CLIMATE ACTION RESERVE

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# Rice Cultivation

## Project Protocol

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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 (t) | 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 in 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 quantify and 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 aggregates 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 a rice cultivation (RC) project.

# 2 The GHG Reduction Project

## 2.1 Background

Methane ($CH_4$), a potent 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 rice cultivation, 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 annual quantity of methane emitted to the atmosphere at a given rice field will depend on numerous factors related primarily to the water 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 $CO_2e$.[2] 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 baseline and project 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 validated 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 the California Sacramento Valley (CSV) rice growing region.

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

## Background on Rice Cultivation Techniques

In the U.S. there are three 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 three to five 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 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 remain flooded until the typical pre-harvest drain.

Producer 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.[3] Fields are typically flooded to a depth of 4 to 5 inches just prior to aerial seeding. While deeper flooding reduces weed pressures, it also can 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. 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. Prior to harvest, water is drained from fields to allow fields to dry, as harvesting equipment cannot function as well on wet soil. The timing of pre-

[3] Correspondence with P. Buttner (CalRice).

harvest field draining varies from field to field, and can influence total yields. The University of California Cooperative Extension (UCCE) recommends growers to drain their fields when the panicles are 100 percent “fully tipped and golden,” although fields are often drained earlier due to other contributing factors such as soil type (e.g. soils with high clay content require longer time for drying) and weather.

A continuous flooding and water seeded regime is estimated to be used on over 96 percent of the acreage in California.[4] A small fraction of the rice acreage is dry seeded in California. The flood for dry seeded rice starts approximately 25 to 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 GHG emissions. Timing of straw amendment/incorporation can impact GHG emissions by altering the timing and availability of substrate (dissolved organic carbon (DOC)) released from the fresh straw to methanogens in the soil. The timing of the residue incorporation relative to the flooding period will impact total methane production, as will the availability of rice straw on the field. Rice straw incorporation is currently the dominant management practice in California.

Burning of rice straw was the prevailing management practice in California 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 to 12 percent of rice acreage in California.[5]

Some growers bale rice straw for off-field uses. The current estimate for baling adoption in California is 2 to 6 percent of California rice acres per year.[6] This fluctuates slightly coincident with the 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 between one and two tons of rice straw per acre, out of an average of about three tons of rice straw available per acre. Of the straw that is baled, much of the straw is sold to end-users, while the straw that goes un-used is typically left onsite. Presently, the majority of rice straw is sold for dairy heifer and beef cattle high roughage feed (estimated to be 75 to 85 percent), with some straw used for erosion control (15 to 25 percent), and very little sold for building construction. The straw that is baled and left onsite is typically composted in large static piles.

[4] Based on communication with P. Buttner (CalRice), R. Mutters, and L. Espino (University of California Cooperative Extension).
[5] Communication with Paul Buttner.
[6] Based on communication with P. Buttner (CalRice), R. Mutters, L. Espino, and G Nader (University of California Cooperative Extension).

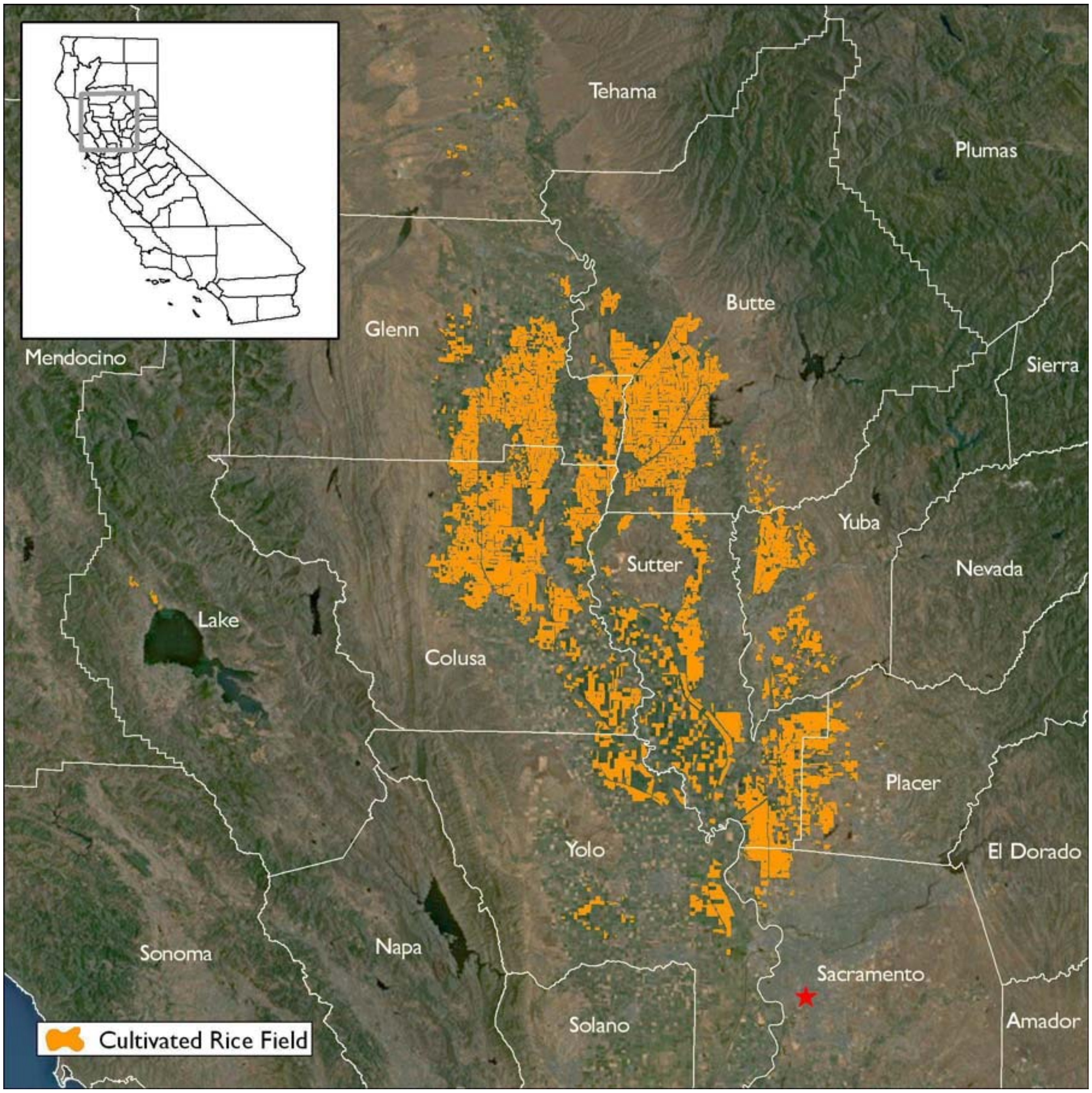


**Figure 2.1.** California Sacramento Valley Rice Growing Region

### Background on Project Aggregation

Incorporated into the RCPP is an option for project aggregation, with clear rules for how aggregation works, that aims ultimately to facilitate participation by farmers. The technical complexities of the methodology and other potential barriers to adopting practice changes in agriculture may be overcome by aggregation. Specifically, aggregators would acquire appropriate technical expertise and fulfill protocol requirements on behalf of farmers while providing other technical consulting services. In addition, aggregation allows for "economies of scale" within the methodology, in terms of streamlined requirements for individual farmers, while upholding rigorous standards at the level of the aggregate. This is primarily accomplished through pooling and sampling fields for verification activities. In addition, aggregation can help to increase the accuracy of GHG reduction estimates at a program level, by encouraging greater participation.

## 2.2 Project Definition

For the purpose of this protocol, a GHG reduction project ("project") is defined as the adoption and maintenance of one or more of the approved rice cultivation project activities[7] that reduce methane ($CH_4$) emissions. Specific project activities must be adopted and maintained on individual rice fields, with at least one approved project activity implemented on each individual field. Approved rice cultivation project activities may be implemented on a single field, known as a "single-field project," or may be implemented on two or more individual fields combined into a single project area, known as a "project aggregate." Specific requirements for project aggregates are outlined in Section 2.4 below. Physical boundaries for individual fields must be defined according to the requirements in Section 2.2.1.

Individual participating fields should be submitted to the Reserve as part of a project aggregate, according to the rules provided in Section 7. Under this protocol, a project comprised of a single field implementing the approved practice changes may not be submitted to the Reserve unless it joins a project aggregate. Aggregation of multiple participating fields is required by this protocol as a means of reducing modeling and quantification uncertainty, but will have the additional benefit of alleviating transaction costs associated with implementation, verification, and registration of RC projects by enabling economies of scale and supporting the marketing of offset credits at volume.

Practice changes described in Table 2.1 below are the approved project activities (by geographic scope).

**Table 2.1.** Approved Project Activities

| Project Activity | Description | Geographic Scope |
|---|---|---|
| Dry seeding (DS) with delayed flood | Adoption of a dry seeding method that involves sowing of dry seeds into dry or moist (non-flooded[8]) soil with field flooding delayed until rice stand is established (typically 25 to 30 days after seeding). 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." Regardless of the dry seeding method utilized, the methane reductions occur due to the subsequent delay in flooding of the dry seeded field. | California |
| 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. Doing so reduces the net soil degradable organic carbon (DOC) and therefore decreases methane production from anaerobic decay over the winter season. Baled straw can be sold even though the market is currently small. In California, rice straw can be used for erosion control, animal bedding or as an alternative feed for cow and calf producers.[9] | California |

[7] Note that a project is defined by the adoption of management changes; however, GHG reductions are quantified based on actual project performance in terms of reduced $CH_4$ emissions.
[8] For the purposes of this protocol, non-flooded should be interpreted to mean that there is not standing water (1 inch or more) on the field.
[9] DANR, publication 8425.

### 2.2.1 Defining Field Boundaries

For the purposes of this protocol, an individual rice field must be defined by the following criteria[10]:

1. The field must be under the direct management control of a single rice producer.
2. The field must be contiguous across field 'checks'
3. Water management (flooding and drainage events) within the field boundary must be relatively homogenous. There is no set definition for homogeneous water management; however standard practice suggests that most rice fields have a flood-up duration across all field checks of less than 96 hours from start to finish (4 acre-inches per acre or more).[11]
4. Fertilizer management must be relatively homogenous. This criterion is met when application rates across the field do not vary by more than 15 percent of the average application rate for the entire field. For each application, fertilizer must be applied on the same day with the same type of fertilizer.
5. The field must have at least five years of yield data available for DNDC model calibration.[12]

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.[13] See Section 6.1 for soil input data collection requirements.

## 2.3 Project Developer

The project developer is an entity that has an active account in good standing on the Reserve, submits a project for listing and registration with the Reserve, and is ultimately responsible for all project reporting and verification. According to this protocol, project developers may also be project aggregators, and can represent one or more projects. Project developers/aggregators may be a corporation or other legally constituted entity, city, county, state agency, agricultural producer, or a combination thereof. An individual rice grower may serve as a project developer of a single-field project, project aggregator for his/her own fields, or as a project aggregator for a group of fields. Rice growers who elect to enroll in a project aggregate and not serve as a project developer are referred to as "project participants." Project participants must have authority to make cultivation management decisions on their fields that are enrolled in the project aggregate.

Project developers/aggregators act as official agents to the Reserve on behalf of project participants and are ultimately responsible for submitting all required forms and complying with the terms of this protocol. Project developers/aggregators manage the flow of ongoing monitoring and verification reports to the Reserve and may engage in other project development activities such as developing monitoring plans, modeling emission reductions, managing data collection and retention etc., or may hire technical contractors to perform these services on their behalf. The scope of project developer/aggregator services is negotiated between the project

[10] The Reserve believes that in most cases a field defined according to the specified criteria in this protocol will be compatible with a field as defined by the UDSA Farm Service Agency (FSA) Field I.D. protocols.
[11] Note that when recording the date of flood-up for modeling purposes, the date shall be equal to the date during which the last field 'check' is flooded to approximately 4 inches or more. This is conservative.
[12] USDA FSA Abbreviated Farm Records may be a useful resource for documenting historical yields and/or practices on a particular rice field, however these reports are not required to be used..
[13] See http://soils.usda.gov/survey/geography/ssurgo/.

participants and the project developer/aggregator and should be reflected in contracts between the project participants and the project developer/aggregator.

Project aggregators have the authority to develop their own internal monitoring, reporting, and other participation requirements for individual fields as they deem necessary, as long as these internal requirements do not conflict with any requirements outlined in this protocol.

Aggregators also have the discretion to exclude individual fields enrolled in their aggregate from participating in verification activities for any given reporting period; however, in such cases there can be no CRTs claimed by those fields in the aggregate total.

In all cases, the project developer/aggregator must attest to the Reserve that they have exclusive claim to the GHG reductions resulting from all fields in the project. The Project developer/aggregator must attest to this requirement by submitting a signed Attestation of Title form for single-field projects or Aggregator Attestation of Title[14] form for project aggregates, prior to the commencement of verification activities each time the project is verified (see Section 8).

Although the aggregator must have exclusive claim to CRTs for the project to complete verification, this protocol does not dictate the terms for how that exclusive title will be established; allowing the aggregator, project participant, and land owner (if separate from the project participant) maximum flexibility for the terms of contracts between the respective parties. In the case of project activities taking place on leased fields (e.g. the project participant is not the land owner, but rather a lessee), the aggregator must notify the land owner with a Letter of Notification of the Intent to Implement a GHG Mitigation Project on the respective field.

As part of verification activities, verifiers shall review contracts and letters of notification as a means of confirming exclusive title to the CRTs. The Reserve will not issue CRTs for GHG reductions that are reported or claimed by entities other than the aggregator.

## 2.4 Project Aggregates

### 2.4.1 Field Size Limits and Other Requirements

The project aggregate does not need to be comprised of contiguous fields, and can encompass fields located on one farming operation or distributed amongst different farms and/or producers.

There is no limit on the total number of rice acres enrolled in a project aggregate, assuming each individual field meets the requirements of Section 2.2.1. There are, however, limits on how large a single field may be, in relation to the total combined acreage in a project aggregate, as defined by Table 2.2 below. Field size limitations are in place to minimize the influence a single large field may have on a project aggregate's calculations.

[14] The Reserve Aggregator Attestation of Title form is available at: http://www.climateactionreserve.org/how/projects/register/project-submittal-forms/

**Table 2.2.** Maximum Field Size, as a Percent of Aggregate Acreage

| Number of Fields in Aggregate | Maximum Acreage of a Single Field (% of Aggregate Acreage) |
|---|---|
| 2 | 70% |
| 3 | 50% |
| 4 | 33% |
| 5 or more | 25% |

## 2.4.2 Entering and Leaving an Aggregate

### 2.4.2.1 Entering an Aggregate

Individual fields may join a project aggregate by being added to the aggregate's Project Submittal Form (if joining at aggregate initiation) or by being added through the New Field Enrollment Form (if joining once the aggregate is underway).

Single-field projects that have already been submitted to the Reserve as such may choose to join an existing aggregate by submitting a "Project Aggregate Transfer Form" to the Reserve. The project aggregator will also need to submit a New Field Enrollment Form, listing that field. However, emission reductions from the single-field project must be reported for a complete cultivation cycle, therefore a field submitted as a single field project cannot join an aggregate mid-cultivation cycle.

### 2.4.2.2 Leaving an Aggregate

Fields must meet the requirements in this section in order to leave or change aggregates and continue reporting emission reductions to the Reserve. In all cases, emission reductions must be reported for a complete cultivation cycle, as defined in Section 3.2, and no CRTs may be claimed for a field that does not participate and report data for a full cultivation cycle.

Project activities on an individual field may be terminated and the field may elect to leave the aggregate at any time.

Individual fields may elect to leave an aggregate and participate as a single-field project for the duration of their crediting period. To leave an aggregate and become a single-field project, the project participant must open a project developer account on the Reserve and submit a "Project Submittal Form" to the Reserve, noting both that it is a "transfer project" and the aggregate from where it transferred.

Fields can change aggregates during a crediting period if and only if:

1. The field changes ownership, tenant occupancy or management control during the crediting period and the new owner, tenant or manager has other fields already enrolled with a different aggregator, or
2. The original aggregate is terminated (e.g. goes out of business)
3. The aggregator breaches its contract with the project participant

Fields seeking to change aggregates during a crediting period under one of the above allowed circumstances must submit a "Project Aggregate Transfer Form" to the Reserve prior to enrolling in the new aggregate.

After completing the crediting period, a field may elect to enroll in a different aggregate when renewing for an additional crediting period.

### 2.4.3 Changes in Land Ownership, Management or Tenant Occupancy

A field in an aggregate may change ownership, tenant occupancy or management control during a crediting period, and remain in the project aggregate with uninterrupted crediting, if and only if the following criteria are met:

1. The contract with the project aggregator is transferred from the old to the new project participant.
2. The new project participant submits a "Field Management Transfer Form" to the Reserve via their project aggregator prior to the beginning of the subsequent cultivation cycle.
3. Implementation of the approved management practices continues without change until the end of the current reporting period.[15]

Where any of the criteria immediately above are not met, a field will forfeit the opportunity to generate CRTs for the cultivation cycle during which the ownership, tenant occupancy or management control change occurs. The field may re-enter the project aggregate at any time during the remainder of the five-year crediting period by fulfilling the three requirements above.

[15] See Section 5 for definition of reporting period.

# 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 | → | *No more than six months prior to project submission* |
| **Eligibility Rule III:** | Anaerobic Baseline Conditions | → | *Demonstrate baseline flooded rice cultivation practice* |
| **Eligibility Rule IV:** | Other Eligibility Conditions | → | *Demonstrate compliance with other eligibility criteria* |
| **Eligibility Rule IV:** | Additionality | → | *Meet performance standard* |
| | | → | *Exceed regulatory requirements* |
| **Eligibility Rule V:** | Regulatory Compliance | → | *Compliance with all applicable laws* |

## 3.1 Location

Projects must be located in approved rice growing regions for which the DNDC model has been validated against field measured methane emissions, and for which a regional performance standard has been developed and included in this protocol. Reductions from projects outside of the approved rice growing regions are not eligible to register with the Reserve at this time.

Rice Growing Regions

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. In the future, projects located in other parts of the United States or on U.S. tribal lands may be eligible to register reductions with the Reserve under this protocol as the DNDC model becomes validated in more regions.

High Carbon Content Soils

Nitrous oxide ($N_2O$) emissions are potentially more variable with increased soil carbon content. Because the DNDC model has not been validated on soils with SOC content, greater than 3 percent, fields that have soil with organic carbon content greater than 3 percent in the top 30 cm of soil are not eligible at this time. The organic carbon content of the field shall be determined by soil sampling or SSURGO data in accordance with Section 6.2.1.

## 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 modeling purposes, 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.

Each field has a unique start date, defined as the first day of a cultivation cycle during which one or more of the approved project activities is implemented at the field. This date may be chosen as any date on or after September 1, 2009 that coincides with the start of a cultivation cycle during which a project activity is implemented. If a field has previously implemented any approved project activities in the five cultivation cycles prior to the declared start date, these activities must be built into the baseline management scenario in accordance with the requirements in Section 5.1.1.1.

To be eligible, a field must submit as a single-field project or join an active or new aggregate before the end of the first cultivation cycle after the start date, unless the field is submitted during the first 12 months following the date of adoption of this protocol by the Reserve board (the Effective Date).[16] For a period of 12 months from the Effective Date of this protocol (Version 1.0), fields with start dates on or after September 1, 2009 are eligible to register with the Reserve if submitted by December 14, 2012. Fields with start dates prior to September 1, 2009 are not eligible under this protocol. Fields may always be submitted for listing by the Reserve prior to their start date.

## 3.3 Crediting Period

The crediting period for fields under this protocol is five years. The crediting period is renewable up to three times (for a potential of 20 years of crediting). During the last six months of a field's crediting period, project developers/aggregators may apply for a field's eligibility under a second, third or fourth crediting period. During a crediting period, project reporting for each field must be continuous with no gaps between reporting periods. Reporting periods in which a field does not meet the performance standard (see Section 3.5) or is not included in the pool of fields potentially selected for verification, for any number of reasons, still count towards the five-year crediting period. If a project developer wishes to apply for another crediting period, the project must meet the eligibility requirements of the most current version of this protocol, including any updates to the Performance Standard Test (Section 3.5.1).

Crediting periods do not apply to project aggregates, only to individual fields within a project aggregate and to single-field projects.

The Reserve will issue CRTs for GHG reductions quantified and verified according to this protocol for a maximum of four five-year crediting periods after the field's start date. Section 3.5.1 describes requirements for qualifying for a second, third, and fourth crediting period.

## 3.4 Anaerobic Baseline Conditions

All fields must demonstrate that previous rice cultivation practices prior to the field's start date resulted in anaerobic conditions. This requirement is met by demonstrating that:

1. Each individual rice field has been under continuous rice cultivation for five years preceding the field's start date, with no more than one fallow season; and

[16] Fields are considered submitted when the aggregator has fully completed and filed the appropriate Aggregate Submittal Form, or the New Field Enrollment form.

2. Each individual rice field was flooded for a period of at least 100 days during each growing season prior to the field's start date; and
3. Management records for each individual rice field are available for each of the five years preceding the field's 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

## 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 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. Although multiple fields are submitted together in the case of a project aggregate, each participating field must separately pass the Performance Standard Test, for each approved project activity that is implemented on the field, in order to be eligible.

The performance standard research, summarized in Appendix D, reviewed common water management, residue management, and other RC management practices in the approved rice growing region.[17] Based on the performance standard analysis, the Reserve has developed Performance Standard Tests for each approved project activity, as defined in Section 2.2.

Table 3.1 below provides the Performance Standard Test for each approved project activity.

[17] 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.

**Table 3.1.** Approved Project Activities

| Region | Approved Project Activity | Performance Standard Test | Justification |
|---|---|---|---|
| CA | Dry seeding (DS) | A rice field passes the Performance Standard Test by implementing a dry seeding technique combined with delayed flooding. | Research indicates that dry seeding is currently practiced on less than 3 percent of the CA rice acreage.[18] |
| | Post-harvest rice straw removal and baling (Baling) | A rice field passes the Performance Standard Test by implementing post-harvest rice straw "baling." | Research indicates that residue removal (baling) is currently very limited and variable, occurring on an estimated 2 to 7 percent of the CA rice acreage. Despite initiatives launched by state agencies and private partnerships, the market for rice straw has not grown as expected.[18] |

### 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, binding contractual obligations or other legally binding mandates (including, but not limited to, conservation management plans and deed restrictions) that require the adoption or continued use of any approved project activities on the project rice fields. Should a field initially pass the Legal Requirement Test, the field will be eligible to earn CRTs from a project activity for the remainder of the five-year crediting period, regardless of changes in legal requirements.

To satisfy the Legal Requirement Test, project developers must submit a signed Attestation of Voluntary Implementation form[19] or, for project aggregates, aggregators must submit a signed Attestation of Voluntary Implementation form on behalf of all project participants in the aggregate, prior to the commencement of verification activities each time the project aggregate is verified (see Section 8). Individual project participants who are part of a project aggregate will not be required to attest to the voluntary nature of project activities to the Reserve. However, supporting documentation should be made available to the verifier during verification, if requested. In addition, the Aggregate Monitoring Plan (Section 6.2) must include procedures that the aggregator will follow to ascertain and demonstrate that all fields in the project aggregate at all times pass the Legal Requirement Test. Similarly, the Single-Field Monitoring Plan (Section 6.1) must include procedures that the project developer will follow to ascertain and demonstrate that the project field at all times passes the Legal Requirement Test.

As of the Effective Date of this protocol, the Reserve could identify no existing federal, state or local regulations that explicitly obligate rice producers to adopt the project activities approved under this protocol.

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[18] See Appendix C for a summary of performance standard research.
[19] Form available at http://www.climateactionreserve.org/how/projects/register/project-submittal-forms/.

### 3.5.3 Ecosystem Services Payment Stacking

When multiple ecosystem services credits or payments are sought for a single activity on a single piece of land, it is referred to as credit stacking or payment stacking, respectively.[20]

As of the Effective Date of this protocol, the Reserve did not identify any ecosystem service markets besides the carbon market that issues credits for the project activities included in this protocol.[21] As such, credit stacking does not need to be addressed by this protocol at this time.

The USDA Natural Resources Conservation Service (NRCS) provides payments for ecosystem services through programs like the Environmental Quality Incentives Program and the Conservation Stewardship Program. These are federal programs that are implemented at the state and local level. In California, NRCS Conservation Practice Standard (CPS) 344A – *Residue Management, Seasonal Rice Straw Residue* provides assistance to farmers to reduce the amount of rice straw residues on their fields through a variety of methods, including baling the rice straw residue[22], and CPS 329 – *Residue and Tillage Management, No Till/Strip Till/Direct Seed* can provide support for dry seeding.[23]

CPS 344A and CPS 329 have primarily been used in California to fund other management practices besides baling and dry seeding.[24] Because baling and dry seeding are expensive, uncommon, and generally not already funded by NRCS programs, the use of NRCS payments to help finance either project activity under this protocol is allowed, except as specified below.

Stacking NRCS payments for baling under CPS 344A with CRTs for baling under this protocol is not allowed if a NRCS contract for baling on a project field was in place and the baling was completed prior to the project being submitted to the Reserve.

Stacking NRCS payments for dry seeding under CPS 329 with CRTs for dry seeding under this protocol is not allowed if dry seeding was specified in the conservation plan developed with NRCS for a project field and dry seeding was implemented prior to the project being submitted to the Reserve.

Note that if a field receives NRCS payments for any activity *other than* baling or dry seeding, those payments do not affect field eligibility, as the payments were awarded for different activities than those credited by this protocol and thus are not considered "stacked."

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[20] Cooley, David, and Lydia Olander (September 2011). "Stacking Ecosystem Services Payments: Risk and Solutions," Nicholas Institute for Environmental Policy Solutions, Duke University. NI WP 11-04. Available at: http://nicholasinstitute.duke.edu/ecosystem/land/stacking-ecosystem-services-payments/.

[21] The Reserve did identify a type of air quality offset that is issued in California under the Connelly-Areias-Chandler Rice Straw Phase-down Act of 1991 (Act); however, credits from the program are not issued for the project activities included in this protocol, but rather for reduced rice straw burning. The Reserve does not consider project participants receiving credits under both the Act and this protocol to be "stacking" credits.

[22] NRCS CPS 344A is available on the NRCS Field Officer Technical Guide website at http://efotg.sc.egov.usda.gov//efotg_locator.aspx. To find the appropriate standard, choose state, county, Section IV: Practice Standards and Specifications, and then the Conservation Practices folder.

[23] NRCS CPS 329 is available on the NRCS Field Officer Technical Guide website at http://efotg.sc.egov.usda.gov//efotg_locator.aspx. To find the appropriate standard, choose state, county, Section IV: Practice Standards and Specifications, and then the Conservation Practices folder.

[24] Personal communication with NRCS field personnel in California.

For informational purposes, any other type of ecosystem service payment or credit received for activities on a project field must be disclosed by the project developer/aggregator to the verification body and the Reserve.

## 3.6 Regulatory Compliance

As a final eligibility requirement, project developers/aggregators must attest that the field (or fields in the aggregate) are in material compliance with all applicable laws relevant to the project activities (e.g. air, water quality, water discharge, nutrient management, safety, labor, endangered species protection, etc.) prior to verification activities commencing each verification. Project developers/aggregators 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 field 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 on that field 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.

