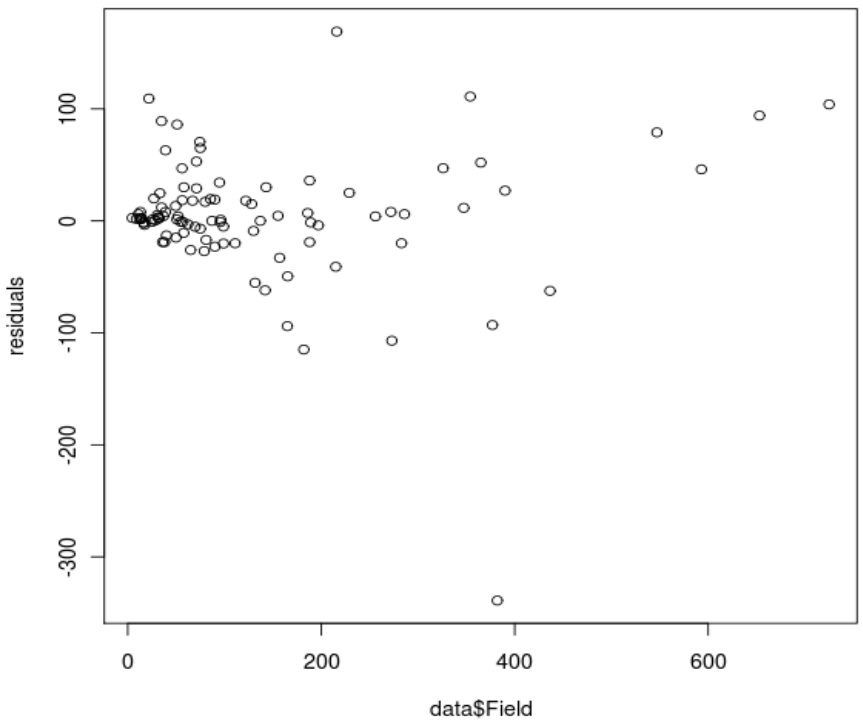
Specific comments and questions for the WG:

1. Is our current approach for addressing model structural uncertainty in Section 5.1.5 adequate? Can we rely on the larger dataset to provide more robust quantification? Note that the analysis below refuted the hypothesis that the CA rice validation results are different from the larger set.
2. The current approach for capturing the uncertainty due to soil inputs is very conservative because it does not account for correlation between soil parameters (e.g. bulk density and clay fraction). We are exploring how best to capture the correlation between soil parameters so we can adjust our PDFs for the Monte Carlo analysis accordingly.

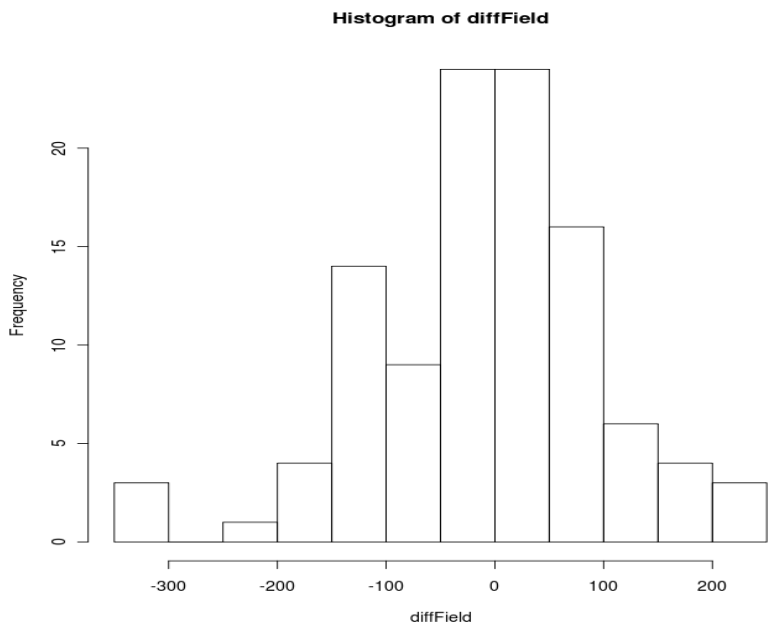
DNDC Uncertainty
Analysis with R and data from
DNDC-Rice_validation_review.xls
23 May, 2011

We have 99 validation data points. The average of the modeled is 139.6 and the average of the observed is 135.1. The median residual is 2.5. The median of the absolute value of the residuals is 18 (i.e. 50% of the residuals are more than 18 or less than -18). The standard deviation of the residuals is 55.9 and the RMSE is 55.8. If the observations are normally distributed and the model is unbiased, we would expect 68% of the model values to be within 56 kg CH4/ha/yr, 90% to be within 92 kg, and 95% to be within 109 kg CH4/ha/yr of the measured. In actuality, we see that 82% (81) of the residuals are smaller than ±56 and 95% (94) are smaller than ±109. So, the Gaussian assumption may be violated. It may be advisable to transform the residual errors (e.g. assume they are distributed with a double sided exponential). Because the mean field measurement is 135 and the typical residual error is around 18, typically error is around 13%.

