Greenhouse Gas Fluxes and Modelling from Rice Workshop

REPORT

1-5 September 2025
International Rice research Institute (IRRI)
Los Banos, Laguna, Philippines

In partnership with:

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I. Acknowledgements

The organizers of the Greenhouse Gas Fluxes and Modeling from Rice Workshop gratefully acknowledge the generous support of the Global Methane Hub (GMH) and the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan, whose contributions made this event possible.

Appreciation is also extended to the partner institutions—International Rice Research Institute (IRRI), the Agricultural Model Intercomparison and Improvement Project (AgMIP), and CGIAR Climate Action— for their collaboration in convening this workshop and for their shared commitment to advancing climate change mitigation in rice systems.

The organizers further recognize the valuable contributions of more than 80 participants, experts, and institutions from across 25 regions who contributed their time, knowledge, and insights. Their active engagement and spirit of collaboration were essential in making the workshop a success and in shaping the joint agenda for advancing greenhouse gas flux measurement and modeling in rice systems.

II. Executive Summary

Methane (CH_4) emissions from paddy fields contribute significantly to agricultural greenhouse gas (GHG) emissions, posing a critical challenge for achieving global climate goals. Despite the availability of the Tier 3 method—which utilizes process-based models and high-resolution datasets to capture variability in site-specific CH_4 emissions, its application has been limited to a few countries. There is still a large gap in establishing country and regional specific emissions factors and an increasing demand to measure actual emissions from the field. These requirements are not only for country-level inventories to the United Nations Framework Convention on Climate Change (UNFCCC) but also for the emerging carbon market in the agricultural sector. Significant efforts are being invested in advancing technologies and options for targeting and supporting climate mitigation initiatives in rice systems. Measurements and monitoring are critical in setting the baseline for these initiatives and in evaluating the progress made. However, their implementation remains challenging due to limited consensus in protocols for measurements, as well as the limited accessibility of tools and technologies for measurements, modeling and monitoring of emissions.

Modeling is central to bridging experimental research data with actionable mitigation and adaptation strategies at scale. Current models can reliably simulate yield, water balance, and basic soil–nutrient interactions, but they struggle with trade-offs between methane reduction and nitrous oxide emissions, or with integrating soil carbon dynamics.

Owing to the serious impacts of the climate crisis in crop production and human health, global assessments of GHG emissions through measurements and modeling are urgently needed to accelerate efforts in developing resilient food systems in all rice-growing countries around the world.

The “Greenhouse Gas Fluxes and Modeling from Rice Workshop” was convened to address these challenges. The workshop was held from 1–5 September 2025 at the International Rice Research Institute (IRRI), Los Baños, Philippines, jointly led by IRRI, AgMIP, and the Global Methane Hub—with support from CGIAR Climate Action and Japan’s Ministry of Agriculture, Forestry and Fisheries (MAFF).The workshop gathered more than 80 participants from 40 organizations across 25 regions and brought together perspectives from research, stakeholders engaged in national GHG inventories, UNFCCC reporting, and the carbon market.

It was delivered in a hybrid format with in-person and online participation. The workshop`s structure was composed of six plenary sessions organized to provide the general overview of the state-of-the-science in GHG measurements and modeling in rice systems and two parallel sessions that were technical focused on the overview of different methodologies in measurements and in modeling, respectively.

Participants underscored the need to bring together field flux measurements, crop simulations, and socio-economic analysis to improve forward-looking impact assessments. Such integration would enable evaluation of how mitigation and adaptation strategies affect farmers’ livelihoods, food security, and resource use, while quantifying the trade-offs and synergies among socio-economic, biophysical, and environmental outcomes.

The different presentations highlighted the data gap in mitigation efforts’ monitoring as current national data collection targets food security. Calibration and validation data for modeling are scarce, especially at regional and national scales. Workshop discussions emphasized that while rice models have advanced significantly—particularly through multi-model ensembles and AgMIP’s coordinated intercomparison efforts—gaps remain in simulating extreme events, trait-based responses, and GHG fluxes beyond methane.

The workshop identified several opportunities to strengthen rice GHG research and implementation and recommendations moving forward include among others: adopting FAIR (Findable, Accessible, Interoperable, Reusable) data principles; piloting joint measurement–modeling projects across diverse rice ecologies; aligning MRV requirements of carbon markets with scientific protocol; and fostering multi-stakeholder platforms that bridge researchers, governments, and private-sector actors.

Key outputs of the workshop include:

- Consensus on minimum protocols for chamber-based measurements (chamber design, sampling frequency, flux calculation, and reporting standards).
- Agreement on the need for harmonized datasets and metadata standards, including soil, water, crop, and weather variables.
- Roadmaps from four breakout groups (water management, methane modeling, management interventions, scaling/upscaling) outlining data needs, priority interventions, and collaborative actions.
- Identification of high-potential innovations such as AWD, improved fertilizer management, and integration of socio-economic models.
- Commitments to develop shared repositories and adopt common reporting templates.

The participants have agreed to the following actionable next steps to confirm their overall commitment to high quality research to address global challenges in facing climate change:

- Continuing communication through shared platforms (e.g., SharePoint, AgMIP frameworks) and periodic follow-up meetings to track progress.
- Co-developing guidelines for GHG measurements across global rice growing areas that will support capacity building for a global network of GHG researchers and long-term flux experimental study.
- Establishing a working group to coordinate model intercomparison, protocol standardization, and joint calibration efforts.
- Launching pilot case studies in Asia, Africa, and Latin America to test harmonized protocols and scale findings.
- Selecting case studies that can be used to conduct integrated assessments of climate change, adaptation, and mitigation using the AgMIP's MAC-B modeling framework.
- Linking workshop outcomes to policy processes, including national GHG inventories, NDC implementation, and Article 6 mechanisms.

Together, these outputs and commitments signal a strong foundation for a coordinated global effort to reduce methane emissions from rice systems, while ensuring that mitigation strategies align with adaptation goals, farmer livelihoods, and sustainable development.