To satisfy this eligibility requirement, the project developer/aggregator must submit a signed Attestation of Regulatory Compliance form or an Attestation of Regulatory Compliance form on behalf of all enrolled project participants prior to the commencement of verification activities each time the project is verified. Individual project participants who are part of a project aggregate will not be required to attest to their status of regulatory compliance to the Reserve. However, the project developer is encouraged to have in place routine procedures for assessing field-level compliance. The verifier may request supporting documentation about the project developer’s procedures or about specific fields and such information should be made available to the verification body during verification, if requested.

### 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. The 1991 Act required a phase down of rice straw burning in the Sacramento Valley over a ten-year period, starting in 1992. Since September 2001, the Conditional Rice Straw Burn Permit Program has limited rice straw burning to less than 25 percent of an individual grower’s planted acreage, not to exceed 125,000 acres in the Sacramento Valley Basin. Initially, rice fields were only allowed to be burned for disease control, which required demonstration of the presence of significant levels of disease in order to secure a Conditional Rice Straw Burn Permit (“Burn Permit”). However, after 100 percent of rice fields were consistently found to have the “significant” level of disease, this requirement was eliminated. Today, rice producers must secure Burn Permits (for up to 25 percent of their rice acreage) in order to burn straw.[25]

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 California Air Resources Board or other appropriate agency. Wherever rice straw burning occurs, the project developer must

[25] Regulations establishing the Conditional Rice Straw Burning Program can be found in the California Code of Regulations, Title 17, § 80156. More information can also be found on the California Air Resources Board webpage at: http://www.arb.ca.gov/smp/rice/condburn/condburn.htm

demonstrate that the amount of burning was within legal limits, if legal limits exist such as in California, and that all necessary permits have been secured.

Burning of rice straw is assumed to be an activity that will occur 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; although 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.

### 3.6.2 Regulations on Special-Status Species

Regulations exist at the federal, state, and local level 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 U.S. Fish and Wildlife Service works with private landowners to develop Habitat Conservation Plans (HCPs) and Safe Harbor Agreements (SHAs). When in effect on a rice field,, an HCP or SHA should be considered a legally binding mandate. Project developers/aggregators should disclose to the verifier any instances of which they are aware when a field is not in compliance with HCP or SHA requirements.”

# 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 rice cultivation (RC) project.[26]

The GHG Assessment Boundary encompasses all the GHG SSRs that may be significantly affected by project activities, including sources of $CH_4$ and $N_2O$ emissions from the soil, biological $CO_2$ emissions and soil carbon sinks, and fossil fuel combustion GHG emissions. For accounting purposes, the SSRs 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 $CH_4$ reduction) or its "secondary effects" (i.e. unintended changes in carbon stocks, $N_2O$ emissions, or other GHG emissions).[27] 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 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 RC Project 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 $CO_2$ (biogenic), $CH_4$, $N_2O$, and changes in soil carbon stocks. GHG flux rates from soils 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 $CH_4$ emissions from soil due to reduced flooding and/or reduced organic residues available for decomposition. |
| | | $N_2O$ | I | Direct: DNDC<br>Indirect: DNDC and IPCC Emission Factors | A significant source affected by project activities if fertilizer application amounts and/or dates are changed, or seeding practice is altered. Increases in direct and/or indirect $N_2O$ must be accounted for. |

[26] The definition and assessment of sources, sinks, and reservoirs (SSRs) is consistent with ISO 14064-2 guidance.
[27] 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 |
|---|---|---|---|---|---|
| **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 or not impact the quantity of water used during the cultivation process as compared to baseline management. |
| | | $CH_4$ | 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 increases from equipment used for field preparation, seeding, fertilizer/pesticide/herbicide application, and harvest | $CO_2$ | I | Emission Factors | Emissions 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. Nitrogen Fertilizer | GHG emissions from synthetic N fertilizer production | $CO_2$ | E | N/A | Excluded, the very small increase in fertilizer demand due to RC projects is unlikely to have an effect on fertilizer production. |
| | | $CH_4$ | E | N/A | Excluded, as this emission source is assumed to be very small |
| | | $N_2O$ | E | N/A | Excluded, the very small increase in fertilizer demand due to RC projects is unlikely to have an effect on fertilizer production. |
| 5. Herbicide | Fossil fuel emissions from Herbicide production | $CO_2$ | E | N/A | Excluded, the very small increase in herbicide demand due to RC projects is unlikely to have an effect on herbicide production. |
| | | $CH_4$ | 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 |
| 6. Crop Residue Baling | Fossil fuel emissions from baling and transportation of baled rice straw for offsite use/management | $CO_2$ | I | Baling Emission Factors | Emissions 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. |
| 7. Crop Residue Management | Fugitive emissions from aerobic or semi-anaerobic rice straw management (onsite or offsite) | $CO_2$ | E | N/A | Biogenic emissions are excluded. |
| | | $CH_4$ | I | Emission Factors | May be a significant source of fugitive $CH_4$ emissions, depending on management/use of rice straw. |

| SSR | Source Description | Gas | Included (I) or Excluded (E) | Quantification Method | Justification/Explanation |
|---|---|---|---|---|---|
| | | $N_2O$ | E | N/A | Due to low N content of rice straw, changes in $N_2O$ emissions from alternative rice straw management are likely insignificant. |
| 8. GHG Emissions from Shifted Production (Leakage) | If project activity results in 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 fields in an aggregate 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

GHG emission reductions from an RC project are quantified by comparing actual project emissions to baseline emissions from rice cultivation. Baseline emissions are an estimate of the GHG emissions from sources within the GHG Assessment Boundary (see Section 4) that would have occurred in the absence of an RC project. Project emissions are actual GHG emissions that occur at sources within the GHG Assessment Boundary. Project emissions must be subtracted from the baseline emissions to quantify the project total net GHG emission reductions. GHG emission reductions are calculated for each individual field and summed together over the entire project area. The calculation approach in this section is applicable to single-field projects and aggregates.

Project emission reductions must be quantified and verified on an annual basis. The length of time over which GHG emission reductions are quantified and verified is called the "reporting period." For an aggregate, the individual fields will likely have cultivation cycles that start on different dates, and the length of the cultivation cycle may be slightly more or less than a full 365 days on each individual field. Therefore, the reporting period must be uniformly defined for the aggregate for reporting purposes. Thus, for reporting reductions from each cultivation cycle to the Reserve, the aggregate reporting period shall be defined as starting on October 1 and ending on September 31 of the following year. This defined reporting period is for reporting purposes only, the calculation of the emission reductions for the aggregate over a reporting period must include the emission reductions achieved over the complete cultivation cycle for each participating field in the aggregate.

For single field projects, the reporting period shall be defined using the exact dates corresponding to the beginning and the end of the cultivation cycle for the particular field.

The primary effect 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 with delayed flood), 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 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 baseline and project emissions from soil dynamics (SSR 1) defined in Section 4. In addition, the DNDC model provides estimates of nitrate leaching, and ammonia and nitric oxide emissions that are used to estimate the changes in indirect $N_2O$ emissions associated with an RC project. If emissions of $N_2O$ (both direct and indirect) increase or soil organic carbon (SOC) decreases due to project activity, these emissions must be deducted from the emission reduction estimate. If $N_2O$ (direct or indirect) emissions are reduced or SOC increased due to the project activity, these changes must be excluded from the emission reduction estimate. 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 in unintended project increases of GHG emissions from other secondary SSRs. Section 5.2 provides requirements for calculating those secondary GHG emissions resulting from the project activity.

Total emission reductions from a field are equal to 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.

**Equation 5.1.** Calculating GHG Emission Reductions

$$ER = MPER - SE$$

| *Where,* | | | Units |
|---|---|---|---|
| ER | = | The total emission reductions from the project area for the reporting period | $tCO_2e$ |
| MPER | = | The total modeled GHG emission reductions from soil dynamics (SSR 1) from the entire project aggregate during the reporting period, as calculated in Section 5.1) | $tCO_2e$ |
| SE | = | The total secondary effect GHG emissions caused by project activity during the reporting period for the entire project aggregate (as calculated in Section 5.2) | $tCO_2e$ |

## 5.1 Modeling Primary Effect 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.[28] A separate and complete model run must be performed for each individual rice field in an aggregate.

Under this methodology, aggregation of multiple rice fields is encouraged because 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. The uncertainty adjustment factors (presented in Section 5.1.7.1 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 aggregate.

Section 5.1.1 through Section 5.1.7 provides the quantification approach for determining the total primary modeled emission reductions for each rice field.

### 5.1.1 Parameterizing the DNDC Model

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 a separate input parameter file (*.dnd) for the baseline scenario and the project scenario. The difference between the two emissions estimates (after accounting for input uncertainty) is the total emission reductions achieved from the project activity at the field. The modeling runs are performed for an entire cultivation cycle to get net reductions for the field over the reporting period.

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

Model inputs are classified into two categories: project inputs and static inputs. The project inputs are those that relate to the management parameters that are being changed as a result of the project activity (i.e. seeding practices and/or residue management practices). The project 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 "static inputs" because once determined for a field for a given cultivation cycle, these inputs must remain unchanged when modeling baseline versus project emission scenarios over the cultivation cycle.

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

#### 5.1.1.1 Determining Baseline Scenario Inputs

To define a baseline scenario for a field, it is necessary to assign values to each of the inputs related to the baseline water, residue, seeding, and fertilizer management. These project inputs make up what is referred to as the "baseline scenario" for each field. Once the baseline project 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.

The following project inputs must be set individually for each rice field included in the project area using field-level management records going back a full five years (five cultivation cycles) prior to the field start date. To set the baseline scenario inputs for each cultivation cycle of the crediting period, the project must use the field management records correspond to the management data from five years prior. Thus, the first cultivation cycle's baseline scenario corresponds to the fifth year prior to the start date, the second cultivation cycle's baseline scenario corresponds to the fourth year prior to the start date, and so on.

**Table 5.1.** Determining Baseline Project Inputs

| Baseline Practice | Project 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 |
| Fertilizer | Dates of all fertilizer applications |
| | Rate, type of fertilizer and application method for each fertilizer application |
| Tillage | Dates and depth of all tillage events for preparing the fields for planting and post-harvest residue management |

#### 5.1.1.2 Static Input Parameters

Static inputs are those that, while absolutely necessary for complete modeling, are not directly related to project activities. All static inputs should be based on actual field-level data for each cultivation cycle (unless otherwise specified), and must be the same when modeling baseline versus project emissions for a specific cultivation cycle.

### Climate Input Parameters

Seasonal weather can significantly affect methane emissions and, hence, the reduction in methane emissions due to project activities. 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, or the nearest station to the field if there are none within 20 miles. 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 20-year historic period modeling run (see Section 5.1.2) must be set by repeating this five-year weather data set four times. 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 wind speed must be collected and formatted according to DNDC's climate file mode 1 format (Table 5.2 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 |
| Wind speed (daily average) | meters/second/day |

### Management Input Parameters

All static management input parameters must be set for each cultivation cycle based on actual data as they are assumed to have been identical regardless of the existence of the project activity. As with all other static 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 variables in Table 5.3 must be collected for each cultivation cycle during the crediting period.

**Table 5.3.** Static Management Parameters

| Input Parameters | Unit |
|---|---|
| Date of pre-planting field preparation | Date |
| Planting date | Date |
| Fertilization amounts and dates, and type of fertilizer used after seeding prior to harvest | Pounds (lbs) per acre, date, type (e.g. nitrate, ammonium, or urea) |
| Rice Straw Fraction Burned | Fraction of total (by area or weight) |
| Harvesting date | Date |
| Winter Flooding Practices | Dates of winter flooding events (single or maintenance) relative to harvest dates |

### Determining Field Soil Input 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 (top 5 cm)
- Soil texture

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

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. Figure 5.1 below illustrates this concept for a rice field in Yolo County.

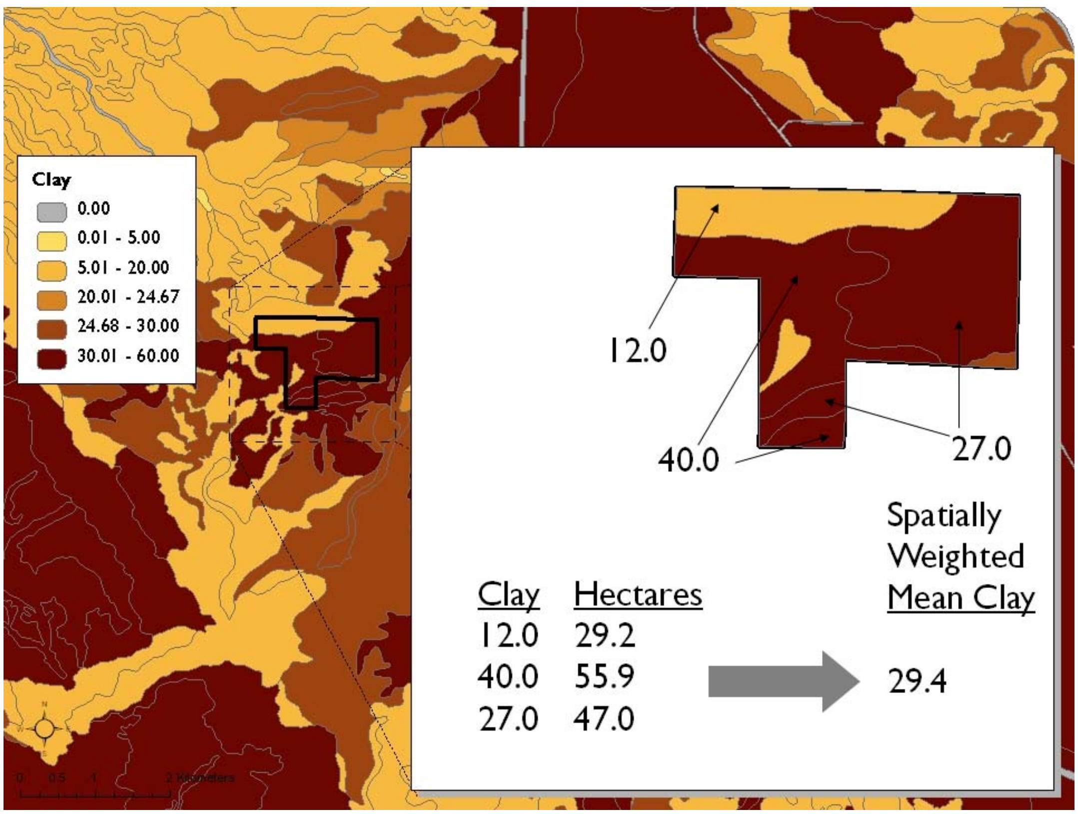



**Figure 5.1.** Example of Soil Parameter Area-Weighting using SSURGO Data

### Soil Sampling Requirements:

DNDC requires inputs of soil organic carbon content of the top 5 cm and soil bulk density, pH and clay fraction of the top 10 cm. If collecting samples for analysis (i.e. not using SSURGO data), the following procedure must be used for each field:

- Samples must be collected at two depth increments: 0-5 cm and 0-10 cm
- Samples must be collected using a core method
- 20 samples must be collected for the entire field (see Box 5.1 for derivation), 16 samples at 0-5 cm depth, and four samples at 0-10 cm depth
- To ensure spatial independence of soil properties, use a random sampling pattern
- Samples should be combined together by depth (i.e. samples from 0-5 cm combined and samples from 5-10 cm combined)
- The GPS coordinates and depth at each sampling location must be recorded
- The combined 0-5 cm samples must be tested for all parameters
- The combined 0-10 cm samples must be tested for soil bulk density, pH, and clay fraction
- Soil samples must be analyzed by a certified soil laboratory

A suggested mass of soil of at least 500 g should be collected from each depth for the initial i.e. time zero sampling. Future soil sample mass can be adjusted for the assessments being conducted.

Soil samples should be kept cool in the field and during transport. Samples should be maintained at 4°C as much as possible during processing. Samples should be sent to a soil lab for measurement of SOC, clay fraction, pH and bulk density.

For each field sampling event, a Soil Sampling Log must be developed, including the following information:

- Date of sampling event
- Description of the core method and compositing procedure
- The GPS coordinates of each sampling location
- The core depth of each sample
- The name/address of the third-party soil sampling contractor (if applicable)
- The name/address of the certified soil laboratory used for analysis

**Box 5.1.** Derivation of the Required Number of Samples

The standard goal of collecting field data on soil properties is to have a sufficient number of soil samples so the soil conditions can be estimated within 10% of the actual mean value with a 90% level of confidence. Most soil chemical and physical properties are not normally distributed, but log-normally distributed. The number of samples required to achieve a given confidence level (e.g. 90%) and acceptable error (10%) was calculated as follows for the necessary soil parameters:[29]

**Using the following equation:**

$$\boldsymbol{n = \frac{t^2 \times C^2}{E^2}}$$

*Where*,

| | | |
|---|---|---|
| n | = | Number of soil samples for a field |
| t | = | Student's t-statistic that is for a 90% confidence interval |
| C | = | Coefficient of variation (standard deviation divided by the mean) |
| E | = | Acceptable error, a value of 10% must be used |

As a rule of thumb the coefficient of variation (%CV) for soil organic carbon and texture are 0.2 and 0.1, respectively. We can assume there is less variation in bulk density and pH in fields that are managed homogeneously. For a 90% confidence interval the t-statistic is 1.96. So with an acceptable error of 10%, one would need to collect 16 samples at the 0-5cm depth (using the 0.2 CV value for SOC) and 4 samples at 5-10cm depth (using CV of 0.1 for texture).

### 5.1.2 Historical Modeling Run and Crop Yield Calibration

Prior to modeling baseline and project emissions for the first cultivation cycle for each field, the DNDC model must be run using baseline input data for a 20-year period prior to the field start date. This is a necessary step in order for the model to attain equilibrium in certain critical variables for which empirical data are lacking, such as the sizes and 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 (see discussion below). Table 5.4 provides the schematic for the modeling period for each field.

[29] Boone et al. 1999

**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 | Crediting Period 1 | Crediting Period 2 |

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

### Crop Model Calibration

Proper parameterization of soil physical conditions (which drive soil moisture dynamics) and crop simulation play 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 soil carbon dynamics and $CH_4$ and $N_2O$ emissions. Users shall calibrate the DNDC crop model for cropping systems to be included in the project. Figure 5.2 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 in Figure 5.2 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.
- ***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 set in the model based on historical yields. 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 with a maximal relative Root Mean Squared Error (RMSE) of 10 percent of the observed mean.

However, project aggregators must demonstrate that DNDC has been properly calibrated to each field using actual site conditions. At least five years of observed crop yields should be used for maximum grain yield (kg C/ha), biomass fraction (% grain and % leaves+stems), and biomass C/N ratio for grain, leaves+stems, and roots. The steps for crop calibration are outlined below and shown in Figure 5.2.

To carry out the crop calibration process, the user must use the following steps for the single year out of the last five that had the maximum observed rice yield.

1. **Adjust maximum biomass parameter**:
    a. Enter observed maximum biomass and fraction for grain, leaves+stems and root;[30]
    b. Provide more than adequate fertilization (i.e. 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 percent:
        i. If the difference is greater than 10 percent and the modeled grain yield is less than the actual yield, increase the maximum biomass parameter;
        ii. If the difference is greater than 10 percent and the modeled grain yield is greater than the actual yield, decrease the maximum biomass parameter.

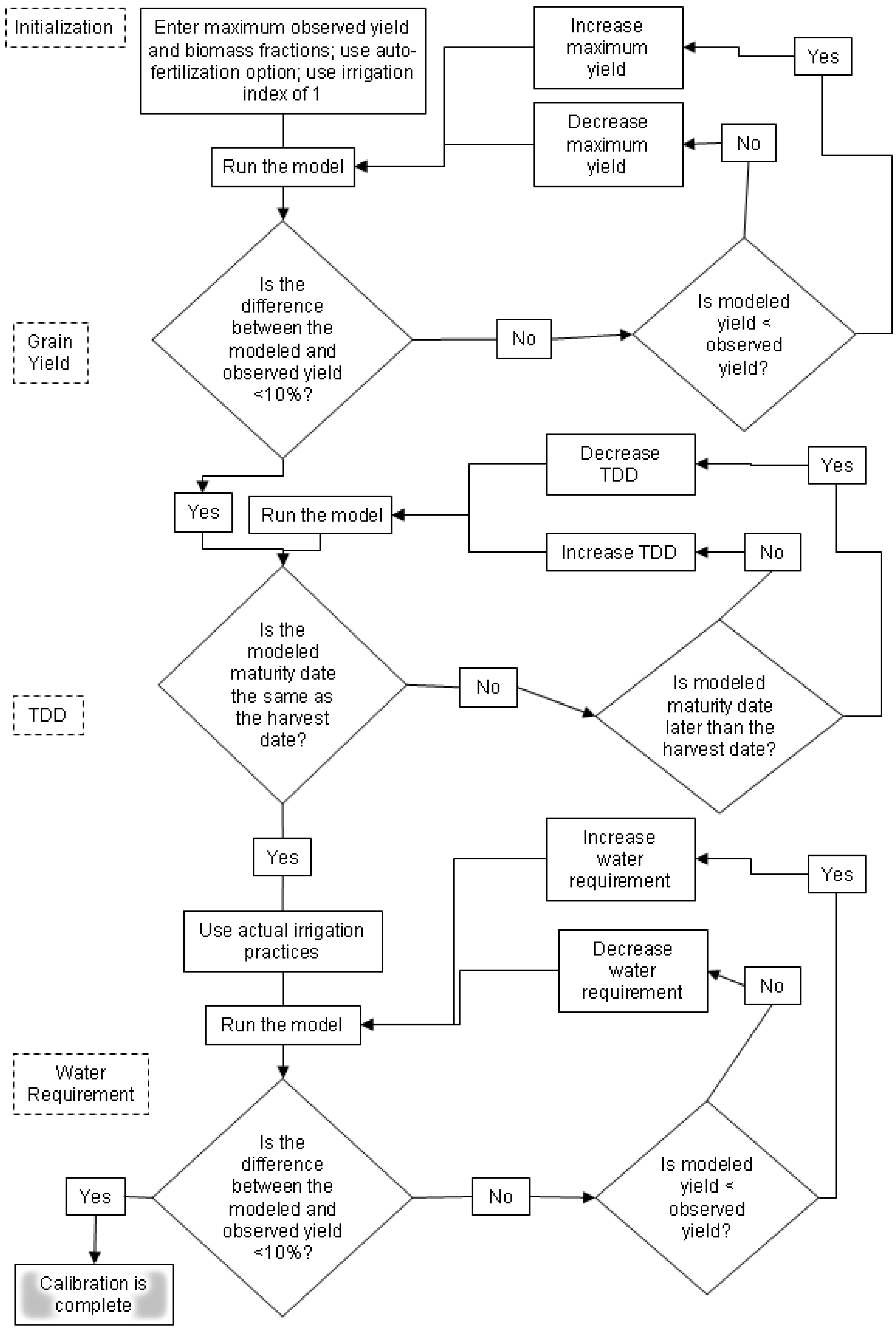
2. **Adjust cumulative thermal degree days (TDD)**: Check the modeled maturity date which can be found in the "Day_FieldCrop.csv" file.[31] The last column of this file, "GrainC," shows daily grain weight (kg C/ha); the maturity date can be inferred by checking the last day where there is an increase 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;
    b. If the modeled yield/biomass is higher than observed yield/biomass, increase the water requirement value.

Figure 5.2 below illustrates this calibration process.

[30] Biomass fraction and C/N ratios are typically constant for a cultivar, so if this data are not available for the farm to be modeled, the information can usually be acquired from the local university extension.
[31] 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 Graphical User Interface (GUI).

**Figure 5.2.** Flow Chart for Calibrating the DNDC Model



### 5.1.3 Monte Carlo Simulations to Account for Soil Input Uncertainty

Soil physical and chemical properties have a significant impact on $CH_4$ and $N_2O$ production, consumption, and emissions. Project aggregators 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 percent of the mean at a 90 percent confidence level. The distribution of the field values shall be assumed to be normally distributed.

If NRCS SSURGO soil survey data[32] 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 5.5. 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.[33]

**Table 5.5.** Uncertainty Estimates and Probability Distribution Functions for Soil Parameters

| 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 |

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

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). The soil parameter combination will be a random selection for each parameter based on the Probability Density Function (PDF) and uncertainty estimates (derived from field measurements). From the Monte Carlo runs, the uncertainty deduction for input uncertainty is calculated as the half-width of the 90 percent confidence interval.

### 5.1.4 Modeling Field Level Baseline Emissions

The baseline GHG emissions ($GHG_{BSL,j,i}$) for each field *i* will be determined by performing a Monte Carlo simulation with 2,000 DNDC simulations using project input parameters determined in the baseline scenario, and static inputs based on actual data for the cultivation cycle.

Because of the uncertainty of input soil parameters (Table 5.5), DNDC must 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 cultivation cycle for the field. The Monte Carlo runs will be accomplished by running DNDC in batch mode with each entry in the batch file list representing a separate Monte Carlo run (see *DNDC User's Guide*[34] 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 direct GHG emission

[32] See http://soils.usda.gov/survey/geography/ssurgo/.
[33] Polygon GIS layers are linked to attribute tables via an attribute called MUKEY.
[34] Available on the Reserve website.

parameters ($N_2O$, $CH_4$, and SOC content), and the indirect parameters ($NO_3$ and $NH_3$+$NO_x$), for each Monte Carlo run *j* in each field *i*.

**Table 5.6.** Extracted Baseline Parameters

| Extracted Parameter | | | Units |
|---|---|---|---|
| $N_2O_{Dir,BL,j,i}$ | = | Baseline $N_2O$ emissions from rice field *i* from Monte Carlo run *j* | kg $N_2O$-N/ha |
| $N_{Leach,BL,j,i}$ | = | Baseline nitrate leaching loss from rice field *i* from Monte Carlo run *j* | kg $NO_3$-N/ha |
| $N_{Vol,BL,j,i}$ | = | Baseline ammonia volatization and nitric oxide emissions from rice field *i* from Monte Carlo run *j* | kg $NH_3$-N + kg $NO_x$-N /ha volatized |
| $CH_{4\ BL,j,i}$ | = | Baseline $CH_4$ emissions from rice field *i* from Monte Carlo run *j* | kg $CH_4$-C/ha |
| $SOC_{BL,j,i}$ | = | Baseline soil organic carbon content of rice field *i* from Monte Carlo run *j* | kg SOC-C/ha |

Using all the extracted parameters, calculate total average baseline GHG emissions in kg $CO_2$e/ha for field *i* for all Monte Carlo runs *j*. See Equation 5.2 below.