Residuals do show limited heteroskedasticity. The error around observations less 100 seem to have a different distribution than the observations greater than 100 kg CH4/ha/year.

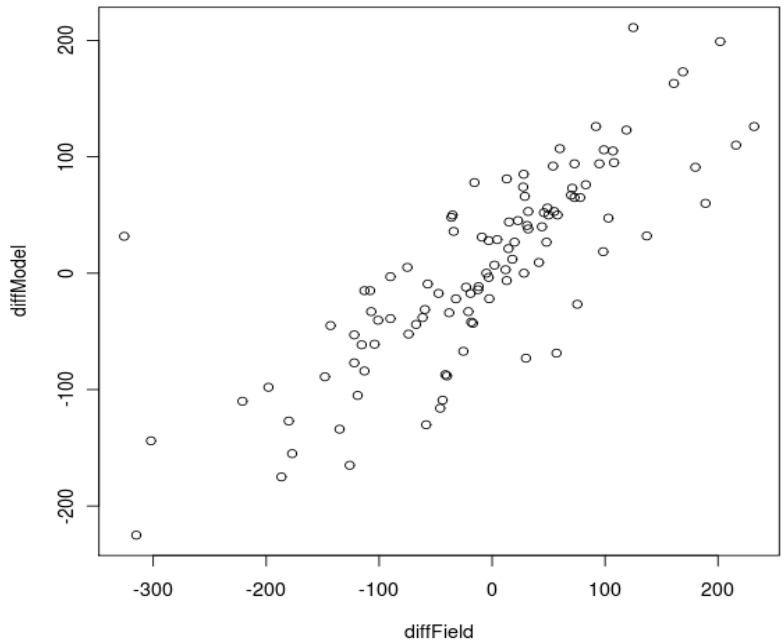


We are interested in the confidence limits on the *differences* in model output, comparing a project result to a baseline. To put confidence limits around differences in model output, we conducted a simple and conservative test by isolating observation pairs in the literature-based DNDC validation data set from the same author, location, and year. We assume the primary difference in this subset of data pairs is the management and treat the difference (108 different pairs) as differences due to management. From the field data, we see this distribution in changes due to management (in kg of methane per hectare per year).



We can then compare the modeled differences to the observed differences. The standard deviation of the modeled vs. field difference residuals is 63 kg. This represents a single standard deviation, meaning 68% of all residuals should fall between -63 and +63 kg, if the model is unbiased and the errors are normally distributed. To extend these limits to 90%, we multiply by 1.645. Therefore, the confidence limits around the difference at a single site is ±105 kg. In other words, to be 90 % sure that the difference is significant, the difference between baseline and project needs to be greater than 105 kg for a single site. This estimate is reinforced by observation that the 90th percentile residual is 100.0.

Aggregation



Aggregation influences the uncertainty. Using the 108 estimated differences from baseline, we randomly aggregated fields and looked at the residuals as function of the number of aggregated fields. When summing the measured and modeled emissions differences from twenty randomly selected fields we see the per field error drop from about 106 down to about 35 at the 90% confidence level.

Number of Fields	Standard Error of Model	90% CL	95% CL	95% CL per field
1	63	100	106	106.0
2	89	134	168	84.0
3	108	173	218	72.7
4	125	207	264	66.0
5	138	240	309	61.8
10	192	382	472	47.2
20	257	602	706	35.3

To be 95% certain that emissions significantly changed, the model would have to show a change of at least 706 kg CH_4/ha/year from 20 aggregated fields (or 35.3 per field).