III. Introduction

A. Background and Context of the Workshop

GHG emission rates are inherently variable in time and space, often associated with high error estimates. Accurate estimates of GHG fluxes are increasingly needed in accounting for GHG inventories and C in-sets at the field to field and global scale benefits. It has been reported that uncertainties may reach 20-35% for inventories of anthropogenic emissions in specific sectors (IPCC, 2021). Many studies have documented that different flux calculation methods can produce substantially different GHG flux estimates for a given set of chamber data (Levy et al., 2011). These flux computations differ not only in their accuracy (close to true flux value) but also in their precision (repeatability).

Crop models are widely accepted to be used to scale emissions data to regional assessments such as done in countries reporting their GHG emissions using the Tier 3 approach. They can use spatial high-resolution datasets to capture site-specific variability that may affect emissions and particularly CH_4 such as climate, management practices, varieties and soils. The application of crop models for GHG inventory is limited to a few countries and this is primarily due to the demanding data requirements for their use and the limited capability of rice crop growth models simulating GHG emissions and particularly methane. Up to date, there has been no systematic intercomparison among rice crop models against observed data to quantify uncertainties associated with CH_4 emission predictions, leaving gaps in understanding the mitigation potential of various strategies. The AgMIP Rice project has a long history of intercomparing crop models to assess climate change impacts and adaptation strategies. Some of these models simulate soil-plant interactions, including soil carbon dynamics, which enable CH_4 emission simulations and present opportunities to enhance GHG estimates.

Precise GHG emissions support robust identification of strategies to mitigate emissions and maintain high integrity of the data for reporting. Therefore, a comprehensive assessment of chamber method, trace gas flux computation and GHG modeling is critical to accurately estimate GHG emissions and mitigation interventions co-benefits at scale.

In addition, AgMIP has extensive experience conducting integrated assessments that link climate, crops, livestock, economic data and models to evaluate the impacts of climate change and agricultural adaptation strategies. Over the past decade, AgMIP has implemented coordinated regional assessments across Africa and Asia, engaging scientists and policymakers to co-develop scenarios that reflect local realities and national priorities. Building on this foundation, AgMIP is now implementing the Mitigation–Adaptation Co-Benefits (MAC-B) framework to assess rice management practices in Vietnam, Bangladesh, and India. This new framework combines field data, crop and livestock modeling, and economic analysis to evaluate how practices such as the System of Rice Intensification (SRI) and Alternate Wetting and Drying (AWD) perform under current and future climates—quantifying their potential to enhance farmer livelihoods, improve resource efficiency, and reduce greenhouse gas emissions.

The five-day scientific workshop held from September 1 to 5, 2025, at the International Rice Research Institute (IRRI) Headquarters aimed to address these gaps and to leverage the different opportunities with the recent advances in measurements in GHG and in rice crop modeling. The document summarizes the insights from the closed interaction among the different experts in GHG measurements and modeling in defining priorities for research and for collaboration. Indeed, the workshop aimed to foster collaboration between greenhouse gas (GHG) emissions researchers, rice crop modelers, agronomists, spatial science and remote sensing experts, and to convene in addressing challenges in CH_4 data availability and collection, as well as mitigation interventions assessment at different scales. The initiative was jointly led by the International Rice Research Institute (IRRI), the Agricultural Model Intercomparison and Improvement Project (AgMIP), and the Global Methane Hub (GMH), in partnership with CGIAR Climate Action and the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan.

B. Objectives of the Workshop

The workshop served as a platform for knowledge exchange, capacity building, and collaboration development. The aim was to advance best practices in chamber method applications, GHG flux analysis, and as well to attempt the development of simplified CH_4 simulation methods to enable broader participation of crop models for Tier 3 approach of GHG in rice systems. This latter will also offer an opportunity for the regional integration of climate change adaptation considerations into rice modeling and integrated assessments to better understand the tradeoffs between mitigation and adaptation strategies.

The specific objectives were to:

- Foster collaboration between rice crop growth modelers, experimentalists, and remote sensing scientists.
- Address challenges in CH_4 data availability and collection
- Enhance data sharing and integration between experimentalists, modelers, and remote sensing experts.
- Foster joint learning on best practices for CH_4 measurement and modeling.
- Develop a roadmap for integrating experimental data with modeling efforts to improve methane emission predictions and mitigation assessments.

C. Target Audience and Participants

The workshop was intended for researchers and practitioners working on greenhouse gas (GHG) measurement and modeling in rice systems (Fig. 1). The primary audience included:

- GHG emissions researchers with expertise in field measurements and flux analysis.
- Crop modelers focusing on CH_4 simulation and climate-rice interactions.
- Agronomists and soil scientists engaged in sustainable rice cultivation and mitigation practices.
- Economists modelers conducting ex-ante impact assessments and integrated assessments
- Spatial science and remote sensing experts applying geospatial tools for large-scale monitoring and systems mapping.

- Policy partners and institutional representatives supporting evidence-based decision-making in climate-smart agriculture.
- Early-career researchers and technical staff seeking capacity building in GHG measurement and modeling approaches.

Overall, there were 40 organizations from 25 regions involved (Fig. 2).

Fig. 1. Participants of the workshop, representing researchers and scientists working on greenhouse gas (GHG) measurement and modeling in rice systems.