**Equation 5.2.** Average GHG Emissions from Monte Carlo Runs for Field *i*

$$N_2O_{BL,i} = \frac{\sum_{j=1}^{N}\{(N_2O_{Dir,BL,j,i} + (N_{Leach,BL,j,i} \times EF_5) + (N_{Vol,BL,j,i} \times EF_4)\}}{n} \times \frac{44}{28} \times 310$$

$$CH_{4_{BL,i}} = \frac{\sum_{j=1}^{N}\left(CH_{4_{BL,j,i}}\right)}{n} \times \frac{16}{12} \times 21$$

$$SOC_{BL,i} = \frac{\sum_{j=1}^{N}\left(SOC_{BL,j,i}\right)}{n} \times \frac{44}{12}$$

*Where,*

| | | | Units |
|---|---|---|---|
| j | = | *1, 2, 3 … n* Monte Carlo runs | |
| $N_2O_{BL,i}$ | = | Annual baseline direct and indirect $N_2O$ emissions from rice field *i*, equal to the average of the values of all Monte Carlo runs *j* | kg $CO_2$e/ha |
| $EF_5$ | = | Emission factor for $N_2O$ emissions from N leaching and runoff. Equal to **0.0075**[35] | kg $N_2O$-N / kg $NO_3$-N |
| $EF_4$ | = | Emission factor for $N_2O$ emissions from atmospheric deposition of N on soils and water surfaces and subsequent volatization. Equal to **0.01**[36] | kg $N_2O$-N / (kg $NH_3$-N + kg $NO_x$-N) |
| $CH_{4,BL,i}$ | = | Annual baseline $CH_4$ emissions from rice field *i*, equal to the average of the values for all Monte Carlo runs *j* | kg $CO_2$e/ha |
| $SOC_{BL,i}$ | = | Annual baseline Soil Organic Carbon content of rice field *i*, equal to the average of the values for all Monte Carlo runs *j* | kg $CO_2$e/ha |

35 IPCC Guidelines for National GHG Inventories (2006), Vol.4 Ch.11 Table 11.3

### 5.1.5 Modeling Field Level Project Emissions

The project GHG emissions ($GHG_{P,j,i}$) in each field *i* for each Monte Carlo run *j* will be determined by running DNDC based on actual project input data. For the field being modeled, the project inputs should be adjusted to represent the project activities that occurred on the field during the cultivation cycle, and the static inputs must not change from the baseline model for the cultivation cycle. Based on the uncertainty of input soil parameters quantified in Section 5.1.3, DNDC will again be run through a Monte Carlo analysis for project emission calculations. The duration of each Monte Carlo run should be the same as the duration of the cultivation cycle for the field. The Monte Carlo runs will be accomplished by running DNDC in batch mode with each entry in the batch file list representing 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 direct GHG emission parameters ($N_2O$, $CH_4$, and SOC content), and the indirect parameters ($NO_3$ and $NH_3$+$NO_x$), for each Monte Carlo run *j* in each field *i*.

**Table 5.7.** Extracted Project GHG Emissions, SOC content, Ammonia and Nitric Oxide, and Nitrate Leaching

| *Extracted Parameter* | | | Units |
|---|---|---|---|
| $N_2O_{Dir,P,j,i}$ | = | Project $N_2O$ emissions from rice field *i* from Monte Carlo run *j* | kg $N_2O$-N/ha |
| $N_{Leach,P,j,i}$ | = | Project nitrate leaching loss from rice field i from Monte Carlo run *j* | kg $NO_3$-N/ha |
| $N_{Vol,P,j,i}$ | = | Project ammonia volatization and nitric oxide emissions from rice field *i* from Monte Carlo run *j* | kg $NH_3$-N + kg $NO_x$-N /ha volatized |
| $CH_{4\ P,j,i}$ | = | Project $CH_4$ emissions from rice field *i* from Monte Carlo run *j* | kg $CH_4$-C/ha |
| $SOC_{P,j,i}$ | = | Project soil organic carbon content of rice field *i* from Monte Carlo run *j* | kg SOC-C/ha |

Using the extracted parameters, calculate total average project GHG emissions in kg $CO_2$e/ha for field *i* for all Monte Carlo runs *j*. See Equation 5.3 below.

**Equation 5.3.** Average GHG Emissions from Monte Carlo Runs for Field *i*

$$N_2O_{P,i} = \frac{\sum_{j=1}^{N}\{(N_2O_{Dir,P,j,i} + (N_{Leach,P,j,i} \times EF_5) + (N_{Vol,P,j,i} \times EF_4)\}}{n} \times \frac{\mathbf{44}}{\mathbf{28}} \times \mathbf{310}$$

$$CH_{4_{P,i}} = \frac{\sum_{j=1}^{N}\left(CH_{4_{P,j,i}}\right)}{n} \times \frac{\mathbf{16}}{\mathbf{12}} \times \mathbf{21}$$

$$SOC_{P,i} = \frac{\sum_{j=1}^{N}\left(SOC_{P,j,i}\right)}{n} \times \frac{\mathbf{44}}{\mathbf{12}}$$

*Where,*

| | | | Units |
|---|---|---|---|
| j | = | *1, 2, 3 … n* Monte Carlo runs | |
| $N_2O_{P,i}$ | = | Annual project direct and indirect $N_2O$ emissions from rice field *i*, equal to the average of the values of all Monte Carlo runs *j* | kg $CO_2$e/ha |
| $EF_5$ | = | Emission factor for $N_2O$ emissions from N leaching and runoff. Equal to **0.0075**[36] | kg $N_2O$-N / kg $NO_3$-N |
| $EF_4$ | = | Emission factor for $N_2O$ emissions from atmospheric deposition of N on soils and water surfaces and subsequent volatization. Equal to **0.01**[36] | kg $N_2O$-N / (kg $NH_3$-N + kg $NO_x$-N) |
| $CH_{4,P,i}$ | = | Annual project $CH_4$ emissions from rice field *i*, equal to the average of the values for all Monte Carlo runs *j* | kg $CO_2$e/ha |
| $SOC_{P,i}$ | = | Annual project Soil Organic Carbon content of rice field *i*, equal to the average of the values for all Monte Carlo runs *j* | kg $CO_2$e/ha |

### 5.1.6 Adjusting Field Model Results for Soil Input Uncertainty

The Monte Carlo analysis performed for the baseline and project GHG modeling must be used to calculate an input uncertainty deduction for each field in order to adjust for model uncertainty due to soil input uncertainties. The input uncertainty ($\mu_{inputs,i}$) for greenhouse gas emissions due to uncertainty in soil input parameters for field *i* shall be calculated as the half-width of the 90 percent confidence interval of the modeled reductions, where the modeled reductions for each Monte Carlo run *j* are calculated as:

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

The deductions for input uncertainty are applied effectively at the field level as shown in Equation 5.4 below.

[36] IPCC Guidelines for National GHG Inventories (2006), Vol.4 Ch.11 Table 11.3.

### 5.1.7 Calculation of GHG Emission Reductions for the Project

The total primary effect greenhouse gas emission reductions ($tCO_2e$) for an entire project aggregate are calculated in Equation 5.4.

**Equation 5.4.** Total Primary Effect GHG Emission Reductions for the Project

$$MPER = \mu_{struct} \times \sum_{i=1}^{m} \mu_{inputs\_i} \times (MPER_i)$$

*Where,* Units

| | | | |
|---|---|---|---|
| MPER | = | Modeled primary effect GHG emission reductions over the entire project area | $tCO_2e$ |
| $\mu_{struct}$ | = | Accuracy deduction from model structural uncertainty (% reduction), values available on Reserve website | |
| 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) | |
| $MPER_i$ | = | Modeled primary effect GHG emission reductions for field *i* * | |

$$MPER_i = \frac{\left\{(N_2O_{BL,i} - N_2O_{P,i}) + (CH_{4_{BL,i}} - CH_{4_{P,i}}) - (SOC_{BL,i} - SOC_{P,i})\right\}}{1000} \times Area_i$$

*Where,* Units

| | | | |
|---|---|---|---|
| $Area_i$ | = | The area of the rice field *i* in hectares | ha |

***** In order to ensure that only reductions in $CH_4$ are credited on each field, the term ($N_2O_{BL,i}$ – $N_2O_{P,i}$), and($SOC_{BL,i}$ – $SOC_{P,i}$) must be set equal to zero if they are > 0. As an example, if both $N_2O$ and SOC terms are > 0 for a particular field *i*, then the Modeled Primary Emission Reductions for that field are equal to the $CH_4$ reductions only: $MPER_i$ = {($CH_{4\ BL,i}$ – $CH_{4\ P,i}$) /1000 x Area} in this case.

#### 5.1.7.1 Structural Uncertainty Adjustments

Inherent in biogeochemical models, like DNDC, are uncertainties due to imperfect science in the models. This uncertainty is often referred to 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 measurements can have sources of uncertainties in practice). Appendix C provides thee structural uncertainty derivation procedure developed to adjust DNDC results for model structural uncertainty. To ensure conservativeness in estimates of project emission reductions, all project aggregates must use the adjustments provided by the Reserve to account for structural uncertainty in the DNDC model, as specified in Equation 5.4.

Because there is ongoing field research actively collecting GHG emissions data for California rice, new data may become available for model validation. Periodically, as data become available, the calculation of model structural uncertainty and the table of structural uncertainty factors will be updated. The most up-to-date factors will be provided on the Reserve website as soon as they're available. All RC project fields reporting to the Reserve must use the uncertainty deduction factor for the reporting year as published on the Reserve website for determining $\mu_{struct}$ at the time of verification.

## 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 5.5, the total secondary effect GHG emissions are equal to:

- Increased $CO_2$ emissions from mobile combustion of fossil fuels by farm equipment used for field preparation, seeding, and cultivation (SSR 3), plus
- $CO_2$ emissions from transport and processing of rice straw residues (SSR 6), and methane emissions from aerobic or semi-anaerobic treatment/use of baled rice straw residue (SSR 7), plus
- Emissions of $CH_4$ and $CO_2$ due to shifted rice production outside the project boundary (SSR 8)

**Equation 5.5.** Total Secondary Effect Emissions from Project Activity for the Project Aggregate

$$SE = \sum_{i} (SE_{FF,i} + SE_{RM,i}) + SE_{PS}$$

*Where,*

| | | | Units |
|---|---|---|---|
| $SE_{FF,i}$ | = | The total secondary effect GHG emissions from increased fossil fuel combustion for field *i*, as calculated in Section 5.2.1 | $tCO_2e$ |
| $SE_{RM,i}$ | = | The total secondary effect GHG emissions from alternative residue management for field *i*, as calculated in Section 5.2.2 | $tCO_2e$ |
| $SE_{PS}$ | = | The total secondary effect GHG emissions for the project aggregate from production shifting outside of the project boundary, as calculated in Section 5.2.3 | $tCO_2e$ |

### 5.2.1 Project Emissions from Onsite Fossil Fuel Combustion (SSR 3)

Included in the GHG Assessment Boundary are secondary $CO_2$ emissions resulting from increased fossil fuel combustion for onsite equipment used for performing RC management activities related to seeding, fertilizer application, and herbicide application. Fossil fuel emissions from baling rice straw are incorporated into the emission calculation in Section 5.2.2 below and are not to be included when quantifying increased fossil fuel emissions per this section.

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 using Equation 5.6 below.

**Equation 5.6.** Project Carbon Dioxide Emissions from Fossil Fuel Combustion

$$SE_{FF,i} = \frac{\sum_i (FF_{PR,t} \times EF_{FF,t})}{1000}$$

| *Where,* | | | Units |
|---|---|---|---|
| $FF_{PR,t}$ | = | Total increase in fossil fuel combustion for field *i* during the reporting period, by fuel type *t* | volume fossil fuel |
| $EF_{FF,t}$ | = | Fuel-specific emission factor | kg $CO_2$/volume fossil fuel |
| 1000 | = | Kilograms per tonne | kg $CO_2$/t$CO_2$ |

### 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. Because the swathing, raking, and baling services are most often performed by third-party contractors, fossil fuel emissions from the swathing, raking, and baling process are estimated using conservative default factors.

For calculating the emissions from rice straw management and/or use, emission factors were developed for the following identified end-uses:[37]

- **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. 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 with 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. Cattle ranchers spread the large bales out on the range in fall and allow the cattle to feed on the bales. Quality of the straw (crude protein content, moisture content, etc.) must meet minimal standards before it can be used. There may be some effects on enteric fermentation by feeding lower quality straw.

- **Fiberboard manufacturing**: Rice straw may be used as an alternative to wood products for the manufacturing of fiberboard. The avoided emissions from harvest and transport of wood products very likely outweigh emissions from transporting rice straw.

- **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 like wheat or barley straw. When used for erosion control,

[37] End-uses and descriptions referenced from ANR, 2010.

rice straw will decompose aerobically because it is spread out on top soil, ensuring an oxygen rich environment during decomposition.

- **Other uses**: Rice straw may be used in small quantities for other uses, such as animal bedding, being stuffed into netted rolls for soil loss prevention, or for use in mushroom farming (among other potential uses). Because of a lack of detailed emissions data, straw that is sent to an end-use other than those specified above must use the default emission factor for 'unknown or other' end-uses in Appendix A.

Each field must use Equation 5.7 to calculate the project $CH_4$ emissions from the end-use of all baled rice straw. Because growers may not be able to track the end fate for some or all of the field rice straw, a conservative default factor can be used in place of an end-use specific default factor. If electing to use end-use specific factors, the project developer must collect and retain straw sales documentation to demonstrate rice straw end-use(s). See Section 6.4.3 for detailed baling monitoring requirements.

Projects must use the emission factor in Table A.1 in Appendix A corresponding to the appropriate end-use, or the default factor. If rice straw is unused and accumulates in piles on or near the field, the portion of rice straw that is left unused must be estimated, and the default factor for unused rice straw must be used to quantify the emissions from this source.

**Equation 5.7.** Emissions from Rice Straw End-Use

$$\boldsymbol{SE_{RM,i}} = (\boldsymbol{W_{RS,i}} \times \boldsymbol{EF_{SWB}}) + \sum_{\boldsymbol{U}} [\boldsymbol{W_{RS,U}} \times \boldsymbol{EF_U}]$$

*Where,*

| | | | Units |
|---|---|---|---|
| $W_{RS,i}$ | = | The total weight of rice straw in dry tonnes that is swathed, raked, and baled on the field *i* | dry tonne |
| $EF_{SWB}$ | = | The emission factor for increased fossil fuel emissions from swathing, raking, and baling. The emission factor shall be equal to 0.01 for all fields[38] | $tCO_2e$ / dry tonne |
| $W_{RS,U}$ | = | The weight of rice straw in dry tonnes with end-use *U*. The sum weight of rice straw for all end-uses must equal the total weight of rice straw baled on the field | dry tonne |
| $EF_u$ | = | The emission factor from Table A.1 in Appendix A for end-use *U* | $tCO_2e$ / dry tonne |

### 5.2.3 GHG Emissions from the Shift of Rice Production Outside of Project Boundaries

If rice yields decrease as a direct result of project activity, to be conservative it is assumed that the decrease in rice production causes a net increase in production elsewhere outside the project boundary. The emissions associated with this shift in production must be estimated if

[38] Emissions from swathing, raking, and baling the rice straw are likely to be similar to emissions from the avoided chopping and disking of the field. From University of California cost and return studies for rice (2007) and orchard grass hay (2006), conservative estimates of fuel usage were obtained for both scenarios. The emission factor assumes an increase in fuel usage equivalent to 2 gallons of diesel fuel per acre for the swathing, raking, and baling. Using EPA diesel emission factor of 8.78 kg $CO_2$ per gallon of diesel, and assuming 3 tonnes of rice straw per acre, the emissions increase from swathing, raking, and baling is estimated to be 5.85 kg $CO_2$ per tonne of rice straw.

project related yield losses are statistically significant compared to historic and average yields. Although rice production in California and the U.S. is likely fairly inelastic in relation to price changes,[39] it is assumed for conservativeness that a statistically significant drop in rice yields due to project activities would result in an increase of production outside of the project boundary.

In order to determine if rice yields have decreased across the project area during the cultivation cycle as a result of project activity, the annual yield from the project area must be compared to historical yields from the same project area. Because yields fluctuate annually depending on numerous climatic drivers, all yields are normalized to average annual county yields using USDA NASS statistics.[40]

The following procedure must be followed for each cultivation cycle to ensure that the yields from the project area have not declined due to project activity. The following procedure is applicable for a single field project. All project aggregates must apply the following procedure to the entire project area, defined as the sum of individual fields included in verification activities:

1. For the five years *t* prior to implementation of the project, normalize the yield of the field by the county average for that year, and, if the project is an aggregate do this for each field in the aggregate and sum the results for all fields in the aggregate, to determine ($\boldsymbol{y\_norm_t}$) for each of the five historic years. This distribution will have five data points.

2. For the present cultivation cycle, normalize the yield of each field by the county average for the growing season for the year, and, if the project is an aggregate, sum the result for all fields in the aggregate, to get ($\boldsymbol{y\_norm_{t_0}}$). This represents one data point.

3. Take the standard deviation and mean of the $\boldsymbol{y\_norm_t}$ distribution:

$$\boldsymbol{s = stdev(y\_norm_t)}$$

$$\boldsymbol{\overline{y\_norm_t} = average(y\_norm_t)}$$

4. Calculate the minimum yield threshold below which normalized yields are significantly smaller than the historical average. This shall be done as follows:

$$\boldsymbol{y\_min = \overline{y\_norm_t} - t(0.05, n-1) \times s}$$

Where **n** is 5, and $\boldsymbol{t(0.05, n-1)}$ the t-distribution value with 95 percent confidence (for a one-tailed test) and $\boldsymbol{n-1}$ degrees of freedom.

5. For every year of the crediting period, calculate $\boldsymbol{y\_norm_{t_0}}$ and compare this value to $\boldsymbol{y\_min}$. If $\boldsymbol{y\_norm_{t_0}}$ is smaller than $\boldsymbol{y\_min}$, it must be assumed that emissions increased outside of the project area. The aggregate must account for increased emissions as specified in Equation 5.8 below.

[39] McDonald et al. (2002), Russo et al. (2008).
[40] Available at (http://quickstats.nass.usda.gov)

**Equation 5.8.** Increased Emissions Outside the Project Boundary

$$SE_{PS} = \left(1 - \frac{y\_norm_{t_0}}{y\_min}\right) \times \frac{\sum_i \left(N_2O_{BL,i} + CH_{4,BL,i} - SOC_{BL,i}\right)}{1000}$$

*Where,*

| | | | Units |
|---|---|---|---|
| $y\_norm_{t0}$ | = | The sum of yields for the current cultivation cycle normalized to the county averages | fraction |
| $y\_min$ | = | The minimum yield threshold below which normalized yields are significantly smaller than the historical average | fraction |
| $N_2O_{BL,i}$ | = | Annual baseline direct and indirect $N_2O$ emissions from rice field *i*, equal to the average of the values of all Monte Carlo runs *j* | kg $CO_2$e/ha |
| $CH_{4,BL,i}$ | = | Annual baseline $CH_4$ emissions from rice field *i*, equal to the average of the values for all Monte Carlo runs *j* | kg $CO_2$e/ha |
| $SOC_{BL,i}$ | = | Annual baseline Soil Organic Carbon content of rice field *i*, equal to the average of the values for all Monte Carlo runs *j* | kg $CO_2$e/ha |

# 6 Project Monitoring

The Reserve requires that Monitoring Plans and Reports be established for all monitoring and reporting activities associated with the project. Under this protocol, two distinct types of Monitoring Plans and Reports must be developed: aggregate level and field level.

## 6.1 Single-Field Monitoring Plan

The Single-Field Monitoring Plan (SFMP) will serve as the basis for verification bodies to confirm that the monitoring and reporting requirements in this section and Section 7 are met for single-field projects, and that consistent, rigorous monitoring and record keeping is ongoing at the project field. The SFMP must be developed and maintained by the project developer. The SFMP must outline procedures on how all of the data included in the Single-Field Report, particularly the parameters in Table 6.1, will be collected, recorded, and managed, as specified below and in Section 7.2.1 (see Section 7.3.1 for minimum record keeping requirements). It is the responsibility of the project developer to ensure that the SFMP meets all requirements specified and is kept on file and up-to-date for verification.

The SFMP will outline the following procedures:

- How the GIS shape file and/or KML file will be created
- How the crediting period, verification schedule, and quantification results will be tracked for each field included in the project aggregate
- How to ensure that the project developer holds title to the GHG emission reductions as required in Section 2.3
- Procedures that the project developer will follow to ascertain and demonstrate that the project field at all times passes the Legal Requirement Test and Regulatory Compliance (Section 3.5.2 and 3.6 respectively)
- A plan for detailed record keeping and maintenance that meet the requirements for minimum record keeping in Section 7.3.1
- The frequency of data acquisition
- The frequency of sampling activities
- The role of individuals performing each specific activity, particularly monitoring and sampling
- QA/QC provisions to ensure that data acquisition is carried out consistently and with precision

## 6.2 Aggregate Monitoring Plan

The Aggregate Monitoring Plan (AMP) will serve as the basis for verifiers to confirm that the project aggregate tracking requirements have been and will continue to be met for each reporting period. The AMP must be developed and maintained by the aggregator. The AMP must outline procedures on how all of the data included in the Aggregate Report will be collected and managed, as specified below and in Section 7.2.2 (see Section 7.3.2 for minimum record keeping requirements).

The AMP will outline the following procedures:

- How the GIS shape file and/or KML file will be created for each field
- How the crediting period, verification schedule, and quantification results will be tracked for each field included in the project aggregate

- How to ensure that the title to the GHG emission reductions has been conferred to the aggregator as required in Section 2.3 for each field in the aggregate
- Procedures that the aggregator will follow to ascertain and demonstrate that all fields in the project aggregate at all times pass the Legal Requirement Test and Regulatory Compliance (Section 3.5.2 and 3.6 respectively)
- A plan for detailed record keeping and maintenance that meet the requirements for minimum record keeping in Section 7.3.2
- The role of individuals performing each specific activity
- QA/QC provisions to ensure that data collected from the field level, according to data acquisition requirements outlined in the Field Monitoring Plan (FMP) described below, is carried out consistently and with precision at the aggregate level

## 6.3 Field Monitoring Plan for Project Participants in an Aggregate

The Field Monitoring Plan (FMP) will serve as the basis for verifiers to confirm that the monitoring and reporting requirements in Sections 6 and 7 are met at each field in a project aggregate, and that consistent, rigorous monitoring and record keeping is ongoing at each field. The FMP 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 are collected and recorded at each field.

One FMP must be developed for each project participant. If a project participant has multiple fields enrolled in the aggregate, only one FMP is required as long as it addresses the monitoring requirements at each field. The FMP can be developed by the project participant or the aggregator, depending on the arrangement specified in contractual agreements. It is the responsibility of the aggregator to ensure that the FMP meets all requirements specified, and is kept on file and up-to-date for verification.

At a minimum the FMP shall stipulate:

- The frequency of data acquisition
- The frequency of sampling activities
- The role of individuals performing each specific monitoring and sampling activity
- A record keeping plan (see Section 7.3.2.2 for minimum record keeping requirements)
- QA/QC provisions to ensure that data acquisition is carried out consistently and with precision

## 6.4 Field Data

All fields, whether enrolled in a project aggregate or participating as a single-field project, must monitor the necessary DNDC input data and field management data as specified below. All field-level data and information specified in Sections 6.4.1, 6.4.2, 6.4.3, and 6.4.4 must be collected and retained for verification purposes.

### 6.4.1 General Field Tracking Data

- Either a GIS shape file or a KML file clearly defining the field perimeter
- The coordinates of the most north-westerly point of the field, reported in degrees to four decimal places[41] (to be used for creating field serial numbers)

[41] Longitude reported in degrees to four decimal places provides a spatial resolution of about 11 meters, the resolution of the latitude is slightly less than that.

- The serial number of the field, constructed as specified in Section 7.2.1
- The start date of the field
- Disclosure of any material and immaterial regulatory violations, with copies of all Notices of Violations (NOVs) included in the report
- A list of the project activities implemented on the field during the cultivation cycle
- Field rice yield during the cultivation cycle and the five years prior to the field start date

### 6.4.2 Field Management Data

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

- Planting preparation description and date
- Planting date and method
- Fertilization types, amounts, and application dates
- Flooding[42] and drainage[43] dates (during the growing season and during post-harvest period)
- Begin and end date of harvesting on the field
- Post-harvesting residue management (e.g. burning, incorporation or baling) description and dates

### 6.4.3 Project Activity Data and Documentation

To corroborate field management assertions, each field must collect and retain the following documentation:

**Dry Seeding with Delayed Flood:**

- Seeding equipment purchase or rental records, and/or seeding service contracts/agreements/receipts
- At least four time-stamped digital photographs per field 'check' taken from various vantage points no more than 15 days after seeding. The pictures must clearly show an establishing stand with no standing water present
- At least four time-stamped digital photographs per field 'check' taken from various vantage points during flood-up. The pictures must clearly show the established stand

**Rice Straw Baling:**

- Baling equipment purchase or rental records, and/or baling service agreements/receipts
- At least four time-stamped digital photographs per field 'check' taken from various vantage points during the swathing, raking, and baling process. Pictures must clearly show the baled hay post-baling
- Log of baling process, recorded at the time of baling, including:
    - Date(s) that each stage of the swathing, raking, and baling process commenced and ended
    - Number of acres baled
    - Quantity of rice straw removed
    - Quantity of rice straw left unused in piles at or near the field
    - List of equipment used
    - Height of the cutting bar used

[42] For each field, the flood date shall be equal to the date that the first 'check' began filling
[43] For each field, the drainage date shall be equal to the date that the last 'check' began draining

    - o Name of third-party baling service provider (if applicable)
- End-use of rice straw (if using an end-use specific emission factor). All sales contracts or receipts for the rice straw must be retained for verification purposes

### 6.4.4 Field Monitoring Parameters

Prescribed monitoring parameters, specifically the DNDC model input parameters, must be determined according to the data source and frequency specified in Table 6.1.

**Table 6.1.** Monitoring Parameters: DNDC Input Parameters

| Parameter | Description | Data Unit | Calculated (c) Measured (m) Reference(r) Operating Records (o) | Measurement Frequency | Comment |
|---|---|---|---|---|---|
| Climate | GPS location of Field | ° decimal to four places | m | Once | |
| | Atmospheric background $NH_3$ concentration | μg N/m$^3$ | r | n/a | Can use default *.dnd file values |
| | Atmospheric background $CO_2$ concentration | ppm | r | n/a | Can use default *.dnd file values |
| | Daily Precipitation | cm | m | Daily | Source: Nearest CIMIS station |
| | Daily maximum Temperature | °C | m | Daily | Source: Nearest CIMIS station |
| | Daily minimum temperature | °C | m | Daily | Source: Nearest CIMIS station |
| | N concentration in rainfall | mg N/l or ppm | r | Each verification cycle | Source: National Atmospheric Deposition Program data |
| Soils** | Land-use type | type | m | Once | |
| | Clay content | 0-1 | m/r | Once | Source: measured or SSURGO |
| | Bulk density | g/cm$^3$ | m/r | Once | Source: measured or SSURGO |
| | Soil pH | value | m/r | Once | Source: measured or SSURGO |
| | SOC at surface soil | kg C/kg | m/r | Once | Source: measured or SSURGO |
| | Soil texture | type | m/r | Once | Source: measured or SSURGO |
| | Slope | % | m | Once | |
| | Depth of water retention layer | cm | r | Once | Default: 30 cm |
| | High groundwater table | cm | r | Once | Default: 9,990 cm |
| | Field capacity | 0-1 | c | Once | DNDC calculates |

| Parameter | Description | Data Unit | Calculated (c) Measured (m) Reference(r) Operating Records (o) | Measurement Frequency | Comment |
|---|---|---|---|---|---|
| | | | | | based on soil texture |
| | Wilting point | 0-1 | c | Once | DNDC calculates based on soil texture |
| Rice Cropping | Planting date | date | m | Annual | Famer records |
| | Harvest date | date | m | Annual | Famer records |
| | C/N ratio of the grain | ratio | m/r | Once per variety | Can use default *.dnd file values |
| | C/N ratio of the leaf + stem tissue | ratio | m/r | Once per variety | Can use default *.dnd file values |
| | C/N ratio of the root tissue | ratio | m/r | Once per variety | Can use default *.dnd file values |
| | Fraction of leaves + stem left in field after harvest | 0-1 | m | Annual | Default values |
| | Maximum yield | kg dry matter/ha | m | Annual | Farmer records |
| Rice Flooding | Date of flood-up for growing season | date | o | Annual | Farmer records |
| | Date of drain for crop harvest | date | o | Annual | Farmer records |
| | Date of flood-up for winter flooding (if applicable) | date | o | Annual | Farmer records |
| | Date of drain for winter flooding (if applicable) | date | o | Annual | Farmer records |
| Tillage System | Number of tillage events | number | o | Annual | Farmer records |
| | Date of tillage events | date | o | Annual | Farmer records |
| | Depth of tillage events | cm (select from 6 default depths) † | o | Annual | Farmer records |
| Synthetic N Fertilizer | Number of fertilizer applications | number | o | Annual | Farmer records |
| | Date of each fertilizer application | date | o | Annual | Farmer records |
| | Application method | surface / injection | o | Annual | Farmer records |
| | Type of fertilizer | type* | o | Annual | Farmer records |
| | Fertilizer | kg N/ha | o | Annual | Farmer records |

| Parameter | Description | Data Unit | Calculated (c) Measured (m) Reference(r) Operating Records (o) | Measurement Frequency | Comment |
|---|---|---|---|---|---|
| | application rate | | | | (field average if using variable rate applications) |
| | Time-release fertilizer (if used) | # days for full release | o | Annual | Farmer records |
| | Nitrification inhibitors (if used) | | o | Annual | Farmer records |
| Organic Fertilizer (if used) | Number of organic applications per year | number | o | Annual | Farmer records |
| | Date of application | date | o | Annual | Farmer records |
| | Type of organic amendment | type | o | Annual | Farmer records |
| | Application rate | kg C/ha | o | Annual | Farmer records |
| | Amendment C/N ratio | ratio | o | Annual | Farmer records |
| Irrigation System | Number of irrigation events | number | o | Annual | Farmer records |
| | Date of irrigation events | | o | Annual | Farmer records |
| | Irrigation type | 3 types‡ | o | Annual | Farmer records |
| | Irrigation application rate | mm | o | Annual | Farmer records |

†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 Reporting and Record Keeping

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.