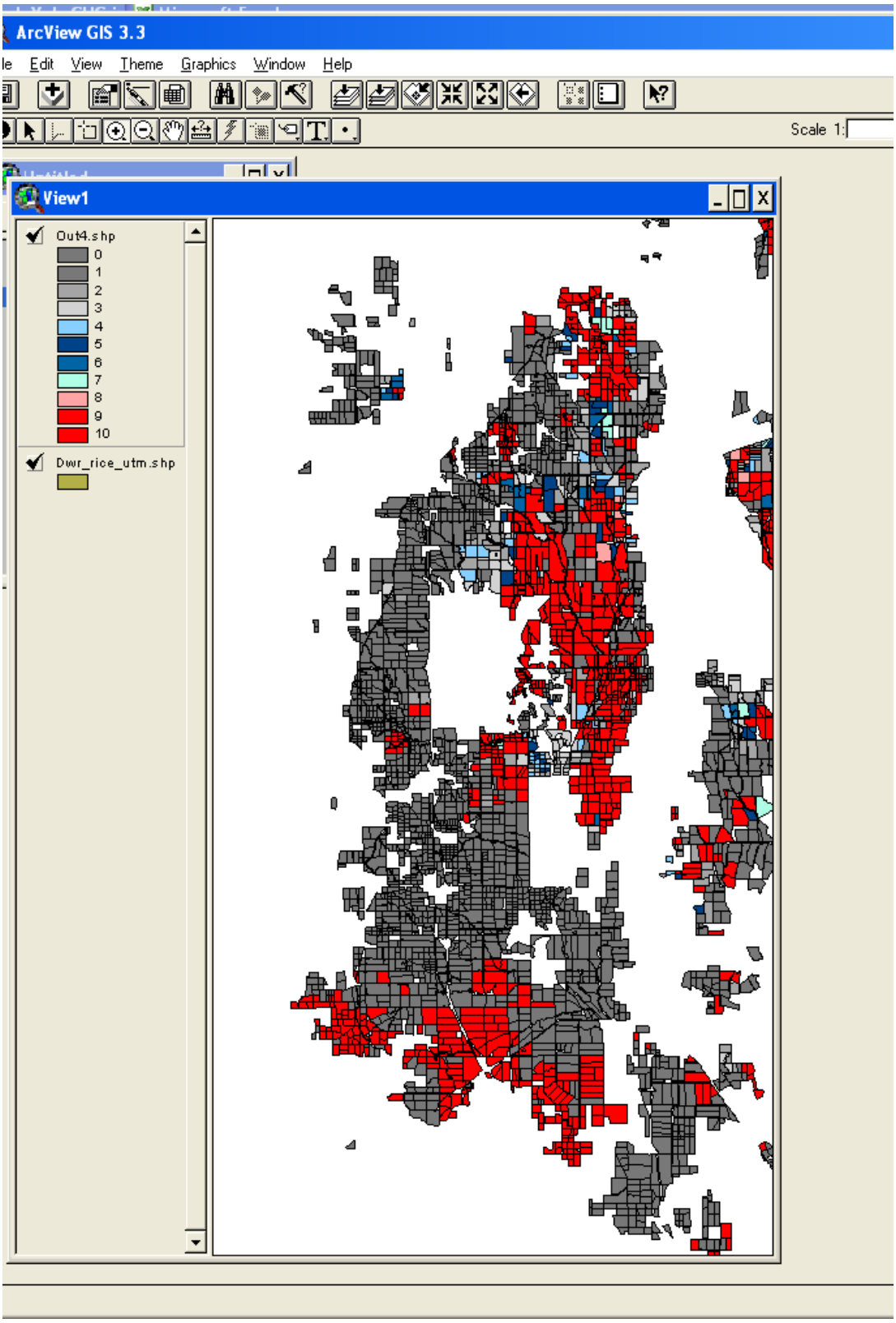
Appendix D Summary of Performance Standard Research

The dominant flood and seeding regimes are continuous flood with conventional seedbeds. Incorporation of rice straw residue is also the dominant practice. The use of winter flooding is quite variable across Sacramento Valley. Variability is due to growers decisions regarding management practices, wild bird habitat creation, hunting contracts, and water availability. Irrigation districts have some statistics on the acreage of winter flooding from one year to the next. However, it appears these numbers are only available in aggregate (with the exception of GCID), so it is difficult to ascertain the spatial and temporal patterns of winter flooding to develop a performance standard. Fortunately, remote sensing can provide us with spatially and temporally explicit information on the extent and duration of winter flooding on a field by field basis.

This figure shows results on a MODIS remote sensing analysis from 2001 through 2010 for the general area of the Glen_Colusa Irrigation District area. Red areas are area that had winter flooding at least 9 of the 10 years from 2001 through 2010. Grey areas had winter flooding rarely during this period (2 or fewer times from 2001 through 2010). We are in the process of validating this approach with field data from GCID.

Workgroup Questions:

Given the variability, how shall we define a performance standard? What is the role of remote sensing for defining the performance standard? How will the performance standard account for inter annual variability in water availability from the irrigation districts? How do we account for differences in duration of flooding due to single versus multiple flooding events?


