White Paper

Environmental
Resources
Management

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ERM

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Subject: White Paper: Review of ARB Compliance Offset Protocol Development: Rice Management Practices

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INTRODUCTION

ERM was retained by CalAg, LLC and CalAg Aggregator LLC ("Aggregator") to prepare a White Paper to identify issues that could be key barriers to developing and registering rice management projects for future compliance carbon offset credits with the California Air Resources Board (ARB). Aggregator is a developer comprised of principals of the manufacturing and operating entity, CalAg, LLC ("CalAg") for a rice straw project in California involving straw removal, baling and conversion to medium density fiberboard (substituting straw for wood fiber). CalAg, as the manufacturing and operating entity, owns the technology to effect this conversion and will sell the resulting product for use in various applications, including green building materials. Aggregator is the project developer for purposes of the proposed Rice Management Protocol ("Protocol"). At this time, CalAg believes their process is the largest commercial rice offset project under this Protocol. The CalAg project potentially represents one of the largest sources of Carbon Offsets under the AB 32 Cap and Trade program if the Protocol is formalized with a commercially viable methodology.

This paper discusses the results of ERM's review of the DNDC Model and modeling results as well as a review of the Rice Management Protocols (RMPs) available from the Climate Action Reserve (CAR) and the American Carbon Registry (ACR). This Paper covers the issues identified for a review of the protocols and the DNDC model, summarizes ERM's analysis of these issues and makes recommendations for a potential path forward.

BACKGROUND

On the advice of the Air Resources Board (ARB), Environmental Resource Management (ERM) and Cooper White & Cooper LLP worked with the Environmental Defense Fund (EDF), the primary recipient of funds for the research and development with the American Carbon Registry (ACR) of a protocol and model for developing offsets from methane reductions from rice management projects.

Over the last eighteen months, CalAg, Aggregator and ERM have analyzed the draft protocols from the ACR and final protocol from the Climate Action Reserve (CAR). ERM has also reviewed the DeNitrification - DeComposition (DNDC) model as developed by the University of New Hampshire and Bill Salas of Applied Geosolutions LLC. Through this process, ERM has identified a number of issues which we believe would ultimately impact the viability of any rice protocol released by the ARB if these issues are not resolved prior.

We understand that ARB is developing the rice compliance protocol from the final CAR Protocol and the Revised Draft ACR Protocol for rice projects. We understand that documents were delivered by EDF to ARB on December 20th 2012 with the model and supporting data delivered to ARB in January 2013. Therefore, we are basing the discussion here on the previous versions of the protocols.

EXECUTIVE SUMMARY

- Both of the existing rice offset protocols published by CAR and ACR rely upon the DNDC Model for on-field emissions reductions for rice management projects; the DNDC Model is a process based model. This type of model has been developed to model biological growth processes including photosynthesis, nutrient cycles, and climate effects. The DNDC Model is considered a Tier 3 method for calculating GHG emissions and represents the highest level of complexity. There are commonly three tiers of GHG emissions inventory calculations referred to by the IPCC, with the tier numbering reflecting an increase in complexity.

- The current version of the DNDC Model that we examined has a very high level of complexity and simultaneously the lowest level of functionality and commercial viability in its current phase. In evaluating the model and its intended uses, ERM determined there are several issues regarding complexity, usability, and variability of model results. These issues are summarized here and discussed in further detail below.

- Primarily, our recommendation is that the DNDC is not suitable for use for commercial applications at this time. The modeling required by rice offset project developers is simply not on par with the stability and usability of the models required in other current ARB-approved offset protocols. Specifically, the current variability of the modeling results and ambiguity of the modeling methodology provides a disincentive for participation in current rice projects.

- For the DNDC Model to be usable by rice offset project developers for commercial application, substantial work would be needed to evolve from the current academic status of the model to a commercial grade model.

    - ERM's review of the DNDC model results showed wider variability than expected for test runs of on-field emissions for the Aggregator project. The wide variability of the DNDC Model results needs to be examined in detail to ensure there is not a mechanistic issue(s) with processes in the model itself.

    - To increase the usability of the model for commercial purposes, several improvements to the DNDC Model would need to be made. Pre- and post- processing tools would need to be developed and made available. This would include parameterization, an Autosave feature, and report option for both a listing of assumptions and results to be exported into standard software formats. The use of standardized data sets should also be provided, where possible. Error messages for incomplete fields and data points outside of the numerical bounds need to be added.

- These concerns are compounded by our assessment that the rice management protocol appears to contain not only a larger number of analytical steps but also more extensive recordkeeping than the existing four ARB compliance offset protocols.

- We also have specific concerns about the costs of monitoring and verification if the analytical methods to be used are unduly complex, especially compared to those contained in the other four Compliance Offset Protocols that the ARB has already approved.

- Thus, based upon our analysis, ERM is concerned that the level of effort and cost to document and calculate the rice project offsets is not proportional relative to the volume of credits generated.

Therefore, the cumulative impact of the requirements is that the carbon credits for rice management projects are the most complex paperwork ever required for generating carbon credits. This has substantial implications for the future viability of the rice management protocol and for rice offset credits. Finally, the costs of implementing the protocol compared to the financial benefits from a rice management project suggest that without further efforts towards streamlining and aggregation, the protocol will not be cost effective for rice project developers which in this case will directly impact the viability of the project.

- To overcome this, rigorous streamlining of the calculation method, whatever the form (model or otherwise) and of the protocol are critically necessary. Since the DNDC Model requires further work and may not be able to be user friendly in time for the ARB Protocol, ERM recommends that a tiered approach to the calculation of rice offset project benefits be allowed under the ARB protocol.

- In addition, calculation methods for off-field emissions benefits associated with the Aggregator rice project should be included. ERM has developed a set of proposed methods for consideration.

REVIEW

Issues from ERM's review are identified below and recommendations are provided for each.

A. Review of DNDC Model Operation

Currently, the DNDC Model is a research grade model and is not developed for commercial use. As such, the DNDC Model needs to move from a research grade model to a user friendly software program for commercial application purposes, and it is necessary to make the changes needed to address these issues listed below. Specific recommendations are provided for each issue below.

A.1. Issue: The DNDC Model results indicate a wide statistical variability from field to field, and renders the model results suspect to challenges to credibility for commercial use of the model. (see Appendix A)

ERM evaluated the only available results from the DNDC Model for California. EDF provided the NRCS Conservation Innovation Grant (CIG project 2010) model run results for California to ERM as the most current results. ERM used these modeling results to perform a statistical analysis. The results showed widely variable results. In ERM's review, there were a number of irregularities in the outputs that could not be accounted for and represent areas of concern. There is 200 to 300+% variations in the model results for CO2e tonnes per acre predicted for side-by-side rice fields. EDF suggested that the variation could be as much as 600% (Email from Robert Parkhurst, EDF on 1/5/2013) based on work in China. It has been suggested by William Salas that much of this variability comes from the variability of soils on a site.

Even beyond the variability in the results, the statistical analysis suggests that either there are errors in the DNDC Model mechanism or in the input data. The ERM Report that further documents these findings is Appendix A.

A. 1. Recommendation: The sources of variability in the DNDC Model results should be further evaluated to resolve whether there is an issue with the biogeochemical mechanism in the model or whether the input data used can explain the variability.

A.2. Issue: Length of time for labor to set up and conduct model runs using the DNDC Model is so very large as to be infeasible for project developers.

With the information that DNDC Model developer, William Salas provided during the CAR verifier training for the Rice Cultivation Protocol in February 2013, ERM estimated the effort needed for CalAg's project. For the planned CalAg project, the DNDC model would require a combination of 12,600 hours of computer run time and labor effort. Alternatively, if cloud computing were used, 4,500 hrs of run time and labor effort was estimated.

For the approximately 90,000 acres providing straw to CalAg, we assumed 900 fields of 100 acres each to produce this estimate. Below are the additional assumptions that were made in this review.

- Each field requires a Parameterization step: Set up climate/soil input, assumed 2 hrs labor/field), Historical Runs/Calibration: Assumed 2 runs that can be evaluated in 2 hrs labor/field; then 2

Monte Carlo Runs (large): Assuming pre- and post- processing tools are available, each of the two runs taking 4 hrs run time, and post processing each for 1 hr labor each/field.

- If the pre- and post- processing tools are not available, ERM estimates there would need to be additional time for assistance from a programmer to create pre/post processing tools. *That labor has not been included here in this estimate.*

- Therefore, ERM assumed one practice per field and estimates that each rice field would require the following technical labor and computer run time:

4 short runs and 2 Monte Carlo (large runs)
= 6 runs * 900 fields = 5,400 runs of the DNDC model

Estimating
4 technical labor hrs/field * 900 fields = 3,600 hrs (labor)
14 hrs/field * 900 fields = 12,600 hrs (computer run time)

Alternatively, if cloud computing is utilized and
expert modeling ability is available, our estimate for the run time
decreases by about 1/3 --
5 hrs/field * 900 fields = 4,500 hrs (computer run time)

- Estimates were made based upon feedback received during the CAR Verifier Training for the DNDC Model held in Los Angeles in February 2013.

Note: If multiple practices per field were used by rice growers, then for each practice, ERM was advised by CAR that multiple model runs would need to be made for each field. For example, to meet verification requirements, a field with two practices would perform 8 short runs and 4 large runs. Assuming 2 practices per field for 900 fields at 100 acres each, then 25,200 hrs or using cloud computing, 9,000 hrs of run time and 7,200 hrs of labor would be required.

Therefore, labor and run time needed for the DNDC Model to produce the results required to meet the requirements for verification presents an almost insurmountable barrier to the Model's commercial usability.

A.2. Recommendation: An alternative calculation method is preferable since the labor effort and run time for use of the DNDC Model is currently so significant that the cost may overcome the carbon offset benefits of a rice project, thereby eliminating the commercial utility of the DNDC Model and usefulness of the rice compliance offset protocol.

A.3. Issue: For rice project applications, there is no Users Manual, no technical documentation, no tutorial and no technical support available for the DNDC Model.

ERM has reviewed the existing documentation for the DNDC Model. The manual available is a generalized User's Manual (undated) for the DNDC Model 9.5 posted to a link at the University of New Hampshire website at: http://www.dndc.sr.unh.edu/?page_id=4

A manual for a specific application of the DNDC Model to a rice offset project is not provided. The CAR and ACR protocols have each provided a substantial amount of support on this issue; however, for model operation, additional guidance to the model user would be a necessity.

A standard practice in air quality modeling is to associate a model used for regulatory purposes with provision of a Technical Document to catalog the scientific content and basis for the model's biogeochemical (in this case) mechanisms. In discussions and Email exchanges with William Salas regarding the DNDC Model, ERM was told that the DNDC Model was never intended for commercial use. As result, such a Technical Document does not even exist for the DNDC Model. ERM was advised that the scientific basis for the biogeochemical mechanisms in the model are contained in multiple literature sources. A list of these sources was requested, but has not yet been provided to ERM.

Currently there is no tutorial for the use of the DNDC Model for rice project applications nor any technical support directly available for model users.

Since there is a lack of adequate user instruction, technical support and documentation, rice project developers are disproportionately disadvantaged in quantifying GHG emissions benefits and the carbon offset value of their projects using the DNDC Model. This is in stark contrast to the other ARB compliance offset protocols where more than one standard model currently in use by regulatory agencies are offered as GHG quantification methodologies (ARB Forestry Protocol, for example).

However, it should be emphasized that even if a User's Manual and a Technical Document were developed for the DNDC Model, this would not resolve the fundamental problems associated with the functionality and variability of results found in applying the Model.

A.3. Recommendation: For the DNDC Model's application for rice compliance offset projects, standardized instructions should be developed and provided in a User's Manual for Rice Projects. Second, a Technical Document should be developed to properly catalog the scientific content and basis for the Model's biogeochemical mechanisms. Third, a tutorial and technical support document should be provided for model users.

To the extent possible, we recommend that instructions be outlined in the Protocol, or in a User's Manual for application of the DNDC Model for rice carbon offset projects. The instructions should be as prescriptive as possible to avert the need for the user to make multiple assumptions. Where assumptions have to be used, standardized instructions should be developed and any model instructions should provide or reference default factors to be used. This may avoid unacceptable variability of emissions benefit results from project to project for fields located side by side and operating under similar soils/conditions and cultivation methods.

A.4. Issue: No error message for data inputs nor for variables selected is available in the DNDC model, nor is there an error message stating that the model run would produce erroneous results.

Based upon ERM's experience implementing the DNDC Model, currently there is no error message in the DNDC Model which flags data inputs nor, for variables selected, to note that either are in error or that the model run would produce erroneous results. For example, there is no error message to note where data entered are outside of the boundaries of the values that would be expected for that data type. There is also no auto- check within the model that flags for blank entries, i.e., where data entries were omitted. Our experience has been that if problems arise, the DNDC Model will crash without warning.

This variability in modeling results creates a disproportionate risk and a potentially insurmountable barrier to entry for project developers.

A.4. Recommendation: The DNDC Model should be updated to automatically flag blank entries and with a function to check for data errors (outside of value ranges).

The DNDC Model should be updated to automatically flag blank entries and to ensure that the user enters data properly (with a function to check for data errors). The data error function can be linked to the values If the DNDC model does crash, there should be support to understand where the error occurred and an ability to recover the data inputs from that run (perhaps with an auto save function).

A.5. Issue: Assumptions are not able to be documented along with the model results reported from the model runs.

Our review reveals that the assumptions applied are not able to be reported out along with the results from a DNDC Model run. During the CAR verifier training in February 2013, the instructor for the DNDC Model, William Salas, recommended that rice project verifiers review the DND input files for assumptions (during verification) as there is no formal process for reporting out the assumptions for each DNDC model run. The assumptions are important in the "tuning" and re-parameterization of the DNDC model" and are opportunities to introduce errors and uncertainty into the results. For the verifiers to have appropriate documentation to review, a list of assumptions applied during DNDC Model runs would be critical to receiving a positive finding for a rice project. A lack of a listing of specific assumptions calls into question the results of any individual DNDC Model run and overall undermines the replicability of the Model.

In our review ERM found that the current DNDC model does not integrate well with existing software programs. The model provides output files into multiple files from the same model into a pre-set file path-- C:\DNDC\Result\Record\Site. This makes it challenging to transfer files and rerun the model. Given that the potential need to continually use the most current version of the DNDC model, the baseline must be rerun with each new version of the DNDC. The challenge of transferring files into the model throughout the five year crediting period is practically insurmountable at this time.

The format of the file outputs of the DNDC model is undefined and by extension virtually unusable. The model saves files in an unknown format on the computer that shows as a text file with several misaligned columns and that can be opened as *.txt file. However, the file is not associated with any specific program in a PC environment or in MSOffice. There is no option within the program to save as MS Excel or other standard file for spreadsheet formats.

A.5. Recommendation: A function for reporting out assumptions and model results should be developed and added to the DNDC Model for use with each model run.

Files should be easier to save and transfer both back into the model or into other formats. ERM recommends a reporting function should be added to the DNDC Model to allow model users to first, opt to report their assumptions in each model run and second, for users to opt to report the model results exported into either MS Excel or other standard spreadsheet software. Providing each of the assumptions documentation and model results summary as a standard practice will ensure transparency, i.e., that the project developers, verifiers, regulators, credit purchasers, and public at large reach the same conclusions about the solvency of the credits.

A.6. Issue: The DNDC Model does not have an Autosave function to recover a list of inputs and assumptions used during a failed model run.

When the DNDC Model crashes during one of the multiple runs required, there is no Autosave function to recover a list of inputs and assumptions used during that run. In addition, there are still a number of technical glitches that seem to be causing the Model to crash. When this occurs, there is no Autosave function in the model to recover the previous inputs and assumptions; instead, all of the data must be re-entered.