## 7.1 Project Submittal Documentation

### 7.1.1 Single-Field Project Submittal Documentation

For each single-field project, project developers must provide the following documentation to the Reserve in order to submit and register the RC project.

- Single-Field Project Submittal form
- Signed Attestation of Title form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of Voluntary Implementation form
- Verification Report
- Verification Statement
- Annual Single-Field Report (see Section 7.2.1 below for specific requirements)

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

- Verification Report
- Verification Statement
- Annual Single-Field Report
- Signed Attestation of Title form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Regulatory Compliance form

With the exception of the Single-Field Report, 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/.

### 7.1.2 Project Aggregate Submittal Documentation

For each project aggregate, aggregators must provide the following documentation to the Reserve in order to submit and register the RC project aggregate.

- Project Aggregate Submittal form
  - Includes the initial number of fields and the names of project participants for each individual enrolled field)
- Signed Aggregator Attestation of Title form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of Voluntary Implementation form
- Verification Report
- Verification Statement
- Annual Aggregate Report (see Section 7.2.2 below for specific requirements)

Aggregators must provide the following documentation each subsequent reporting period in order for the Reserve to issue CRTs for quantified GHG reductions.

- Verification Report
- Verification Statement
- Annual Aggregate Report
- Signed Aggregator Attestation of Title form
- Signed Attestation of Regulatory Compliance form
- Signed Attestation of Voluntary Implementation form

With the exception of the Aggregate Report, 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/.

## 7.2 Annual Reports to be Submitted

### 7.2.1 Single-Field Report

For each cultivation cycle, the following information must be included in an annual report that will be submitted to the Reserve as a *.csv file:

- The field serial number, to be determined by the following algorithm:
  - First letter of the County, followed by degrees of the most north-western point of the field, (latitude, then longitude, both reported to four decimal places), followed by the acreage of the field. (Example: *B-39.6123-121.5332-76* would be a 76 acre field in Butte County, CA)
- The acreage of the field (acres)
- Start date of the field
- Whether the field had previously been enrolled in an aggregate
  - If so, include the name of the project aggregate and dates of enrollment
- The field's emission reduction calculation results for the current verified cultivation cycle (corrected for model structural uncertainty)

### 7.2.2 Aggregate Report

For each cultivation cycle, all aggregate-level monitoring information must be included in an annual Aggregate Report that will be submitted to the Reserve as a *.csv file, with accompanying documentation, at verification. The Aggregate Report must contain a list of all fields and the following information for each field:

- The field serial number, to be determined by the following algorithm:
  - First letter of the County, followed by degrees of the most north-western point of the field, (latitude, then longitude, both reported to four decimal places), followed by the acreage of the field. (Example: *B-39.6123-121.5332-76* would be a 76 acre field in Butte County, CA)
- The acreage of the field (acres)
- Start date of the field
- Date field enrolled in the aggregate

    - Including a flag specifying whether the field is a new addition to the aggregate in the particular year
- Current status of field (active, terminated, transferred to a different aggregate)
- Name of project participant associated with the field
- A flag for which fields had site visit or desktop verifications, or were unverified
- The emission reduction calculation results for each field (uncorrected for structural uncertainty)
- The total verified emission reductions for the aggregate (corrected for model structural uncertainty and any deductions due to errors or misrepresentations at the verified fields)

## 7.3 Record Keeping

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

### 7.3.1 Record Keeping for Single-Field Projects

The project developer should retain the following records and documentation, as well as documentation to substantiate the information in the annual Single-Field Report and all field-level data and calculations. These records include:

- Contractual arrangements with each project participant and/or land owner (if applicable)
- Copies of letters of notification sent to land owners, including the dates letters were sent
- GIS or KML shape files
- North-western latitude/longitude coordinates of field (to four decimal places)
- Serial number of field (according to the guidance in Section 7.2.1)
- Data inputs for the calculation of the project emission reductions, including all required sampled data and all DNDC input files (*.dnd files)
    - Copies of the *.dnd file for the baseline scenario and project scenario
    - Copies of all DNDC modeling results, adjusted for input uncertainty
- Copies of air, water, and land use permits relevant to project activities; Notices of Violations (NOVs) relevant to project activities; and any administrative or legal consent orders relevant to project
- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Voluntary Implementation forms
- Field management data (as specified in Section 6.4.2)
- Onsite fossil fuel use records
- Fertilizer purchase records
- Project activity data (as specified in Section 6.4.3), including:
    1. All time-stamped digital photographs of the seeding, flooding, and baling activities
    2. Rice baling logs
    3. Rice straw sales receipts or contracts (if applicable)
    4. All maintenance records relevant to the farm equipment and monitoring equipment
- Rice sales/milling records
- Copies of soil laboratory statements and the Soil Sampling Log (Section 5.1.1.2) for any sampled soil parameters
- Results of $CO_2$e annual reduction calculations
- Initial and annual verification records and results

### 7.3.2 Record Keeping for Project Aggregates

#### 7.3.2.1 Aggregate-Level Record Keeping

The aggregator should retain the following records and documentation, as well as documentation required by Section 6 to substantiate the information in the annual Aggregate Report. System information must be retained for each field, yet collected and managed at the aggregate level. These records include all:

- Contractual arrangements with each project participant and/or land owner
- Copies of letters of notification sent to land owners, including the dates letters were sent
- GIS or KML shape files for all fields in the aggregate
- North-western latitude/longitude coordinates for each field (to four decimal places)
- Serial numbers for each field (according to the guidance in Section 7.2.2)
- Data inputs for the calculation of the project emission reductions, including all required sampled data and all DNDC input files (*.dnd files)
    - Copies of the *.dnd file for the baseline scenario and project scenario
    - Copies of all DNDC modeling results, adjusted for input uncertainty
- Copies of air, water, and land use permits relevant to project activities; Notices of Violations (NOVs) relevant to project activities; and any administrative or legal consent orders relevant to project activities
- Executed Aggregator Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Voluntary Implementation forms
- Results of $CO_2$e annual reduction calculations
- Initial and annual verification records and results

#### 7.3.2.2 Field-Level Record Keeping

The project developer/aggregator should retain the following records and documentation, as well as documentation required in Section 6.4 for each field. At each field, the following records should be retained for verification purposes:

- Field management data (as specified in Section 6.4.2)
- Onsite fossil fuel use records
- Fertilizer purchase records
- Project activity data (as specified in Section 6.4.3), including:
    - All time-stamped digital photographs of the seeding, flooding, and baling activities
    - Rice baling logs
    - Rice straw sales receipts or contracts (if applicable)
    - All maintenance records relevant to the farm equipment and monitoring equipment
- Rice sales/milling records
- Copies of soil laboratory statements and the Soil Sampling Log (Section 5.1.1.2) for any sampled soil parameters

## 7.4 Reporting Period and Verification Cycle

Project developers must report GHG reductions resulting from project activities for all fields during each reporting period, which represents a complete cultivation cycle. A complete cultivation cycle may be slightly greater or less than 365 days for each field depending on planting/harvest dates. The reporting period must be uniformly defined for the aggregate. Thus, for reporting purposes, the aggregate reporting period shall always be defined as starting on October 1 and ending on September 31 of the next year. Each field must quantify their emission reductions for the entire cultivation cycle, and the aggregate reductions will be reported on the uniform reporting period. Both reporting periods and cultivation cycles must be contiguous; there can be no time gaps in reporting during the crediting period of an aggregate once the initial reporting period has commenced.[44] Because a single reporting period spans two calendar years (from fall of one year to late summer/fall of the next), the aggregator must assign each reporting period 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 reporting cycle. For instance, all GHG reductions from a cycle beginning in fall 2012 and ending with harvest in late summer 2013 shall be assigned a 2013 "vintage" when reporting reductions to the Reserve.

For project aggregates, no more than a one reporting period can be verified at once, except during an aggregate's first verification, which may include historical emission reductions from prior years.

### 7.4.1 Additional Reporting and Verification Options for Single-Field Projects

For single-field projects, however, there are three verification options to choose from, which provide the project developer more flexibility and help manage verification costs associated with RC projects. The project developer may choose from these additional options after a project has completed its initial verification and registration.

A project developer may choose to use one option for the duration of a project's crediting period. Regardless of the option selected, reporting periods must be contiguous; there may be no time gaps in reporting during the crediting period of a project once the initial reporting period has commenced.

If a single-field project joins a project aggregate, that field will immediately be subject to the verification schedule of the aggregate moving forward.

If a field exits a project aggregate to become a single-field project, that project is subject to the reporting and verification requirements of an initial reporting and verification period. In other words, that single-field project's first verification as a single-field project may not take advantage of Options 2 or 3, below.

#### 7.4.1.1 Initial Reporting and Verification Period

The reporting period for projects undergoing their initial verification and registration cannot exceed one complete cultivation cycle. Once a project is registered and has had at least one complete cultivation cycle of emission reductions verified, the project developer may choose one of the verification options below.

[44] An entire aggregate can willingly forfeit CRTs for an entire cultivation cycle in accordance with the Reserve's zero-crediting period policy, available at http://www.climateactionreserve.org/how/program/program-manual/.

#### 7.4.1.2 Option 1: Twelve-Month Maximum Verification Period

Under this option, the verification period may not exceed one complete cultivation cycle, which may be slightly greater or less than 365 days. Verification with a site visit is required for CRT issuance.

#### 7.4.1.3 Option 2: Twelve-Month Verification Period with Desktop Verification

Under this option, the verification period cannot exceed one complete cultivation cycle. However, CRTs may be issued upon successful completion of a desktop verification as long as: (1) Site visit verifications occur at two-year intervals; and (2) The verification body has confirmed that there have been no significant changes in selected project activities, field management or ownership and/or management control of the field since the previous site visit. Desktop verifications must cover all other required verification activities (i.e. a full desktop verification of the Single-Field Report).

Desktop verifications are allowed only for a single 12-month verification period in between 12-month verification periods that are verified by a site visit.

#### 7.4.1.4 Option 3: Twenty-Four Month Maximum Verification Period

Under this option, the verification period cannot exceed two complete cultivation cycles (approximately 730 days or 24 months) and the project monitoring plan and Single-Field Report must be submitted to the Reserve for the interim cultivation cycle’s reporting period. The project monitoring plan and report must be submitted for projects that choose Option 3 in order to meet the annual documentation requirement of the Reserve program. They are meant to provide the Reserve with information and documentation on project operations and performance. They also demonstrate how the project monitoring plan was met over the course of the first half of the verification period. They are submitted via the Reserve online registry, but are not publicly available documents. The monitoring plan and report shall be submitted within 30 days of the end of the reporting period.

Under this option, CRTs may be issued upon successful completion of a site visit verification for GHG reductions achieved over a maximum of 24 months. CRTs will not be issued based on the Reserve’s review of project monitoring plans or reports. Project developers may choose to have a verification period shorter than 24 months.

# 8 Verification Guidance

This section provides verification bodies with guidance on verifying GHG emission reductions associated with the project activity. This verification guidance supplements the Reserve's Verification Program Manual and describes verification activities specifically related to RC projects.

Verification bodies trained to verify RC projects must be familiar with the following documents:

- Climate Action Reserve Program Manual
- Climate Action Reserve Verification Program Manual
- Climate Action Reserve Rice Cultivation Project Protocol

The Reserve Program Manual, Verification Program Manual, and project protocols are designed to be compatible with each other and are available on the Reserve's website at http://www.climateactionreserve.org.

Only ISO-accredited verification bodies with lead verifiers trained by the Reserve for this project type are eligible to verify RC project reports. Verification bodies approved under other project protocol types are not permitted to verify RC projects. Information about verification body accreditation and Reserve project verification training can be found on the Reserve website at http://www.climateactionreserve.org/how/verification/.

In addition, all verification bodies must have an accredited Professional Agronomist, Crop Advisor or similar agricultural specialist on the verification team in order to verify RC projects.

## 8.1 Preparing for Verification

The project developer is responsible for coordinating all aspects of the verification process, coordinating with the verification body, project participants (in the case of a project aggregate), and the Reserve, and submitting all necessary documentation to the verification body and the Reserve.

The project developer is responsible for selecting a single verification body for the entire project or project aggregate for each reporting period. The same verification body may be used up to six consecutive years (the number of consecutive years allowed, according the Reserve Verification Program Manual[45]). Verification bodies must pass a conflict-of-interest review against the project developer, and in the case of project aggregates, all project participants and the aggregator.

Each year, project developers of single-field projects must make the Single-Field Report, which is submitted to the Reserve annually, and the Single-Field Monitoring Plan available to the verification body. These documents must meet the requirements in Sections 6 and 7.

In project aggregates, each year, project participants must submit all field data to the aggregator according to the guidelines in Sections 6 and 7. Aggregators must make all Field Monitoring Plans (FMPs) available to the verification body, as well as the Aggregate Monitoring Plan (AMP) and the Aggregate Report.

[45] http://www.climateactionreserve.org/how/verification/verification-program-manual/

In all cases, the above documentation should be made available to the verification body after the NOVA/COI process is complete.

Aggregators may assist project participants in preparing documents for verification and in facilitating the verification process. The scope of these services is determined by the specific contract between project participants and the aggregator. However, the ultimate responsibility for monitoring reports and verification compliance is assigned to the aggregator.

For project aggregates, a field is considered verified if it is in the pool of fields for which site visits or desktop verifications are conducted, even if not selected for either a site visit or desktop verification. As a preliminary step in preparing for verification, the aggregator may choose to exclude fields from the pool of fields that may be selected for verification activities. Aggregators must report to the verification body all instances of field exclusion. The excluded fields shall be removed from the acreage totals and from field numbers used to determine field eligibility and verification sampling methodologies (in Section 8.2) and are therefore not considered verified.

## 8.2 Verification Schedule for Single-Field Projects

Single-field projects are comprised of exactly one field, and as such, there is no sampling methodology to select the fields undergoing verification. The single-field project shall be verified according to the verification schedule outlined below.

This protocol provides project developers three verification options, Sections 8.2.1 to 8.2.3, for a single-field project after its initial verification and registration in order to provide flexibility and help manage verification costs associated with rice projects. For each option, verification bodies may need to confirm additional requirements specific to this protocol, and in some instances, utilize professional judgment on the appropriateness of the option selected.

The actual requirements for performing a site visit verification and desktop verification are the same. A desktop verification is equivalent to a full verification, without the requirement to visit the site. A verification body has the discretion to visit any site in any reporting period if the verification body determines that the risks for that field warrant a site visit.

### 8.2.1 Option 1: Twelve-Month Maximum Verification Period

Option 1 does not require verification bodies to confirm any additional requirements beyond what is specified in the protocol.

### 8.2.2 Option 2: Twelve-Month Verification Period with Desktop Verification

Option 2 requires verification bodies to review the documentation specified in Section 7.4.1.3 in order to determine if a desktop verification is appropriate. The verifier shall use their professional judgment to assess any changes that have occurred related to project data management systems, equipment or personnel and determine whether a site visit should be required as part of verification activities in order to provide a reasonable level of assurance on the project verification. The documentation shall be reviewed prior to the NOVA/COI renewal submitted to the Reserve, and the verification body shall provide a summary of its assessment and decision on the appropriateness of a desktop verification when submitting the NOVA/COI renewal. The Reserve reserves the right to review the documentation provided by the project developer and the decision made by the verification body on whether a desktop verification is appropriate.

### 8.2.3 Option 3: Twenty-Four Month Maximum Verification Period

Under Option 3 (see Section 7.4.1.4), verification bodies shall look to the project monitoring report submitted by the project developer to the Reserve for the interim 12-month reporting period as a resource to inform its planned verification activities. While verification bodies are not expected to provide a reasonable level of assurance on the accuracy of the monitoring report as part of verification, the verification body shall list a summary of discrepancies between the monitoring report and what was ultimately verified in the List of Findings.

## 8.3 Verification Sampling and Schedule for Project Aggregates

Guidelines for verification sampling of the aggregate and the aggregate's verification schedule are different for "small aggregates," "large single-participant aggregates," and "large multi-participant aggregates." This approach allows a consistent application of verification requirements across all aggregates regardless of size or number of participants.

In all cases, the verification schedule shall be established by the verification body using random sampling, according to the verification schedule and sampling methodologies outlined in Sections 8.3.1, 8.3.2, and 8.3.3. These sampling methodologies establish the minimum verification frequencies; the verification body may at any time add fields beyond the minimum number required for site visit and/or desktop verification and may use verifier judgment to determine the number of additional fields and method for selecting fields if a risk-based review indicates a high probability of non-compliance. The verification sampling requirements are mandatory regardless of the mix of entry dates represented by the group of fields in the project aggregate.

The initial site visit verification schedule for a given year shall be established after the completion of the NOVA/COI process and prior to the commencement of any verification activities. This is meant to allow for the aggregator and verification body to work together to develop a cost-effective and efficient site visit schedule. Specifically, once the sample fields designated for a site visit have been determined, the verification body shall document all fields selected for planned site visit verification and provide a list to the aggregator and the Reserve. The aggregator shall be responsible for informing project participants of their selection for a planned site visit. Following this notification, the aggregator shall supply the verification body with all the required documentation to demonstrate field-level conformance to the protocol. When a verification body determines that additional sampling is necessary, due to suspected non-compliance, however, a similar level of advance notice may not be possible.

Aggregators and project participants shall not be made aware, in advance, of which fields' data will be subject to desktop verification in a given year.

Regardless of the size of an aggregate, if the aggregate contains any fields that did not pass site visit verification the year before and wish to re-enter the aggregate, those fields must have a full verification with site visit for the subsequent reporting period. These fields must be site visited *in addition* to the verification sampling methodology and requirements outlined below in Sections 8.3.1, 8.3.2, and 8.3.3.

For the purposes of verification, a "small aggregate" is defined as an aggregate comprised of 10 or fewer fields, regardless of the number of project participants. Small aggregates will meet fixed site visit and desktop verification frequency requirements based on a verification schedule determined by the verifier, in compliance with Section 8.3.1 of this protocol.

A “large single-participant aggregate” is defined as an aggregate comprised of more than 10 fields all managed by one single project participant. For large single-participant aggregates, fields will be randomly selected for site visit and desktop verification, according to the sampling method in Section 8.3.2, which is based on a non-linear scale where the relative fraction of fields undergoing verification activities gets smaller as the aggregate size gets larger.

A “large multi-participant aggregate” is defined as an aggregate comprised of more than 10 fields and more than one project participant. For large multi-participant aggregates, participants and their fields will be randomly selected for site visit and desktop verification, according to the sampling method in Section 8.3.3, which is based on a non-linear scale where the relative fraction of participants undergoing verification activities gets smaller as the aggregate size, in terms of number of participants, gets larger.

In all cases, when determining the sample size for site visits and desktop verifications, the verification body shall round up to the nearest whole number.

The actual requirements for performing a site visit verification and desktop verification are the same. A desktop verification is equivalent to a full verification, without the requirement to visit the site. A verification body has the discretion to visit any site in any reporting period if the verification body determines that the risks for that field warrant a site visit.

### 8.3.1 Verification Schedule for Small Aggregates

#### 8.3.1.1 Site Visit Verification Schedule for Small Aggregates

Each field in a small aggregate shall undergo initial site visit verification within the first two cultivation cycles for each crediting period. In the first year of the aggregate or in subsequent years when new fields enter the aggregate, a minimum of 30 percent of the newly enrolled fields shall complete the initial site visit verification in their first year of enrollment.

In addition, site visit verifications must be conducted on a schedule such that:

1. Each field in the aggregate must successfully complete a minimum of two site visit verifications per crediting period (e.g. the initial site verification in addition to one more).
2. A minimum of 20 percent of the fields in the aggregate shall be site verified in any given year, selected at random.

#### 8.3.1.2 Desktop Verification Schedule for Small Aggregates

In any given year, a number of desktop verifications of field data must be conducted, with the number inversely related to the number of fields undergoing a site visit that year. Specifically, the number of desktop verifications (**D**) shall equal 50 percent of the number of fields (**n**) in the aggregate that will not receive a site visit that year, rounding up in the case of an uneven number of fields. In other words,

$$\boldsymbol{D} = \frac{(\boldsymbol{n} - \boldsymbol{S})}{\boldsymbol{2}}$$

*Where,*

| | | |
|---|---|---|
| n | = | Number of fields in the aggregate |
| S | = | Number of site visits |
| D | = | Number of desktop verifications |

Fields shall not be selected for a desktop verification in years that the field is undergoing a site visit. If a site visit is planned for a field randomly selected for a desktop verification, the verification body will continue randomly drawing additional fields until the total number selected for a desktop verification reaches the value of (**D**) per the equation above.

### 8.3.2 Verification Schedule for Large Single-Participant Aggregates

In contrast to small aggregates, it is possible that a field in a large aggregate is never verified, either via site visit or desktop verification, during its entire crediting period. Therefore, random sampling is a particularly important component of enforcement.

#### 8.3.2.1 Sampling for Site Visit Verification for Large Single-Participant Aggregates

The verification body determines the number of enrolled fields that must be randomly selected for site visit verification in a given year. The required number of site visits (**S**) shall equal the square root of the total number of fields (**n**) enrolled in the large single-participant aggregate that year (i.e. $\boldsymbol{S} = \sqrt{\boldsymbol{n}}$ rounded up to the nearest whole number).

#### 8.3.2.2 Sampling for Desktop Verification for Large Single-Participant Aggregates

In addition to site visit verifications, verification bodies shall randomly select a sample of fields to undergo a desktop verification (**D**) equal to two times the square root of the total number of fields in the aggregate.

Fields shall not be selected for a desktop verification in years that the field is undergoing a site visit. If a site visit is planned for a field randomly selected for a desktop verification, the verification body will continue randomly drawing additional fields until the total number selected for a desktop verification reaches the square root of the total number of fields in the aggregate.

### 8.3.3 Verification Schedule for Large Multi-Participant Aggregates

The random sampling methodology shall be applied first at the project participant level and then at the field level. A random sampling methodology will be applied for site visit and desktop verification selection. However, the verification body shall select fields for site visits first as described in Section 8.3.3.1 and desktop verifications second as described in Section 8.3.3.2.

In contrast to small aggregates, it is possible that a field in a large aggregate is never verified, either via site visit or desktop verification, during its entire crediting period. Therefore, random sampling is a particularly important component of the enforcement mechanism.

#### 8.3.3.1 Sampling for Site Visit Verification for Large Multi-Participant Aggregates

1. The verification body shall determine the number of project participants that must be randomly selected for a site visit in a given year, as follows:

$$\boldsymbol{S} = \left(\boldsymbol{1} + \left(\frac{\boldsymbol{P}}{\boldsymbol{500}}\right)\right) \times \sqrt{\boldsymbol{P}}$$

*Where,*

| | | |
|---|---|---|
| S | = | Number of site visits required (rounded up to the nearest whole number) |
| P | = | Number of project participants in the aggregate |

2. The verification body shall randomly select (**S**) project participants to receive site visits that year.

3. The verification body shall select which fields of the selected project participants will receive a site visit. For project participants with six enrolled fields or fewer, the verification body shall site visit at least 50 percent of the fields, selected at random. For project participants with more than six fields enrolled in the aggregate, the verification body shall site visit at least 33.3 percent of the fields, selected at random.

4. A minimum of the square root of the total number of fields in the aggregate must be site visited. If this number is not met after following Steps 1 to 3, then the verification body shall randomly select one additional project participant and the sample of fields, according to Step 2 and 3 above, and repeat this until the number of site visits meets this minimum requirement. Note that Step 3 must be completed in full and therefore could result in a greater number of fields selected for site visits than the minimum requirement.

#### 8.3.3.2 Sampling for Desktop Verification for Large Multi-Participant Aggregates

In addition to site visit verifications, each year verification bodies shall also randomly select fields to undergo a desktop verification of their field data. Verification bodies shall randomly select a sample of fields to undergo a desktop verification equal to two times the square root of the total number of fields in the aggregate (rounded up to the next whole number).

Fields shall not be selected for a desk-audit in years that the field is undergoing a site visit. If a site visit is planned for a field randomly selected for a desktop verification, the verification body will continue randomly drawing additional fields until the total number selected for a desktop verification reaches the square root of the total number of fields in the aggregate.

## 8.4 Standard of Verification

The Reserve's standard of verification for RC projects is the Rice Cultivation Project Protocol (this document) and the Reserve Program Manual and Verification Program Manual. To verify a RC project aggregate, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in Sections 2 through 7 of this protocol. Sections 2 through 7 provide eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve.

## 8.5 Monitoring Plan

The Aggregate Monitoring Plan (AMP) and Field Monitoring Plan (FMP) serve as the basis for verification bodies to confirm that the monitoring and reporting requirements in Section 6 and Section 7 have been met, and that consistent, rigorous monitoring and record keeping is ongoing by the aggregator and all enrolled fields. Verification bodies shall confirm that the Monitoring Plan covers all aspects of monitoring and reporting contained in this protocol and specifies how data for all relevant parameters in Table 6.1 are collected and recorded.

### 8.5.1 Annual Reports

The single-field project's project developer must annually submit field data for single-field projects to the Reserve. The Single-Field Report will consist of a *.csv file and attachments, as described in Section 7.2.1. Verification bodies must review the Single-Field Report to confirm project information and data collected according to the SFMP.

The project aggregate must annually submit an Aggregate Report to the Reserve. The report will consist of a *.csv file and attachments, as described in Section 7.2.2. Verification bodies must review the Aggregate Report to confirm project information and data collected according to the AMP.

The verification body will need to review field data during desktop verifications of randomly selected fields in an aggregate. The field data must be made available to the verification body in order to confirm field-level information collected according to the FMP.

## 8.6 Verifying Eligibility at the Field Level

Verification bodies must affirm each project field's eligibility during site visit and/or desktop verifications according to the rules described in this protocol. The table below outlines the eligibility criteria for each project field. This table does not present all criteria for determining eligibility comprehensively; verification bodies must also look to Section 3 and the verification items list in Table 8.2.