ArcView GIS 3.3
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Appendix E Additional Aggregation Guidelines

E.1 Number of Landowners

An aggregate must consist of at least 5 or more individual fields under different management control and/or ownership. There is no limit to the number of fields in an aggregate,

E.2 Acreage Limitations

There is no upper or lower limit on the total number of rice acres enrolled in an aggregate. However, no single field may comprise more than 33 percent of the total combined acreage in an aggregate. This is to prevent any one field from disproportionately affecting the statistics.

E.3 Qualifications and Role of Aggregators

An Aggregator may be a corporation or other legally constituted entity, city, county, state agency, individual or a combination thereof. An Aggregator must have an account on the Reserve. A rice farmer or field owner may serve as their own Aggregator or as an Aggregator for a group of fields when it is the owner of one or more of the fields.

Once approved for an account on the Reserve, an Aggregator must remain in good standing or all of the Aggregator's account activities will be suspended until issues are resolved to the satisfaction of the Reserve. In order for an Aggregator to remain in good standing, Aggregators must:

- Execute contracts with all rice farmers/land owners that include the mandatory components as defined below in Joining an Aggregate, Section E.5.
- Select a single verification body for each project aggregate in any given year or set of years.
- Ensure the verification schedule for all fields in the aggregate meets the verification standards according to the RCPP and these guidelines. (See Monitoring and Verification, Section 7)
- Maintain a Reserve account to which CRTs will issued and from which CRTs must be transacted.

Aggregators may act as official agents to the Reserve on behalf of rice farmers; and are ultimately responsible for submitting all required forms and complying with the terms of the RCPP. Aggregators shall manage the flow of ongoing monitoring and verification reports to the Reserve ,and also may engage in other project development activities such as developing monitoring plans, modeling emission reductions, managing data collection and retention etc.. The scope of aggregator services may be negotiated between farmers and the Aggregator and should be reflected in contracts between the farmers and the Aggregator.

E.4 Forming an Aggregate

In order to form an aggregate, Aggregators are required to establish a "Project Developer" account on the Reserve (see http://www.climateactionreserve.org/open-an-account/).

Aggregators must also submit an "Aggregator Document" that includes the following information:

- The name, description, and contact information of the Aggregator.

- Proof of incorporation and/or good standing as corporate entity or other legally constituted entity, city, county, state agency, individual or a combination thereof.
- A list of initial rice field participants (which must be greater than one).

The Aggregator Document will be available to the public on the Reserve's website, and will require approval by Reserve staff. It must be modified any time a participant joins or leaves an aggregate (triggered by the submission of an "Aggregate Entry" or "Aggregate Exit" form as described below).

E.5 Joining an Aggregate

To join an aggregate, rice farmers or land owners may approach the Reserve staff for assistance, or may work outside of the Reserve system to find interested aggregation bodies. Upon submittal of a project aggregate to the Reserve, all rice farmers/land owners participating in the aggregate will be required to submit an Aggregate Entry form along with the project aggregate submittal form. This form may be included at the time of project submittal, or at any time thereafter. This form will require Reserve staff's approval and will contain:

- Statement that the rice farmer wishes to join a specific aggregate with a specific Aggregator. A participating field may only have one Aggregator for each field enrolled.
- Copies of any contract(s) between rice farmer and Aggregator. Contracts will not be made available to the public.

E.6 Leaving an Aggregate or Termination of Contract Between Forest Owner and Aggregator

[UNDER DEVELOPMENT]

E.7 Accounts on the Reserve, Transfers of CRTs

Each Aggregator must have an account with the Reserve. It is entirely up to the Aggregator and each farmer / land owner to determine the distribution of CRTs and/or compensation to all participants. The arrangements must be detailed in the contractual agreements. If it is arranged for a farmer/land owner to take ownership of all or a portion of the CRTs issued to the Aggregator for the project aggregate, the farmer/land owner must have a separate account on the Reserve prior to transfer of CRTs. The timing, pricing, ownership and other details of the transfer of CRTs are up to arrangements between the farmer/land owner and the Aggregator.

E.8 Monitoring and Verification

The Aggregator is responsible for selecting a single verification body for the entire project aggregate for each reporting period. Verification bodies must pass a conflict-of-interest review against all enrolled farmers / land owners and the Aggregator.

The Aggregator must also coordinate a verification schedule that meets the requirements described in this section. The Aggregator must document the verification work and provide a report to the Reserve every 12-month period, from the date of its formation, showing how the verification schedule demonstrates compliance with these guidelines.

Required Site-Visit Verification Schedule for Aggregates

[UNDER DEVELOPMENT]