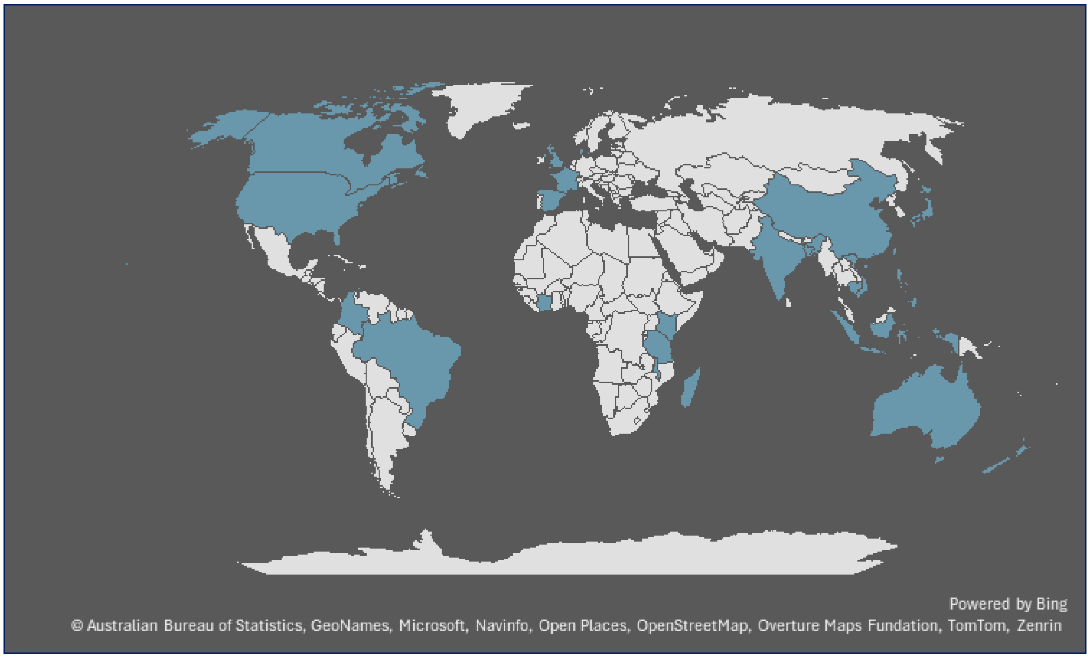


Fig. 2. Geographic and institutional diversity of workshop participation, with 40 organizations from 25 regions involved in the workshop.

D. Workshop Agenda

The workshop was an event of five days with a combination of six plenary, two panels discussions and two parallel sessions followed by several breakout sessions that comprises of breakout groups for four specific themes of discussion (Tables 4 and 5).

The six plenary sessions were organized to provide a general overview of the state of the arts in GHG measurements and in modeling in rice systems. The two panel discussion sessions were also scheduled to capture the perspectives of different stakeholders that are involved in national efforts for GHG inventory and NDCs monitoring and in private initiatives developing rice carbon project and service providers supporting these carbon projects. The workshop's two parallel sessions were technical and focused on the overview of different methodologies in measurements and in modeling, respectively. The breakout sessions aimed to identify opportunities for collaboration and actionable next steps as outputs of the workshops.

To facilitate wider dissemination and reference, the workshop program and all the presentations used during the sessions are made available online. The access link is provided in Annex C. Workshop Materials.

IV. Plenary Sessions

A. Opening Session Day 1

Day 1 of the workshop opened with three consecutive presentations. Dr. Reiner Wassmann delivered a comprehensive overview of different national initiatives and efforts toward climate mitigation, with a focus on the ASEAN region. This was followed by presentations from Dr. Cynthia Rosenzweig and Dr. Toshi Hasegawa, who shared the history and evolution of AgMIP and the AgMIP Rice Team.

Dr. Wassmann presentations have shared the current context and targets in mitigation efforts in ASEAN countries, the need of monitoring, reporting and verification tools and the emerging carbon market pathways (Fig. 3).

Fig. 3. Dr. Reiner Wassmann presenting ASEAN climate mitigation initiatives and emerging carbon market pathways.

ASEAN countries recognized the role of rice as a major source of GHG emissions while no country has established rice-specific mitigation targets. Most national commitments remain conditional, set as objectives that depend on international funding support. The Global Methane Pledge, signed by 150 countries including six ASEAN members, commits to reducing methane emissions by 30% by 2030. A simple computation suggests that meeting this target in the rice sector would require 60% of rice areas to adopt Alternate Wetting and Drying (AWD), assuming an average reduction of 30 -50% from currently harvested areas.

Achieving such ambitious targets requires robust tools for monitoring and measurement. Modeling is considered critical to support the reliability, transparency, and robustness of these tools. The presentation also stressed the importance of distinguishing between scientific estimates and schematic estimates, noting that clarity on this distinction is key to ensuring credibility in mitigation reporting.

The carbon market is becoming an important arena for mitigation initiatives, with six possible schemes identified:

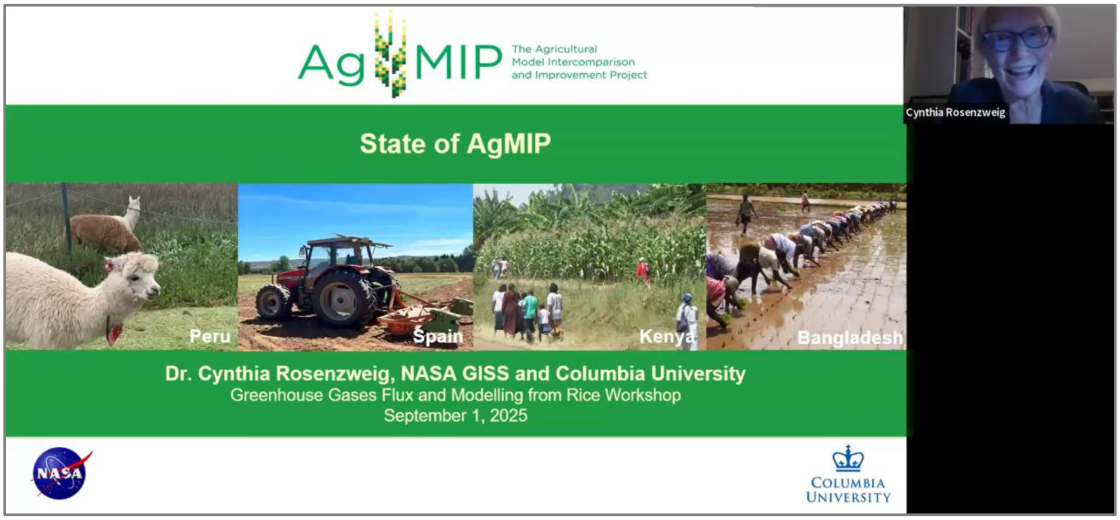
1. Compliance market under the UNFCCC framework.
2. Voluntary market systems led by Gold Standard and Verra. Currently, 348 rice carbon projects are registered under the UC Berkeley VCS open registry: 298 were rejected, 47 remain in the pipeline, and only one project has been certified.
3. Internationally Transferred Mitigation Outcomes (ITMOs) through bilateral country agreements (e.g., Vietnam's 1 million ha program under the JCM scheme).
4. Overseas development aid (ODA) enabling climate financing, such as the Thai Rice NAMA program.