**Table 8.1.** Summary of Eligibility Criteria for a Rice Cultivation Project

| Eligibility Rule | Eligibility Criteria | Frequency of Rule Application |
|---|---|---|
| Start Date | The first day of the cultivation cycle, which begins immediately after completion of a rice crop harvest, in which one or more of the approved project activities is adopted at the field.<br><br>For 12 months following the Effective Date of this protocol, a pre-existing field with a start date on or after September 1, 2009 may be submitted for listing; after this 12 month period, projects must be submitted for listing within 6 months of the project start date | Once during first verification |
| Location | Approved rice growing regions in the United States and United States tribal areas | Once during first verification |
| Anaerobic Baseline | All fields must demonstrate that previous rice cultivation practices resulted in anaerobic conditions | Once during first verification |
| Performance Standard | The field passes the Performance Standard Test for at least one of the approved project activities | Every verification |
| Legal Requirement Test | Signed Attestation of Voluntary Implementation form and monitoring procedures for ascertaining and demonstrating that the project passes the Legal Requirement Test | Every verification |
| Legal Title to CRTs | Aggregator Attestation of Title to CRTs | Every verification |
| Regulatory Compliance | Signed Attestation of Regulatory Compliance form and disclosure of all non-compliance events to verification body; project must be in material compliance with all applicable laws | Every verification |

## 8.7 Core Verification Activities

The RCPP provides explicit requirements and guidance for quantifying the GHG reductions associated with the implementation of approved RC management practice changes on project fields. The Verification Program Manual describes the core verification activities that shall be performed by verification bodies for all project verifications. They are summarized below in the context of an RC project, but verification bodies must also follow the general guidance in the Verification Program Manual.

Verification is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The three core verification activities are:

1. Identifying emission sources, sinks, and reservoirs (SSRs)
2. Reviewing GHG management systems and estimation methodologies
3. Verifying emission reduction estimates

**Identifying emission sources, sinks, and reservoirs for each field**
The verification body reviews for completeness the sources, sinks, and reservoirs identified for a single-field project or project aggregate, ensuring that all relevant secondary effect SSRs for each field are identified.

**Reviewing GHG management systems and estimation methodologies at the field level**
The verification body reviews and assesses the appropriateness of the methodologies and management systems that are used to gather data and calculate baseline and project emissions for each field.

**Reviewing GHG management systems and estimation methodologies at the aggregate level**
The verification body reviews and assesses the appropriateness of the methodologies and management systems that the project aggregator uses to gather data and calculate baseline and project emissions on the aggregate level.

**Verifying emission reduction estimates at the field level**
The verification body further investigates areas that have the greatest potential for material misstatements and confirms whether or not material misstatements have occurred for all fields undergoing verification. This involves site visits to a random sample of project fields, according to the sampling methodology outlined in Section 8.3.2.1, to ensure systems on the ground correspond to and are consistent with data provided to the verification body, combined with a random sample of desktop verifications of remaining project fields according to Section 8.3.2.2. In addition, the verification body recalculates a representative sample of the performance or emissions data from fields for comparison with data reported by the project aggregator in order to confirm calculations of GHG emission reductions.

**Verifying emission reduction estimates at the aggregate level**
The verification body further investigates areas that have the greatest potential for material misstatements at the aggregate level, including whether the appropriate modeling structural uncertainty factors (Section 5.1.7) and yield-loss statistical tests (Section 5.2.3) have been performed for the aggregate.

## 8.8 Project Type Verification Items

The following tables provide lists of items that a verification body needs to address while verifying a RC project. The tables include references to the section in the protocol where requirements are further specified. The table also identifies items for which a verification body is expected to apply professional judgment during the verification process. Verification bodies are expected to use their professional judgment to confirm that protocol requirements have been met in instances where the protocol does not provide (sufficiently) prescriptive guidance. For more information on the Reserve's verification process and professional judgment, please see the Verification Program Manual.

***Note: These tables shall not be viewed as a comprehensive list or plan for verification activities, but rather guidance on areas specific to RC projects that must be addressed during verification.***

### 8.8.1 Project Eligibility and CRT Issuance

Table 8.2 lists the criteria for reasonable assurance with respect to eligibility and CRT issuance for RC project aggregates. These requirements determine if the aggregate is eligible to register with the Reserve and/or have CRTs issued for the reporting period. If any one requirement is not met, either for one or more fields, then the entire aggregate may be determined ineligible or the GHG reductions from the reporting period (or subset of the reporting period) may be ineligible for issuance of CRTs, as specified in Section 3.

**Table 8.2.** Eligibility Verification Items

| Protocol Section | Eligibility Qualification Item | Apply Professional Judgment? |
|---|---|---|
| 2.2 | Verify that all verified fields meet the definition of an RC project | No |
| 2.3 | Verify ownership of the reductions by reviewing Aggregator Attestation of Title | No |
| 2.3 | Verify ownership of the reductions by reviewing Letters of Notification and contracts between aggregators, project participants, and land owners | No |
| 3.2 | Verify project start date for all fields | No |
| 3.2 | Verify accuracy of project start date for all verified fields based on operational records | Yes |
| 3.3 | Verify that each field is within the 5-year crediting period (or a subsequent 5-year crediting period) | No |
| 3.4 | Verify that the management records at each verified field are adequate to document the anaerobic baseline requirements | No |
| 3.4 | Verify that all verified fields have a SOC content less than 3% in the top soil | No |
| 3.5.1 | Verify that each field meets the Performance Standard Test | No |
| 3.5.2 | Confirm execution of the Attestation of Voluntary Implementation form to demonstrate eligibility under the Legal Requirement Test | No |
| 3.5.3 | Verify that any ecosystem service payment or credit received for activities on a project field has been disclosed and is allowed to be stacked. | No |
| 3.6 | Verify that the project activities at all verified fields comply with applicable laws by reviewing any instances of non-compliance provided by the aggregator and performing a risk-based assessment to confirm the statements made by the project developer in the Attestation of Regulatory Compliance form | Yes |

| Protocol Section | Eligibility Qualification Item | Apply Professional Judgment? |
|---|---|---|
| 6.1, 6.2, 6.3 | Verify that the project Monitoring Plan contains a mechanism for ascertaining and demonstrating that all fields pass the Legal Requirement Test at all times | No |
| 6.1, 6.3, 6.4 | Verify that field-level and aggregate-level monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations | No |

### 8.8.2 Quantification

Table 8.3 lists the items that verification bodies shall include in their risk assessment and re-calculation of the GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project aggregate GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before CRTs are issued.

**Table 8.3.** Quantification Verification Items

| Protocol Section | Quantification Item | Apply Professional Judgment? |
|---|---|---|
| 4 | For each field, verify that all SSRs in the GHG Assessment Boundary are accounted for, particularly secondary effect emissions | No |
| 5.1.1 | For each field, verify that the project parameters and the static parameters are represented by the appropriate data and the DNDC input files are accurate for the baseline modeling and the project modeling | Yes |
| 5.1.2 | For each field, verify that the DNDC model is adequately calibrated to historical yields, and that the 20-year historical calculation was run correctly | Yes |
| 5.1.3, 5.1.4, 5.1.5 | For each field, verify that the Monte Carlo analysis was performed correctly for the baseline and project modeling runs for each field | No |
| 5.1.4, 5.1.5 | For each field, verify that the baseline and project emission models have the same static parameters, and that the project model adequately represents the project activities during the cultivation cycle | No |
| 5.1.6 | For each field, verify that the soil input uncertainty discount is quantified and applied correctly | No |
| 5.1.7 | For the aggregate, verify that all field emission reductions are summed correctly, and that the structural uncertainty factor is properly applied | No |
| 5.2.1 | Verify that the aggregator correctly monitored, quantified and aggregated fossil fuel and electricity use changes | Yes |
| 5.2.2 | For each field, verify that baled rice straw end-uses are properly characterized, and the appropriate emission factors are used | Yes |
| 5.2.3 | For the aggregate, verify that the statistical test for reduced yield is properly performed, and that increased emissions outside the project boundary are properly quantified for significant yield losses | No |

### 8.8.3 Risk Assessment

Verification bodies will review the following items in Table 8.4 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

**Table 8.4.** Risk Assessment Verification Items

| Protocol Section | Item that Informs Risk Assessment | Apply Professional Judgment? |
|---|---|---|
| 6 | Verify that all contractors are qualified to perform the duties expected. Verify that there is internal oversight to assure the quality of the contractor's work | Yes |
| 6.1, 6.2, 6.3 | Verify that the project has documented and implemented the Single-Field Monitoring Plan or Aggregate Monitoring Plan, and all necessary Field Monitoring Plans | No |
| 6.1, 6.2, 6.3 | Verify that the project monitoring plans are sufficiently rigorous to support the requirements of the protocol and proper operation of the project | Yes |
| 6.4 | Verify that appropriate monitoring data is measured or referenced accurately | No |
| 6, 7 | Verify that the individual or team responsible for managing and reporting project activities are qualified to perform this function | Yes |
| 6, 7 | Verify that appropriate training was provided to personnel assigned to GHG reporting duties | Yes |
| 7.2 | Verify that the Single-Field Report or Aggregate Report was uploaded to the Reserve software | No |
| 7.2, 7.3 | Verify that field data has been gathered by project participants and made available to the aggregator | No |
| 7.3 | Verify that all required records have been retained by the project developer | No |

## 8.9 Successful and Unsuccessful Verifications

Successful verification of each field in the sample of fields selected for site visit and desktop verifications results in the crediting of all fields participating in the entire project aggregate, as calculated by the aggregator according to the quantification methodology in Section 5.

Verification may uncover any number of material and immaterial errors at the field, project participant or aggregate level, and the extent to which an error was propagated through the aggregate can affect whether a verification is determined to be "unsuccessful."

### 8.9.1 Field-Level and Project Participant-Level Errors

If material issues arise during verification of a participating field, verification bodies shall issue Corrective Action Requests, as needed. The aggregator will need to work with the project participant to independently address the issues and required corrective actions using the same process taken with standalone projects. These are described in the verification guidance of this protocol and the Reserve Verification Program Manual. If the error can be corrected at the field level and is the type of error which will not be propagated across an individual participant's fields or the entire aggregate, then the error shall be corrected and the field verification shall be considered successful. Errors shall be considered immaterial at the field level if they result in a discrepancy that is less than 5 percent of the total emission reductions quantified for that field.

If verification of a field reveals material non-compliance with the protocol, and no corrective action is possible, that field shall receive a negative verification and no CRTs shall be issued for that field, effectively removing the field from the aggregate for that year. When verification is unsuccessful for a participating field, the verification body must verify additional fields until the total number of successful verifications reaches the required number (as described in Section 8.2), starting with fields managed by the same participant, as follows. If the project participant managing the unsuccessfully verified field also manages other fields enrolled in the aggregate, the verification body shall site visit a minimum of two additional fields or 50 percent of the remaining unverified fields, whichever is larger, that are managed by that project participant. If the verification of the additional fields is also unsuccessful, no CRTs shall be issued for any of the fields managed by the project participant.

Deliberate non-compliance may result in disqualification of the project participant including all of their enrolled fields. Additionally, if the project participant failing verification and their negatively verified fields re-enter the aggregate the following year, each of the fields that failed verification the previous year shall be required to undergo a site visit, in addition to the minimum sampling requirements in Section 8.2.

Whenever a project participant receives a negative verification for all of their enrolled fields, the verification body shall use their professional judgment and a risk-based assessment to determine whether sampling additional project participants for site visit verification, beyond the minimum requirements of this protocol, is necessary to verify the entire aggregate to a reasonable level of assurance.

#### 8.9.1.1 Cumulative Field-Level Error of Sampled Fields

Total errors and/or non-compliance shall be determined for the sampled fields and the offset issuance for those fields corrected, as required, by the Verification Program Manual. Should the aggregated error and/or non-compliance rate for the sampled fields be less than 5 percent, CRT issuance for fields not subjected to site visit or desktop verification shall be equal to the amount reported by the aggregator. However, if the aggregated percent error and/or non-compliance rate (i.e. the percentage of verified fields failing verification) for sampled fields is greater than 5 percent, CRT issuance for fields not subjected to site visit or desktop verification shall be reduced by the total amount of aggregated percent error or non-compliance rate.

### 8.9.2 Aggregate-Level Errors

If verification reveals a potential systemic error, which may be propagated out to the aggregate level (e.g. a qualitative error with regard to the model input parameters or a quantitative error repeated in multiple field-level model runs), the verification body shall use their professional judgment to sample additional fields, as necessary, to determine whether the error is truly systemic. Systemic errors must be corrected at the aggregate level.

## 8.10 Completing Verification

The Verification Program Manual provides detailed information and instructions for verification bodies to finalize the verification process. It describes completing a Verification Report, preparing a Verification Statement, submitting the necessary documents to the Reserve, and notifying the Reserve of the project’s verified status.

# 9 Glossary of Terms

| | |
|---|---|
| Accredited verifier | A verification firm approved by the Climate Action Reserve to provide verification services for project developers. |
| Additionality | 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 resulting 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. |
| 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). |
| Field checks | Low dikes that are employed by rice farmers to control water distribution to their fields. |
| 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 or “tonne” (MT, t) | 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. |
| 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 GHG 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 statement and provide verification services for operators subject to reporting under this protocol. |

# 10 References

American Carbon Registry. (2010). *American Carbon Registry Methodology for N2O Emission Reductions through Changes in Fertilizer Management.* Winrock International. Little Rock, Arkansas. Available at: http://www.americancarbonregistry.org/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management

Boone, R.D., Grigal, D.F., Sollins, P., Ahrens, .R.J., Armstrong, D.E. (1999). *Soil Sampling, Preparation, Archiving, and Quality Control*. Standard Soil Methods for Long-Term EcologicalResearch. Oxford Press, New York.

Cai, Z., Sawamoto, S., Li, C., Kang, G., Boonjawat, J., Mosier, A., et al. (2003). Field Validations of the DNDC Model for Greenhouse Gas Emissions in East Asian Cropping Systems. *Global Biogheochem. Cycles 17(4), doi: 10.1029/2003GB002046*.

California Air Resources Board (CARB), Department of Food and Agriculture, et al. (1995). *Report of the Advisory Committee on Alternatives to Rice Straw Burning*. Available at: http://www.arb.ca.gov/smp/rice/aac/aac95.htm

California Rice Production Workshop (2003). University of California. Rice Research and Information Program. Godfrey, L.D., *Invertebrate Pest Management in Rice*, 2003-1; Whisson, D., *Vertebrate Pests of Rice*, 2003-2. Available at: http://www.plantsciences.ucdavis.edu/uccerice/index.htm

California Rice Production Workshop (2004). University of California. Rice Research and Information Program. Greer, C., *Diseases*, 2004-1; Williams, J., *Land Formation, Planting and Stand Establishment*, *Water Management*, 2004-1; Williams, J., & McKenzie, K., *Variety Selection and Management*, 2004-1. Available at: http://www.plantsciences.ucdavis.edu/uccerice/index.htm

California Rice Production Workshop (2005). University of California. Rice Research and Information Program. Hill, J., *Rice Growth and Development*, 2005-1. Available at: http://www.plantsciences.ucdavis.edu/uccerice/index.htm

California Rice Production Workshop (2006). University of California. Rice Research and Information Program. Fischer, A.J., & Hill, J.E., *Weed Control Programs*, 2006-1; Mutters, R., Horwath, W., von Kessel, C., & Williams, J., *Fertility and Crop Nutrition*, 2006-1. Available at: http://www.plantsciences.ucdavis.edu/uccerice/index.htm

Cooley, David and Lydia Olander. (September 2011). "Stacking Ecosystem Services Payments: Risks and Solutions." Nicholas Institute for Environmental Policy Solutions, Duke University. NI WP 11-04. Available at: http://nicholasinstitute.duke.edu/ecosystem/land/stacking-ecosystem-services-payments/at_download/paper

Environmental Defense Fund. (Period Covered by Report: October 1, 2007 to September 30, 2010). *Creating and Quantifying Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley: Accounting for Multiple Benefits for Producers and the Environment*. Final Report for Conservation Innovation Grant (CIG). Agreement Number: NRCS 69-3A75-7-87 Report published: 2011.

Garnache, C., Rosen-Melina, J.T., Sumner, D. *Economics of Carbon Credits from Voluntary Practices on Rice Farms in the Sacramento Valley*. University of California Agricultural Issues Center. (2011).

Jenkins, B.M., Bakker-Dhaliwai, R., Summers, M.D., Bernheim, L.G., Lee, H., Huisman, W., Yan, L. *Equipment Performance, Costs, and Constraints in the Commercial Harvesting of Rice Straw for Industrial Applications.* ASAE Meeting Presentation, Paper No. 006035.(2000).

Livezy, J., Foreman, L. *Characteristics and Production Costs of U.S. Rice Farms*. United States Department of Agriculture, Statistical Bulletin Number 974-7. March 2004.

Markum, D.B., Klonsky, K.M., Livingston, P. *Sample Costs to Establish and Produce Orchardgrass Hay*. University of California, Cooperative Extension. (2006).

McDonald, J.D., Sumner, D.A. *The Influence of Commodity Programs on Acreage Response to Market Price: With an Illustration concerning Rice Policy in the United States*. University of California Agricultural Issues Center (2002).

Mutters, R., Greer, C. Klonsky, K.M., Livinsgston, P. *Sample Costs to Produce Rice*. University of California, Cooperative Extension. (2007).

Nader, G.A., & Robinson, P.H. (October 2010). *Rice Producers' Guide to Marketing Rice Straw*. Agriculture and Natural Resources (ANR) of the University of California. ANR Publication 8245. Available at: http://anrcatalog.ucdavis.edu/pdf/8425.pdf

Petrie, M., & Petrik, K. (May 2010). *Assessing Waterbird Benefits from Water Use in California Ricelands*. Report prepared by Ducks Unlimited for the California Rice Commission. Sacramento, CA. Available at: http://www.calrice.org/pdf/DucksUnlimited.pdf

Revenga, C., et al. (2000). *Pilot Analysis of Freshwater Ecosystems: Freshwater Systems*. World Resources Institute. Washington, D.C. Available at: http://www.wri.org/wr2000

Russo, C., Green, R. Howitt, R. *Estimation of Supply and Demand Elasticities of California Commodities*. Department of Agricultural Resource Economics, University of California, Davis. Working Paper No. 08-001. (2-\008).

Sterling, J., & Buttner, P. (2009) *Wildlife Known to Use California Ricelands*. Report prepared by ICF Jones & Stokes for the California Rice Commission. Sacramento, CA. Available at: http://www.calrice.org/pdf/Species+Report.pdf

Terra Global Capital, Environmental Defense Fund, California Rice Commission, Applied Geosolutions. (2011). *Emission Reductions in Rice Management Systems. Version 1.0. Public Consultation Draft.* Verified Carbon Standard (VCS). Available at: http://www.v-c-s.org/methodologies/calculating-emission-reductions-rice-management-systems

U.S. Environmental Protection Agency. (April 2011). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*. Washington, D.C. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

World Resources Institute / World Business Council on Sustainable Development (WRI/WBCSD). (2005). *The Greenhouse Gas Protocol for Project Accounting*, World Resources Institute, Washington, DC. Available at: http://www.ghgprotocol.org

# Appendix A Parameter Look-Up Tables

## Rice Straw End-Use Emission Factors

The emission factors included in Table A.1 below were derived based on the conservative use of best available information regarding emissions associated with the transport and decay of rice straw given various end-use scenarios. Transportation energy use data came primarily from California rice straw time and motion studies[46] that examined, through survey responses within the industry, the costs associated with collection, storage, and transport of rice straw to various end-uses (primarily for use as cattle feed). Because of the uncertain nature of these emissions factors, the Reserve consistently applied conservative assumptions to estimate each emission factor, as described in the footnotes to Table A.1. A conservative default factor for 'unknown' or 'non-specified' offsite management has been included for cases where the ultimate fate of the rice straw is unknown.

**Table A.1.** Rice Straw End-Use Emission Factors

| Rice Straw End-Use | Emission Factor ($tCO_2e$/t baled straw) |
|---|---|
| Unknown (or 'other' offsite management) | 0.083 [1] |
| Dairy and Beef Cattle Feed | 0.075 [2,4] |
| Fiberboard Manufacturing | 0 [5] |
| Spread on Bare Soils for Erosion Control | 0.012[2,3] |
| Unused (left piled/stacked onsite) | 0.210[6] |
| 1. Using survey responses from California rice baling experts, end-use emission factors were determined for each of the expert's estimates of the current rice straw end-use market. The most conservative estimate was used for this emission factor. The scenario that is used assumes that close to 100% of rice straw goes to Dairy and Beef Cattle Feed, with negligible amounts going to other end-uses. The resulting estimate of 75 kg $CO_2e$ was increased by 10% for conservativeness<br>2. Transportation emissions per MT of rice straw are estimated using the following assumptions:[46]<br>a. Bales are transported 200km<br>b. Average truck capacity of 16 MT rice straw<br>c. Diesel fuel efficiency of 6 MPG<br>3. Anaerobic decay is unlikely because the straw is spread across the landscape, therefore maximizing oxygen availability during decomposition.<br>4. Change in enteric emissions may occur due to low nutritional quality of rice straw. It is assumed for conservativeness that the enteric $CH_4$ conversion factor is increased by 1% due to switching to low-digestible food (2006 IPCC *Guidelines for National Greenhouse Gas Inventories*, Vol. 4, pg. 10.30). Emission factor assumes a calorific value of dry rice | |

[46] Transport distance and truck capacity assumptions are conservative estimates based on information from time and motion studies in California (Jenkins et al. (2000), Table 3).

| | |
|---|---|
| straw of 15 MJ/kg (Putun et al., 2004), and an energy content of $CH_4$ of 55.65 MJ/kg (2006 *IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 4, pg. 10.32).<br>5. Rice straw replaces wood products for manufacturing of fiber board. Avoidance of harvesting and transport of wood products provides likely net-positive GHG benefits.<br>6. Equal to the IPCC default emission factor for aerobic composting (0.10 kg $CH_4$/t input). Low N residues (such as rice straw) would have discounted fugitive emissions compared with other compostable organic residues (Brown et al., 2008). | |

# Appendix B RCPP Quantification Guide

**Quantification Guide Index:**



## Introduction

This guide describes the use of the DNDC model for the Reserve Rice Cultivation Project Protocol (RCPP). This guide assumes a basic familiarity with the model and its use and is meant to be used in conjunction with the *User's Guide for the DNDC Model (Version 9.3)* (*DNDC User's Guide*), which explains the background mechanics of the model as well as the functionality of the DNDC graphical user interface (GUI).

### Development of *Ex Ante* Input Data and Assessment of Offset Potential

Prior to developing rice offset projects, project developers may want to assess opportunities prior to implementing projects. This assessment entails several steps, including collection of current agricultural management data, *ex ante* modeling of general baseline emissions and a suite of mitigation options, and first order assessment of economic feasibility of the mitigation measures.

The first step in developing rice offset projects and applying the DNDC model to evaluate the potential magnitude of emission reductions requires collection of basic rice management (plant/harvest dates, flooding/irrigation and tillage practices, fertilizer use, etc). Collection of soils and climate data for DNDC modeling is discussed below.

Farmers decisions regarding when to plant rice, how much fertilizer to apply, when to till the soils, when to flood and when to harvest are driven by a combination of factors including commodity prices, prices of resources (e.g. fertilizer) and weather patterns. Over a crop season it is possible that farmers have a good estimate of commodity prices and cost of inputs. However, prediction of weather and its impact on agricultural management decisions are difficult to predict prior to the growing season. We also know that management practices and weather both have a significant impact on greenhouse gas (GHG) emissions from agricultural soils.

Given the reliance on weather patterns for decisions regarding agricultural management practices, the *ex ante* modeling is based on an estimation of what the growers think they will do in the future. The *ex ante* input data on management (see detailed discussion below on DNDC model inputs) for the baseline scenario should be based on recent management practices to satisfy both the performance standard criteria and simplify *ex ante* calculations. Once the baseline management practices are set, the project developers can assess what eligible mitigation measures they wish to implement by running DNDC with those changes in management that are both economically viable and have potential to reduce GHG emissions. Later in this document we present an example of the mechanics in using DNDC to evaluate potential offset management changes.

Once a project is implemented, the project developer must collect all of the necessary input data for running the DNDC model. These data are collected through the growing season to insure that the data reflect exactly what the farmer did. The change in approved practice changes implemented by the project must be represented in the model inputs. The key to reliable and genuine project modeling is to define what and how management practices are changed under the project scenario.

### Collection of Climate Data for DNDC Modeling

The DNDC model requires daily data on maximum and minimum temperature, precipitation and average wind speed. In California, these data can be collected from the CIMIS (California Irrigation Management Information System) network of weather stations.

### Collection of Climate and Soil Data for DNDC Modeling

DNDC requires inputs of soil organic carbon content (top 5 cm) and soil bulk density, pH and clay fraction of the top 10 cm. Data on soil conditions for a given field can either be collected from existing soil surveys (NRCS SSURGO) or through direct measurement. The RCPP describes some general guidelines on soil sampling for measuring soil properties for DNDC model simulations.

### Calculation of Input for *Ex Post* Offset Calculations

The *ex ante* calculations are just an estimate of the potential reductions from implementing one or more of the approved project activities. The *ex post* calculations, performed in accordance with Section 5.1 of the RCPP, determines the primary effect GHG reductions that occur on a field due to RC project activity. Once a farmer implements a project and changes management practices from what they would have done in the “baseline,” the baseline becomes a fictitious scenario that represents what the grower “would have done” in the absence of the RC project.

The *ex post* model simulations are done for both the project management practices (what was actually done and recorded by the project) and the “baseline” management. The baseline management practices are the same as the project except for the specific changes in management selected for the project (e.g. those management practices that are recognized as approved project activity practices in Section 2.2 of the RCPP). Because *ex post* calculations represent the real reductions achieved at the field over the course of a complete cultivation cycle, actual weather data must be used for the *ex post* model simulations.

### Example: Assessing Impact of Input Uncertainties on Modeled Offsets

This section describes how to calculate the impact of input uncertainties on DNDC modeled emission reductions following the procedures summarized in Section 5.1.3 of the RCPP. Input uncertainty must be quantified when using the DNDC model because the DNDC model can be sensitive to changes in input parameters, specifically changes in soil conditions. The Monte Carlo Input Uncertainty assessment models the GHG emissions thousands of times for a specific field, with each model run using slightly different soil parameters. The soil parameters for each Monte Carlo run are randomly selected based on the probability distribution function (PDF) expected for each soil input used to parameterize the model. Project developers can choose to use either the SSURGO database or field sampling to characterize the soil input parameters.

The following example demonstrates the Monte Carlo modeling approach described in Section 5.1.3 of the RCPP. To apply this method for assessing the impact of uncertainty of soil conditions, the first step entails defining a possible range and probability distribution of the soil conditions. For this example, we use soil databases developed by the U.S. Department of Agriculture Natural Resources Conservation Services (USDA NRCS). The general approach is to assume some variability in site soil attributes (clay fraction, organic matter fraction, bulk density, and pH) as modeled in the USDA NRCS SSURGO soil model. Using a Monte Carlo simulation, one must model identical crop management practices and meteorological conditions while varying soil conditions through the expected range of conditions. The current uncertainty tool in DNDC allows users to run thousands of model simulations in a Monte Carlo mode for most input parameters. However, the current tool in the model assumes an *even* distribution (PDF) for each parameter. The RCPP requires the Monte Carlo run to assume a *log-normal* distribution of each of the soil attributes as well as some amount of correlation between them. A separate, standalone software tool is being developed to automatically process the baseline and project DNDC input files ("*.dnd" files) based on the protocol assumptions regarding soil PDFs. The software tool will automate much of the three steps described below. Here we describe the three steps for running the model in Monte Carlo mode:

1. An analysis of correlation between the four soil attributes. In the development of the RCPP an analysis of SSURGO soil data for over 6000 rice fields was completed to develop default correlation coefficients for key soil input parameters. The default correlation coefficients are provided in Table B.1 below.
2. Programmatic generation of DNDC inputs based on the Monte Carlo method and pre-defined correlation coefficients.
3. Running the DNDC model in site mode using the batch processing option and synthesizing the results.