Using the model crash as an indicator that something has gone wrong with the modeled data or assumptions is both confusing and time consuming to the user. The DNDC model is highly complex, and there are multiple variables aggregated over many fields and other factors that could introduce errors in the calculation process. As a result, it could take hours (or days) for the aggregator, verifier, and regulator to isolate the problem to determine if it is a data or software issue and to correct any mistakes in the model runs.

A.6. Recommendation. An Autosave function should be developed to recover a list of inputs and assumptions used during a failed model run.

A.7. Issue: The volume of input data needed for the DNDC Model including historical baseline information is so substantial to be unrealistic and the recordkeeping required may be unachievable for rice growers.

The DNDC model requires a large volume of detailed data to generate results for a project, including for setting the historic baseline, data for five years prior is required. It is expected that farmers will keep records on all field management activities (date of seeding, tillage, flooding, seeding method, fertilization, drainage, baling, harvest date, yield, and residue management). This data will be used in conjunction with data that are externally collected. Overall, the complexity of the data collection is of concern and may be a barrier to rice project implementation and increases the expense and challenges for the aggregator, verifier, and regulator.

This complexity is apparent in the number of variables being collected. For the general DNDC model setup and baseline for the project, there are 11 variables that must be collected and another 14 that must come from monitoring records for a total of 25 unique variables. In addition, at a minimum there are 13 variables that must be collected annually. These are categorized below by the data that can be compiled from publicly and readily available sources compared to the unique data points that must be monitored. Overall, there are over twice as many data points that must be monitored versus the 12 that can be compiled from available sources. There are a total of 38 data points that need to be collected for the general model setup, baseline and first year. For a 5 year crediting period, there are 90 data points needed.

Project Data Level	Collected	Monitored
General	4	9
Baseline	7	5
Annual	1	2
Each Event	0	10
Total	12	26
5 Year Crediting Period	16	74

When these data are inserted into the model, there is no way to know if the result is reasonable or an outlier. As a result, even if the other issues raised are corrected, the DNDC Model is still unusable because the results simply cannot be trusted with any certainty. If the model results are unbalanced, the developer is being asked to re-parameterize the model by working with the different climate/soil inputs. This “tuning” or re-parameterizing of the model is a further concern. The protocol specifies that the values for water demand and temperature demand cannot exceed the values for water uptake and thermal degree days of maturity and must be reduced until they are equal. If this does not lead to sufficient correspondence, the model must be recalibrated across other parameters including biomass allocations. In relation to how this must be accounted, the protocol merely states that the project proponents must “provide all the necessary justification to the third-party validator.” There is no standard template or format for addressing errors. This is an opportunity to introduce errors and uncertainty and would require a more sophisticated understanding of the model from the aggregators, verifiers, and regulators.

The historical period model equilibration is used for setting the baseline emissions. The model equilibration is completed by taking the five years of crop yield calibration historical data and repeating it four times to get 20 years of past data. By multiplying the crop yield calibration data by four, the model is placing more weight on the last five years. This is rendering the model more inaccurate because extending the same data back further distorts the baseline. This distortion could be problematic if the crop yield calibration data are an anomaly or has errors because it will be artificially weighting the historical period more heavily in the model. This could result in the distortion of the structural uncertainty and other outputs and lead to the need to further “tune” or re-parameterize the model.

A.7. Recommendation: Consistent and credible data sets for use in the DNDC model should be provided to minimize the existing burden of data collection by the rice grower and aggregator.

The DNDC Model is not commercially usable by project developers at this state in development. To alleviate the data collection and compilation burden on rice growers and aggregators, several specific steps should be taken. Where possible regional and industry specific averages and factors should be used to minimize the use of field specific data. Field specific data may still be required. However, by providing a uniform data set for factors that represent field conditions by county, data may be more consistent across fields, while errors and variability could be minimized. For averages, ARB could collect and collate static climate input parameters and make them available as standardized inputs to streamline input into the DNDC Model. For the other data that cannot be streamlined in this way, ARB should provide templates for both collecting data and inputting that data into the model. This will lead to more standardized runs of the DNDC model and consistent results for a more discrete subset of field types and conditions, dramatically streamline the application of the Protocol. Conversely, if the emissions calculations are not systemized in a manner to make the Protocol usable by a project developer, the DNDC Model will serve no regulatory purpose.

A.8. Issue: The current DNDC Model requires programming background for development of both pre- and post-processing tools, and therefore, is not accessible for typical users of regulatory models.

The DNDC Model is not automated and therefore, does not save data inputs so that each time the program is run, data must be manually uploaded again. This means that it is cumbersome and repetitive to rerun the model. Given the number of model runs that need to be undertaken under the Rice Protocols and the unique format of the file types, there is a need for pre- and post- processing tools. At the CAR Rice Protocol Training for verifiers during the session on the DNDC Model in February 2013, William Salas suggested that the best way to run the DNDC model is to have someone with a programming background support the development and ongoing use of pre- and post-processing tools.

Thus, the current DNDC Model version is unwieldy for average users and requires a programming background to streamline the data integration and review process. There are few if any economies of scale from being a project aggregator and verifier without these new tools. EDF and CAR have both suggested to ERM that new tools are forthcoming; however, we are uncertain as to the time schedule for their availability and their usability.

A.8. Recommendation: A complete set of tools to support pre- and post-processing of the DNDC Model should be provided. These tools would also potentially resolve several Issues/Recommendations listed above.

Since the DNDC Model is currently a critical step to being able to develop offsets for rice projects, the ability to run the model should be accessible to all types of users and to facilitate that, the issue of pre- and post-processing tools should be addressed in a reasonably prompt timeframe, if the model is to continue to be relied upon as the estimation method of choice.

<u>Conclusion</u>: The Usability and Reliability of the Results from the DNDC Model for Project Developers and Verifiers are Currently Unacceptably Limited.

Given the importance and complexity of the DNDC model, we recommend ARB and the offset registries make a commitment to develop the infrastructure to provide on-going improvements to the model for usability, user training, and a help desk to support the technical capacity to run the model. The ARB must simplify and streamline the DNDC Model to increase the potential that rice compliance offset credits can actually be documented and registered. Otherwise, the DNDC Model is not useful to support the ARB compliance offset protocol for rice projects.

B. Review of DNDC Modeling Requirements in Protocols

B.1. Issue: Multiple runs for each field are needed to meet verification requirements.

For example, under the current DNDC Modeling regime, two management practices that occur in one rice field requires two model runs. No realization of any economies of scale are possible due to the repetition of runs required for each field.

B.1. Recommendation: Allow the use of Scaling Factors or other streamlining where two practices are utilized in the same rice field.

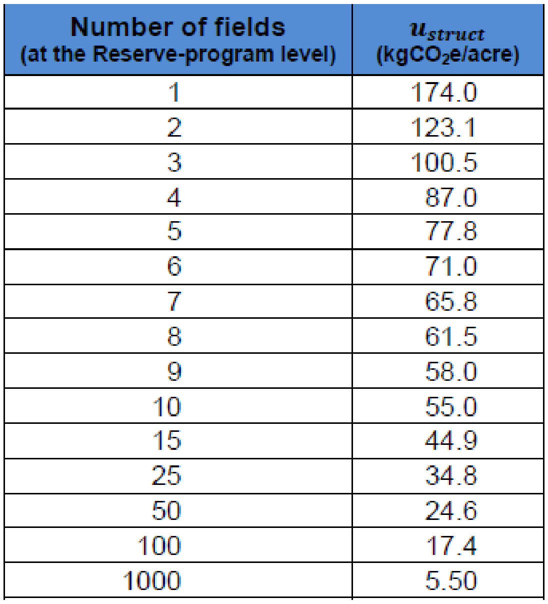
B.2. Issue: For the Structural Uncertainty Deduction for the DNDC Model, the CAR and ACR protocols each have adjustment factors with different bases.

The structural uncertainty deduction factors provided in Table 10 of the ACR protocol differ in the bases than those for the DNDC model that were published for use by CAR (Applying the Accuracy Deduction for Structural Uncertainty in the Rice Cultivation Project Protocol, Version 1.0, September 27, 2012. http://www.climateactionreserve.org/how/protocols/rice-cultivation/

CAR is reporting the factor in kg CO2e per acre and ACR is providing the factor as a percentage.

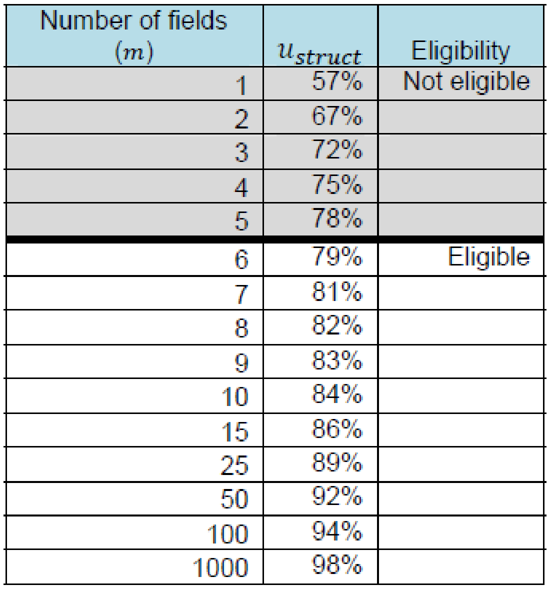
Given that these structural uncertainty deduction factors are generated from the same “calibrated” DNDC model, ERM believes that the structural uncertainty should be the same (or within a range of 5% difference) or even better, based upon the improvements that have been made to the DNDC model.

Structural Uncertainty Factors, Climate Action Reserve, 2012



Number of fields (at the Reserve-program level)	u_{struct} ($kgCO_2e$/acre)
1	174.0
2	123.1
3	100.5
4	87.0
5	77.8
6	71.0
7	65.8
8	61.5
9	58.0
10	55.0
15	44.9
25	34.8
50	24.6
100	17.4
1000	5.50

Structural Uncertainty Factors, American Carbon Registry 2011



Number of fields (m)	u_{struct}	Eligibility
1	57%	Not eligible
2	67%	
3	72%	
4	75%	
5	78%	
6	79%	Eligible
7	81%	
8	82%	
9	83%	
10	84%	
15	86%	
25	89%	
50	92%	
100	94%	
1000	98%	

At this time, ERM cannot account for the difference in the bases for these two adjustment factors.

B.2. Recommendation: Structural Uncertainty factors for the DNDC Model should be provided in the rice protocols in one consistent metric.

B.3. Issue: At this time, ERM is uncertain whether verifiers can realistically verify the DNDC model runs for a project developer.

Several soil scientists were trained and certified as verifiers by CAR on 2/14/2013. When ERM asked them to provide verification services for rice projects, they did not feel confident in their ability to verify runs from the model much less perform the complicated "tuning" that is required to adjust the "maximum biomass parameter" or if this fails to re-parameterize the model.

One major challenge with the DNDC model is that it requires unusually specialized academic expertise. Without previous experience working with the DNDC model, there is no way to know if the results from a model run are reasonable or are an outlier. If the yield data are unbalanced, the developer is being asked to tune the model by adjusting the "maximum biomass" parameter by adjusting water and temperature. If this "tuning" does not lead to enough correspondence between modeled and actual results, project developers must re-parameterize the model by calibrating the biomass and C/N allocation to roots, leaves/stems and grain. The ACR protocol states that VVB can request the results be reviewed by an independent expert.

B.3. Recommendation: ARB should allow alternative calculation methods, preferably a three-tiered approach; this would add a Tier 1 and Tier 2 calculation method to the existing Tier 3 method (using the DNDC Model).

See ACR Nitrogen Management Protocol provisions for examples of a Tiered approach allowing alternative calculation methods, in addition to DNDC Model.

In addition to the option of running the DNDC model (a Tier 3 approach), ERM recommends a scientifically credible and stable set of calculations be established for rice project developers to use. As we have indicated above, while we are not questioning the scientific credibility of the DNDC model as an academic research tool, the ultimate usability of the DNDC Model by potential rice project developers at this point in the model's development precludes its adoption by the ARB. Therefore, an approach should be applied for rice projects similar to ARB's Compliance Offset

Protocols for Livestock Management and Ozone Depleting Substances. In those protocols, there are several equations specified for use along with look-up tables containing specific factors for key variables and emissions. This type of technical approach should thus be used for a Rice Management Protocol. The Livestock Management protocol looks to be the most applicable since it is also oriented to agricultural operations; several look-up tables provide detailed factors to apply by geographic region, livestock type and other specifics. Similar look-up tables are used in other standard air quality calculations used for regulatory purposes such as AP-42. These factors have been in use for years, with periodic updates made. AP-42 factors are all based upon reasonable assumptions with a technical basis that has been vetted with experts. We are hoping for a similar methodology for this type of carbon project. If generalizations could be made from DNDC model runs, for example, these factors could be provided in look up tables along with a methodology that employs a step by step set of equations.

ERM piloted the use of a simplified Tier 1 approach to calculating the results for fields in California. When the IPCC Tier 1 results are annualized (Tier 1 calculation provides emissions per day), emissions benefits from removal of available rice straw (and avoided decomposition) equals about 2 metric tonnes CO2e/acre/year. The 2 metric tonnes/acre is similar to the results from model runs of the DNDC Model as provided to ERM by EDF in earlier communications. This calculation produces essentially the same results as the average of the more complex DNDC Model, which requires multiple runs and time consuming pre- and post-processing. In addition, this simplifies the verification and review, saving time and money at every step in the process while still producing scientifically credible results. This approach should be used here. (A copy of a short report on the Tier 1 Calculation is attached here as Appendix B.)

Recent field data can help to establish a Tier 2 Estimation Method. Recent data from field measurements of methane from rice fields agrees generally with estimations made using the DNDC Model and bode well for development of a Tier 2 methodology.

Recent field measurements by Peischl et al. (2012) show that airborne measurements (i.e., 7.8 – 9.3 x 10^{10} g CH4/yr) are consistent with estimations made by Salas et al. (2006) during a warm, dry spring (6.7 x 10^{10} g CH4/yr), and a cool, wet spring in the Sacramento Valley (7.6 x 10^{10} g CH4/yr). Thus, since field measurements are confirming model estimates, field measurements could contribute to establishing a simpler calculation approach in the future. Other recent rice field measurement data are also available for California.

C. Off-field Emissions Benefits Quantification (for Rice Straw to MDF)

C.1. Issue: Need for an estimation method for quantifying off-field emissions benefits of the CalAg Aggregator Project (rice straw conversion to MDF)

A calculation for estimating the off-field emissions benefits of Aggregator's project is not available in the rice project protocols that are currently published by CAR and ACR. Carbon emissions reductions from incorporating rice straw into medium density fiberboard (rice fiberboard) would occur and should be fully accounted for in the ARB rice protocol since rice straw fully replaces wood fiber in the manufacturing process. According to CAR's existing Rice Management Protocol, rice straw replacement of wood fiber in manufacturing fiberboard is recognized as a likely net positive GHG benefit for the avoidance of harvesting and transport of wood products (CAR 2011, v. 7-0, p. 63). Although the potential was recognized, a calculation for these specific emissions benefits was not provided in the CAR Protocol. CAR has indicated their willingness to review a potential calculation method proposed for CalAg Aggregator's project (CAR, 2013) and ERM submitted a copy of our recommended calculation methods to CAR on 3/21/2013.

ERM has also tracked the successive iterations of the draft ACR rice protocol and though improvements have been made in accounting for the emissions reductions, the latest version of the ACR Rice Protocol accounts for most, but not all of the benefits of rice fiberboard. The ACR Rice Protocol, v.8-0 dated December 2012, Table 6 on page 33, outlines the following three categories of (avoided) emissions for fiberboard manufacturing:

1. reduced emissions from avoided post-harvest chopping and disking
2. increased emissions from swathing, raking, and bailing
3. non-CO2 emissions during the life cycle of the fiberboard

C.1. Recommendation: ARB Protocol should include quantification of off-field emissions benefits of rice straw conversion to fiberboard

An additional fourth benefit that is not currently captured in the quantification is the incorporation of rice straw into fiberboard. Manufacturing fiberboard from rice straw sequesters the carbon and avoids the release of methane that would occur during the anaerobic or aerobic decomposition through the other current end-uses of the rice straw removed from the fields. Therefore, fiberboard manufacturing with rice straw provides the most complete reduction available as it prevents any decomposition from occurring, until the end of life of the fiberboard (durability is typically assumed to be 60 to 80 years in uses for building construction).