5. Financial institution projects supported by mechanisms like the Green Climate Fund (GCF) and Global Environment Facility (GEF).
6. Scope 3 emissions reductions along product supply chains. Scope 1 refers to direct emissions from production; Scope 2 covers emissions from energy and utilities in processing; Scope 3 refers to emissions linked to upstream supply chains.

Key Discussion Points

Discussions highlighted the limited success of rice carbon projects and raised concerns over the viability of voluntary markets. Questions were raised on the importance of exploring mitigation options beyond AWD, including emerging technologies such as biochar from straw and enhanced rock weathering (ERW). However, challenges remain for the accuracy of verification tools for any mitigation interventions. Attention was given to the inherent uncertainties of tiered measurement approaches. Particularly in the use of Tier 1 and Tier 2 approaches that are inherently uncertain. Transparency in reporting and a shared understanding of these uncertainties are critical to building confidence in measurement and verification systems. An open conversation on different methodologies available may improve common understanding but also to establish their relevance, feasibility, practicality and limitations among others.

The second opening presentation of the workshop was delivered by Dr. Cynthia Rosenzweig, founder and Executive Committee member of the Agricultural Model Intercomparison and Improvement Project (AgMIP) (Fig. 4). The first AgMIP studies date back to 1994, focusing on simulations of wheat and maize yield responses to climate change, including rising CO_2 concentrations and surface temperature. These early studies reported shifts in land suitability, yield losses in low-altitude cropping areas, and yield gains in mid- to high-latitude regions. They also suggested adaptations benefits from adjusting planting dates. As climate modeling advanced, results became more accurate as shared with IPCC's AR6 findings.


AgMIP The Agricultural Model Intercomparison and Improvement Project

State of AgMIP

Dr. Cynthia Rosenzweig, NASA GISS and Columbia University
Greenhouse Gases Flux and Modelling from Rice Workshop
September 1, 2025

Fig. 4. Dr. Cynthia Rosenzweig presenting the evolution of AgMIP studies and their contributions to climate impact assessments in agriculture.

The AgMIP community was established formally in 2010. AgMIP has grown into a global science community of crop modeling experts. The initiative has since expanded to include multiple disciplines such as socio-economic modeling. It has also developed tools for climate adaptation studies, now extending into mitigation studies.

AgMIP offers a platform for the science community to tackle challenges in climate adaptation and mitigation. It promotes model improvement, collaboration between experimenters and model developers, and scaling of insights from field to regional and global levels. Ongoing efforts are looking into integration with emerging technologies such as machine learning, artificial intelligence, digital twins and broaden the scope to cover orphan/emerging crops, low-input systems, soil carbon accumulation monitoring, the Regional Integrated Assessments (RIA) which combine crop modeling, climate modeling, socio-economic context, and changing environmental conditions and recently the Mitigation-Adaptation Co-Benefits (MAC-B) modeling framework.

The integration of AgMIP in the workshop is expected to facilitate policy linkages by applying upscaling and outscaling methodologies. A key contribution planned will be addressing data gaps, especially in low-yield environments, which are often also low-data environments. To achieve this, the team plans to identify representative systems and pathways for adaptation and mitigation, run these scenarios with climate models, and generate model-based hypotheses of solutions. These would emphasize adaptation and mitigation co-benefits, supported by rigorous protocols, multi-scale relevance, and transparent uncertainty reporting. As an example of this strategy is the AgMIP led Regional Integrated Assessment conducted in Bangladesh on the System of Rice Intensification (SRI) and Alternate Wetting and Drying (AWD). The study suggested that adopting these technologies could reduce both methane emissions and poverty levels.

In brief, AgMIP applies protocols like those used in ensemble climate model intercomparison studies, ensuring robust methodologies for quantifying and reporting uncertainties. AgMIP demonstrates the value of combining mitigation and adaptation studies (MAC-B) within a single framework to maximize co-benefits. By offering standardized protocols, innovative tools, and rigorous uncertainty quantification, it provides a strong foundation for developing and disseminating climate-smart technologies.

Key Discussion Points

Questions were raised on whether the analyses accounted for the costs of transitioning to the mitigation practices, the costs of monitoring, and the indicators used in estimating poverty reduction. The RIA approach relies on household survey data to establish baselines for farmer practices. These are aggregated by the district for reporting.

The third presentation on the day was delivered by Dr. Toshi Hasegawa presenting the current priorities of the AgMIP Rice Team, which include climate change adaptation simulations, representation of different rice varieties, and the integration of pest and disease impacts in crop growth and yield modeling (Fig. 5).

Fig. 5. Dr. Toshi Hasegawa presenting the current priorities of the AgMIP Rice Team.

Since its establishment, the AgMIP Rice Team has produced several important studies, including:

- Evaluation of models' uncertainties for yield and climate change impacts across four sites (China, India, Japan, and the Philippines).
- Classification of models based on their formalisms.
- Ensemble modeling evaluations using data from FACE (Free-Air CO_2 Enrichment) experiments.
- Integration of genomics data for phenotyping/ ideotyping applications.
- Exploration of genotype × environment × management (G×E×M) interactions in rice systems.

Key Discussion Points

Discussions underscored the complexity of rice production, management practices, and environmental interactions. The pre-survey on modeling of the workshop documented the use of 19 different models. The AgMIP Rice team will aim to use these tools and for the workshop their objectives were:

- Establishing a draft protocol for ensemble modeling studies targeting adaptation–mitigation co-benefits in rice.

- Developing a roadmap to enable data availability, accessibility, and the sharing of results.
- Identifying knowledge gaps in rice modeling, particularly related to model formalisms and capabilities.

These will be initiated through breakout group discussions during the workshop on water productivity, methane emissions modeling, management practices, and scaling approaches from field to regional levels.