We demonstrate this approach in two ways; the first assumes no correlation between soil parameters, which is conservative since we know that there is significant correlation between soil parameters. The second set of Monte Carlo runs utilized correlation statistics as part of the sampling procedure.

Soil attributes are stored within the SSURGO database according to the following relationships:

| | |
|---|---|
| Horizon | Contains soil attribute data (low, representative, and high values) based on an assessment of soil field conditions |
| ⇩ | [one to many] |
| Component | The basic soil type (roughly equivalent to soil series) – soil components have many horizons and have no explicit spatial location |
| ⇩ | [one to many] |
| Map Unit | The smallest mapped polygon in the SSURGO model – soil map units have many components of varying fractions |

To assess correlation among soils in rice growing areas of California, all map units intersecting rice fields as mapped in the California Department of Water Resources land use database were selected. From this selection, we identified all soil components contained within the map units. Soil attribute data came from the top horizon for each component. Thus, the final database represents all soil horizons intersecting rice fields.

Pearson correlation coefficients we calculated for each set of pairs for representative values of the four soil attributes:

**Table B.1.** Soil Correlation Coefficients

| | Clay fraction | OM fraction | Bulk Density | pH |
|---|---|---|---|---|
| Clay Fraction | 1 | - | - | - |
| OM Fraction | 0.139 | 1 | - | - |
| Bulk Density | -0.526 | -0.685 | 1 | - |
| pH | 0.263 | 0.098 | -0.126 | 1 |

The Monte Carlo simulation should randomly generate 2,000 numbers for each of the four soil properties with the correlation matrix and with each following a log-normal distribution. This can be done by using the Cholesky decomposition of the correlation matrix to transform a set of standard-normal random numbers in the logarithm space. The representative value are used as the mean, while the low and high values are transformed into log space and treated as a range of +/- 3 standard deviations. This will result in four sets of 2,000 correlated random numbers, normally distributed. The soil properties, other than pH, are then calculated by taking the exponent of the numbers.

The DNDC model should then be run as a batch using the DNDC site mode (see DNDC *User's Guide*). To demonstrate this, we ran two scenarios (one with a winter flood, one without a winter flood) for a single field as follows:

- Rice planted May 1, harvested September 11
- Tillage on April 23, April 26, April 27, April 29, and September 15
- Fertilizer on April 30 (injected anhydrous ammonia), May 1 (surface application of $(NH_4)_2HPO_4$), May 26 (surface application of $(NH_4)_2SO_4$)
- Flooded from May 1 to September 1
- Winter flood from November 15 to January 31 (only for the winter flood scenario)
- Rice straw burned once every eight years

These results indicate the modeled methane emissions and net GHG emissions are quite sensitive to soil conditions. At 90 percent confidence interval, the range in modeled $CH_4$ and net

GHG emissions were significant (over 14 percent in both baseline and project simulations) (see Table B.2 below). However, the impact of soil uncertainties on modeled changes in emissions from baseline to project conditions were quite small (<3 percent). Figure B.1 below shows the histogram of the Monte Carlo simulation results for the case assuming no correlation between soil input parameters. It is clear for this baseline and project scenario, that uncertainty in soil input parameters impacted both baseline and project modeled emissions in a similar degree. Accounting for correlation between soil input parameters reduced uncertainties. The table below summarizes these results.

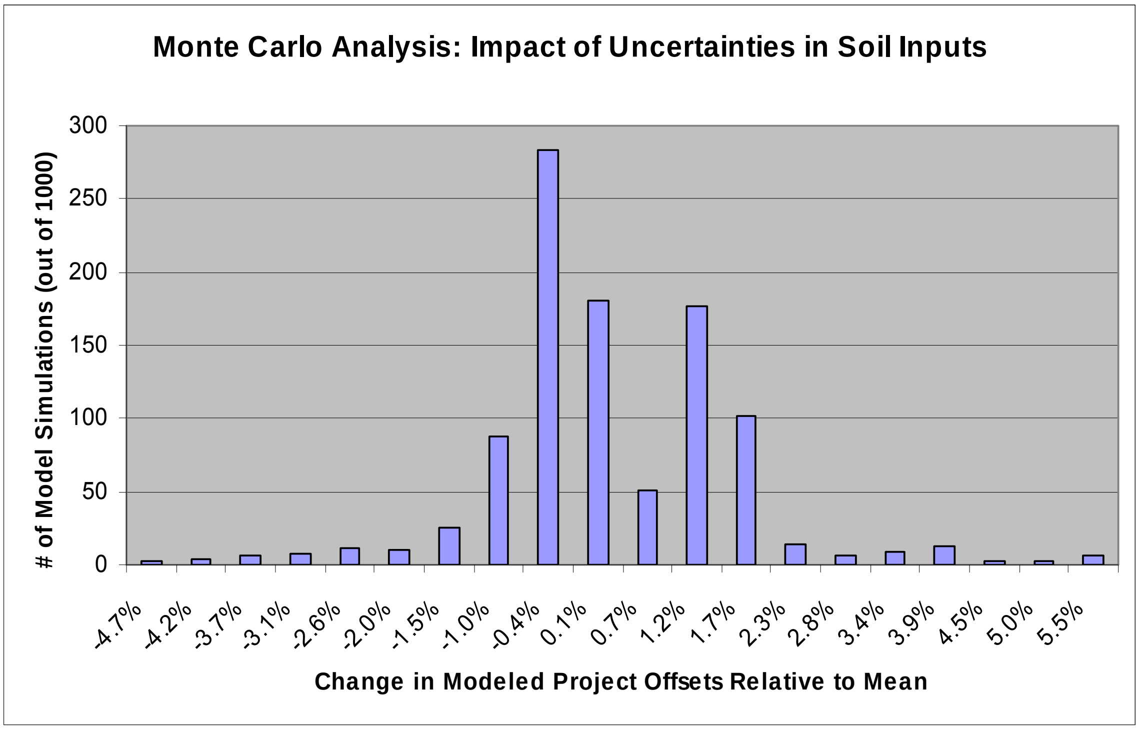



**Figure B.1.** Change in Modeled Offsets Based on Running Monte Carlo Analysis on Soil Input Uncertainty

**Table B.2.** Uncertainty in Modeled GHG Emissions and Change in Emissions at 90 Percent Confidence Interval due to Uncertainty in Soil Values

| | Assuming No Correlation in Soil Input Parameters | | Accounting for Correlation of Soil Input Parameters | |
|---|---|---|---|---|
| | $CH_4$ GWP (90% CI / Mean) | Total GHG GWP (90% CI / Mean) | $CH_4$ GWP (90% CI / Mean) | Total GWP (90% CI / Mean) |
| Baseline | 14.7% | 14.4% | 14.0% | 13.7% |
| Project | 18.5% | 20.0% | 17.5% | 19.1% |
| Baseline-Project | **1.0%** | **2.2%** | **0.2%** | **1.4%** |

## DNDC Modeling Overview

This section of the guide is a general overview of the modeling process to give the user a sense of the steps involved in evaluating various land management scenarios. It presents material on gathering input data for the model, using the DNDC GUI to enter data, setting up appropriate soil conditions for the model, calibrating parameters for crops, viewing results, and estimating model uncertainty.

### Sources of Data

Prior to running the DNDC model, numerous input data are required, including information on soil, meteorology (climate), and management practices. As DNDC looks principally at soil dynamics, accurate soil parameters are critical: at a minimum, users should gather precise data for soil organic matter content (kg C/kg soil), bulk density (g/cm$^3$), soil texture (soil clay fraction can be used as a proxy here), and pH. Daily meteorological data for the modeling timeframe should include maximum and minimum air temperatures (°C) and precipitation (cm).

### Creating Site Input Files

Once the user has gathered natural conditions and management information for the site, DNDC input files can be created using the DNDC GUI. The user will enter information for the following twelve thematic areas:

- Site
- Climate
- Soil
- Farming rotation management
- Crop
- Tillage
- Fertilization
- Manure amendment
- Irrigation
- Flooding
- Plastic mulch (not relevant for RCPP)
- Grazing and cutting (not relevant for RCPP)

For a step-by-step guide to data input, the user may refer to the *DNDC User's Guide*, Section III-1.1.

### Crop Model Calibration

Crop simulation plays a crucial role in modeling carbon and nitrogen biogeochemistry in and greenhouse gas emissions from the agroecosystems. DNDC default parameters for California rice are provided. The parameters are:

- ***Maximum biomass (kg C/ha)***: The maximum biomass productions for grain, leaves and 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). If local data are not available, then California default values must be used.
- ***Biomass fraction***: The grain, leaves and stem, and root fractions of total rice biomass at maturity.
- ***Biomass C/N ratio***: Ratio of C/N for grain, leaves and stem, and roots at maturity.
- ***Thermal degree days (°C)***: Cumulative air temperature from seeding until rice maturity.
- ***Water demand (g water/g dry matter***): Amount of water needed for the rice crop to produce a unit of dry matter of biomass (also known as transpiration efficiency).

- ***N fixation index***: The default number is 1 for non-legume crops. For legume crops, the N fixation index is equal to the ratio of total plant N content to plant N taken from soil. For rice, this value must be set at 1.

Default values for these parameters are provided with DNDC and can be found in the "C:\DNDC\Library\Lib_crop directory." The "crop.lst" file provides the look-up table for crop numbers for each crop. In addition to the crop libraries included with DNDC, the Crop Creator feature (see "Tools" tab on DNDC user interface) allows the user to create a new crop library (by entering in all of the parameters listed above) or modify an existing crop library. Figure B.2, below, shows the DNDC Crop Creator interface. For information on using the Crop Creator, the user may refer to *DNDC User's Guide*, Section III-2.3. The crop creator tool can be used to develop the input parameters for a new rice variety. ***However, unless field measurements of the input parameters are available, the user must use the default values for rice.***

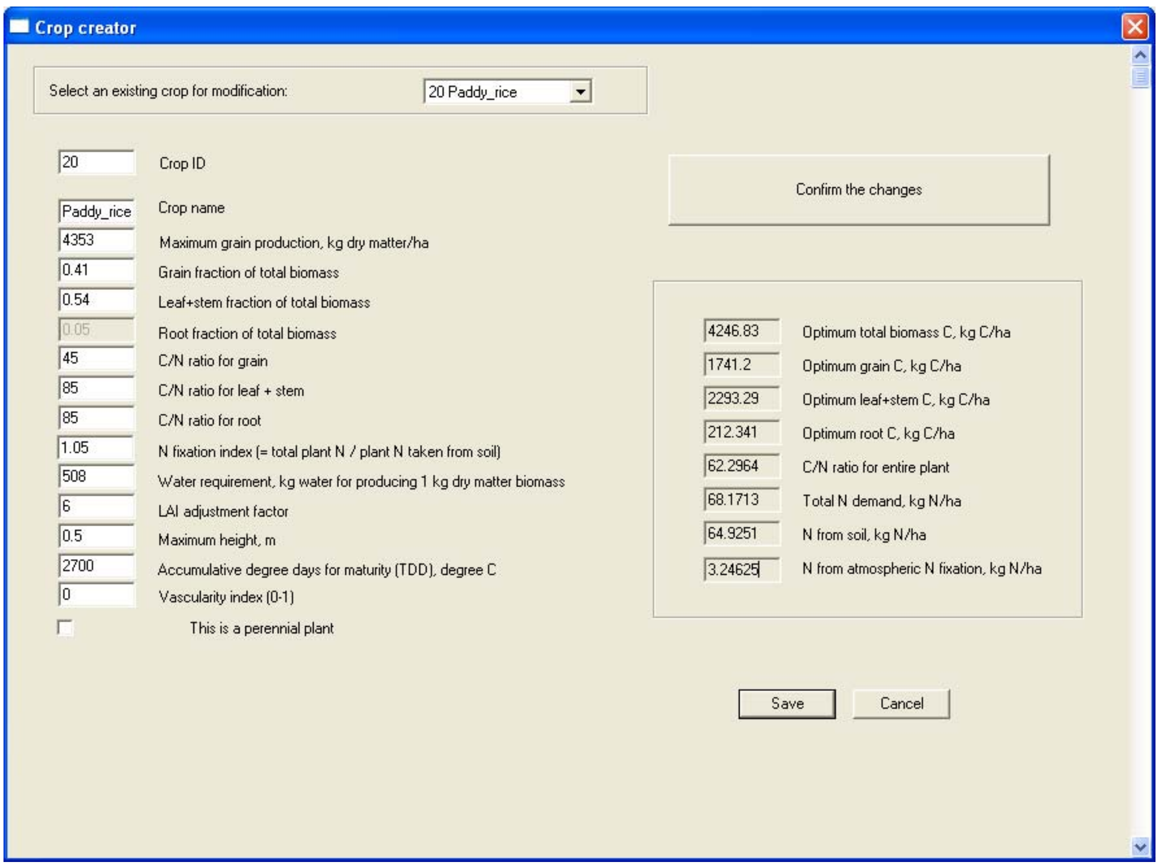



**Figure B.2.** DNDC Crop Creator

To use the model according to the RCPP, the user must calibrate the DNDC crop model based on actual site conditions. At least five years of observed crop yields should be used for setting maximum rice grain yield (kg C/ha). In addition, for the particular rice variety used, the biomass fraction (% grain and % leaf and stem), and biomass C/N ratio for grain, leaves and stem, and roots should be obtained from the look up tables derived from UC Davis Jenkins lab (tables will be provided and available on the Climate Action Reserve website). The steps for crop calibration are outlined in the RCPP.

### Running the Model and Viewing Results

Once soil and crop calibration are complete, input parameters are entered, and input files are saved for later use the model can be run. For details on running the model, the user may refer to the *DNDC User's Guide*, Section III-1.3. Model run results can be viewed either through the DNDC GUI or in text files saved to the user's hard-drive. Results in the DNDC GUI give a quick overview of results by year for crop(s), nitrogen, carbon, water, and greenhouse gas emissions. Viewing results via the GUI is described in detail in the *DNDC User's Guide*, Section III-1.4. Daily and annual results are saved in text file format so that they can be retrieved and reprocessed with any spreadsheet or word processor tools (e.g. Microsoft Excel or OpenOffice Calc). Daily results include information on crop growth, soil carbon and nitrogen pools and fluxes, soil climate, and water budget. In addition, summarized annual results are saved in report and tabular format. Text file results are described in detail in the *DNDC User's Guide*, Section IV-1.

## Greenhouse Gas Emissions Scenarios: Overview

This section provides an overview of the GHG emission evaluation process using DNDC. While this document is not intended to be used to select the actual scenarios to be used, we provide some background material here on the general effects of parameter changes in DNDC and a brief discussion of trade-offs between management practices, GHG emission, and crop yield. In addition, we describe the general framework for the ideal approach to scenario evaluation.

### General Effects of Model Parameter Changes

The user should consider what GHG mitigation options make sense for their particular application and set-up DNDC modeling appropriately. Seeking input from local experts and surveying literature specific to the system of interest is the preferred approach. This section (and the accompanying tables in the appendix) provides a very general overview of methane mitigation options.

Reductions to $CH_4$ emissions fall into four categories: changes to soil character, organic matter management, crop/plant management, and flooding. Changes to soil character (such as by converting wetland soils to upland crop) often affect other GHG emissions such as C sequestration or $N_2O$ emissions. Crop or plant management and organic matter management are typically effective in wetlands soils. Changes to flooding regime are often the most feasible option, but can also influence $N_2O$ emissions.

### Modeling Potential Project Scenarios

Ideally, each scenario should be run for the same time period, using the same site characteristics for several years (five or more): because of climate-related interannual variability, emissions and yields can vary significantly from year to year. Running the model for several years will ensure a reasonable average. If a multi-year run is not possible, a Monte Carlo simulation may provide better results.

The general process for evaluating scenarios is as follows (a specific example can be found in the Case Studies section):

- Create baseline input files for DNDC (including *.dnd file and climate files)
- Create management alternatives based on approved project activities
- Run baseline and project management scenarios

- Import text results into spreadsheet software (e.g. Microsoft Excel or OpenOffice Calc) and generate mean annual per hectare values (in $CO_2$ equivalents) for the principal parameters;
  - Change to soil organic carbon (dSOC)
  - Methane ($CH_4$)
  - Nitrous oxide ($N_2O$)
- Sum $CO_2$ equivalents to derive total annual GHG emissions (zeroing out any net emission reductions from SOC or $N_2O$, as reductions to these gases are not credited in the RCPP)
- Useful graphs might include:
  - bar chart comparing total GHG emissions by scenario
  - bar chart comparing grain yield by scenario

## Case Study: Paddy Rice

In this section we will provide a step-by-step example of an evaluation of management scenarios for a 20.8 hectare rice paddy in California. In this case, we are using data from an actual field, with six years of detailed management, meteorological and atmospheric, and soils data. Here is the baseline management scenario:

- Single crop: rice
- No removal of crop residue
- Tillage prior to and after cropping
- Fertilizer applications prior to and after planting
- Flooded field from late May through early September
- Winter flood from December through February/March

### Entering Input Data

As one would do with any DNDC model site run, we will begin by entering all of the site, soil, and cropping information available to us; this initial set-up will form the basis for the crop calibration process and the baseline run. Figure B.3 shows the basic site information and climate information for our rice paddy. Climate files were created based on data from a nearby agricultural weather station. Nitrogen concentration from rainfall was generated from data from a nearby monitoring station and represents annual average total deposition averaged over the six years.

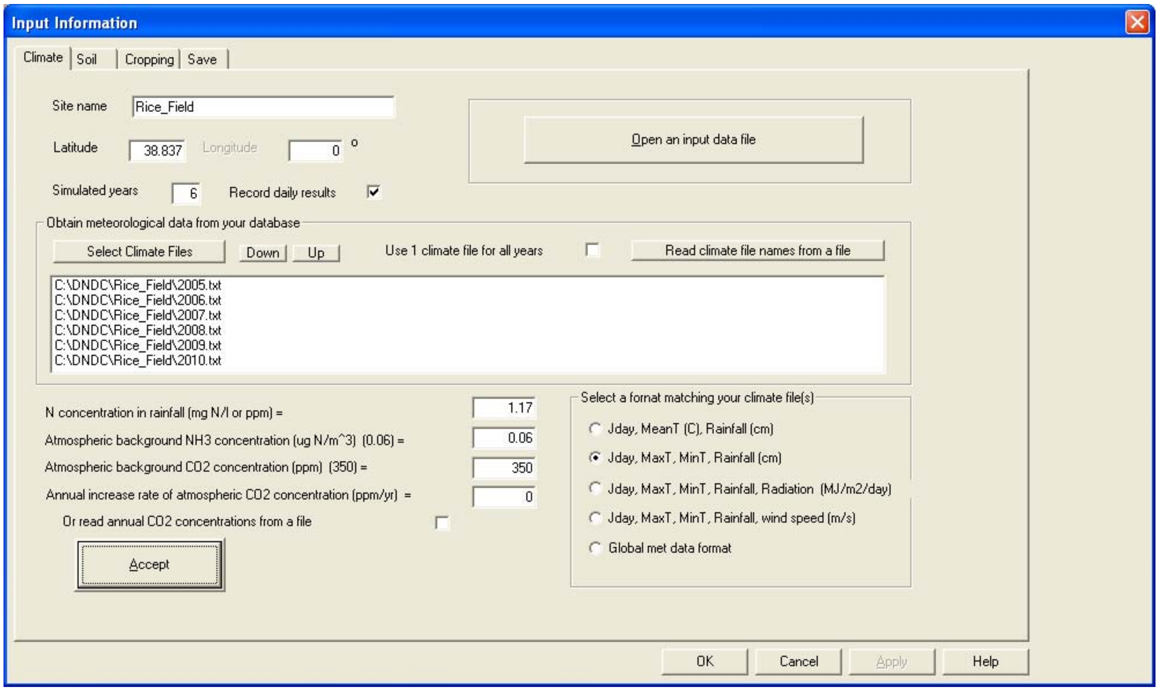



**Figure B.3.** Rice Site and Climate Input

Figure B.4 shows the soil data for our rice field based on site soil sampling. In this case we have data for the land use type (rice paddy), clay fraction (0.31), bulk density (1.45 g/cm$^3$), soil pH (7.5), and surface soil organic carbon (0.75 percent). For the rest of the parameters we will use the DNDC defaults.

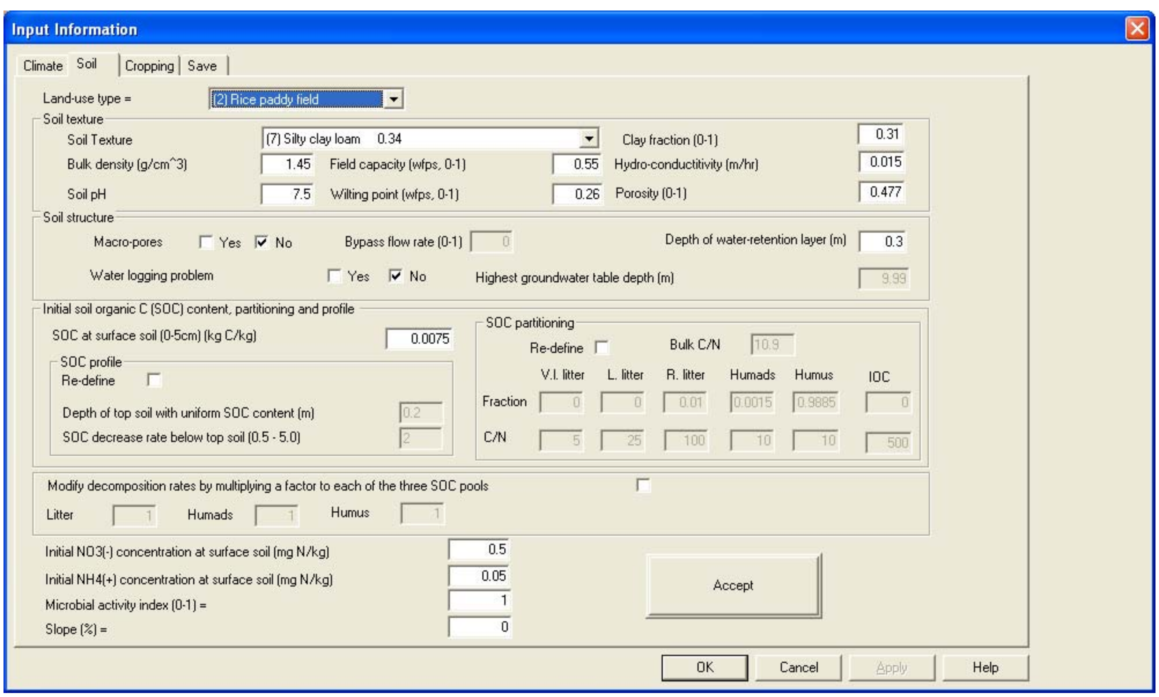



**Figure B.4.** Rice Soil Input

Next we will setup the cropping systems for our rice paddy. Figure B.5 shows how our cropping systems will be arranged for our six-year time period. The total years of the model run will be six years (based on the input in the Climate/Site tab); since each year of the run will have slightly different parameters, we will set these up as six different cropping systems (i.e. “Number of cropping systems applied…” should be set to 6) each of which lasts one year (i.e. “Duration of this cropping system…” should be set to 1 for each year).

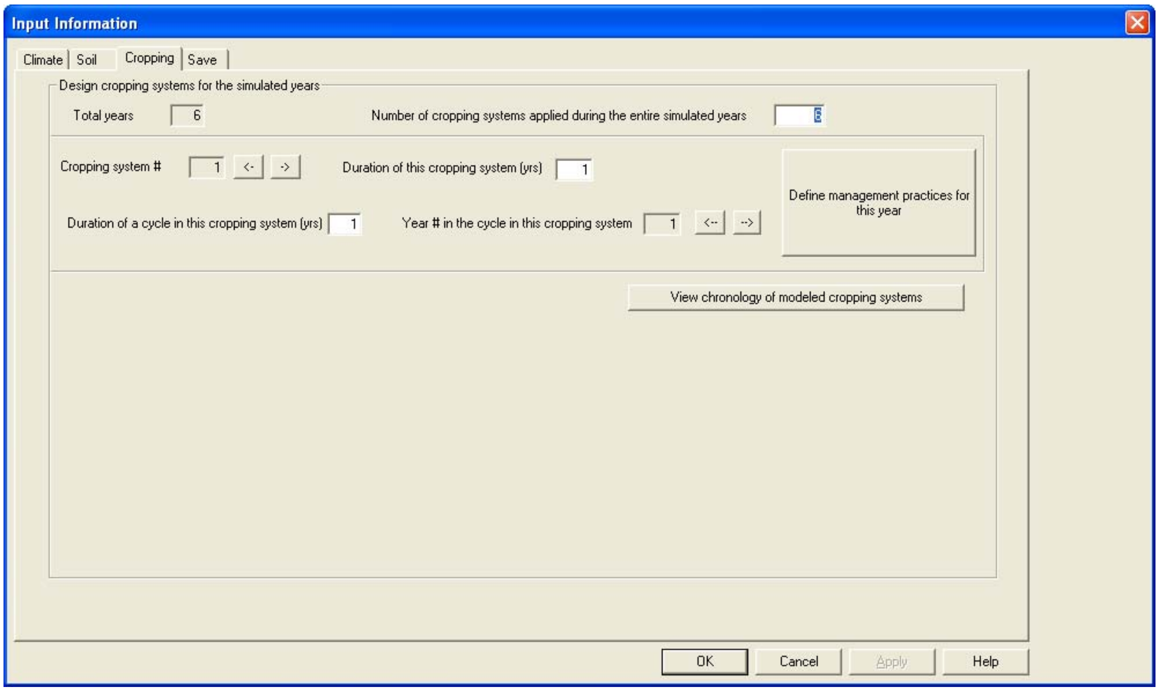



**Figure B.5.** Rice Cropping Systems

For this demonstration, we will show a single cropping system (year 1) as entered into DNDC (Figure B.6 through Figure B.8). The user can enter the cropping information for years 2 through 6 based on the information shown in Table B.3.