A fifth benefit is the avoided wood harvest from not using wood fiber in MDF manufacture, and instead substituting an agricultural waste, rice straw.

Thus, in addition to the three categories of emissions recognized in the ACR protocol currently, ERM recommends two additional emissions categories be considered:

1. avoidance of end of life emissions from decomposition of straw

2. avoidance of wood harvest from rice straw substitution for wood fiber

The ARB rice protocol should include credit for and quantification of appropriate off-field GHG emissions benefits associated with the rice straw conversion to fiberboard manufacture. These activities are involved in the CalAg Aggregator Project. Attached for ARB consideration and review is a calculation method proposed by ERM for use to quantify the carbon benefits of the CalAg Aggregator project (see Appendix C).

D. Provisions in the Existing Protocols

D.1. Issue: Provisions for Additionality tests administered by rice field appear burdensome.

Instead of simplifying the project development process, using the ACR approved additionality tool appears to add a new series of steps for project developers. One of the options for this test is cited as an ACR-approved additionality tool or a comparable ACR-approved tool, such as outlined by ACR for REDD. We believe this would be an arduous and burdensome task, i.e., to develop an additionality test for each rice field.

There are also varying definitions of additionality and they impact upon planning by project developers. In the CAR protocol, project eligibility is disallowed if baling was previously conducted. In the ACR protocol, if baling was already conducted, there is an additionality test to pass.

D.1. Recommendation: Additionality requirements for rice projects should be consistent and allow prior baling of rice straw.

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Appendix A

Review of DNDC Model Results for a CalAg Project Example in Four California Counties

DRAFT Memorandum

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ERM

To:	Keith Casto, on behalf of CalAg Aggregator LLC
From:	Victoria Evans, Judy Nedoff, Ariane Burwell, Natasha Hausmann and Rick Shih
Date:	February 22, 2013
Subject:	Statistical Analysis of the DNDC Model Results Received from EDF

1.0 INTRODUCTION

At the advice of the ARB, ERM collaborated with EDF to review the draft protocol and model for Rice Management Practices. As part of this effort, ERM explored the validity of the DNDC model as an approach to calculating the methane reductions from rice management practices.

1.1 SUMMARY

EDF provided to ERM the most current DNDC model results that they had for California. ERM used this to perform statistical analysis. Our results showed that there were a number of irregularities in the model outputs that ERM could not account for and these represent areas of concern for future resolution. For example, there were 200 to 300+% variations in the model results for CO2e tonnes per acre predicted for side-by-side rice fields.

ERM's statistical analysis suggests that the DNDC model itself has a mechanistic issue and/or there are errors in input data. These input data and model results had previously been analyzed and published as part of the CIG Report. The CIG Report identifies that the results for the midseason drainage are not statistically significant and will need to have more trials to be able to validate the DNDC model. However, without more information, it is impossible for ERM to know what the root cause of the variability might be. In addition, the calculation methods and underlying equations in the model are not available to view, thus they are not 'transparent'. Further, the technical documentation on the DNDC model is not available in a single document, since it is apparently contained in numerous peer literature articles. Thus, the model cannot be externally validated by ERM as to whether or not it is supported by accurate science.

1.1 BASIS FOR THE ANALYSIS

In response to ongoing DNDC model version 9.3 results requests from ERM, EDF provided detailed data for four scenarios across the four California counties of interest to CalAg Aggregator. ERM first requested this data from EDF on 12/19/2012 and 12/21/2012. EDF forwarded the results on 1/17/2013. ERM requested a complete set of the modeling assumptions used to generate the DNDC model runs, EDF has not provided these to ERM to date. On 2/5/2013, ERM did receive the soil data.

The DNDC modeling results provided to ERM is from 2009 and EDF states that these results represent the best available data presently available. EDF has informed ERM that new runs for California made with a more current version of the DNDC will not be available until April 2013 due to the slow processing time for DNDC the model. Therefore, although dated, these results represent the best available information on the DNDC model results.

DNDC model version 9.3 outputs were provided by EDF for four counties (Butte, Colusa, Glenn and Sutter) in four scenarios:

- A – residue incorporation and winter flooding (baseline for winter flooded fields)
- B – Winter flooding and baling (removal of significant portion of straw prior to flooding)
- G – Residue incorporation and no winter flooding (baseline for fields not flooded in winter)
- H – No winter flood and baling

Additional assumptions provided by EDF:

- Mid-season drainage is not currently included as an option in the ACR protocol
- To calculate the reduction in GHG resulting from baling/straw removal, the baling scenario is subtracted from the baseline scenario (Scenario A minus Scenario B and Scenario G minus Scenario H for a given field).
- Off-site emissions of 0.3028 tons/acre from offsite decomposition of straw used for erosion control or other uses were accounted for in the baling scenario results provided by EDF. ERM assumed that meant it had been added to Scenarios B and H. Because

manufacture of MDF avoids this decomposition, 0.3028 tons/acre were subtracted by ERM from the emissions reported for Scenarios B and H for each field.

Straw Management Practices Assumed for Each Scenario

	Residue incorporation	**Winter flooding**	**Baling**
Scenario A	X	X	
Scenario B		X	X
Scenario G	X		
Scenario H			X

EDF provided data and model outputs for the following:

- Four counties: Butte, Colusa, Glenn, and Sutter
- Field size (acres)
- Yield (cwt/acre)
- Greenhouse gas emissions (tCO_2e/acre) for each of the four scenarios described above.

The objectives of the statistical analyses were:

- Visualize the relationships among model inputs and outputs
- Characterize the variability in the model parameters
- Compare the different scenarios in each county
- Summarize trends and implications for carbon offsets

2.0 APPROACH

The DNDC outputs provided by EDF were evaluated by ERM by a variety of statistical methods. Initial calculations were conducted to adjust the outputs to reflect the use of straw for MDF rather than for offsite uses that have GHG emissions associated with them. The calculations on a per field and per county basis are described in Section 2.1. After the calculations were complete, descriptive statistics were compiled (Section 2.2).

2.1 CALCULATIONS

Various calculations were required to prepare the model output data for the comparisons of interest, as described in the following sections.

2.1.1 Correction for Offsite Emissions

Of primary interest in this project is estimating the reduction in GHG emissions that may be gained from converting baled straw from rice production into usable building material instead of using it offsite for other purposes. The modeled values that were provided had already accounted for the carbon emissions created by the use of baled straw offsite by adding 0.3028 tons/acre to Scenarios B and H. Because building materials will avoid these offsite emissions from decomposition at end of life, current uses of baled straw, this correction factor for offsite carbon emissions was subtracted from the estimated emissions (tCO_2/acre) for each scenario that includes baling and removal of straw from the fields (Scenario B and H). These corrected emissions values are summarized in Table A-1 in the appendix and are reported throughout this memo).

2.1.2 Evaluating Emission Reductions due to Straw Removal

Some rice straw management practices are expected to reduce GHG emissions. To determine the reduction in emissions due to removal of straw from the fields after harvest for the winter flooding and the no winter flooding scenarios, the baling scenario is subtracted from the residue incorporation scenario (i.e., Scenario A minus Scenario B and Scenario G minus Scenario H). These differences are recorded in Table 1.

2.1.3 Calculating Total Emissions for Each County

The total emissions for each county under each scenario were calculated by multiplying the emissions per acre (tCO_2e/acre) by the acreage for each field and summing the products. The equation for the calculation is as follows:

$$Total\ Emissions = \sum^{n} E_n * A_n$$

Where:

n is the field number for that county

E_n is the greenhouse gas emissions (tCO_2e/acre) for each field

A_n is the acreage for each field

2.2 *DESCRIPTIVE STATISTICS*

Describing the data is an important exploratory step in assessing modeled data and understanding the results. Descriptive statistics were used to evaluate and summarize the data. The following parameters were calculated for each variable of interest:

- Number of fields
- Minimum value
- Maximum value
- Median or the middle of the rank-ordered value
- Mean or the average value
- Standard deviation which is a measure of the variance
- Coefficient of variation[1] which is a standardized measure of the variance
- Shapiro-Wilk's test for normality (normal or log-normally distributed).

Descriptive statistics were calculated for each of the following variables of interest:

- Greenhouse gas emissions (tCO2e/acre)
- Greenhouse gas emissions (tCO2e/acre) with scenarios B and H corrected for offsite emissions
- Number of acres per field
- Yield (cwt/acre, centum weight per acre equivalent to 100 pounds per acre)

The descriptive statistics are provided in Table 2.

Determining the underlying distribution of the data is a fundamental step in selecting appropriate downstream analyses. Data that are normally distributed will follow a classic bell-shaped curve when plotted in a histogram. Both normally distributed data and lognormally distributed data lend themselves to parametric tests while data that do not fit a typical distribution type are more appropriately analyzed with non-parametric

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[1] Coefficient of variation is calculated as the standard deviation divided by the mean and is often expressed as a percent.

techniques. A Shapiro-Wilks test[2] was used to determine the data distribution type of each of the model parameters. The results of the test provide a p-value. P-values that are greater than 0.05 indicate that the data violates the normal or lognormal data distribution type. The results of the Shapiro-Wilks test for normality are provided as part of the descriptive statistics in Table 2.

2.3 DATA VISUALIZATIONS

Plotting the data in various ways is a helpful diagnostic tool to understand the underlying distribution of the data. These visualization tools facilitate the identification of multimodal and skewed distributions, as well as identification of points that are potential outliers. Visualization is a confirmatory tool that tests for normality. In addition, these tools can assist in identifying potential data transformations that may be applied so that the data conform to the requirements of parametric statistical tests. Common data visualizations used for exploratory data analysis include:

- Histograms
- Boxplots
- Scatterplots

2.3.1 Histograms

Histograms are a tool for seeing the shape of the data distribution and the effect of a data transformation (for example, log transformation) on the overall data shape. Histograms provide a visual estimate of the probability distribution of a continuous variable. The range of values for the variable of interest lies on the x-axis while the frequency with which each value is found in the dataset is plotted on the y-axis.

Histograms were generated for each county for the following parameters and are available in an appendix to this document:

- Greenhouse gas emissions (tCO2e/acre) with scenarios B and H corrected for offsite emissions
- Number of acres per field

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[2] Shapiro-Wilk's test is sensitive to departures from normality, especially for larger datasets with more than 50 observations. For this reason, the results of a Shapiro-Wilks test should be coupled with visual observations of the data distribution.

- Yield (cwt/acre)

2.3.2 *Boxplots*

Boxplots assess the shape and distribution of a dataset and are helpful in identifying potential outliers. When plotted side-by-side, boxplots are a tool for comparing the distribution, spread, and shape among datasets.

Boxplots are constructed with a horizontal line that represents the median. The lower edge and upper edge of the box represent the 25th and 75th quartiles respectively. The upper and lower extremes of the "whiskers" represent 1.5 times the inter-quartile range. Points that lie beyond the whiskers should be examined in more detail as potential outliers (Figure 1).

Boxplots were generated for greenhouse gas emissions (tCO_2e/acre) with scenarios B and H corrected for offsite emissions (Figure 2).

2.3.3 *Scatterplots*

Scatterplots examine the relationship between two or more variables, particularly for datasets consisting of multiple observations per sampling point. For this study, the following relationships were plotted:

- Total emissions per field (tCO_2e) versus total yield per field (cwt). The values presented here had scenarios B and H corrected for offsite emissions.
- Emissions per acre (tCO_2e/acre) versus yield per acre (cwt/acre). The values presented here had scenarios B and H corrected for offsite emissions.

The scatterplots are presented in Figures 3 and 4.

2.3.4 *Bar Plots*

Bar plots are a way to visually compare the central tendency of multiple populations of data. Typically, a single variable is plotted on the y-axis with the mean and standard deviation of each group of interest plotted as the height and "whiskers" of the bar respectively.

The bar plots that were plotted for this study include the following variables:

- Greenhouse gas emissions (tCO_2e/acre) for each county-by-scenario combination (Figure 5).
- Greenhouse gas emissions (tCO_2e/acre) for each county-by-scenario combination with scenarios B and H corrected for offsite emissions (Figure 5).
- Average yield per county (cwt/acre) (Figure 6)

3.0 RESULTS

3.1 DATA DISTRIBUTION

For all scenarios in all counties, greenhouse gas emissions (tCO_2e/acre) departed from both a normal and lognormal distribution according to the Shapiro-Wilk's test for normality. This test is sensitive to departures from normal in larger data sets, therefore, it is helpful for the data set tested here.

Upon visual inspection of the data, the histograms (in the Figures) revealed that the data are slightly bimodal (i.e., there are two "peaks" in the distribution). This is especially pronounced for Glenn and Sutter Counties. These patterns remain the same regardless of the scenario examined. In essence, the histograms describe a high frequency of emissions below 2 tCO_2e/acre with emissions exceeding 6 tCO_2e/acre relatively infrequently. A second peak in emissions occurs between 3 and 6 tCO_2e/acre. The underlying cause of this second peak in the modeling results is unclear. ERM would benefit from reviewing other analyses of input data and modeling results to explore accounting for this variability. Currently, ERM is unable to explain the variability with any certainty.

Boxplots of greenhouse gas emissions (Figure 2) show that for a dataset of this size, there are relatively few potential outliers at the high end of the distribution. Formal outlier tests performed in conjunction with a more detailed investigation of these points should be pursued. This will explain why the outliers differ so markedly from the majority of the data. However, since ERM has an incomplete set of the assumptions from EDF, it is impossible for ERM to identify what factors might be causing the outliers. Therefore, ERM's primary finding is that the large number of outliers are a concern and might suggest underlying problems with the input data or more problematically, the biogeochemical mechanisms of the DNDC model ver. 9.3.

3.2 COMPARISON of the SCENARIOS

As shown on the boxplots (Figure 2) and bar plots (Figure 5) and summarized in Table 1, GHG emissions from winter flooding scenarios (A and B) are consistently higher than emissions from scenarios that do not include winter flooding (G and H), as expected. Note that Figure 5 indicates that for non-winter flooded scenarios, average offsite emissions if straw is diverted to typical current uses are higher than reincorporation of the straw into the fields (average scenario H emissions [uncorrected] are greater than average scenario G emissions). Use of the straw for MDF reduces the emissions for scenario H (corrected for offsite emissions) to be the same as or slightly lower than scenario G. However, it has been shown that GHG emissions during the growing season are about 50% of the annual output, and may be a greater proportion for non-winter flooded fields (Fitzgerald et al., 2000).

This brings up the question of whether the EDF model outputs are only for the winter or are for an entire growing/fallow annual cycle (reincorporation emissions – Scenario G – would be expected to be higher if the model output is for the entire year).

3.3 COMPARISON of COUNTY EMISSIONS

Comparing emissions on a county basis (Table 1 and Figure 5), it is noted that Colusa and Sutter Counties have significantly higher total emissions than Butte and Glenn Counties. Rice acreage in Colusa is 33% higher than Butte, but total emissions are about 41 to 59% higher in Colusa than in Butte, depending on the scenario. In addition, Sutter County has about the same rice acreage as Butte, but has 37 to 73% higher emissions than Butte, depending on the scenario. ERM notes that the source of this variability between counties is unknown.

EDF has suggested to ERM that it is the soil characteristics can result in variability of up to 600%.

3.4 RELATIONSHIP between YIELD and EMISSIONS

Scatterplots were used to visualize the relationship between yield and emissions. For fields that yield more than 10,000 cwt, total emissions on a field-basis plateaus. In other words, increasing yield above 10,000 cwt generally does not substantially increase emissions. Scenarios A and B were highly overlapping as were scenarios G and H. Interestingly, all scenarios show a strong bifurcation in the emissions data. Although the underlying cause of this is unclear, possible explanations could include but are not limited to:

- Different options in model output
- Different existing management practices in some fields
- Different varieties of rice
- Seasonal differences caused by variation in the planting dates

ERM recommends that the reasons for the non-linearity in the DNDC model output should be explored further.