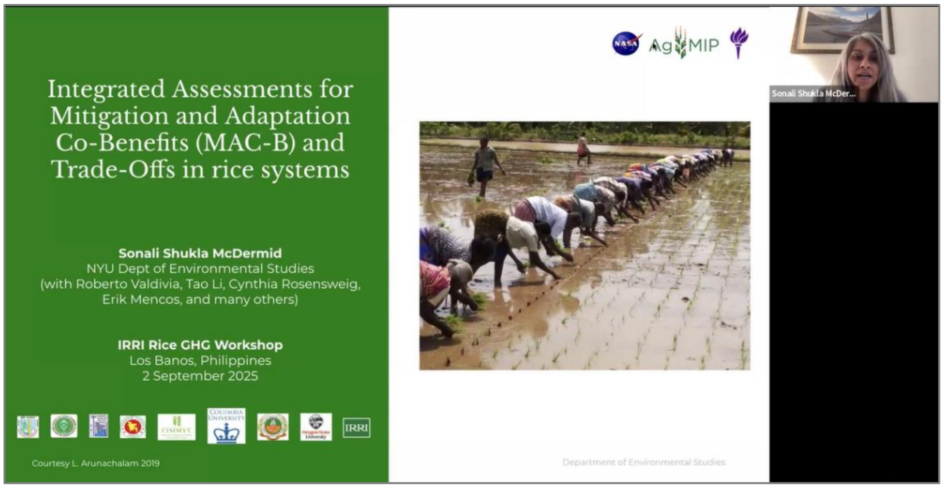
Questions were raised on the relevance of ratoon cropping as both an adaptation and mitigation option, and on whether current models adequately represent such systems—not only from a biophysical perspective but also in terms of economic importance. Additional modeling gaps were identified in the areas of grain nutrition and quality, including arsenic content, starch properties, and chalkiness.

Participants noted opportunities to strengthen collaboration between modeling and GHG measurement teams, particularly by updating baselines using ensemble modeling. Data requirements for such work need to be clearly identified and established. Furthermore, key individuals need to be identified for coordination and continuous engagement to sustain progress in addressing the identified priorities and gaps.

B. Plenary Session Day 2

Day 2 sessions included two presentations by Dr. Alisher Mirzbaev and Dr. Katie Nelson providing an overview of how national GHG inventories and private initiatives in rice carbon projects are implemented and what are current challenges and opportunities in these efforts (Fig. 6); and one presentation by Dr. Sonali McDermid on regional integrated assessment of mitigation and adaptation interventions co-benefits for farmers socio-economic conditions in additions to the improvement of productivity and the reduction in GHG emissions (Fig. 7). These were followed by panel discussions (Fig. 8) focused on the perspectives of different key stakeholders' players in national GHG inventory for baseline, UNFCCC reporting and in carbon market scheme under ITMO and VCs.

Fig. 6. Dr. Alisher Mirzbaev presenting on national GHG inventories and private rice carbon initiatives.



Integrated Assessments for Mitigation and Adaptation Co-Benefits (MAC-B) and Trade-Offs in rice systems

Sonali Shukla McDermid
NYU Dept of Environmental Studies
(with Roberto Valdivia, Tao Li, Cynthia Rosensweig, Erik Mencos, and many others)

IRRI Rice GHG Workshop
Los Banos, Philippines
2 September 2025

Courtesy L. Arunachalam 2019

Department of Environmental Studies

Fig. 7. Dr. Sonali McDermid presenting on regional integrated assessments of mitigation and adaptation co-benefits for farmers.

Fig. 8. Panel discussions on stakeholder perspectives in national GHG inventories, UNFCCC reporting, and carbon market schemes.

National GHG inventory systems and UNFCCC reporting processes currently rely on limited, non-targeted data collection with most efforts focused on food security rather than mitigation monitoring. Data for model calibration and validation is rarely available, especially at regional and national scales. The concept of baseline in rice production with continuous flooding field can be challenged as unintentional AWD practices are widespread. Furthermore, straw management is largely excluded, despite its major influence on GHG outcomes.

Significant data gaps remain in rice systems evaluation such as:

- Irrigated rice areas quantification and mapping.
- Adoption rates of AWD.
- The discrepancies in indicators for extension bulletin AWD definitions and farmers' practices.
- Soil organic carbon dynamics under AWD.
- Straw management variability in rice systems.

There are however some identified opportunities that can be explored moving forward such as:

- Establish systematic ground-truthing for validation of upscaling assessments.
- Leverage remote sensing (RS) and AI tools for scalable, cost-effective monitoring.

To be effective, this would require a data-sharing platform as well as long-term studies combined with modeling. An example shared was IRRI's efforts to establish a framework linking farm survey data with district-level RS information, which is then integrated into GHG calculators and models for regional assessments. Currently, data collection lacks incentives, and there are no standardized protocols for cross-checking these data.

From the private sector and carbon market perspective, main challenges discussed include:

- The need for stratification, each requiring its own emission factor (EF).
- While rice areas may be mapped and identified using ALU software, the central challenge—the "million-dollar question"—remains how to scale measurements. There are concerns about whether measurements can be standardized and made comparable.
- Existing policies for model evaluation are less accessible and may not be fit for purpose. A proposal was raised on whether a different cost of carbon could be applied based on the robustness of estimation approaches.

Lessons from JCM implementation by Green Carbon highlighted difficulties in applying methodologies consistently.

While data collection initiatives are performed by different rice carbon developers the challenge is making these data useful for research. Suggestions included creating benefit-sharing mechanisms to cover the costs of data collection, transition, and implementation, with particular attention to ensuring local governments also benefit. In addition, several critical questions were raised, such as:

- Can the measurements be standardized and made comparable across regions and contexts?
- How to balance cost and accuracy in model-based estimates for carbon pricing?

The presentation shared by Dr. Sonali Shukla McDermid on integrated assessments linking climate, crop, and economic models provided a different perspective on the valuation of mitigation efforts beyond the climate targets and the carbon credits estimate. She shared the work on RIA that builds on AgMIP's history of intercomparisons and expands toward addressing greenhouse gases, farmer adoption, and regional scaling relevant to national climate commitments (NDCs).

The AgMIP Mitigation and Adaptation Mitigation Co-Benefits (MAC-B) framework was developed to standardize evaluation of multi-model uncertainty and regional heterogeneity of climate change impacts. The framework:

- Links climate models, multiple crop models, and the economic trade-off analysis model (TOA-MD).

- Captures uncertainty across scenarios and sites, calibrated/validated with field data.

A recent case study focusing on combined mitigation + adaptation in rice was shared using the coupled crop–soil models (ORYZA + DNDC) applied in Bangladesh (3 districts, 6 strata, ~432 farms) and evaluating AWD and SRI.