**Table B.3.** Rice Cropping System Information

| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| **Cropping System** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Plant Date** | 5/19 | 6/1 | 5/22 | 5/22 | 5/21 | 5/30 |
| **Harvest Date** | 10/12 | 10/30 | 10/15 | 10/13 | 10/29 | 11/12 |
| **Tillage 1** | 5/12 – 10 cm | 5/25 – 10 cm | 5/15 – 10 cm | 5/15 – 10 cm | 5/14 – 10 cm | 5/23 – 10 cm |
| **Tillage 2** | 5/13 – 10 cm | 5/26 – 10 cm | 5/16 – 10 cm | 5/16 – 10 cm | 5/15 – 10 cm | 5/24 – 10 cm |
| **Tillage 3** | 5/14 – 0 cm | 5/27 – 0 cm | 5/17 – 0 cm | 5/17 – 0 cm | 5/16 – 0 cm | 5/25 – 0 cm |
| **Tillage 4** | 10/18 – 5 cm | 11/5 – 5 cm | 10/21 – 5 cm | 10/19 – 5 cm | 11/4 – 5 cm | 11/18 – 5 cm |
| **Tillage 5** | 10/19 – 5 cm | 11/6 – 5 cm | 10/22 – 5 cm | 10/20 – 5 cm | 11/5 – 5 cm | 11/19 – 5 cm |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fertilization 1** | 5/14 - 114.33 kg N/ha Urea | 5/27 - 112.09 kg N/ha Urea | 5/17 - 116.57 kg N/ha Urea | 5/17 - 121.05 kg N/ha Urea | 5/16 - 134.5 kg N/ha Urea | 5/25 - 146.83 kg N/ha Urea |
| | injected to 10 cm | injected to 10 cm | injected to 10 cm | injected to 10 cm | injected to 10 cm | injected to 10 cm |
| **Fertilization 2** | 6/29 – 168.13 kg N/ha Ammonium Sulfate | 7/13 - 168.13 kg N/ha Ammonium Sulfate | 7/25 - 168.13 kg N/ha Ammonium Sulfate | - | 6/25 - 168.13 kg N/ha Ammonium Sulfate | 7/4 – 196.15 kg N/ha Ammonium Sulfate |
| | applied to surface | applied to surface | applied to surface | - | applied to surface | applied to surface |
| **Fertilization 3** | - | - | - | - | 7/10 – 196.15 kg N/ha Ammonium Sulfate | 7/17 – 168.13 kg N/ha Ammonium Sulfate |
| | - | - | - | - | applied to surface | applied to surface |
| **Flood Date** | 5/15/2005 | 5/27/2006 | 5/17/2007 | 6/11/2008 | 6/20/2009 | 5/24/2010 |
| **Drain Date** | 9/8/2005 | 9/24/2006 | 9/15/2007 | 9/10/2008 | 9/22/2009 | 10/2/2011 |
| **Additional Info** | | | | two "flushes" this year, entered as single day floods on 5/17 and 6/2 | two "flushes" this year, entered as single day floods on 5/23 and 6/7 | |
| **Winter Flood Date** | 12/1/2005 | 12/1/2006 | 12/1/2007 | 12/1/2008 | 12/1/2009 | 12/1/2010 |
| **Winter Drain Date** | 2/28/2006 | 2/28/2007 | 2/28/2008 | 2/28/2009 | 3/15/2010 | 3/15/2011 |
| **Leak Rate** | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| **Yield (kg/ha)** | 9,796 | 9,097 | 10,882 | 8,980 | 10,087 | 7,220 |
| **Yield (kg C / ha)** | 3,918 | 3,639 | 4,353 | 3,592 | 4,035 | 2,888 |

Figure B.6 shows crop information for year 1. In this case we have entered crop type (paddy rice), planting dates, and fraction of leaves and stems left in the field (assumed to be all of the crop residue or 100 percent). In addition, in preparation for the crop calibration process we have entered in the maximum biomass for grain based on our measured data (4,353 kg C/ha) and the biomass C/N ratio from field measured data – we have accepted the default values for the rest of the crop parameters for now.

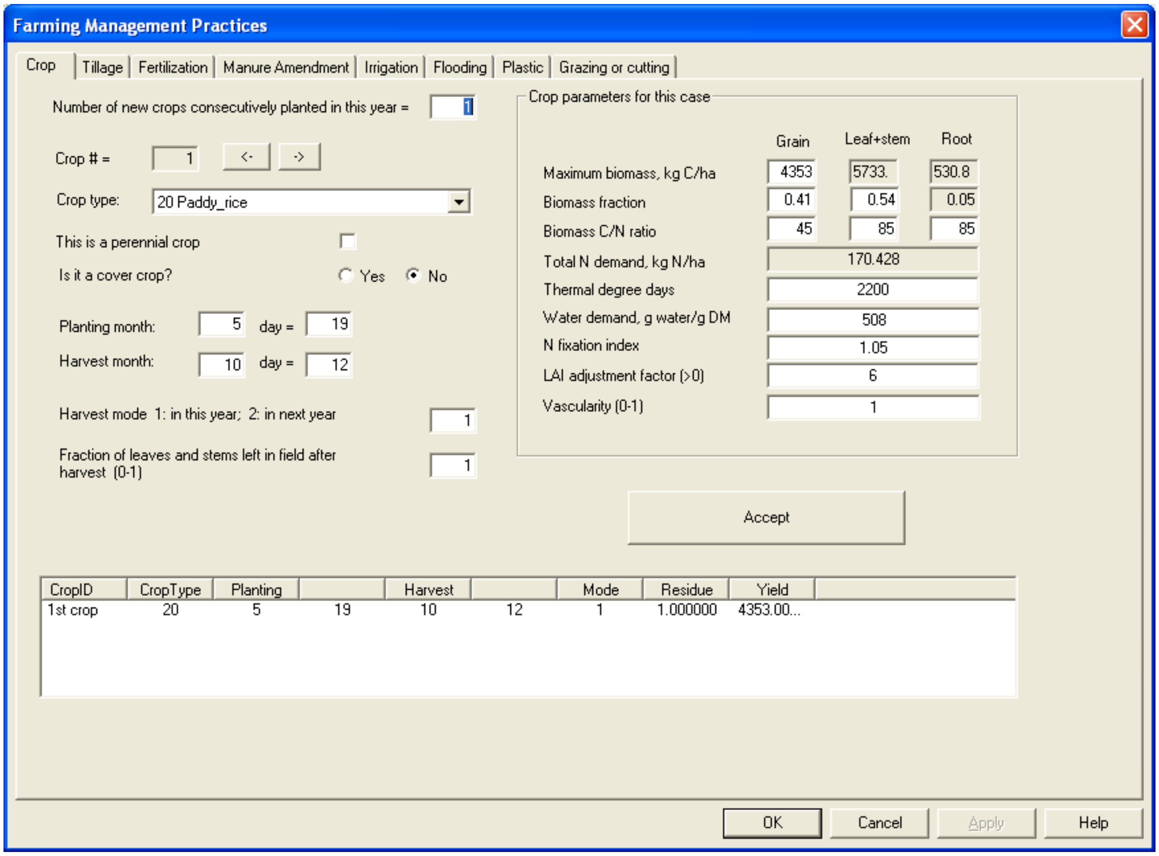



**Figure B.6.** Rice Farming Management Practices – Crop

Figure B.7 shows tillage practices. We have entered in all five applications and their associated dates and methods.

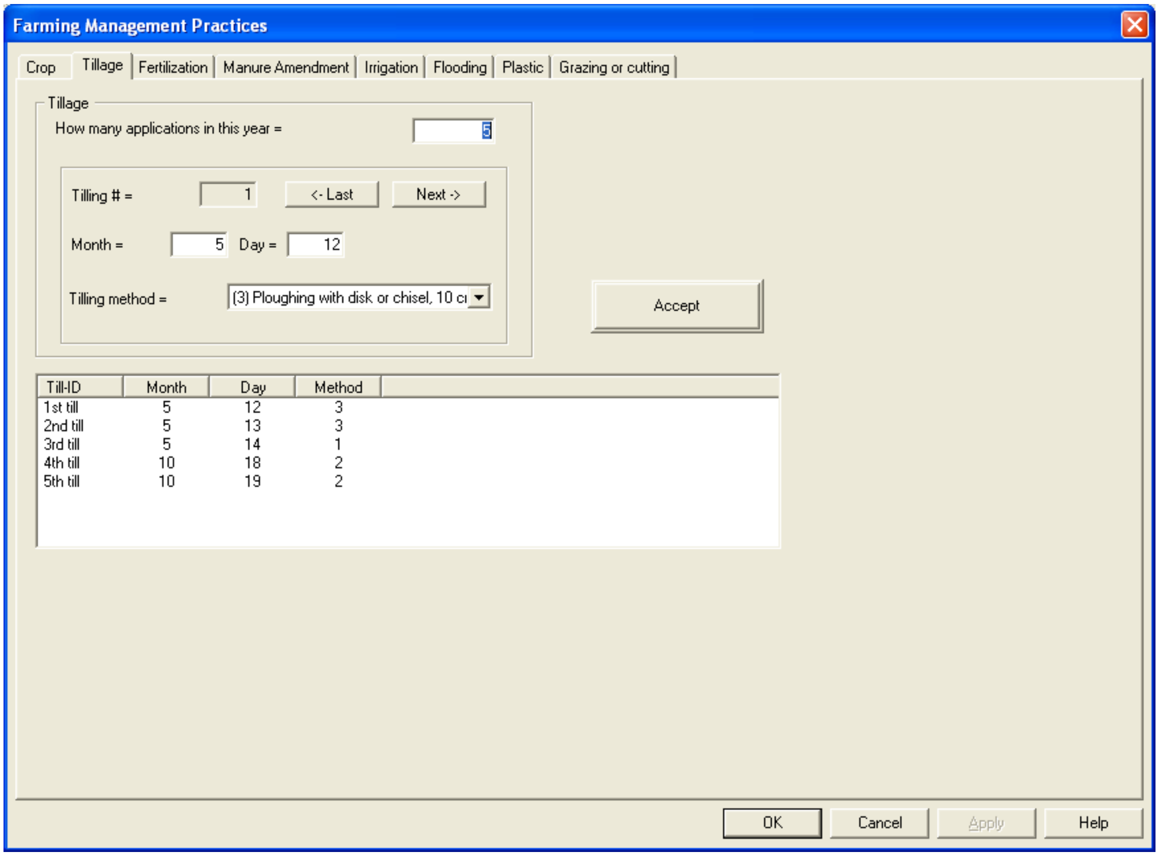



**Figure B.7.** Rice Farming Management Practices – Tillage

Figure B.8 shows fertilizer applications. We have entered in two applications and their associated dates, depths, and amounts.

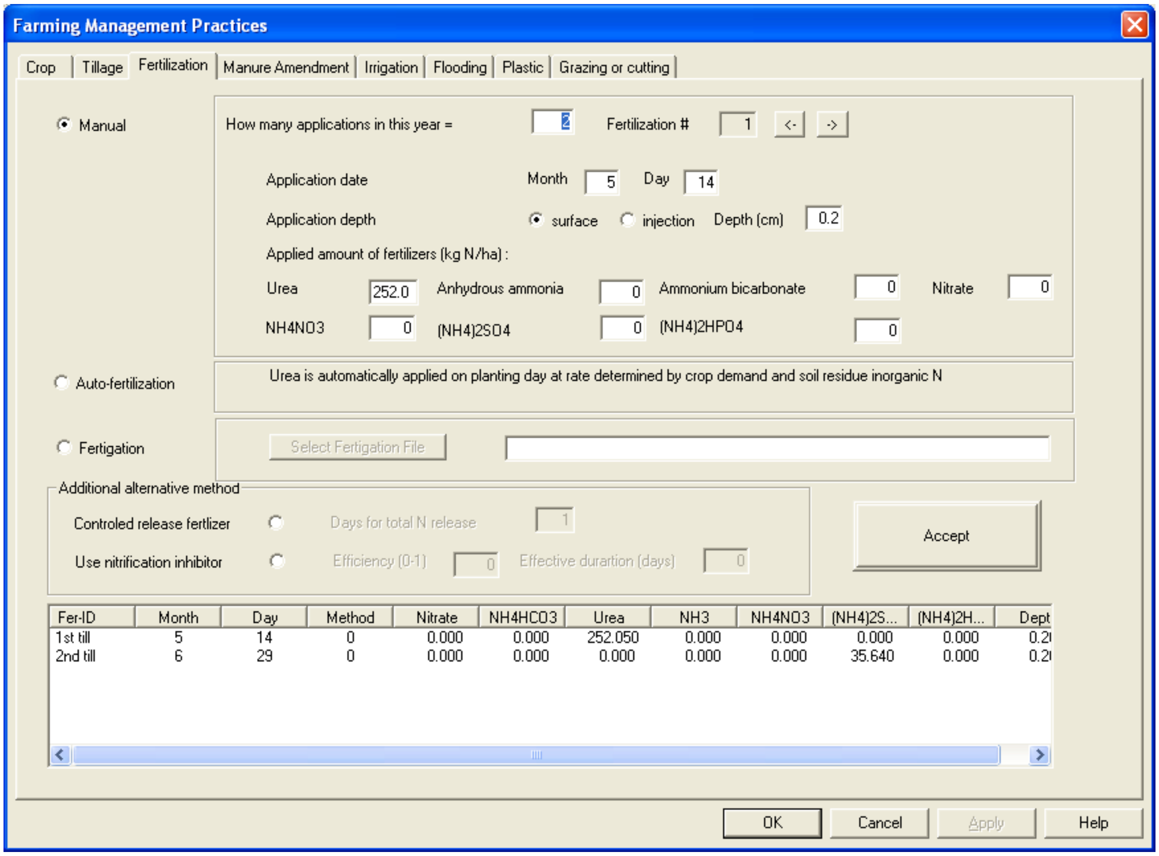



**Figure B.8.** Rice Farming Management Practices – Fertilization

Figure B.9 shows flooding management. We have entered in two floods (one seasonal and one winter flood) and their associated start and end dates as well as a leak rate of 0.08.

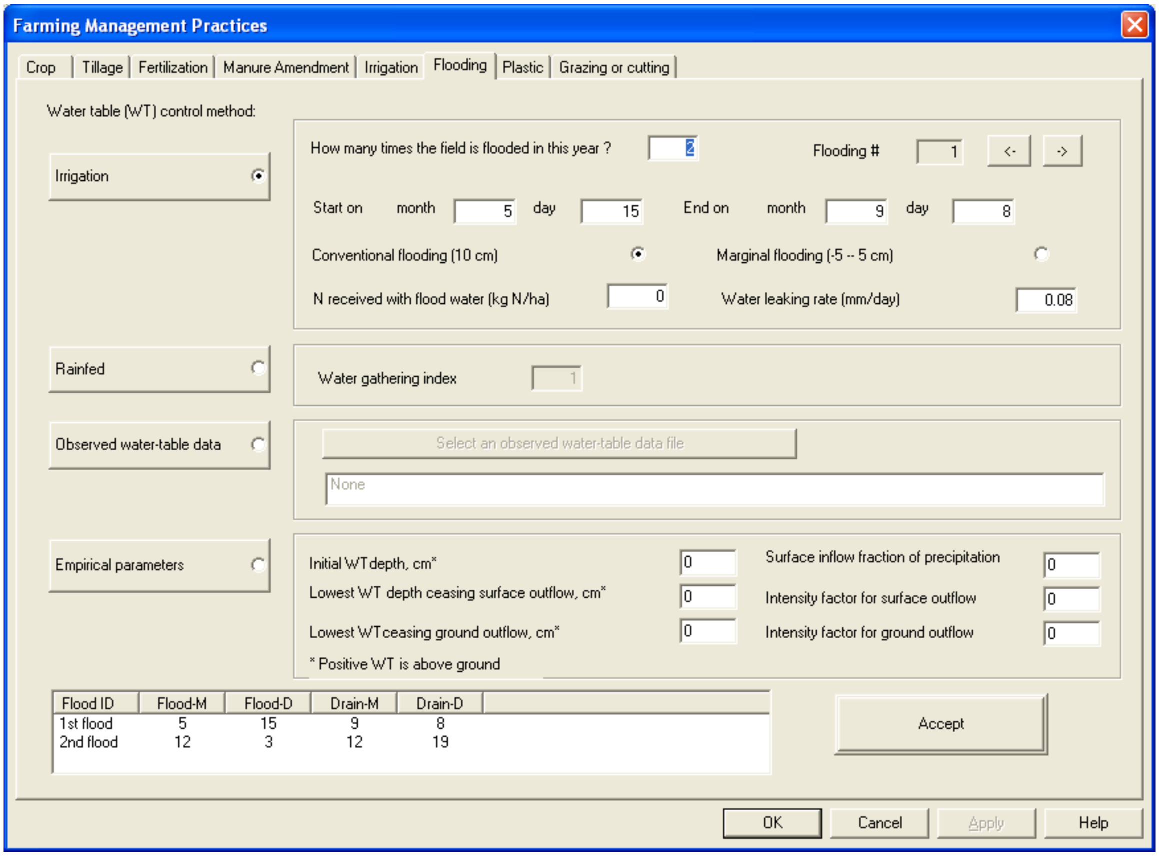



**Figure B.9.** Rice Farming Management Practices – Flooding

Since the farming management practices for this particular paddy do not involve any manure amendments, irrigation, plastic applications, or grazing/cutting, we will not enter any information on these tabs. The user should ensure that no residual information remains on these tabs from previous model runs.

When all of the information is entered, the user should save the results to a *.dnd file – we will call this "Baseline.dnd"; this file can be used later to set-up alternative management scenarios or to re-run model results.

## Crop Model Calibration

The model can now be run to prepare for the crop model calibration – this can be done on the main DNDC screen by clicking the site mode "Run" button. Results are put in the "C:\DNDC\Result\Record\Site" directory.

To review the first iteration of the crop calibration process, we need to compare the modeled yield with measured yield. Modeled yield can be found in "Multi_year_summary.csv" in the "Yield_GrainC" field. These values can be compared with measured yields as in Table B.4. In this case, the maximum absolute difference between measured and modeled yields is large (48 percent) so we will opt to run another iteration with adjusted crop parameters.

**Table B.4.** Rice Crop Model Calibration - Iteration 1

| Year | DNDC Yield (Yield_GrainC) | Measured Yield | Absolute Difference | Absolute Difference Percent |
|---|---|---|---|---|
| *1* | 4,041 | 3,918 | 123 | 3% |
| *2* | 4,012 | 3,639 | 373 | 10% |
| *3* | 4,134 | 4,353 | 219 | 5% |
| *4* | 3,266 | 3,592 | 326 | 9% |
| *5* | 3,506 | 4,035 | 529 | 13% |
| *6* | 4,266 | 2,888 | 1,378 | 48% |

We will start the calibration process by modeling a single year: the year with the maximum measured yield (year 3). We will create the run using all of the site characteristics (climate, soil, and known crop parameters), and, as suggested in step 1 of the calibration process, we will use optimal fertilization (i.e. use the auto-fertilization setting). When this iteration is run, grain yield is 4,264 kg C/ha/y; a difference of only two percent. Since this difference is small, we will use the maximum measured yield as the maximum biomass parameter.

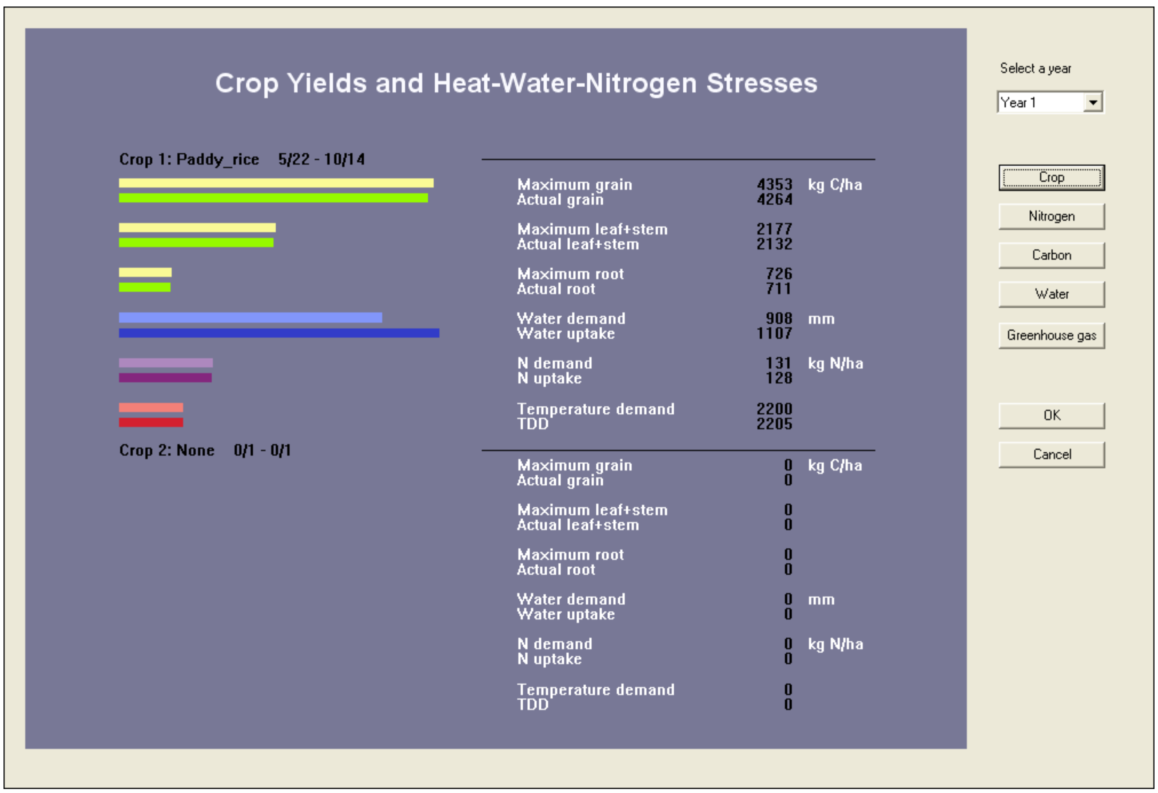



**Figure B.10.** Rice Crop Yields - Iteration 1

Next, we will check the modeled grain maturity date in the “Day_FieldCrop.csv” file: grain matures on day 238 (August 26) – this appears to be too early as the maturity date should be approximately the same date as the seasonal flood drain date (September 15). By increasing the thermal degree days parameter from 2200 to 2700 and re-running the model, we arrive at a more reasonable maturity date (day 260 or September 17).

Since there is no irrigation for paddy rice crops we can skip step 3 of the calibration process. We can now make one minor adjustment to the baseline scenario based on the calibration process: change the crop thermal degree days parameter from 2200 to 2700.

### Creating Alternative Management Scenarios

For this rice paddy example we will look at two scenarios:

- Water seeded rice with all crop residue left onsite, with a winter flood (the baseline scenario)
- Dry seeded rice with all crop residue left onsite, with a winter flood (the dry seeded scenario)

To do this, we will make a copy of the baseline scenario (“Baseline.dnd”) to be adjusted for the alternative scenarios. Each file can be renamed to represent a scenario. We will use the following file names:

- “Baseline.dnd”
- “DrySeeded.dnd”

There are two ways to change the parameters in each *.dnd file. The first is through the DNDC GUI. For a complicated, multi-year run, this is straightforward and a less error-prone method. Users who familiarize themselves with the *.dnd file format (see *DNDC User’s Guide*, Section III-1.2) may be able to make these same changes in a text editor.

We will go through the revision process for the above-listed scenarios here (“DrySeeded.dnd”).

Here are the key changes to the baseline to create the dry seeded scenario:

- Site name → dry seeded[47]
- Adjust the timing of the flood-up period relative to seeding, shift from May 17 to June 12
- Add two irrigation events (May 23 and June 1)

Open the “DrySeeded.dnd” scenario on the DNDC Input Information dialogue (click on “Open an input data file”). The site name can be changed on the Climate tab of the Input Information dialogue. We will call this scenario “DrySeeded.”

For each of the cropping systems (years), we will change the flooding information. Baseline flooding is shown in Figure B.11. And, since we are shifting to dry seeding, we will shift the second flood start date from May 17 to June 12 (see Figure B.12).

[47] We will eventually be running these scenarios in batch mode, so it is important to change the site name so that we will be able to distinguish the various results from each other.

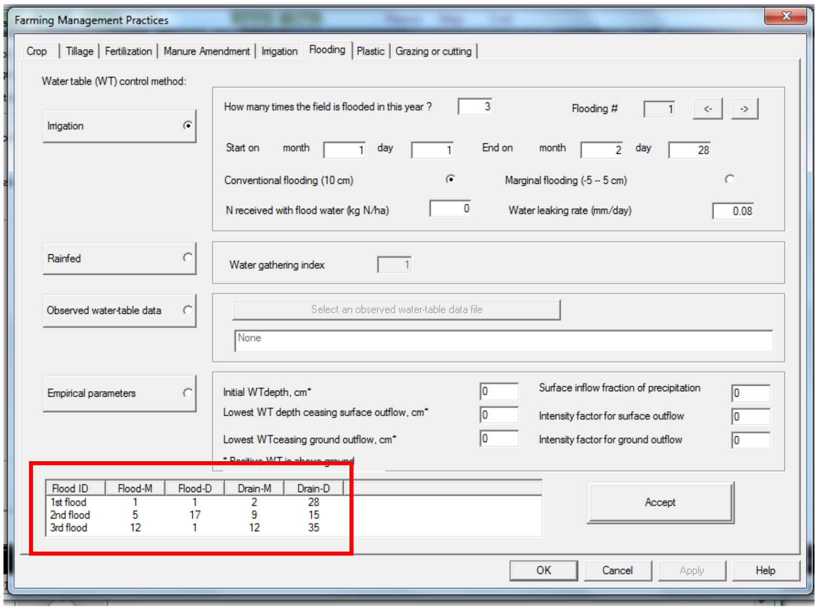



**Figure B.11.** Baseline to Flooding

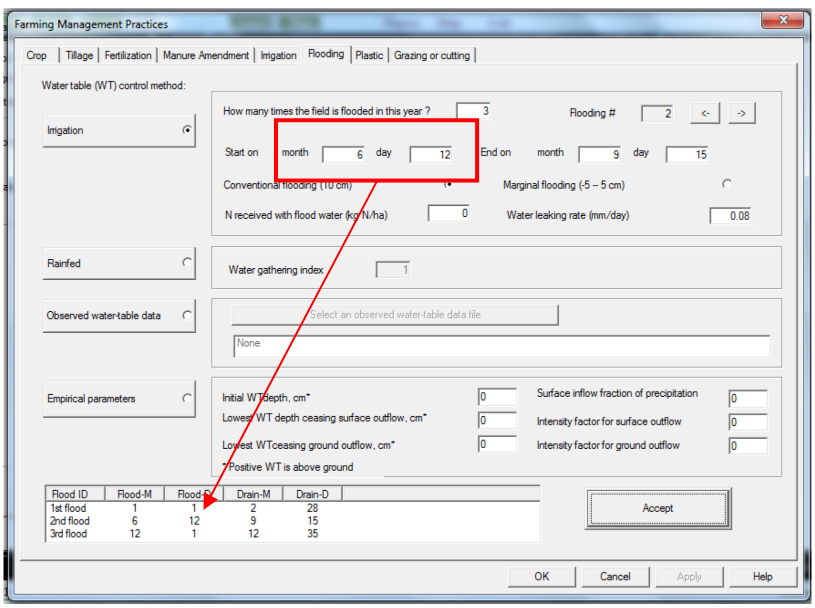



**Figure B.12.** Dry Seeding Flooding

In addition to a shift in when the fields are flooding for the rice growing season, dry seeding requires irrigation events following seeding to establish a good crop canopy prior to flooding. For this example we illustrate use of two irrigation events (May 23 and June 1) with 10 cm irrigation water for each event. Figure B.13 illustrates the DNDC irrigation tab with these two 10 cm irrigation events scheduled for May 23 and June 1.