When the relationship between yield and emissions are examined on a per-acre basis, a slightly different pattern emerges. All of the counties show very limited variability in yields. In fact, nearly all of the fields in Butte and Sutter have yields that are approximately 83 cwt/acre, while Colusa and Glenn County fields have average yields of 87 cwt/acre (Figure 6). The possible reasons for these sharp differences in yield are unclear from the data provided. It is unclear why the model output is so consistent for yield; it may be based on a set of assumptions that differ slightly between the two sets of counties for management practices, seasonal effects, or variety of rice planted, or other factors. All counties also have a small number of fields that performed poorly (Figure 4). Colusa County seems to have a higher frequency of poorly performing fields compared to other counties. These plots also show the variation in GHG emissions for a given yield (cwt/acre) within a county.

ERM finds that clearly a factor other than yield alone is contributing to this variation. The driver for the observed variation in emissions (tCO_2e/acre) merits further investigation.

4.0 CONCLUSIONS

Based on the evaluations discussed in the previous sections, ERM finds that there appears to be more unexpected and unexplained variability in the DNDC model results, than would be expected. This is true whether evaluated model results are evaluated on a per acre, per field, or per county basis. ERM recommends that the sources of the variability should be investigated further. Questions prompted by ERM's statistical evaluation are summarized in Section 5.

Beyond the scientific concerns, ERM notes that this variability in the results has significant implications for the ability of rice protocol developers, verifiers, and regulators to successfully use the model. There is no way to look at the results and identify outliers that are unreasonable. Therefore, the challenges of independent verification by verifiers are significantly higher, and therefore, the verification of these results is expected to be time consuming and costly.

5.0 FURTHER QUESTIONS

The following questions arose during ERM's review of the statistical evaluation of the model outputs:

1. There are two peaks in frequency of emissions seen in the histograms. There is a high frequency of emissions below 2 tCO_2e/acre; emissions exceeding 6 tCO_2e/acre are relatively infrequent. A second peak in emissions occurs between 3 and 6 tCO_2e/acre. The underlying cause of this second peak is unclear and warrants investigation.

2. A few potential outliers are seen on the boxplots. Formal outlier tests need to be performed in conjunction with a more detailed investigation of these points if there is interest in knowing why they differ so markedly from the majority of the data.

3. Results for scenarios G and H (no winter flooding) indicate that removal of straw makes little to no difference in emissions when winter flooding is not employed. Fields in which straw is reincorporated generate similar emissions during the growing season while the fields are flooded whether or not the fields were flooded in the winter. If the model outputs are for annual emissions, scenario G would be expected to be higher, or removal of straw would be expected to result in greater reductions (relatively lower emissions for scenario H).

4. On a county basis, emissions are not consistent with acreage. Emissions/acre tend to be fairly consistent, but summed emissions on a county-wide basis for Sutter and Colusa show significant differences from expected based on emissions in Butte.

5. All scenarios show a strong bifurcation in the emissions data. The reasons for the non-linearity in the model output should be explored further.

6. There is little variability in yield/acre; nearly all fields have either 83 or 87 cwt/acre. ERM questions why the model output is so consistent for yield.

7. There is variation among the counties in the distribution of yields and in emissions per acre vs. yield (Figure 4). ERM questions what assumptions are driving this distribution.

Tables

Table 1. Comparison of Total Emissions for Each Scenario in Each County

Winter Flooding

County	Total Yield (cwt)	Total Acres	Total Emissions Scenario A Winter Flooding Residue Incorporation (tCO2e)	Total Emissions Scenario B Winter Flooding Straw Baled/Removed (tCO2e)	Total Emissions Scenario B [corrected for offsite emissions] (tCO2e)	Change in Total Emissions (A-B) [corrected for offsite emissions] (tCO2e)
Butte	9,280,000	111,000	277,000	269,000	236,000	40,800
Colusa	12,900,000	147,000	395,000	379,000	335,000	60,200
Glenn	8,080,000	92,600	290,000	273,000	245,000	44,500
Sutter	9,280,000	111,000	277,000	269,000	236,000	40,800

No Winter Flooding

County	Total Yield (cwt)	Total Acres	Total Emissions Scenario G No Winter Flooding Residue Incorporation (tCO2e)	Total Emissions Scenario H No Winter Flooding Straw Baled/Removed (tCO2e)	Total Emissions Scenario H [corrected for offsite emissions] (tCO2e)	Change in Total Emissions (G-H) [corrected for offsite emissions] (tCO2e)
Butte	9,280,000	111,000	179,000	222,000	189,000	-9,200
Colusa	12,900,000	147,000	286,000	333,000	288,000	-2,480
Glenn	8,080,000	92,600	219,000	241,000	213,000	5,370
Sutter	9,330,000	109,000	311,000	332,000	299,000	11,900

Table 3. Descriptive Statistics by County and Straw Management Scenario

County	*Scenario*	*Number of fields*	*Minimum*	*Median*	*Mean*	*Maximum*	*SD*	*%CV*	*Shapiro-Wilk's test for normality*	
									normal distribution	*lognormal distribution*
GHG Emissions (tCO2e/acre)										
Butte	A	1774	1.806	1.946	2.974	6.896	1.486	50%	1.23E-47	2.61E-47
Colusa	A	2212	1.806	1.94	2.779	7.743	1.285	46%	6.42E-53	3.19E-52
Glenn	A	1436	1.802	2.754	3.321	8.22	1.406	42%	2.44E-33	6.05E-33
Sutter	A	300	1.849	3.538	3.705	11.21	1.857	50%	2.88E-16	1.54E-16
Butte	B	1774	1.843	1.98	2.825	6.113	1.23	44%	1.43E-47	3.08E-47
Colusa	B	2212	1.86	1.938	2.66	6.834	1.096	41%	5.54E-53	1.87E-52
Glenn	B	1436	1.805	2.634	3.109	6.905	1.186	38%	5.41E-33	2.15E-32
Sutter	B	300	1.852	3.268	3.417	8.318	1.536	45%	5.11E-16	2.10E-16
Butte	G	1774	0.966	1.013	2.116	6.131	1.544	73%	4.81E-48	7.51E-48
Colusa	G	2212	1.165	1.184	2.04	7.006	1.313	64%	2.95E-53	1.11E-52
Glenn	G	1436	0.9991	1.895	2.553	7.708	1.435	56%	2.82E-34	1.99E-34
Sutter	G	300	1.063	2.753	2.927	10.45	1.861	64%	4.14E-16	1.34E-16
Butte	H	1774	1.458	1.509	2.422	5.793	1.29	53%	3.63E-48	4.37E-48
Colusa	H	2212	1.59	1.621	2.344	6.596	1.116	48%	1.68E-53	3.67E-53
Glenn	H	1436	1.488	2.224	2.766	6.669	1.218	44%	1.00E-34	5.36E-35
Sutter	H	300	1.53	2.96	3.09	7.982	1.552	50%	3.16E-16	7.75E-17
GHG Emissions (tCO2e/acre); Scenario B & H corrected for offsite emissions										
Butte	A	1774	1.806	1.946	2.974	6.896	1.486	50%	1.23E-47	2.61E-47
Colusa	A	2212	1.806	1.94	2.779	7.743	1.285	46%	6.42E-53	3.19E-52
Glenn	A	1436	1.802	2.754	3.321	8.22	1.406	42%	2.44E-33	6.05E-33
Sutter	A	300	1.849	3.538	3.705	11.21	1.857	50%	2.88E-16	1.54E-16
Butte	B	1774	1.541	1.678	2.523	5.81	1.23	49%	1.43E-47	3.59E-47
Colusa	B	2212	1.557	1.636	2.357	6.531	1.096	46%	5.54E-53	2.15E-52
Glenn	B	1436	1.502	2.332	2.806	6.603	1.186	42%	5.41E-33	2.50E-32
Sutter	B	300	1.55	2.966	3.114	8.015	1.536	49%	5.11E-16	1.83E-16
Butte	G	1774	0.966	1.013	2.116	6.131	1.544	73%	4.81E-48	7.51E-48
Colusa	G	2212	1.165	1.184	2.04	7.006	1.313	64%	2.95E-53	1.11E-52
Glenn	G	1436	0.9991	1.895	2.553	7.708	1.435	56%	2.82E-34	1.99E-34
Sutter	G	300	1.063	2.753	2.927	10.45	1.861	64%	4.14E-16	1.34E-16
Butte	H	1774	1.156	1.206	2.119	5.49	1.29	61%	3.63E-48	4.87E-48
Colusa	H	2212	1.287	1.318	2.041	6.293	1.116	55%	1.68E-53	4.02E-53
Glenn	H	1436	1.185	1.921	2.463	6.366	1.218	49%	1.00E-34	4.79E-35
Sutter	H	300	1.227	2.657	2.788	7.679	1.552	56%	3.16E-16	6.27E-17
Area (acres/field)										
Butte	All	1774	0.3003	41.52	62.29	408.4	57.93	93%	2.76E-38	5.44E-17
Colusa	All	2212	0.2001	46.02	66.68	530.3	60.68	91%	1.54E-45	1.78E-14
Glenn	All	1436	0.7676	46.7	64.47	538.8	57.23	89%	7.61E-38	1.00E-10
Sutter	All	300	0.7117	113.5	363.2	10370	1077	297%	2.15E-32	4.83E-06

County	*Scenario*	*Number of fields*	*Minimum*	*Median*	*Mean*	*Maximum*	*SD*	*%CV*	*Shapiro-Wilk's test for normality*	
									normal distribution	*lognormal distribution*
Yield (cwt/acre)										
Butte	A	1774	68.02	83.3	84.28	88.32	2.31	3%	7.33E-54	2.86E-54
Butte	B	1774	67.35	83.26	84.24	88.32	2.343	3%	8.85E-54	3.01E-54
Butte	G	1774	68.14	83.3	84.3	88.33	2.297	3%	4.38E-54	1.81E-54
Butte	H	1774	67.53	83.31	84.27	88.32	2.322	3%	5.71E-54	2.07E-54
Colusa	A	2212	73.76	88	87.45	88.35	2.127	2%	3.76E-66	2.42E-66
Colusa	B	2212	73.07	87.99	87.38	88.35	2.31	3%	4.20E-66	2.71E-66
Colusa	G	2212	73.93	88	87.47	88.35	2.076	2%	3.68E-66	2.37E-66
Colusa	H	2212	73.29	87.99	87.41	88.35	2.237	3%	3.99E-66	2.57E-66
Glenn	A	1436	79.6	88.27	87.28	88.6	2.083	2%	7.67E-50	6.58E-50
Glenn	B	1436	78.63	88.25	87.26	88.6	2.098	2%	1.52E-49	1.30E-49
Glenn	G	1436	79.81	88.27	87.29	88.6	2.079	2%	7.12E-50	6.10E-50
Glenn	H	1436	79.03	88.25	87.27	88.6	2.09	2%	1.27E-49	1.09E-49
Sutter	A	300	84.57	84.84	86.09	88.32	1.647	2%	2.51E-22	2.56E-22
Sutter	B	300	84.53	84.84	86.08	88.32	1.648	2%	4.12E-22	4.22E-22
Sutter	G	300	84.57	84.84	86.09	88.32	1.648	2%	2.61E-22	2.66E-22
Sutter	H	300	84.53	84.84	86.08	88.32	1.65	2%	4.29E-22	4.39E-22

Notes:

Number of fields is a tally of the number of fields per county

Minimum is the smallest value in the dataset

Median is the middlemost value of the rank-ordered dataset

Mean is the average value of the dataset

Maximum is the largest value in the dataset

SD is the standard deviation, a measure of the variance

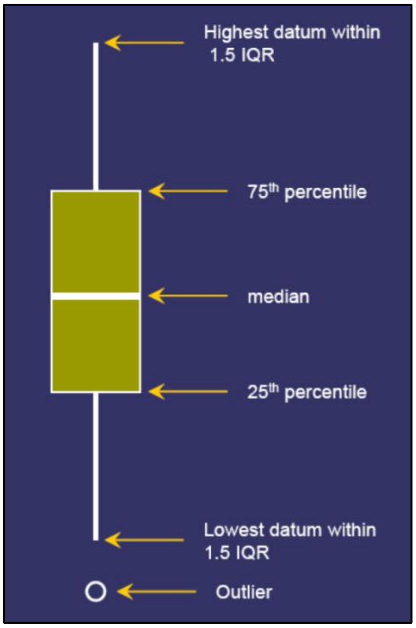
% CV is the percent coefficient of variation or the SD divided by the mean. This is a standardized measure of variance.

Shapiro-Wilk's test for normality tests to see if the data follow a normal distribution or lognormal distribution.

Values < 0.05 indicate a departure from normal

cwt = Centum weight (100 pounds in US)

Figures



The distance from the bottom to the top of the box is the interquartile range (IQR)