Key findings suggested that integrated modeling frameworks enable assessment of both biophysical and socioeconomic trade-offs. AWD and SRI increased yields slightly, reduced methane and improved water-use efficiency. SRI delivered greater net farm return gains than AWD alone. Dr Sonali has emphasized the need of comprehensive and consistent data collection on yields, GHGs, soils, and socioeconomic conditions. The RIA models require multi-factor sensitivity tests (temperature + CO_2 + precipitation) to capture uncertainty, and results are sensitive to genotype x environment x management interactions.

She emphasized the approach in RIA needs to be co-developed with stakeholders to ensure alignment of strategies evaluated with farmer incentives, biodiversity, and policy goals. Governance priorities differ (local water scarcity vs national GHG targets) and the emerging carbon markets and incentives may alter adoption behavior.

Furthermore, addressing uncertainty and heterogeneity is essential before scaling recommendations. The team is currently conducting a project on RIA for a case study in India (Tamil Nadu) where a new survey data has been conducted. An incoming paper with results from Vietnam will be soon published.

Questions were raised on the challenges in defining strata for the study and the consideration of the biodiversity trade-offs (e.g., amphibian mortality increase with AWD) with practice change. Stratification based on farm size may be improved by capturing heterogeneity across farms and practices

C. Plenary Session Day 3

The Day 3 session centered on technical presentations that highlighted and reviewed the key tools of focus for the workshop, delivered by Dr. Arlene Adviento-Borbe and Dr. Tao Li.

Dr. Adviento-Borbe delivered a crash course on the history of GHG measurements and the current protocols in use. She shared as well the learning from the parallel sessions conducted during Days 1, 2 and 3 including the general principle of the flux chamber method, the GHG flux computations and emissions reporting aiming for consensus on minimum requirements and standardization (Fig. 9).

Fig. 9. Dr. Arlene Adviento-Borbe presenting GHG measurement protocols, flux chamber methods, and emissions reporting standards.

Dr. Adviento-Borbe acknowledged the global collaboration nature of the workshop with participants from major rice regions: U.S., Colombia, Spain, China, Japan, Indonesia, Vietnam, India, Africa, and Taiwan which formed a network of researchers built on earlier collaborations (e.g., IRRI–NARS collaboration, 1993–1998) in assessing rice as a source of GHG and a sink of CO_2. She provided a brief history and the status of mitigation study in rice in the US rice sector dated back from 1980s–to present with focus on major drivers of emissions, mitigation strategies, upscaling models.

She reiterated the challenges in GHG measurements such as the

- GHG production mechanism in the soil that has multiple processes, highly variable in time & space.
- The labor-intensive nature of GHG measurements (requires many people per field campaign)
- The lack of harmonized protocols across regions.

The parallel sessions on GHG fluxes discussed the diverse measurement practices across the different regions and established a classification of required and preferred approaches to unify protocol for GHG measurements. These parallel sessions discussed the comparability of the measurements and as well as how to allow cross validation for verification. The agreed protocol emphasizes mandatory requirements for producing robust estimates, and suggestions were made to reduce uncertainties and harmonize practices across rice studies (Table 2).

Dr. Adviento-Borbe ended her presentation with recommendations well aligned with the workshop objectives which are:

- Establish standardized chamber protocols globally.
- Consolidate datasets to define global emission ranges.

- Improve reporting consistency (SI units, GWP, yield-scale).
- Enhance data collection efficiency (automation, coordinated campaigns).
- Integrate GHG with crop & soil models for better prediction.
- Broaden international collaboration for policy-relevant reporting.

Dr. Tao Li highlighted the role of modeling as a research tool that can be used to

- Extrapolate experimental results.
- Interpret field studies.
- Generate insights to optimize systems and designs for adaptation, mitigation, productivity, and yield. (Fig. 10)

Fig. 10. Dr. Tao Li presenting the role of modeling as a tool for advancing research on GHG in rice systems.

Current models used for climate change adaptation can predict yields while fewer can directly quantify GHG emissions. He identified Gaps and Challenges and opportunities for rice modeling as below:

<u>Gaps and challenges</u>

- Inconsistent GHG responses to elevated CO_2 across studies and timescales.
- Model uncertainties stem from both structure and input data quality.
- Lack of modules for certain mitigation options (e.g., biochar, inhibitors).
- GHG measurements are often localized, limiting scalability.
- Data-related issues are the hardest to resolve and significantly affect quantification.

Opportunities for Improvement

- Collaboration and data sharing across modeling groups.
- Standardization of protocols, modules, and MRV alignment with NDCs.
- Development of shared calibration protocols to avoid over- or under-calibration.

Discussion points after this presentation were critical including:

- Water management representation -There is a concern in models capability to adequately capture positive yield effects of AWD and drainage events. Most models can simulate water balance (evapotranspiration, drainage, runoff), but accuracy may vary. Root growth and soil physical change effects are partially handled by some models; there are areas for improvement to consider in rice modeling.
- Model improvement and data sharing - For improved modeling of water depth effects on methane, nitrous oxide emissions, lodging impacts, and mitigation opportunities like mid-season drainage, standardized calibration protocols are key to avoid overfitting and improve model comparability. The adoption of AI-ready data for standardization and the sharing of protocols for model calibration and the validated model post-calibration may offer opportunity for continuous collaboration between modelers and experimentalists.

Modeling offers opportunities to standardize GHG measurements datasets, making them Findable, Accessible, Interoperable and Reusable but as well to capture the variability of rice systems and address challenges of heterogeneity in GHG emissions due to differences in environments, management, and varieties.

The discussion on data for modeling identified the potential to build an inventory of datasets linked to 1) searchable metadata, and 2) structured into portable, harmonized inputs usable not only for modeling but also for broader applications and analyses.

The implementation of these required, however, an open discussion on data sharing and ownership, and acknowledgement in co-authorship. It was suggested to consider the AgMIP's concept of FAIRER data principles: Findable, Accessible, Interoperable, Reusable, Ethical, and Responsible use. FAIRER could serve as a guiding framework, going beyond the standard FAIR principles for the onwards collaboration among the workshop participants.