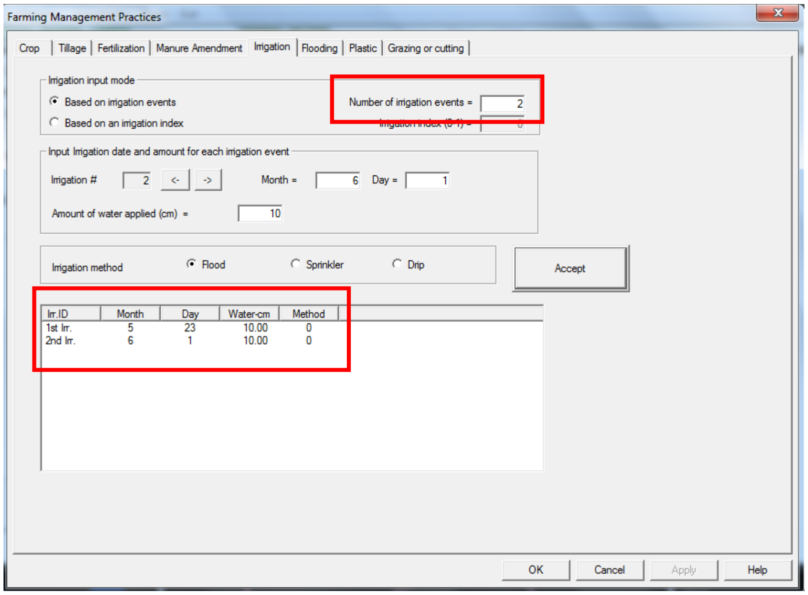



**Figure B.13.** Irrigation Events for Dry Seeding Scenario

Results for each site run can be examined using the DNDC results tab. Annual emissions for year 20 of a 20-year run for both baseline and dry seeded scenarios are presented in Figure B.14 and Figure B.15, respectively.

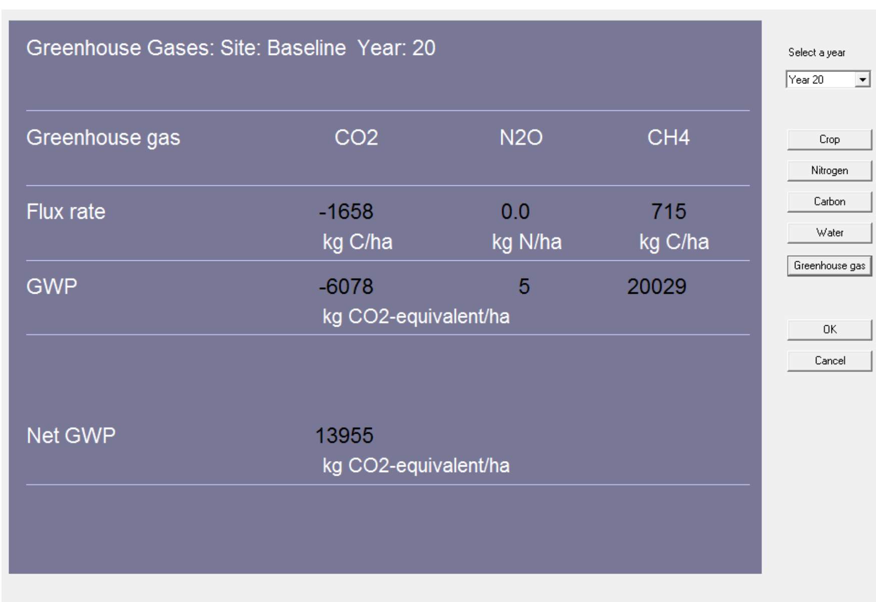



**Figure B.14.** DNDC Results Panel for Baseline Scenario

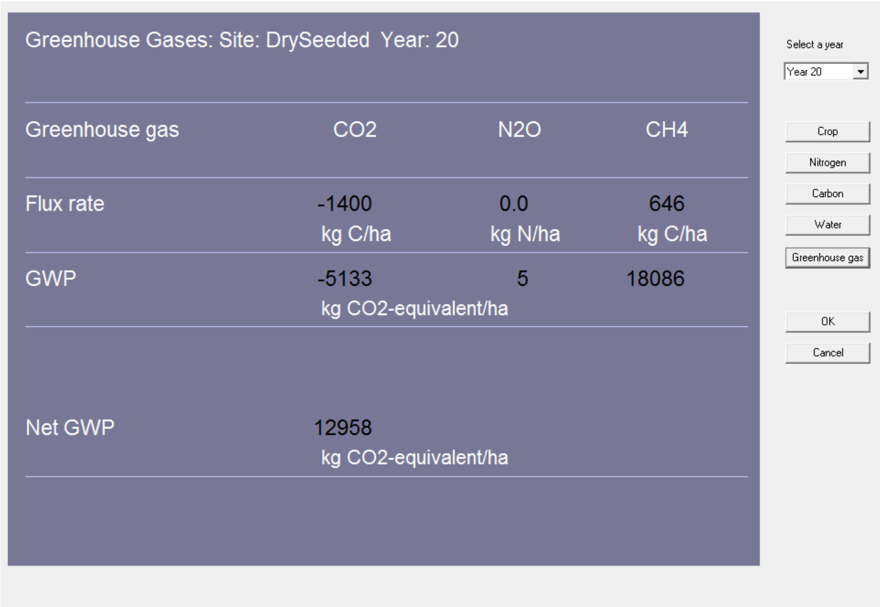



**Figure B.15.** DNDC Results Panel Dry Seeding Scenario

For this example shift from wet seeded rice to dry seeded, the modeled reduction in GHG emissions was 0.997 $tCO_2e$/ha.

Once the site level *.dnd files are created for both the baseline and project scenarios, the new software tool for creating all the batch file inputs following the Monte Carlo sampling procedures described in the RCPP can be run. Once the input files are complete, the user can then select batch mode from the tools menu in DNDC (see Figure B.16) and run DNDC in batch mode. A second software tool will then compile all the results from the batch run and provide the model estimates of GHG reductions.


**Figure B.16.** Batch Mode in DNDC

# Appendix C Derivation of Structural Uncertainty Deduction Factors

## C.1 Overview

As described in Section 5.1.7.1 of the protocol, the deduction factor to account for DNDC model structural uncertainty will be published on the Reserve's website (and periodically updated), and will be effective immediately for all fields registering emission reductions with the Reserve. This section explains the methodology used by the Reserve to determine the deduction factor.

The structural uncertainty deduction factor will be a function of the total number of fields registering emission reductions with the Reserve in any given cultivation cycle. The procedure described in this appendix will be performed for each region for which the RCPP is applicable in order to determine the appropriate uncertainty deduction factor to be used for each region. For each region, the Reserve will determine the exact deduction factors to be used, and whether the deduction factors are additive or multiplicative (determined as described below). This version of the RCPP is applicable to the California Sacramento Valley Region.

The structural uncertainty deduction factor $\boldsymbol{u_{struct}}$ is defined such that, after application of the uncertainty deduction factor to the direct emission reductions the following inequality holds in 95 percent of the cases, i.e. with 95 percent confidence:

$$\mathbf{DERs} < \boldsymbol{BE_{meas}} - \boldsymbol{PE_{meas}}$$

The uncertainty deduction can be either added or multiplied to the gross difference between project and baseline emissions, depending on whether the error structure of the residuals is additive or multiplicative. In the additive case:

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

In the multiplicative case:

$$\mathbf{DERs} = \boldsymbol{u_{struct}} \times (\boldsymbol{BE_{meas}} - \boldsymbol{PE_{meas}})$$

*Where,*

| | | |
|---|---|---|
| $u_{struct}$ | = | Structural uncertainty factor |
| $PE_{model}(i\,)$ | = | Model results for project emissions |
| $BE_{model}(i\,)$ | = | Model results for baseline emissions |
| $PE_{meas}(i\,)$ | = | Field results for project emissions |
| $BE_{meas}(i\,)$ | = | Field results for baseline emissions |

Before the derivation of $\boldsymbol{u_{struct}}$ is continued, the lack of bias is confirmed and it is determined whether the error structure of the residuals is additive or multiplicative.

## C.2 Confirming the Lack of Bias

The derivation of the structural uncertainty term assumes that no bias exists between measured and modeled results, or that $\langle \boldsymbol{Y_{meas}} \rangle = \langle \boldsymbol{Y_{model}} \rangle$. 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. For each region, it is explicitly tested that the model calibration strategy does not lead to bias by comparing modeled and measured emissions using a paired t-test.

## C.3 Verification of the Nature of the Structural Error

The structural error induced by a biogeochemical model such as DNDC is either multiplicative or additional.

In case the error is additive:

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

In case the error is multiplicative:

$$\boldsymbol{Y_{model,i} = Y_{meas,i} \times e^{\varepsilon_i}} \text{ with } \boldsymbol{\varepsilon \sim \mathcal{N}(0, \sigma)}$$

For each region, it is explicitly determined whether an additive or multiplicative error model must be assumed. The deviation between modeled and measured results will be multiplicative if residuals increase with increasing modeled values. However, if the deviation between modeled and measured results is additive, the residuals will be constant across modeled values. This is verified by investigating the heteroscedasticity of the residuals or by plotting the residuals versus the model values. In case of doubt, the additive case will lead to more conservative crediting than the multiplicative case and may be used as a default.

## C.4 Derivation of the Structural Uncertainty Deduction in Case the Error Term is Additive

If the error is additive and the model is bias-free, the following error model can be assumed for the project and baseline emissions:

$$\boldsymbol{PE_{model} = PE_{meas} + \varepsilon_1} \text{ with } \boldsymbol{\varepsilon_1 \sim \mathcal{N}(0, \sigma^2)}$$
$$\boldsymbol{BE_{model} = BE_{meas} + \varepsilon_2} \text{ with } \boldsymbol{\varepsilon_2 \sim \mathcal{N}(0, \sigma^2)}$$

A correlation between the project and baseline residuals may exist:

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

*Where:*

| | | |
|---|---|---|
| $u_{struct}$ | = | Structural uncertainty factor |
| $PE_{model}(i)$ | = | Model results for project emissions |
| $BE_{model}(i)$ | = | Model results for baseline emissions |
| $PE_{meas}(i)$ | = | Field results for project emissions |
| $BE_{meas}(i)$ | = | Field results for baseline emissions |
| $\varepsilon_1$ | = | Error term for project emissions |
| $\varepsilon_2$ | = | Error term for baseline emissions |
| $\sigma$ | = | Standard deviation of the residuals between modeled and measured values |
| $\rho$ | = | Correlation between project residuals and baseline residuals |

If the direct emission reductions are the difference between project and baseline, one can write:

$$\boldsymbol{DER_{model} = BE_{model} - PE_{model}}$$
$$\boldsymbol{DER_{meas} = BE_{meas} - PE_{meas}}$$

*Where:*

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

Because there is no bias between the model and the measurements, the average of the difference between $\boldsymbol{DER_{model} - DER_{meas}}$ is 0. The variance of this difference is:

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

In case there are multiple fields **n**, the inequality introduced in the beginning of this section has to hold only for the sum of the direct emission reductions, and for the direct emission reductions of each individual field. In this case, the variance of the sum of the emission reductions is:

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

If s is the standard deviation of the model residuals based on a limited set of k calibration values, the one-sided 95 percent confidence interval around the sum of the differences $\boldsymbol{DER_{model} - DER_{meas}}$ is:

$$\boldsymbol{DER_{model} - DER_{meas}} < s\sqrt{\boldsymbol{2(1-\rho)}} \times \boldsymbol{t_{inv}(0.95, k)}$$

In other words:

$$\boldsymbol{u_{struct}} = \frac{\boldsymbol{s\sqrt{2(1-\rho)}}}{\boldsymbol{\sqrt{n}}} \times \boldsymbol{t_{inv}(0.95, k)}$$

*Where:*

| | | |
|---|---|---|
| $u_{struct}$ | = | Structural uncertainty factor |
| $s$ | = | Standard deviation |
| $\rho$ | = | Correlation between project residuals and baseline residuals |
| $t_{inv}$ | = | Inverse of the cumulative t-distribution with a specific confidence and degrees of freedom |
| $k$ | = | Number of pairs of modeled and measured values used for model verification. |
| $n$ | = | Number of fields within the project “aggregate” |

## C.5 Derivation of the Structural Uncertainty Deduction in Case the Error Term is Multiplicative

If the error is multiplicative and the model is bias-free, the following error model can be assumed for the project and baseline emissions:

$$\boldsymbol{PE_{model} = PE_{meas}} \times \boldsymbol{e^{\varepsilon_1}} \text{ with } \boldsymbol{\varepsilon_1 \sim \mathcal{N}(0, \sigma^2)}$$
$$\boldsymbol{BE_{model} = BE_{meas}} \times \boldsymbol{e^{\varepsilon_2}} \text{ with } \boldsymbol{\varepsilon_2 \sim \mathcal{N}(0, \sigma^2)}$$

A correlation between the project and baseline residuals may exist:

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

*Where:*

| | | |
|---|---|---|
| $PE_{model}(i)$ | = | Model results for project emissions |
| $BE_{model}(i)$ | = | Model results for baseline emissions |
| $PE_{meas}(i)$ | = | Field results for project emissions |
| $BE_{meas}(i)$ | = | Field results for baseline emissions |
| $\varepsilon_1$ | = | Error term for project emissions |
| $\varepsilon_2$ | = | Error term for baseline emissions |
| $\sigma$ | = | Standard deviation of the residuals between modeled and measured values |
| $\rho$ | = | Correlation between project residuals and baseline residuals |

We will use the same terminology $\boldsymbol{DER_{model}}$ and $\boldsymbol{DER_{meas}}$ as introduced in the additive case in the subsequent derivation. The derivation is similar to the additive case if the following log-transformation is applied:

$$\boldsymbol{\ln\left(\frac{DER_{meas}}{DER_{model}}\right) = \ln(PE_{meas}) + \varepsilon_1 - \ln(BE_{meas}) - \varepsilon_2 - \ln(PE_{meas}) + \ln\,(BE_{meas})}$$

The variance of this ratio can be derived similarly as for the additive case:

$$\mathbf{Var}\boldsymbol{\left(\ln\left(\frac{DER_{meas}}{DER_{model}}\right)\right) = 2\sigma^2(1-\rho)}$$

The quantity $\boldsymbol{\sigma}$ can be estimated by the standard deviation of the difference of the log-transformed project and baseline emissions based on a limited set of **k** calibration values on the condition that a student-t distribution is used in the subsequent one-sided confidence interval:

$$\boldsymbol{\sum_{i=1}^{n} \ln\left(\frac{DER_{meas}}{DER_{model}}\right) < s\frac{\sqrt{2(1-\rho)}}{\sqrt{n}} \times t_{inv}(0.95, k)}$$

Rearranging this equation yields:

$$\boldsymbol{\ln\left(\frac{DER_{meas}}{DER_{model}}\right) < s\frac{\sqrt{2(1-\rho)}}{\sqrt{n}} \times t_{inv}(0.95, k)}$$

$$DER_{meas} < DER_{model} \times e^{s\frac{\sqrt{2(1-\rho)}}{\sqrt{n}} \times t_{inv}(0.95,k)}$$

In other words:

$$u_{struct} = e^{-s\frac{\sqrt{2(1-\rho)}}{\sqrt{n}} \times t_{inv}(0.95,k)}$$

## C.6 Quantifying the Standard Deviation $s$ and the Correlation ρ

The calculation of $u_{struct}$ is critically dependent on the standard deviation of the residuals (i.e. the difference between modeled and measured values) s and the correlation between the residuals of the project emissions and the residuals of the baseline emissions $\rho$.

These quantities are calculated based on at least 8 pairs of measured and simulated annual emissions that have been measured over at least 2 growing seasons.
In case only annual fluxes are available, $k$ pairs of $(Y_{meas}(i), Y_{model}(i))$ will be available with $k \geq 8$.

**In the additive error case**, the quantity $s$ can be calculated as the standard deviation of the difference between $Y_{meas}(i)$ and $Y_{model}(i)$. Note that the student-t distribution includes a deduction due to the standard deviation being estimated on a limited set of values. Lower deductions will be achieved if $k$ is higher and more measurements are available.

The quantity ρ can be estimated by dividing the measurements in "baseline" cases, $BE_{meas}(i)$ and "project cases", $PE_{meas}(i)$. In conventional language, the baseline would be the control or conventional treatment. Subsequently, pairs of measured and simulated emission reductions $DER_{meas}(i)$ and $DER_{model}(i)$ can be calculated as the difference between $PE_{meas}(i)$ and $BE_{meas}(i)$, and $PE_{model}(i)$ and $BE_{model}(i)$, respectively. $\rho$ is calculated as the correlation coefficient between $DER_{meas}(i)$ and $DER_{model}(i)$. Smaller correlation coefficients will result in greater uncertainty deductions. Therefore, a set of correlation coefficients is calculated through leave-one-out jackknifing and the correlation coefficient set to the low range of this set of values.

**In the multiplicative error case**, the quantity $s$ can be calculated as the standard deviation of the difference between $\ln Y_{meas}(i)$ and $\ln Y_{meas}(i)$. Similarly as for the additive case, smaller deductions will be achieved if $k$ is higher and more measurements are available. $\rho$ is calculated as the correlation coefficient between $\ln\left(\frac{PE_{meas}(i)}{BE_{meas}(i)}\right)$ and $\ln\left(\frac{PE_{model}(i)}{BE_{model}(i)}\right)$.

However, if a set of daily fluxes are available, the quantities $s$ and $\rho$ are calculated with more accuracy based on daily values of these quantities as:

$$s_{annual} = 365 \times s_{daily}$$
$$\rho_{annual} = \rho_{daily}$$

Note that any other time period (i.e. 3-daily or weekly) can be used.

# Appendix D Summary of Performance Standard Research

This section summarizes research on industry trends in the use of water and residue management practice in rice cultivation that have the potential to reduce methane emissions. The research focused on three practices that had previously been identified in other methodologies as having GHG mitigation potential: dry seeding, reduced winter flooding, and residue management. The outcomes of the research were used to develop performance standards in this protocol.

## D.1 Background on Water and Residue Management Practices

Rice is a unique agricultural system due to the use of flooding to meet the plant physiological demands and to control weeds. There are unique advantages of flooding and maintaining a flood throughout the growing season. These advantages include: (1) easier water management and less water use, (2) red rice and grass suppression, (3) less seedling stress from cool weather, (4) elimination of early-season blackbird problems, and (5) reduction in seedling loss due to salt.

Producers' decisions regarding which seeding method to use are targeted at selecting the method that will result in proper seedling emergence that will lead to a uniform canopy. Seeding methods depend on soil type, weather conditions, and producer preferences. Seeding methods for rice production include both water seeding and dry 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** simply describes sowing seed into a dry seedbed by drilling or broadcasting. Dry seeding method usually offers more flexibility in planting but may require more time to do so. The flood for dry seeded rice starts approximately 25 to 30 days after seeding. During the dry period, fields are periodically irrigated to promote germination and stand establishment. This system is also weather dependent. A small fraction of the rice acreage is dry seeded in California.

In California, water seeding with continuous flood is predominant during the growing season. Continuous flood regime is used on over 96 percent of the acreage in California. Fields are flooded to a depth of 4 to 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 reproductive organs from cool nighttime temperatures that can lead to reduced yields via blanking. 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. Fields are also drained near the harvest date. The exact timing for draining the fields can vary and can influence total yields.

The University of California Cooperative Extension (UCCE) recommends that growers drain their fields when the panicles are "fully tipped and golden." This is done through visual inspection and is typically two to four weeks prior to anticipated harvest date. According to UCCE, there is a large variability in when growers choose to drain the fields. Some growers choose to drain when the rice is partially or 50 percent "tipped," some wait until 75 percent tipped, and others follow UCCE guidelines of 100 percent or fully tipped.

After the growing season, winter flooding can be used to enhance rice straw decomposition. With a winter flood system, the flood water is introduced to the field shortly after harvest is completed. Growers either maintain flooded conditions until spring by reapplying flood waters or they just use a single flood event. Growers' decisions to flood the field after harvest are influenced by timing of the harvest, habitat goals, and expectations regarding availability of water (Term 91).

## D.2 Industry Trends in the Use of GHG Mitigation Practices

### Winter Flooding

Two sources of data were used to characterize the use of winter flooding in California rice systems. Site-specific records on the use of winter flooding were collected from the following four irrigation districts: Glen-Colusa, RD 108, Richvale, and Western Canal. In addition, multi-temporal remote sensing data (MODIS and Landsat) were analyzed to map spatial patterns of winter flooding from 2005 to 2010 for the entire California Sacramento Valley.

The data from the Glenn-Colusa Irrigation District (representing over 20 percent of California rice acreage) were analyzed in a GIS to assess acreage of winter flooding from 2007 to 2010 and persistence of winter flooding from one year to the next for each rice field. Approximately 40 percent of the fields did not use winter flooding from 2007 to 2010 (Table D.1). Of the 60 percent of the fields that did use winter flooding at some point, less than one percent of the fields winter flooded for all four years. The data from the other irrigation districts (RD 108, Richvale, and Western Canal) showed similar variability in the fraction of fields with winter flooding.

**Table D.1.** Presence and Frequency of Winter Flooding in Glenn-Colusa Irrigation District (2007-2010)

| Class | Acreage | % |
|---|---|---|
| No Floods | 42161.9 | 40.0% |
| 1 Yrs | 20314.3 | 19.3% |
| 2 Yrs | 22346.9 | 21.2% |
| 3 Yrs | 17566.9 | 16.7% |
| 4 Yrs | 1912.6 | 1.8% |
| Other | 977.4 | 0.9% |

In addition, multi-temporal remote sensing data (MODIS and Landsat) was analyzed in order to map spatial patterns of winter flooding for rice growing areas for all of California from 2005 to 2010. These results also indicated that the use of winter flooding varies from one year to the next and there is no clear trend in the extent and frequency of use of winter flooding for all rice growing regions. Details of the spatial analysis of winter flooding are provided in a separate background research paper that will be published on the Reserve website.

The results of this research show that the use of winter flooding every year is virtually non-existent; it is more typical for winter flooding to be used one, two or three years out of every five years with no winter flooding during the other years; and 40 percent of acres appear to never be flooded during the five year interval investigated. Data reported in the background paper[48] affirm

[48] Background paper will be made available on the Climate Action Reserve Website

these same findings over a longer historical period. Therefore, reduced winter flooding (i.e. the absence of winter flooding) is already somewhat common in the California Sacramento Valley. In addition, the intermittent trend in use/non-use of winter flooding, make it difficult to reliably determine what expected levels of reduced winter flooding would be in any given year under "business as usual." These findings, combined with concerns about negative impacts on waterfowl habitat, led to a decision to exclude reduced winter flooding as an eligible project activity in the protocol.

**Rice Straw Residue Management**

Rice straw represents a significant challenge to rice farmers. Techniques for managing rice straw can be categorized into the following management alternatives: burning, baling, soil incorporation without winter flooding, and soil incorporation with winter flooding for enhanced straw decomposition.

Rice straw may or may not be prepared by chopping or soil-incorporating before flooding. After flooding, many fields are rolled with specially built "cage rollers" which help create soil/straw contact. Decomposition of straw in this system is not limited by moisture and has consistently given more complete decomposition compared to non-flooded systems.

Most potential uses of rice straw can be categorized into energy use, manufacturing and construction, environmental mitigation or livestock use. Environmental mitigation includes the use of rice straw for erosion control on construction areas or for rehabilitation on burned slopes. Small amounts of rice straw are used in composting, mushroom production, and livestock feed and bedding.

There are many potential uses of rice straw, yet few are currently being used. The reasons appear to be related to 1) technical constraints, 2) economic feasibility, particularly related to the cost of removing straw from the field, and 3) supply and storage problems.

Until 1991, burning rice straw was the most common practice. Following the 1991 Rice Straw Burning Reduction Act, burning of rice straw decreased dramatically on an annual basis. By 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 to 12 percent of rice acreage in California.[49]

If the straw is not burned, then growers will either retain and incorporate all of the straw on the field or they will bail the rice straw for off-field uses. The current estimate from the California Rice Commission (CalRice) for baling in California is 6 to 8 percent of the acreage per year. This estimate was further corroborated by the Reserve through analysis of previous research,[50] and through the use of a survey of University of California Cooperative Extension (UCCE) rice farm advisors and straw balers in California. Results from the survey suggest that rice baling has declined in recent years due to a loss of demand from the building and construction industry. Estimates from UCCE Rice Farm Advisors ranged from 2 to 6 percent of the California acreage in a given year. This obviously fluctuates a bit with various straw markets. It is also important to note that baling does not remove all of the rice straw following harvest. Due to operational constraints and the market for straw, baling typically removes one to two tons of rice straw per acre out of approximately three tons per acre that is produced. Therefore, anywhere

[49] Personal communication with Paul Buttner.
[50] Garnache et al. 2011.

from 50 percent to 33 percent of the rice straw remains on the field. On an annual basis, 80 to 84 percent of all rice fields have 100 percent of the rice straw incorporated into the soil.

Based on the evidence presented by California rice industry experts, the Reserve has concluded that baling of rice straw is not a common practice in California, with a likely adoption rate of between 2 to 7 percent of the acreage. Thus, the Reserve has concluded that switching from rice straw incorporation to baling constitutes an additional GHG reduction practice in California.

**Dry Seeding**

According to the USDA Economic Research Service ERS data analyzed by Livezey et al. in 2001, a dry seeding method is relatively common in most U.S. rice growing regions; however, it is not common practice in California. In 2001, the estimated acreage of rice that was dry seeded was 5 percent according to the ERS data.[51] To confirm that dry seeding is still not a common practice in California, the Reserve again relied on the estimates provided in survey responses from UCCE Rice Farm Advisors, as well as estimates from the California Rice Commission. According to experts from the UCCE and CalRice, dry seeding is occurring on *less than* 3 percent of the rice acreage in California.

Based on the evidence presented by California rice industry experts, the Reserve has concluded that dry seeding is not a common practice in California, with a likely adoption rate of less than 3 percent of the acreage. Thus, the Reserve has concluded that switching from water seeding to dry seeding constitutes an additional GHG reduction practice in California.

[51] Livezy et al., (2001) Table 5, pg. 10.

# Appendix E Wildlife Habitat Conservation and the Rice Industry

In California's Central Valley, approximately 95 percent of the original existing wetlands have been converted from their natural state.[52]

As native wetland habitats have been increasingly degraded, wetland-dependent species, such as waterfowl and shorebirds, have adapted to using flooded rice lands as a substitute for their native habitat. Rice fields may be flooded 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, more species data are available for California's Central Valley than for other U.S. rice growing regions. In California, seven million waterfowl and several hundred thousand shorebirds are supported by rice lands annually,[53] and over 230 species have been identified in the state's rice lands, including waterfowl (e.g. ducks), shorebirds, wading birds, raptors, reptiles, amphibians, and small mammals.[54] 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.

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."

The adoption of dry seeding is expected to result in a delay in winter flooding by a few days, meaning that though there is a slight delay in the provision of surrogate habitat (e.g. flooded rice fields) to wetland-dependent species, the quality of the surrogate habitat will not be affected. The effect of baling on the quality of flooded rice lands as surrogate habitat is somewhat less clear. In one study of species preferences for different rice straw management options, wetland-dependent bird species appeared to have a slight preference for fields where rice straw had been left on the field (whether spread or incorporated) than fields where the rice straw residue had been removed (by baling).[55]

The Reserve will continue to monitor the impacts on wildlife habitat that result from the above two RC management changes, as well as other potential management changes that may be allowed in subsequent versions of this protocol. Should it be determined that a certain activity is resulting in negative impacts, mitigation options and/or changes in approved project activities may be required under subsequent protocol versions.

[52] Petrie et al (DU report).
[53] Petrie et al (DU report).
[54] Sterling et al.
[55] Elphick, Chris and Lewis Oring, "Conservation implications of flooding rice fields on winter waterbird communities," *Agriculture, Ecosystems, and Environment* 94 (2003).