Figure 1. Anatomy of a boxplot

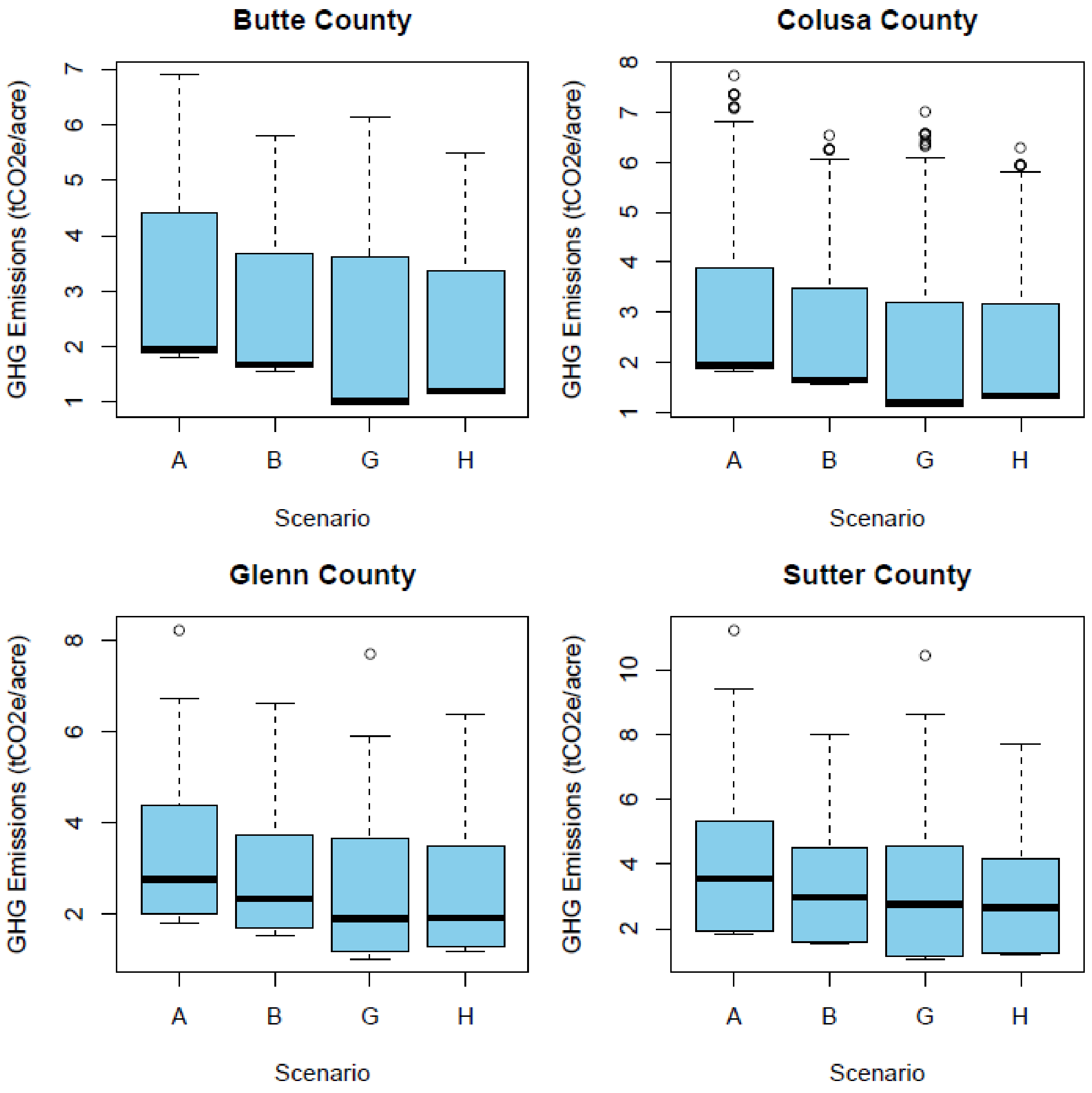
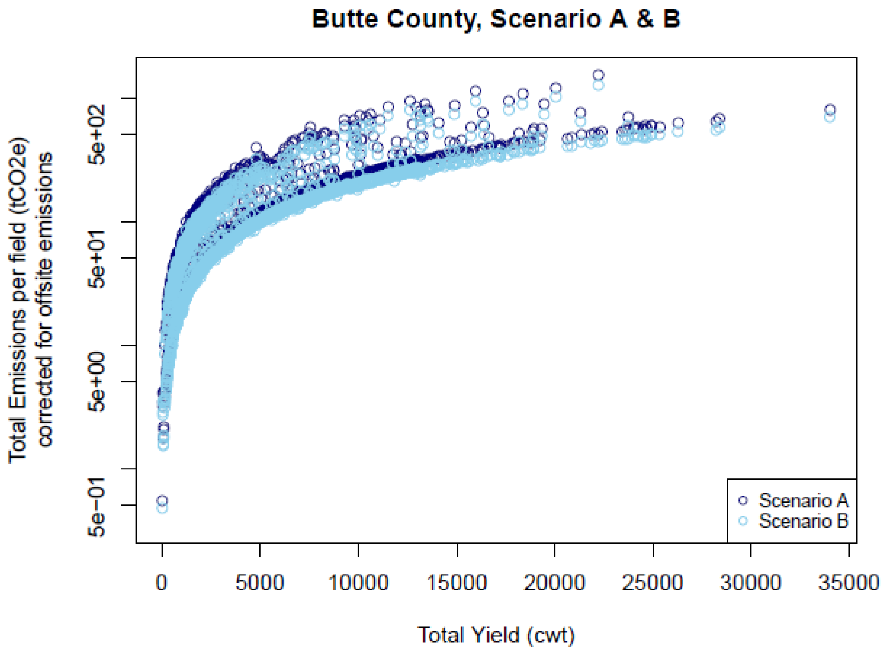


Figure 2. Boxplots showing GHG emissions (tCO_2e/acre) for each county and scenario with scenarios B and H corrected for offsite emissions.


Butte County, Scenario A & B

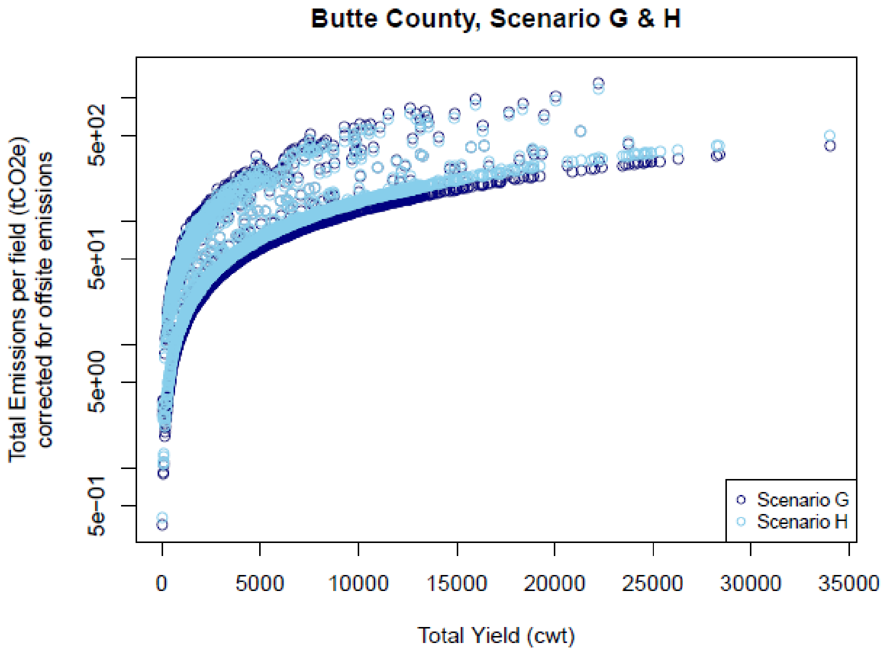
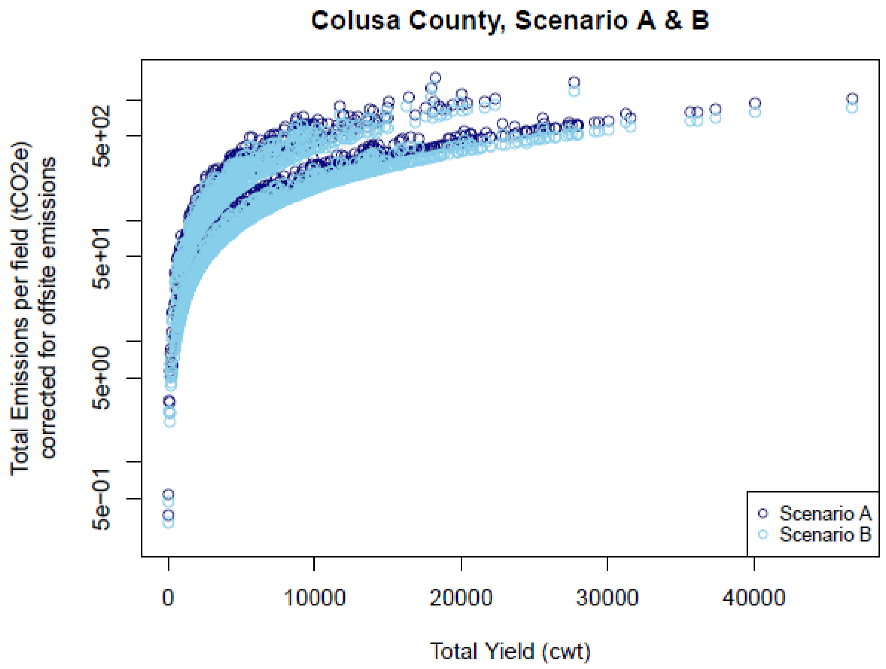

Butte County, Scenario G & H

Figure 3a. Scatterplots for Butte County showing the total emissions per field (tCO_2e) versus total yield per field (cwt). The values presented here had scenarios B and H corrected for offsite emissions. Note that the y-axis is plotted on a log-scale.



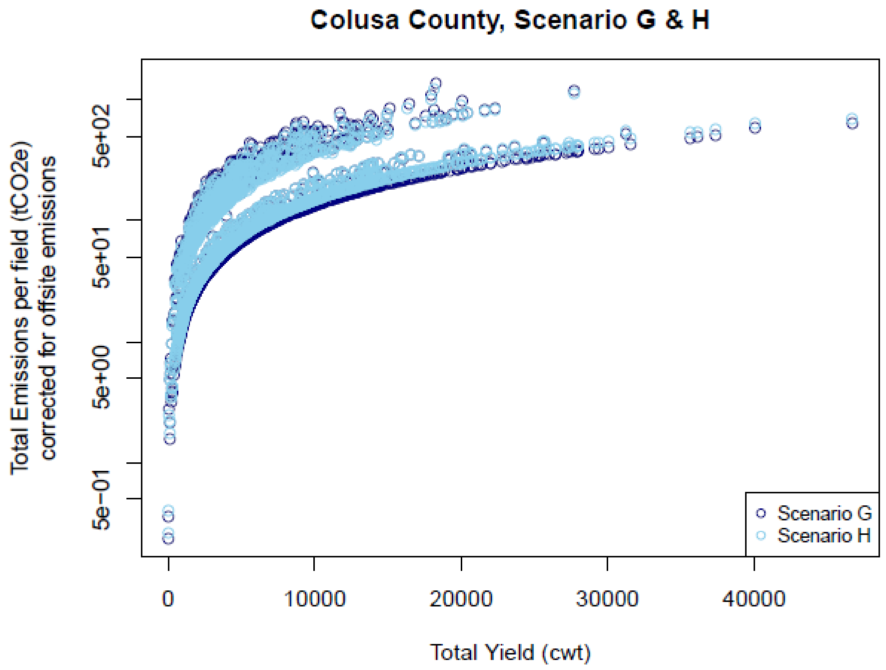
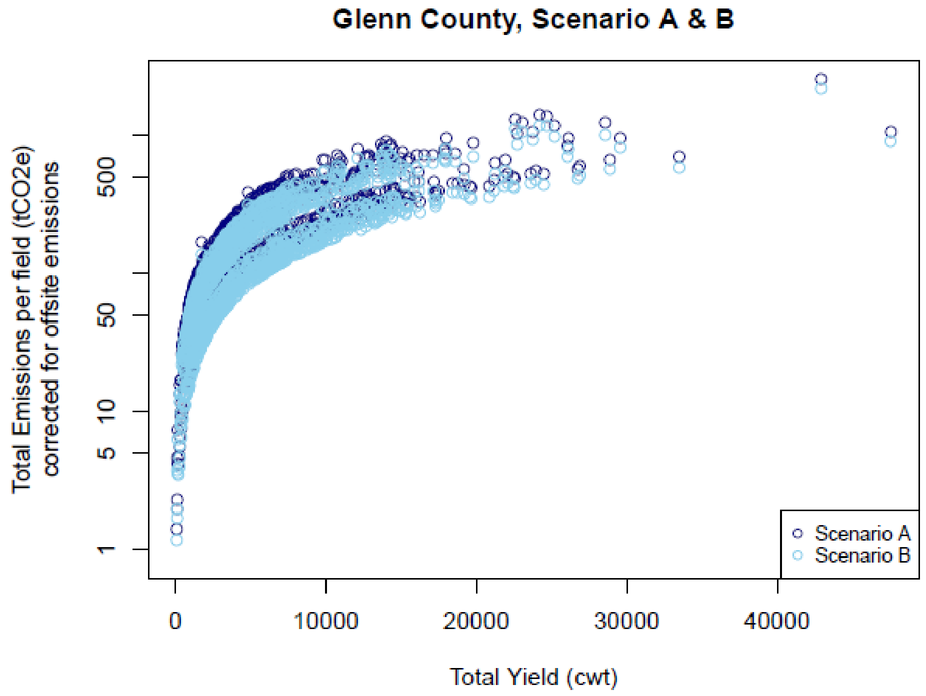


Figure 3b. Scatterplots for Colusa County showing the total emissions per field (tCO_2e) versus total yield per field (cwt). The values presented here had scenarios B and H corrected for offsite emissions. Note that the y-axis is plotted on a log-scale.



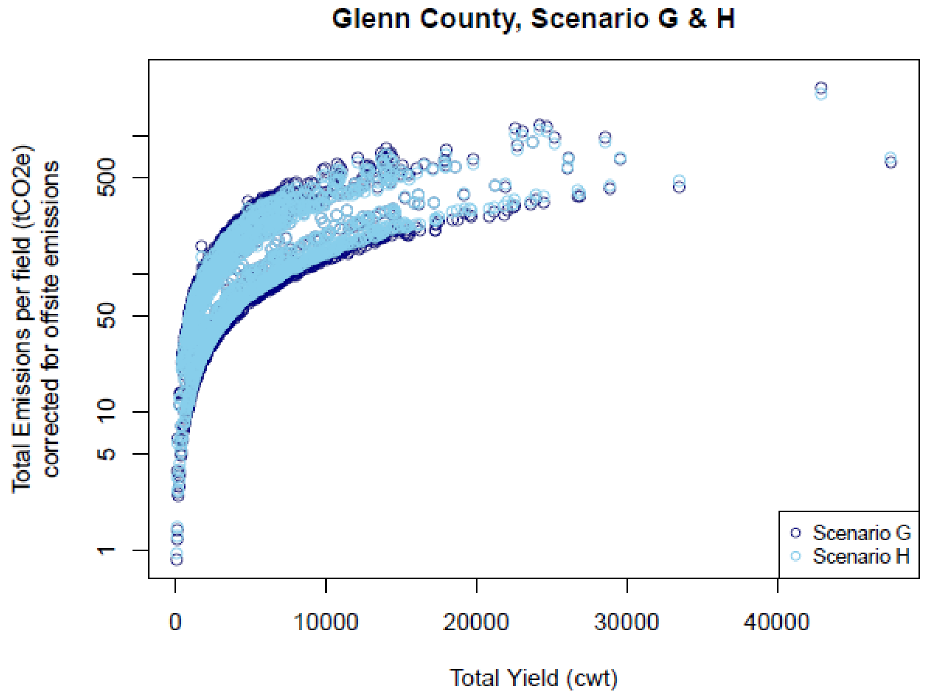
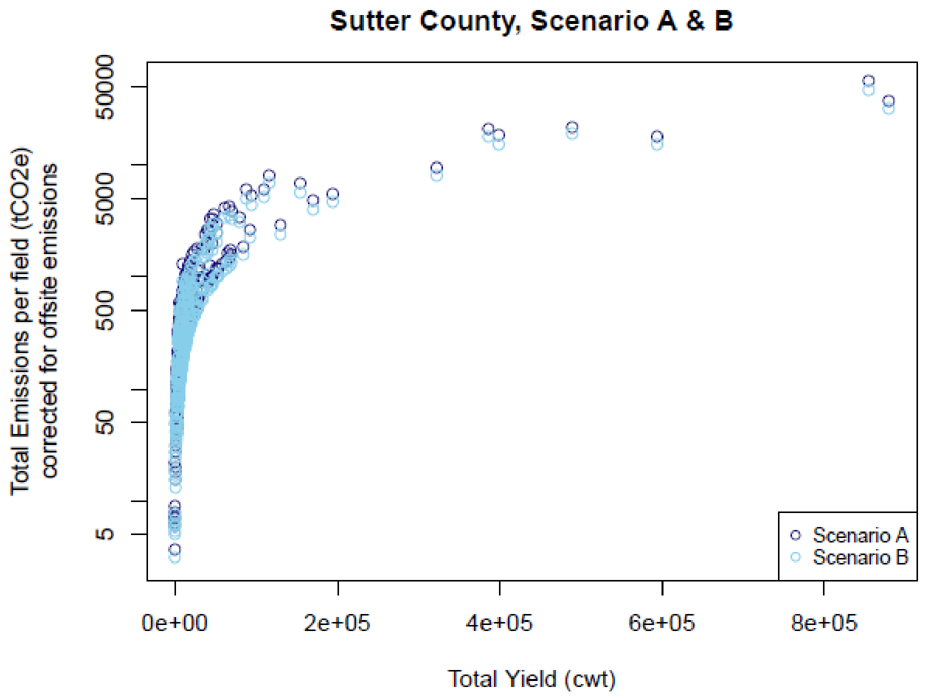


Figure 3c. Scatterplots for Glenn County showing the total emissions per field (tCO_2e) versus total yield per field (cwt). The values presented here had scenarios B and H corrected for offsite emissions. Note that the y-axis is plotted on a log-scale.