V. Parallel Sessions

A. GHG Measurements Session

Following intensive review of literature on GHG emissions in paddy rice systems, the organizing team of the workshop chose scientists and researchers who are actively conducting GHG emissions studies in major rice regions of the world (Table 1). The team invited nine scientists/professors to speak about chamber methods for GHG flux measurements from eight (8) regions representing Asia, Americas, Europe, and Africa (Fig. 11). Additionally, the team invited two scientists to speak on analytics and tools that improve computation of GHG emissions from chamber method. Participants who are involved in GHG emission data assessment, inventories and sustainability program were also invited to share their knowledge and experiences in using GHG data for their applications. Annex B. Table 2 summarizes the information about speakers and participants of the meeting and the table below shows the specifications of the different GHG measurements approaches shared during the sessions.

Table 1. Ancillary data measurements and descriptions of flux chamber method used by major rice growing regions globally.

Country	Chamber design	Gas sampling	Gas storage	Gas analyses	Flux calculation	Ancillary data
Japan	•Rectangular - transplanted •Base •Water sealing	•Mid-morning •20-30 min •3-4 gas samples •>3 reps	•Pre-evacuated glass container	•GC •External calibration	•Linear	Temperature
Indonesia	•Rectangular – transplanted •Base •Water sealing	•Mid-morning •20-40 min •4 gas samples •3 reps	•Pre-evacuated glass container	•GC •External calibration	•Linear	Eh, pH, plant height, tiller number, grain yield, weight of biomass
India	•Rectangular – transplanted •Base •Water sealing	•Mid-morning •20-60 min •4 gas samples •3 reps	•N_2 flushed, pre-evacuated glass container	•GC •External calibration	•Linear •Non-linear	Temperature, water depth, MC, WFPS, grain yield, LAI, Eh, pH, EC, N uptake
China	•Rectangular – transplanted •Round – CO_2 •Base •Water sealing	•Mid-morning •30 min •4 gas samples •automated	•Pre-evacuated glass container	•GC	•Linear	Temperature
Taiwan	•Rectangular – transplanted •Base •Water sealing	•Mid-morning •5 min •4 gas samples •Smart chamber	•Not applicable	•LICOR-8710 •LICOR-8720	•Linear	Temperature, water depth, Eh, soil texture, grain yield
Vietnam	•Rectangular – transplanted •Base •Water sealing •Water holes	•Mid-morning •30 min •4 gas samples	•Pre-evacuated glass container	•GC •LICOR-8710	•Linear	Temperature, floodwater depth, MC, grain yield, nutrient uptake, Eh, pH, OC, N
US	•Round – drill seeded •Base •Silicon band •Water holes	•Mid-morning •60 min •4-5 gas samples •3-10 reps	•Pre-evacuated Exetainer glass vial •Double Si seal	•GC •External calibration •3 levels	•Linear •Non-linear (HMR)	Temperature, water depth, MC, yield, grain quality, soil properties, nutrients
Colombia	•Round – drill seeded •Base •Silicon band •Water holes	•Mid-morning •60 min •4-5 gas samples	•Pre-evacuated glass container	•GC •External calibration •5 levels	•Linear	Temperature, floodwater, MC, yield, grain quality, EC, pH, soil texture, N
Spain	•Rectangular – drill seeded •Base •Water sealing	•10:00 – 15:00 •10-30 min •4-5 gas samples •3 reps	•Pre-evacuated glass container	•GC •Photoacoustic gas analyzer	•Linear	Temperature, Eh, EC, pH, OC, NPK, soil texture, yield, C:N ratio

GC= gas chromatograph, LAI = leaf area index, WFPS = water filled pore spaces, MC = moisture content, OC = organic C, N = nitrogen.

Generally, the chamber method involves the installation of a chamber base (rectangular or cylindrical) over the soil surface, which is closed with a chamber cover.

Many of the studies on soil-atmosphere exchange of soil trace gases from paddy rice have used chamber method because it is common and the most suitable for the study of the effects of different factors. It is as well less expensive for field installation and operations, compared to micrometeorological techniques (e.g. eddy covariance or gradient techniques). Many researchers have long acknowledged the occurrence of the "chamber effect" due to the disruption of natural conditions and the diffusion of gas after chamber deployment in case of inattention, resulting in an over- or under-estimation of the actual trace gas flux. Studies have demonstrated that chamber data can suffer from negatively biased flux estimates when addressing chamber effects. Additionally, there is wide variation in the application of chamber types and techniques (Table 1), so the magnitude of flux estimation is also expected to vary widely across studies.

Given this uncertainty and variation, the standardization to improve the chamber method and computation of GHG fluxes may require an innovative approach than a simple attempt of unification. Also, the sensitivity of the chamber effects to variations of climate, soil and crop properties which influence the interpretation of treatment effects within a given study is minimized when datasets are processed and analyzed using a similar approach across rice cropping regions. Standardizing the chamber method and flux computation when feasible will widen the implementation of the robust chamber method protocol in rice studies.

Following an exhaustive review of the many chamber methods across rice regions the group reached a strong consensus on minimum required metrics, sampling principles, flux calculation methods, and reporting standards (Table 2). These agreements are intended to strengthen data integrity, reduce variability across studies, and make results more useful for both scientific modeling and climate policy applications.

Table 2. Requirements guide for GHG measurements. Required is the minimum you need to ensure your measurements meet the standard. Preferred is what you need to optimize your conditions of measurements to minimize uncertainties.

Parameter	Required	Preferred	Key considerations
Chamber size area (24-250 L)	Yes		Volume to surface area ratio should be sufficient to avoid dilution effect, minimize warming, adequate air mixing and made of non-permeable and inert material. (Parkin and Venterea, 2010, Healy et al., 1996)
Chamber base (0.03 to 0.15 m soil depth insertion)	Yes		Assure good chamber-to-soil seal, minimize disturbance to root system, shelter effects (rain, fertilizer, amendments), account for the porosity of the topsoil and minimize microenvironment perturbations. (Pavelka et al. 2018). Installed base at least 24 hr prior to sampling (Bahn et al., 2009)
Fan	Yes		Better mixing of the enclosed air, avoid dead space in corners for rectangular (Livingston and Hutchinson, 1995, Livingston et al., 2006, Maier et al. 2022, Pavelka et al., 2018)
Boardwalk	Yes		Avoid soil disturbance, pumping effect, plant damages, and compacts soil (Maier et al., 2022)
Glass sample container	Yes	Use of Exetainer vials	Ability to hold vacuum and pressure and preserve gas concentration >1 week (Glatzel and Well, 2008, Rochette and Eriksen-Hamel, 2008, Laughlin and Stevens, 2003, Rochette and Bertrand, 2003)
Gas overpressure for transport and storage	Yes		The use of butyl rubber stopper and Exetainer vials are recommended for long-term storage and transport (Glatzel and Well, 2008, Rochette and Eriksen-Hamel, 2008)
Syringe needle size	Yes		22- 25-gauge needle provides minimal pressure losses (Parkin and Venterea, 2010)
Time 0	Yes		Measured gas concentration represents pre-deployment soil-chamber vertical GHG profile (Rochette, 2011)
Overhead ambient gas sampling		Yes	Minimize elevated ambient gas concentrations during gas sampling (Rochette, 2011, Parking and Venterea, 2010)