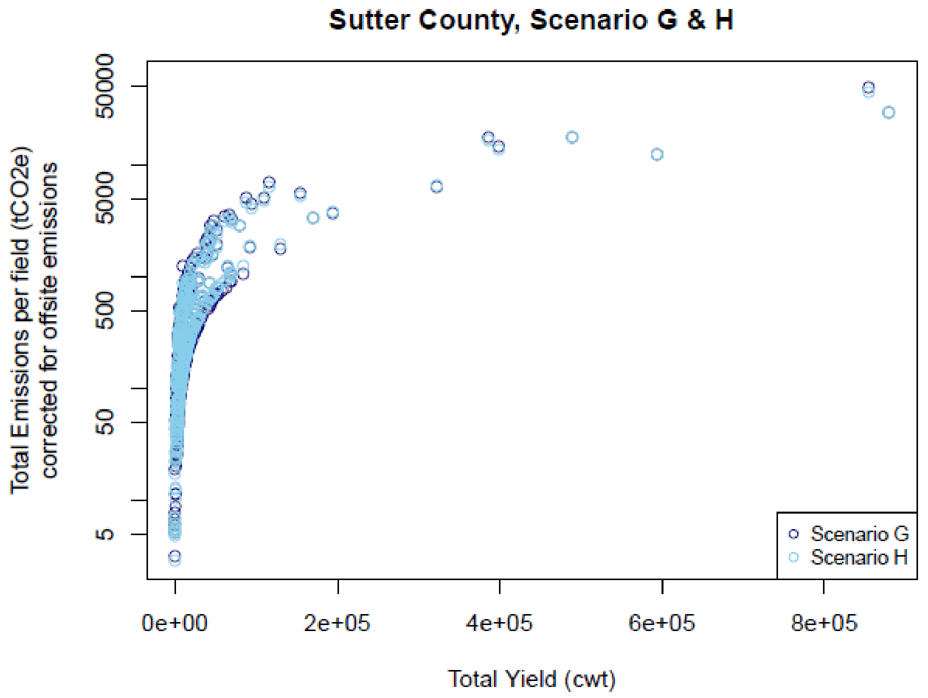


Figure 3d. Scatterplots for Sutter County showing the total emissions per field (tCO$_2$e) versus total yield per field (cwt). The values presented here had scenarios B and H corrected for offsite emissions. Note that the y-axis is plotted on a log-scale.

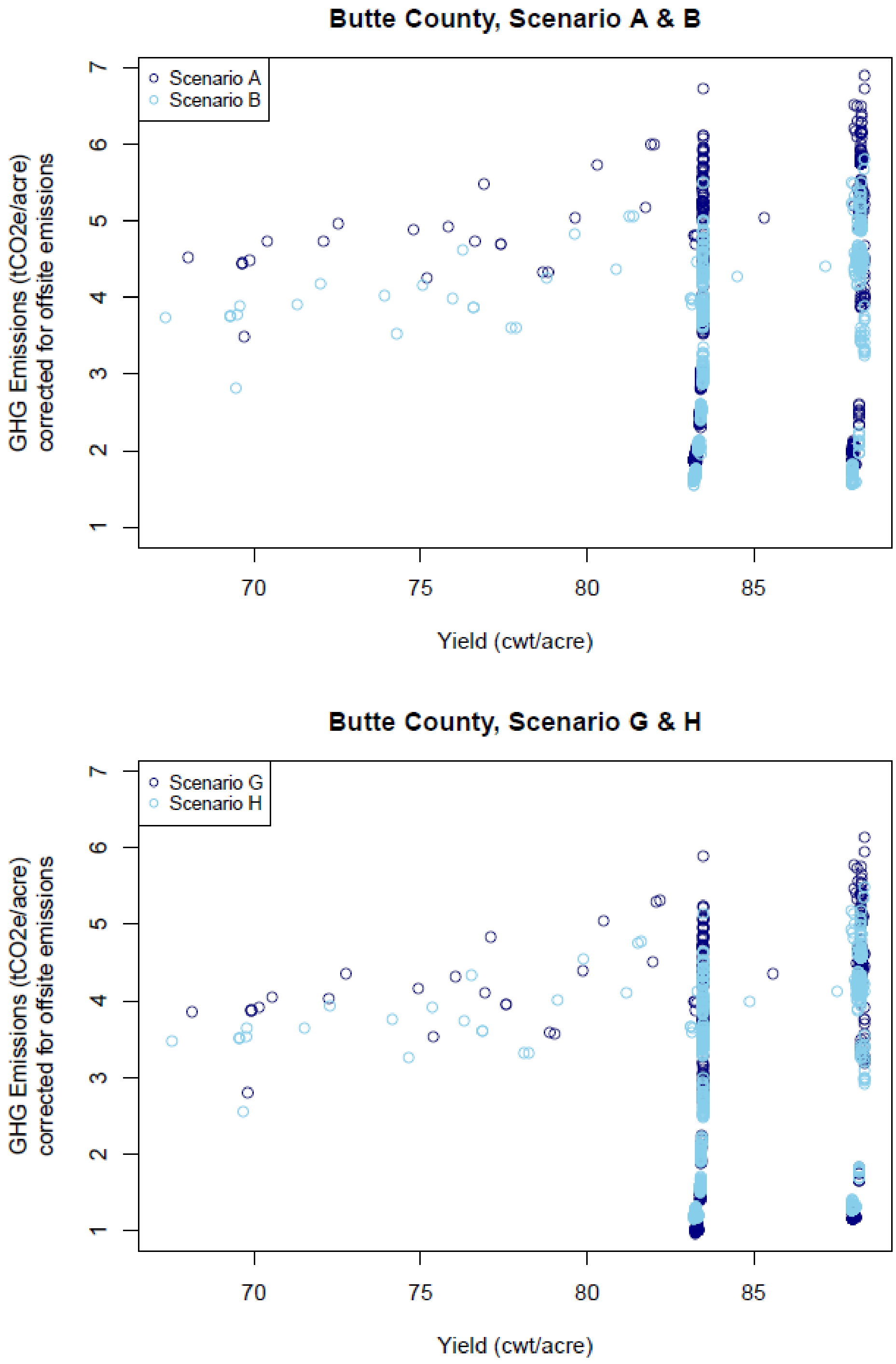
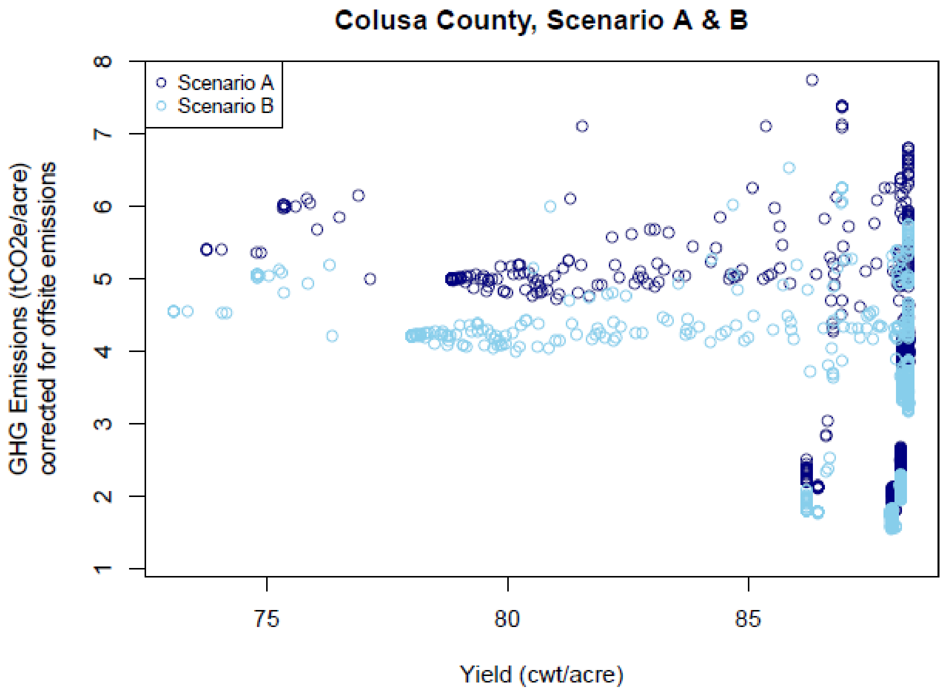


Figure 4a. Scatterplots for Butte County showing emissions per acre (tCO_2e/acre) versus yield per acre (cwt/acre), with scenarios B and H corrected for offsite emissions.



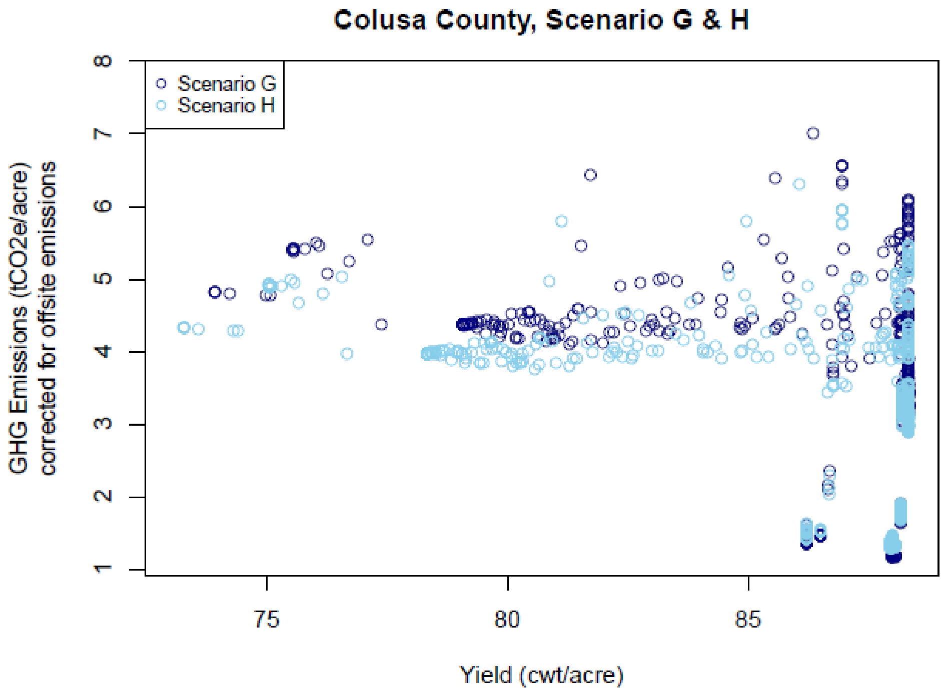


Figure 4b. Scatterplots for Colusa County showing emissions per acre (tCO_2e/acre) versus yield per acre (cwt/acre, with scenarios B and H corrected for offsite emissions.

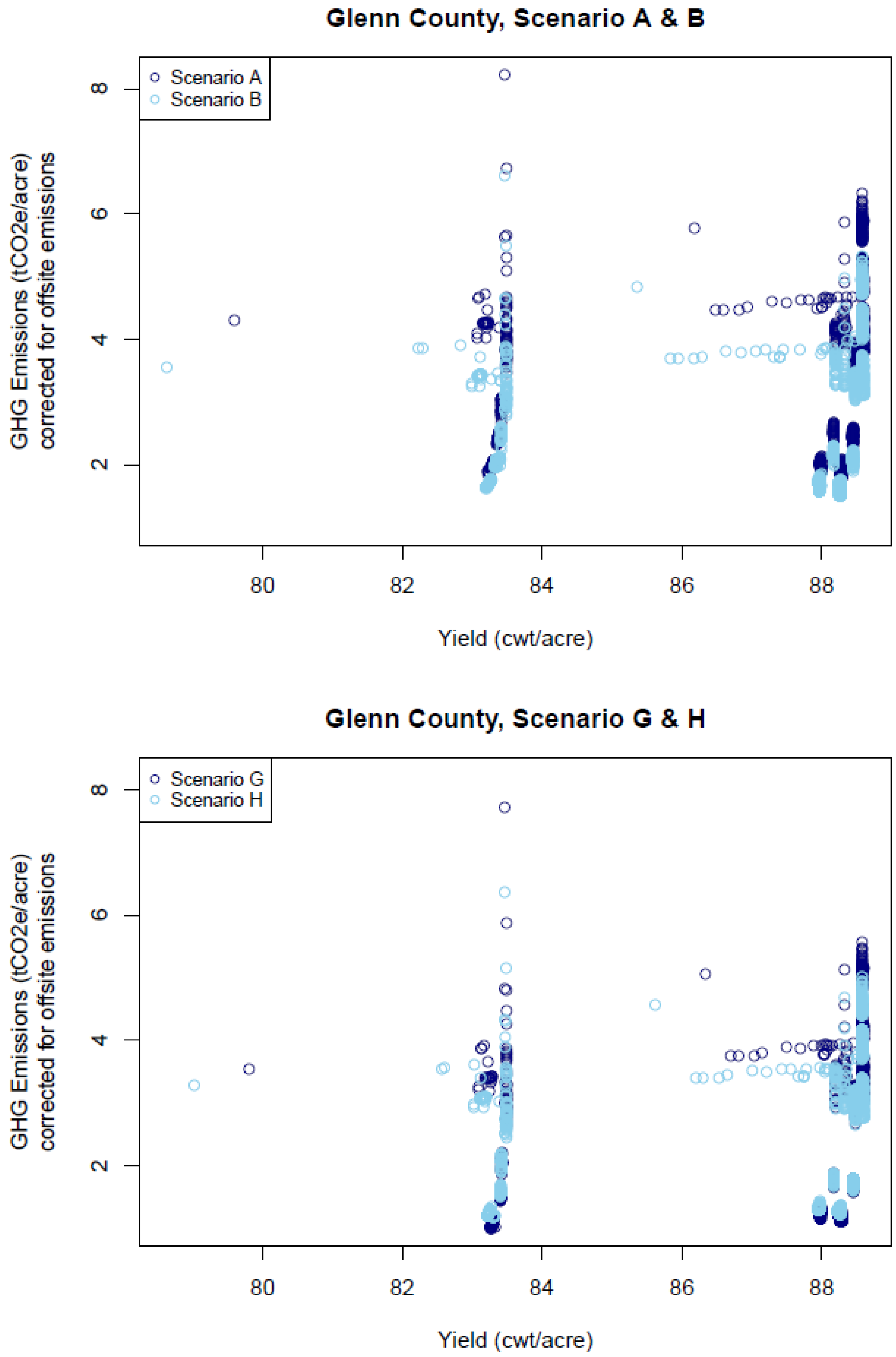


Figure 4c. Scatterplots for Glenn County showing emissions per acre (tCO_2e/acre) versus yield per acre (cwt/acre), with scenarios B and H corrected for offsite emissions.

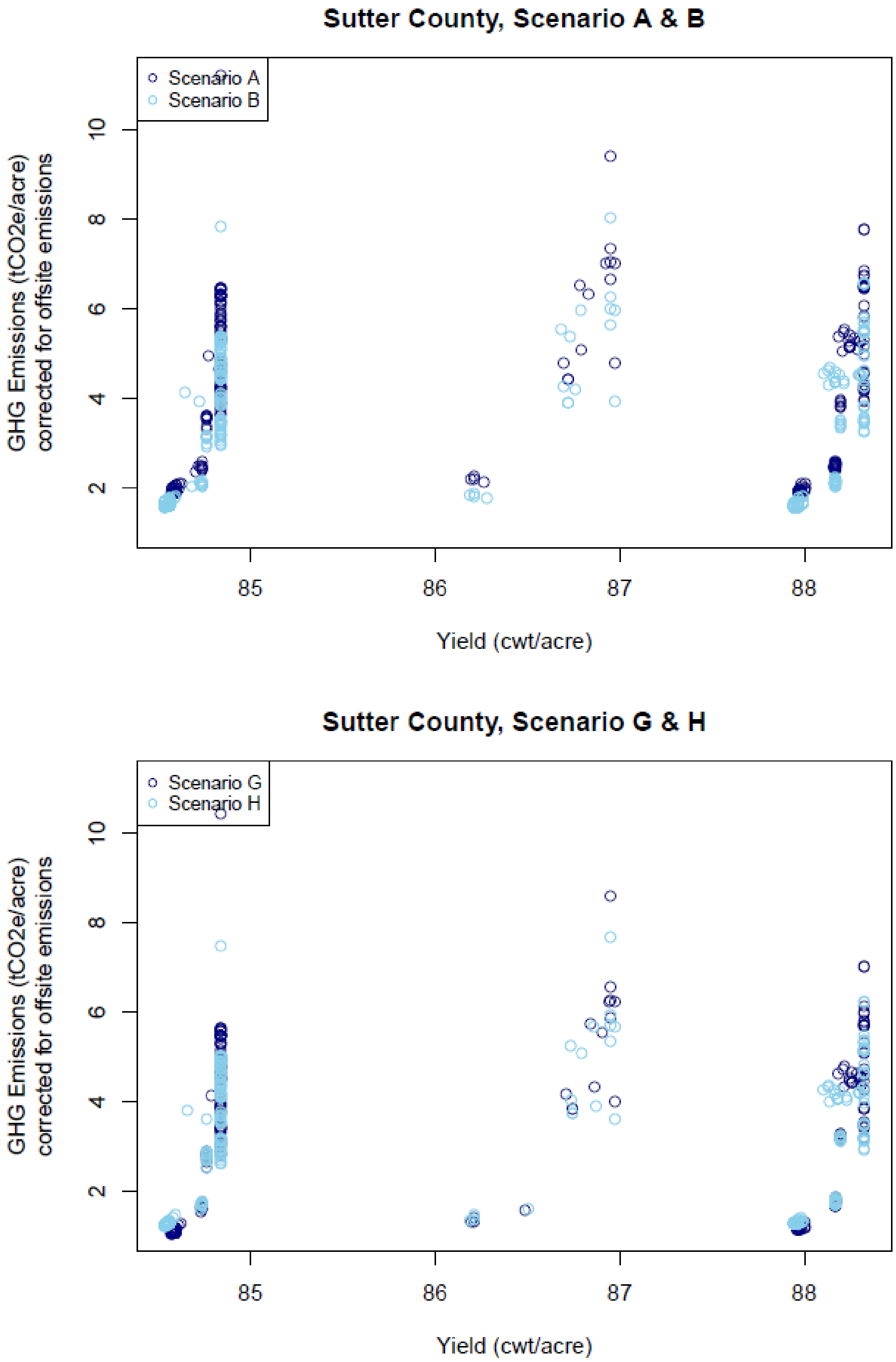


Figure 4d. Scatterplots for Sutter County showing emissions per acre (tCO_2e/acre) versus yield per acre (cwt/acre), with scenarios B and H corrected for offsite emissions.

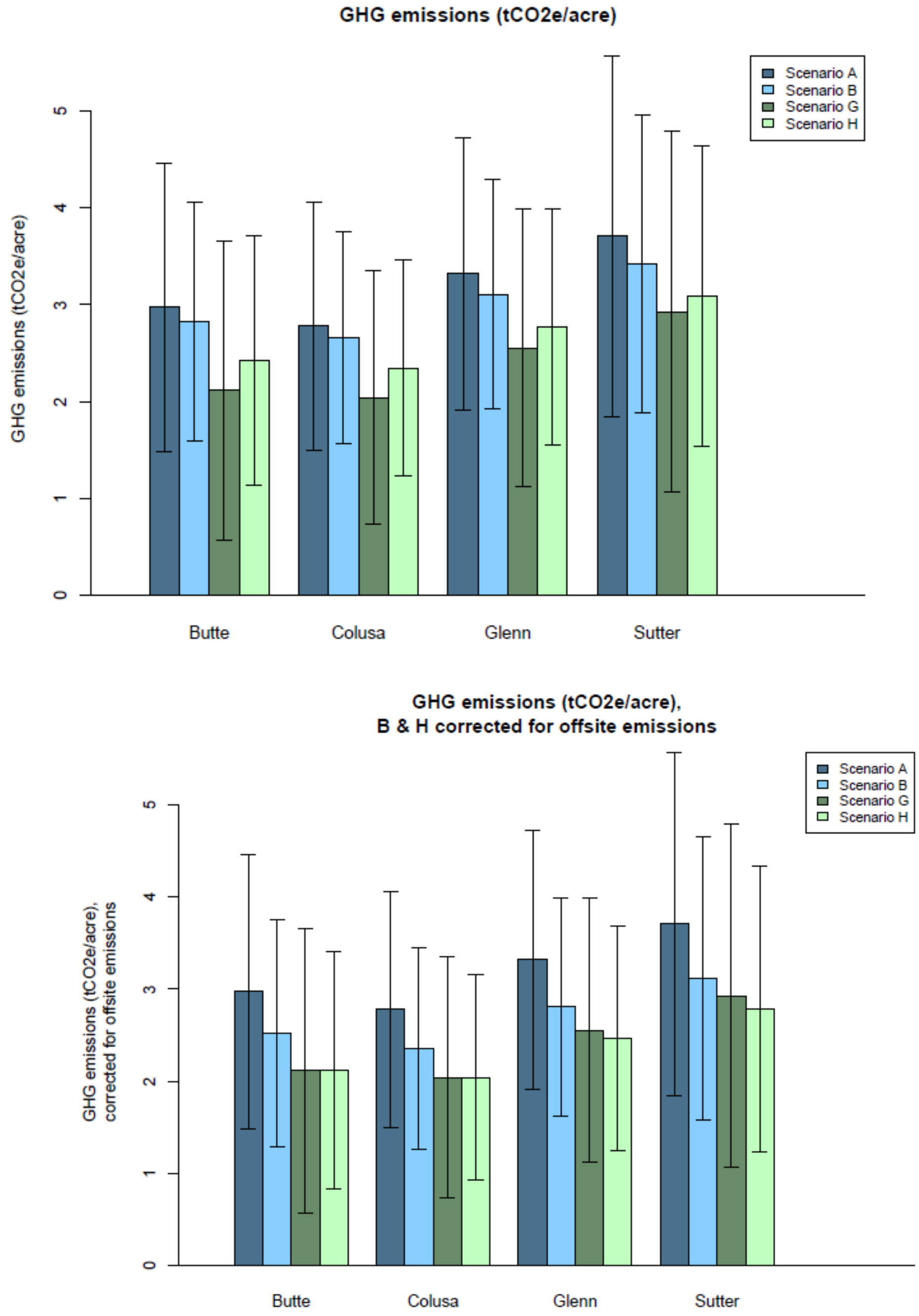


Figure 5. Bar plots of mean and standard deviation for GHG emissions (tCO_2e/acre) for each scenario by county combination. The top figure shows B and H without the offsite emissions correction. The bottom figure shows B and H corrected for offsite emissions.

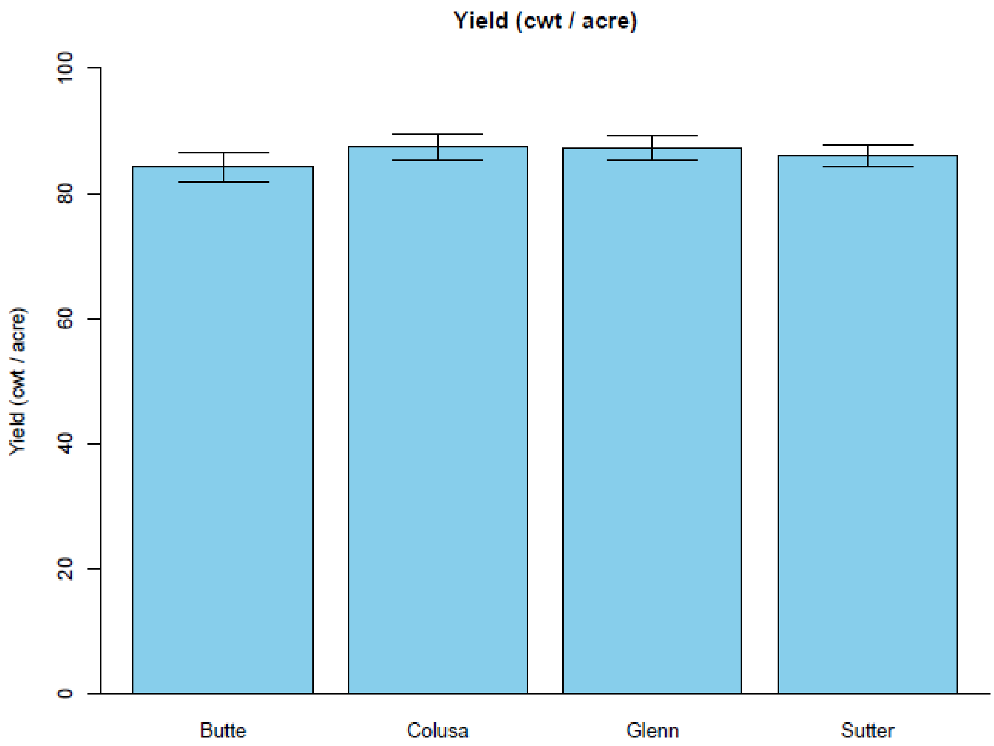


Figure 6. Bar plot comparing the mean and standard deviation for yield per acre (cwt/acre) for each county.

Appendix B

GHG Emissions Benefits of a CalAg Rice Project Using a Tier 1 IPCC Approach

REPORT

Environmental
Resources
Management

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ERM

Prepared For: CalAg Aggregators LLC

From: Victoria Evans, Judy Nedoff, Kristie Klose, Ariane Burwell

Date: March 11, 2013

Subject: Methane Reductions from Rice Management Using the Tier 1 IPCC Approach

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Introduction

ERM-West, Inc. (ERM) was commissioned by CalAg Aggregators to evaluate the results of applying a Tier 1 IPCC approach for calculating methane reductions from a rice management project. The current method used is the DNDC Model (utilized in both rice protocols published by each of the two carbon registries certified by the California Air Resources Board). ERM performed a review of the DNDC Model and through these reviews, and those of others, several issues with the application of the DNDC model were identified. ERM was requested to explore alternative approaches and subsequently recommended use of a Tier 1 IPCC calculation.

As defined by the IPCC (2006), the calculation approach currently being used by the DNDC model is the IPCC Tier 3 approach. IPCC has defined three tiers of models based on the complexity and detail:

Tier 1

Employs the basic method and default emission factors from the IPCC Guidelines.

Tier 2

Uses the same methodological approach as Tier 1 with emission factors and activity data are applied at a country scale for land uses and activities. Higher resolution activity data are typically used in Tier 2 to correspond with country-defined coefficients for specific regions and specialized land use categories.

Tier 3

Higher order methods are used including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by high-resolution activity data and disaggregated at sub-national to fine grid scales. These higher order methods provide estimates of greater certainty than lower tiers and have a closer link between biomass and soil dynamics.

A member of the Environmental
Resources Management Group

The DNDC model represents a Tier 3 approach. At CalAg Aggregator's request, ERM explored using a Tier 1 approach to quantify the methane reductions from rice cultivation practices. ERM applied the IPCC 2006 approach and displays the results in the accompanying MS Excel file. The following outlines the approach and results derived from application of the Tier 1 IPCC approach.

IPCC Tier 1 Approach (2006)

The IPCC published guidance on conducting greenhouse gas inventories in 2006, and standardized approaches for region/country specific values for methane emissions in rice field (IPCC 2006). This is a guidance document and workbook wherein rice is classified as part of the cropland chapter. The following Tier 1 approach is directly applied from this guidance. Where possible, recommended factors from the IPCC were used including Yan 2005.

The Tier 1 calculation of a daily methane emission factor - Adjusted Daily Emission Factor (EFi) is calculated as follows:

$$EFi = EFc * SFw * SFp * SFo * SFs,r$$

Where:

EFi = Adjusted daily emission factor for a particular harvested area (kgCH4/ha/day)

EFc = Baseline emission factor for continuously flooded fields without organic amendments (kgCH4/ha/day)

SFw = Scaling factor to account for the differences in water regime during the cultivation period

SFp = Scaling factor to account for the differences in water regime in the pre-season before the cultivation period

SFo = Scaling factor should vary for both type and amount of organic amendment applied

SFs,r = Scaling factor for soil type, rice cultivar, etc. if available

In this equation, EFc is the starting point and the scaling factors are used to adjust the equation for the different conditions that influence methane emissions including water, soil, and organic amendment.

Factors Applied for California in Test Calculations

EFc = Adjusted daily emission factor for California (kgCH4/ha/day)

According to the California Air Resources Board (CARB), rice cultivation accounts for approximately 1.8% of California's annually averaged anthropogenic CH4 emissions. However, the majority of these emissions occur during the growing season, therefore, rice cultivation should account for 6 to 7% of California's anthropogenic methane emissions during the growing season (May 15 – Aug 15) (CRC). According to Fitzgerald et al (2000), the rice growing season in California is actually a couple of months longer at approximately 140 days (~May 20 – Oct 8) with some variations from year to year. On the other hand, McMillan et al. (2007) put the growing season from mid-May to the end of August, so there is some discrepancy and variation among the length and dates of the rice growing season.

SFw = Scaling factor for water regime during the cultivation period

The selection of which default scaling factors from the IPCC 2006 to account for differences in water regime during the cultivation period, was based upon Email correspondence with Paul Buttner, California Rice Commission (CRC). The rice fields in CA are considered flooded for a significant period of time and the water regime is fully controlled (i.e., Irrigated) and continuously flooded (Continuously flooded: Fields have standing water throughout the rice growing season and may only be drained for harvest (end-season drainage)).

SFp = Scaling factor to account for the water regime in the pre-season before the cultivation period

According to Paul Buttner, CRC (2013), 500,000 acres (202,343 hectares) of rice fields are flooded in California during the growing season (May 15 – Aug 15). About half that amount (250,000 acres/ 101,171 ha) is flooded during winter (~Oct 25 – Feb 25, ~ 120 days [Fitzgerald et al., 2000]).

SFo = Scaling factor for both type and amount of organic amendment applied

Based on Wong (2003), in the Sacramento Valley, 2.21 million tonnes of above ground straw is produced from rice cultivation annually. Therefore, assuming that all rice straw is applied to the soil as organic amendment, the following ROAi (application rate of organic amendment) would be (measured as tonne /ha-1) =

2.21 M tonne straw x 2.47 acres x 1 tonne = 10.917 tonnes/hectare

Assuming 60% of the rice straw is harvestable, this equals 6.55 tonnes/hectare.

According to Wong (2003), 60% of available rice straw (2.21 million tonnes annually) in California is harvestable. Therefore, based upon this assumption, 1.33 million tonnes of rice straw is available for harvest annually, in total.

SFs,r = Scaling factor for soil type and rice cultivar type

A definitive scaling factor for SFs,r was collected from the CRC (2003): >90% of the rice grown in California is medium grain rice (primarily "New Variety" and Calrose varieties).

Soil types in the Sacramento Valley (where most rice is grown in CA) are primarily composed of soils with poor drainage (i.e., clay - 50.5% and silt – 45.0%) (Fitzgerald et al., 2000).

Results

When the IPCC Tier 1 results are annualized (Tier 1 calculation provides emissions per day), emissions benefits from removal of available rice straw (and avoided decomposition) equals about 2 metric tonnes CO2e/acre/year (including a reduced period of flooding pre-season). This is for the scenario that is closest to the CalAg Aggregator example.

Note that 2 metric tonnes/acre is similar to the results from model runs of the DNDC Model as provided to ERM by EDF in earlier communications (for the counties where CalAg expects to source rice straw). This calculation produces essentially the same results as the average of the more complex DNDC Model, which requires multiple runs and time consuming pre- and post-processing.

The specific assumptions are tabulated in the attached MS Excel spreadsheet.

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Buttner, Paul. Environmental Affairs Manager, California Rice Commission (CRC). 2013. *Email Correspondence*. 25 January 2013.

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Wong, A. 2003. *Comparative emission of methane from different rice straw management practices in California – a statewide perspective.* Journal of Sustainable Agriculture 22: 79–91.

Table 1. IPCC Tier 1 Model for Non Winter Flooded - Emissions Reduction Due to Removal of Straw

	EFc (kg CH4/ha/day)	SFw (unitless)	SFp (unitless)	SFo (unitless)	EFi (kg CH4/ha/day)	EFi (converted to acres) (kg CH4/acre/day)
3 tonnes/ha	1.3	1	0.68	1.447	1.279	0.518
7 tonnes/ha	1.3	1	0.68	1.923	1.700	0.688
Difference (7 tonne/ha -3 tonne/ha residue)					0.421	0.171

Conversions:

total CH4 reduction from 93k acres	kg CH4/day	15863
total CO2e reduction from 93k acres	kg CO2e/day	333122
	MT CO2e/day	333
	MT CO2e/year	121590
Emissions reduction/acre if straw is removed	**MT CO2e/acre/year**	**1**

Rice cultivation scenarios at 3 and 7 tonnes straw residue per hectare for single crop harvest

Calculated as per IPCC 2006, Adjusted Daily Emission Factor (EFi) for a particular harvested area (kgCH4/ha/day)

EFi = EFc *SFw*SFp*SFo*SFs,r

IPCC default	**Assumption**	**Factor and definition**
1.3		EFc = Baseline emission factor for continuously flooded fields without organic amendments (kgCH4/ha/day) and long drainage
1	continuously flooded	SFw = Scaling factor to account for the differences in water regime <u>during</u> the cultivation period (unitless)
0.68	nonflooded pre-season (winter)	SFp = Scaling factor to account for the differences in water regimen in pre-season before the cultivation period (unitless)
calculated	**see below**	SFo = Scaling factor should vary for both type and amount of organic amendment applied (unitless)
3	manually harvested to ground level, very little stubble/ root residues only	ROA = application rate of organic amendment type i, in dry weight for straw. Assume no other organic amendments applied. (tonne/ha)
7	mechanically harvested, large amount of residue on field	ROA = application rate of organic amendment type i, in dry weight for straw. Assume no other organic amendments applied. (tonne/ha)
0.29	field not flooded for long period before next crop	CFOA = conversion factor for organic amendment type i (in terms of its relative effect on CH4 wrt straw applied shortly before cultivation) (unitless)
not available		SFs,r = Scaling factor for soil type, rice cultivar, etc., if available
SFo = (1+ Σi ROAi * CFOAi)^0.59		Calculated using 7 and then 3 to estimate difference between leaving straw on field during winter flooding and removing most straw prior to flooding.

CO2e/year = CO2e/day * 365 days of emissions

hectare = 2.47 acres

CO2e = CH4*21 The global warming potential (GWP) for methane = 21 (IPCC Fourth Assessment Report, 2007; http://epa.gov/climatechange/ghgemissions/gases/ch4.html)

MT = 1000 kg

SFs,r (scaling factor) for the soil type and rice cultivar is not considered due to lack of data.

🟩 variables that change in different runs of model

Table 2. IPCC Tier 1 Model for Winter Flooded - Emissions Reduction Due to Removal of Straw (CFOA = 1)

	EFc (kg CH4/ha/day)	**SFw** (unitless)	**SFp** (unitless)	**SFo** (unitless)	**EFi** (kg CH4/ha/day)	**EFi (converted to acres)** (kg CH4/acres/day)
3 tonnes/ha	1.3	1	1	2.266	2.945	1.193
7 tonnes/ha	1.3	1	1	3.411	4.434	1.795
Difference (7 tonne/ha -3 tonne/ha residue)					1.488	0.603

Conversions:

total CH4 reduction from 93k acres	kg CH4/day	56034
total CO2e reduction from 93k acres	kg CO2e/day	1176705
	MT CO2e/day	1177
	MT CO2e/year	429497
Emissions reduction/acre if straw is removed	**MT CO2e/acre/year**	**5**

Rice cultivation scenarios at 3 and 7 tonnes straw residue per hectare for single crop harvest

Calculated as per IPCC 2006, Adjusted Daily Emission Factor (EFi) for a particular harvested area (kgCH4/ha/day)

EFi = EFc *SFw*SFp*SFo*SFs,r

IPCC default	**Assumption**	**Factor and definition**
1.3		EFc = Baseline emission factor for continuously flooded fields without organic amendments (kgCH4/ha/day) and short drainage (= winter flooded)
1	continuously flooded	SFw = Scaling factor to account for the differences in water regime during the cultivation period (unitless)
1	short drainage pre-season (winter flooded)	SFp = Scaling factor to account for the differences in water regimen in pre-season before the cultivation period (unitless)
calculated	see below	SFo = Scaling factor should vary for both type and amount of organic amendment applied (unitless)
3	manually harvested to ground level, very little stubble/ root residues only	ROA = application rate of organic amendment type i, in dry weight for straw. Assume no other organic amendments applied. (tonne/ha)
7	mechanically harvested, large amount of residue on field	ROA = application rate of organic amendment type i, in dry weight for straw. Assume no other organic amendments applied. (tonne/ha)
1	field flooded for long period before next crop	CFOA = conversion factor for organic amendment type i (in terms of its relative effect on CH4 wrt straw applied shortly before cultivation) (unitless) [IPCC calls this double cropping factor, but accounts for winter flooding] May be too high. See Table 3.
not available		SFs,r = Scaling factor for soil type, rice cultivar, etc., if available
SFo = (1+ Σi ROAi * CFOAi)^0.59		Calculated using 7 and then 3 to estimate difference between leaving straw on field during winter flooding and removing most straw prior to flooding.

CO2e/year = CO2e/day * 365 days of emissions

hectare = 2.47 acres

CO2e = CH4*2 The global warming potential (GWP) for methane = 21 (IPCC Fourth Assessment Report, 2007; http://epa.gov/climatechange/ghgemissions/gases/ch4.html)

MT = 1000 kg

SFs,r (scaling factor) for the soil type and rice cultivar is not considered due to lack of data.

🟩 variables that change in different runs of model

Table 3. IPCC Tier 1 Model for Winter Flooded - Emissions Reduction Due to Removal of Straw (CFOA = 0.29)

	EFc (kg CH4/ha/day)	SFw (unitless)	SFp (unitless)	SFo (unitless)	EFi (kg CH4/ha/day)	EFi (converted to acres) (kg CH4/acres/day)
3 tonnes/ha	1.3	1	1	1.447	1.881	0.761
7 tonnes/ha	1.3	1	1	1.923	2.500	1.012
Difference (7 tonne/ha -3 tonne/ha residue)					0.620	0.251
	Conversions:					
	total CH4 reduction from 93k acres				kg CH4/day	23328
	total CO2e reduction from 93k acres				kg CO2e/day	489886
					MT CO2e/day	490
					MT CO2e/year	178808
Emissions reduction/acre if straw is removed					**MT CO2e/acre/year**	**2**

Rice cultivation scenarios at 3 and 7 tonnes straw residue per hectare for single crop harvest

Calculated as per IPCC 2006, Adjusted Daily Emission Factor (EFi) for a particular harvested area (kgCH4/ha/day)

EFi = EFc *SFw*SFp*SFo*SFs,r

IPCC default	Assumption	Factor and definition
1.3		EFc = Baseline emission factor for continuously flooded fields without organic amendments (kgCH4/ha/day) and short drainage (= winter flooded)
1	continuously flooded	SFw = Scaling factor to account for the differences in water regime during the cultivation period (unitless)
1	short drainage pre-season (winter flooded)	SFp = Scaling factor to account for the differences in water regimen in pre-season before the cultivation period (unitless)
calculated	see below	SFo = Scaling factor should vary for both type and amount of organic amendment applied (unitless)
3	manually harvested to ground level, very little stubble/ root residues only	ROA = application rate of organic amendment type i, in dry weight for straw. Assume no other organic amendments applied. (tonne/ha)
7	mechanically harvested, large amount of residue on field	ROA = application rate of organic amendment type i, in dry weight for straw. Assume no other organic amendments applied. (tonne/ha)
0.29	single crop; field not flooded for long period between crops	CFOA = conversion factor for organic amendment type i (in terms of its relative effect on CH4 wrt straw applied shortly before cultivation) (unitless) [IPCC calls this single cropping, dry winter fields] This factor may be too low. See Table 2 for calculation with different factor.
not available		SFs,r = Scaling factor for soil type, rice cultivar, etc., if available
SFo = (1+ Σi ROAi * CFOAi)^0.59		Calculated using 7 and then 3 to estimate difference between leaving straw on field during winter flooding and removing most straw prior to flooding.

CO2e = CH4*21

MT = 1000 kg

SFs,r (scaling factor) for the soil type and rice cultivar is not considered due to lack of data.

🟩 variables that change in different runs of model

Appendix C

Proposed Calculation Methods for Quantification of Off-field Emissions Benefits

Memorandum

Environmental Resources Management

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To:	Teresa Lang, Sami Osman, Climate Action Reserve
CC:	Keith Casto, Cooper White & Cooper LLP
From:	Victoria Evans, Rick Shih, Ariane Burwell, ERM-Walnut Creek, California on behalf of CalAg Aggregator LLC
Date:	21 March 2013
Subject:	Off-field Emissions Reduction Calculation Methods: Rice Straw to MDF

Note: All calculations shown throughout are in metric tonnes.

Introduction

CalAg Aggregator LLC is working to develop a project to generate carbon emissions reductions from incorporating rice straw into medium density fiberboard (rice fiberboard), thus, it is CalAggregator's viewpoint that these reductions should be fully accounted for in any Rice Management System protocol. The rice straw replaces wood fiber in the manufacturing process.

ERM has been contracted by CalAg Aggregator to review the extent to which these emissions benefits have been properly quantified. ERM has tracked the successive iterations of the protocol and though improvements have been made in accounting for the emissions reductions, the latest version of the American Carbon Registry (ACR) Rice Protocol still does not fully account for the benefits of rice fiberboard. The Climate Action Registry (CAR) Rice Protocol mentions rice fiberboard but does not provide a specific calculation method at this time; CAR staff managing this protocol indicated a willingness to review potential calculation methods for incorporating into a revised protocol.

This memo to CAR provides a summary of ERM's proposed calculation methods for these off-field emissions reductions of GHG associated with rice straw to fiberboard manufacturing.

1. Off field – Avoidance of End Use Methane

The ACR Rice Protocol, v8-0 dated December 2012, Table 6 on page 33, outlines the following categories of (avoided) emissions for fiberboard manufacturing:

1. reduced emissions from avoided post-harvest chopping and disking
2. increased emissions from swathing, raking, and bailing
3. non-CO_2 emissions during the life cycle of the fiberboard

However, a fourth additional benefit not currently captured in these emission categories is the incorporation of rice straw into fiberboard instead of incorporating wood fiber. Manufacturing fiberboard from rice straw sequesters the carbon associated with the rice straw. Production of the fiberboard avoids the release of methane that would occur during the decomposition through other current end-uses of the rice straw (erosion control, animal bedding or feed, etc.). Therefore, the fiberboard is the most holistic and complete reduction available as it prevents any decomposition from occurring, until the end of life of the fiberboard (typically 60 to 80 years in building applications).

To capture this benefit, ERM proposes to use the following method to calculate the avoided decomposition.

According to CAR's existing Rice Management Protocol, 3 to 5% of rice straw is used for end uses, while the rest decomposes in the rice field. The existing end use market for rice straw in California is for dairy and beef cattle feed where 75% of the rice straw is used and 25% goes to erosion control (CAR Rice Protocol 2011, pg 63). See also similar discussion beginning on page 34, ACR Rice Protocol, v8-0 dated December 2012.

This category of emissions reductions for the end use should be proportionally weighted and added to account for avoided decomposition of rice straw from accumulation in fields, feed use, and erosion control to the manufacture of MDF.

If displacing the proportions of current rice straw as consumed in the end use market, then the GHG reduction could be calculated as:

*([[(MT rice straw/yr used) * 0.75 *(45 kg* CO_2*e/MT t dry straw used for feed)]+*

*[(MT rice straw/yr used) * 0.25* (40 kg* CO_2*e/MT dry straw used for erosion control)]]*0.05)*

+

*[(MT rice straw/yr used) * ((250 kg CO_2e/MT non-CO_2 emissions during the decomposition of the straw)+(30 kg CO_2e/MT from avoided past-harvest chopping and disking and increase from swathing, raking, and baling))*0.95])*

** 0.001 (kg to MT)*

= MT CO_2e /yr

Where:

MT rice straw/yr used= Rice straw use in manufacturing MDF per year in MT (dry basis)

All of the factors for sources of avoided emissions are from Table 6 on page 33, ACR Rice Protocol, v8-0 dated December 2012.

2. Off-field – Carbon from substitution of rice straw for wood fiber in MDF. (Not currently included)

A fifth category of potential emission benefit of the CalAg Aggregator project is the substitution of rice straw for wood fiber in manufacturing fiberboard. According to CAR's existing Rice Management Protocol, replacement of wood fiber with rice straw in manufacturing fiberboard is recognized as a likely net positive GHG benefit for the avoidance of harvesting and transport of wood products (CAR 2011v. 7-0, p. 63). The calculation for these emissions benefits was not provided.

Below we describe a proposed methodology to apply. We propose to multiply the volume of rice straw used per year to manufacture MDF by the percentage of carbon content in wood, to calculate the carbon in the wood fiber as displaced by the substitution of rice straw instead. This provides a calculation of the amount of carbon in wood fiber that is no longer needed in this manufacturing process and assumes harvest of wood fiber is no longer required for the manufacture of the quantity of MDF produced by this plant each year.

*(MT Rice straw used/yr) * (% carbon content, wood fiber)*

= MT CO_2e

Where:

= MT rice straw/yr used in MDF manufacturing

48% = carbon content, wood fiber, dry basis

37.7% = carbon content, rice straw, dry basis

Source of wood fiber and rice straw carbon content information: http://www.knowledgebank.irri.org/rkb/rice-milling/contributions-and-references-milling/further-information-byproducts/husk-and-straw-properties.html

3. Off field – Avoided fossil fuel use for haul of straw to MDF manufacturing plant

Since, on average, the rice straw fields are closer to the MDF facility (Willows plant) than the source of wood, using rice straw instead of wood would result in fewer GHG emissions. The average distance from the source of wood to the MDF plant is estimated to be about 250 miles while the average distance from the source of rice straw to the MDF is estimated to be 25 miles. The basis for the rice straw to MDF plant is calculated with respect to the location of CalAg manufacturing plant in Willows, California, and the intention to source rice straw from a 25-mile radius. The basis for the average distance for hauling wood fiber to an MDF plant is currently based upon the results of a recent proprietary study, and ERM has not been able to derive a citation for the source of the data to support this average distance. Thus, another source of data to support this distance would need to be sought.

Nonetheless, based on these distances, the reduction in GHG emissions can be estimated using the following equation.

$$[(250\ \text{miles/trip}) * (\ \#\ \text{trips/year}) - (25\ \text{miles/trip}) * (\ \#\ \text{trips/year})]\ [(9.07\ \text{kg of}\ CO_2\text{/gal of diesel fuel})/(5.787\ \text{miles per gal})] -$$

$$= \mathbf{MT\ CO_2e}$$

The above equation conservatively only accounts for the reduction in CO_2 emissions. Methane and nitrous oxide emissions would also be reduced but typically, these emissions only account for less than a few percent of the total CO_2e.).

The emission factors and fuel economy were derived using CARB's EMFAC2011 emission factor model based on the following assumptions:

- Using statewide average data
- Using the fleet of heavy-heavy duty diesel tractor trucks in calendar year 2020 (calendar year 2013 data would result in an about 10% additional emission reduction benefits)

To use the above equation, the developer would have to estimate the number of truck trips per year. If this approach is used for a different MDF facility, the 250 miles and 25 miles data would need to be modified accordingly.

Conclusion

ERM recognizes that there may be other calculation approaches for beneficial aspects of the CalAg project, and would welcome an opportunity to further discuss any or all of these proposed methods with CAR.