Time of gas sampling	Yes		Diurnal GHG emission measurements provide daily emission estimates yielding the smallest average bias (Wu et al., 2021). It is recommended to do measurements every 4 hr with minimum 4 measurements during the day (Pavelka et al., 2018, Darenova et al., 2014)
Separate chamber for N_2O flux			This practice is implemented in Indonesia for low range of N_2O emissions (IAERI)
Number of chambers per plot		≥3 or depends on project	Number of chambers needed adequately estimate the mean and variance of gas fluxes within a site (Davidson et al., 2002, Livingston and Hutchinson, 1995)
Vent tubes and dimensions	Yes		Proper vent tube dimensions transmit changes in external pressure to chamber headspace, thus minimizing suppression by deployment on gas fluxes (Hutchingson and Livingston, 2001, Parkin and Venterea, 2010, Xu et al., 2006, Davidson et al., 2002). Dimensions of vent tubes for selected wind speeds and enclosure volumes are described by Parkin and Venterea, 2010)
Duration of chamber closure		Depending on the project	Duration should be based on expected flux and precision of gas analyses. 20-60 min for GC is recommended (Maier et al., 2022, Parkin and Venterea, 2010, Rochette and Hutchinson, 2015, de Klein and Harvey, 2012)
Number of gas samples		≥4 (min of 3 if linear)	Gas samples withdrawn at regular intervals during closure of <60 min. At least 3 time points are required for flux calculation. Use of fitting models and uncertainty in dC/dt requires >2 samples (Parkin and Venterea, 2010, Pedersen et al., 2010)
End of the season flux		Depending on research or field condition and management	Short-lived CH_4 peaks occurred after dry event due to champagne effect or physical release of entrapped gas during soil drying before harvest. Can contribute to 10-15% of total growing season emissions (Adviento-Borbe et al., 2015, van der Gon and Neue, 1995)
Gas sampling during drain events (AWD, Furrow)	Yes		Short-lived CH_4 peaks occurred after dry event due to champagne effect or physical release of entrapped gas during dry cycle (Adviento-Borbe et al., 2015, van der Gon and Neue, 1995)
Frequency of response curve for GC calibration		Depending on stability of GC	Quality control needed in separation of N_2O and CO_2 with similar retention times, check non-linearity of ECD at high N_2O concentrations using multipoint calibration. Include check standard every 10 samples to account for instrument drift, check calibration curve using control values and CV of 1 to 3% (Harvey et al., 2020, de Klein & Harvey, 2012, Pavelka et al., 2018).
Parameters for GC calibration and check	Yes		Instrument metrics for GC calibration depend on GC brand, this includes span calibration, column cleaning, pneumatic line checks, sample loop. Best sensitivity is achieved in P_5 gas for ECD detection (N_2O (Maier et al., 2022, Pavelka et al., 2018)
Regular standard check per samples analyzed	Yes		To avoid bias in analytical response, include standard checks every 10 randomized samples;), about 20% of analyzed samples are adequate number of standard gases for calibrating instrument to cope with temporal drift (Parkin and Venterea, 2010, Pavelka et al., 2018).
Linear flux equation	Yes		GHG fluxes are computed from rate of change of gas concentration over time of closure, when rate of change is constant, linear regression is appropriate (Lundegardh, 1927, Venterea et al., 2009). Dasig model is software to compute linear increase of gas content over time (Adviento-Borbe et al., 2025)
Non-linear flux equation	Yes		GHG fluxes are computed from rate of change of gas concentration over time of closure, when rate of change is not constant, non-linear regression is appropriate. HMR model provides non-linear flux estimates and Dasig software incorporated the HMR equation (Pedersen et al., 2010, Adviento-Borbe et al., 2025).
Parameters for linearity	Yes		Use R2 value that close to 1, variance associated with slope is considered, use at least three datapoints, and implement significant test for slope and minimum detection limit of ambient air (Parkin and Venterea, 2010, Maier air et al., 2022)
Zero flux	Yes		Consider zero flux when gas concentrations are above minimum detection limit of chamber and gas analyzers (Adviento-Borbe et al., 2025, Parkin et al., 2012).
Negative flux	Yes		Consider negative flux when R_2 is high, gas concentrations are above minimum detection limit (Adviento-Borbe et al., 2025).
Linear interpolation of missing days of samples		Depending on project objectives	Daily GHG emissions are computed using trapezoidal time integration either seasonal or annual estimates (Adviento-Borbe et al., 2025).
Fallow emissions		Depending on project objective	Total GHG emissions during the non-growing season are relevant in the assessment of annual emissions and impacts of straw, tillage and cropping practice on GHG emissions from next cropping (Fitzgerald et al., 2000, Adviento-Borbe et al., 2013)
IPCC conversions using 100-yr and 20-yr time horizon	Yes		Emission metric that is crucial tool in setting effective exchange rates between non-CO_2 gases with arbitrary choice of time horizon. (Abernethy and Jackson, 2022, Allen et al., 2016)
Data reporting		Depending on project objectives	Consider unit as elemental or compound form of GHG emissions for modeling and flux estimates i.e. $CH_4/m^2/hr$; CH_4 kg/ha/d or $CH_4\text{-}C/m^2/hr$; $CH_4\text{-}C$ kg/ha/d. Yield-scaled and area-scaled GWP units express both yield and emission potential of mitigating practice (Adviento-Borbe et al, 2013)
Ancillary data	Yes		Include measurement of grain yield expressed at 14% moisture content and milling quality.

The next steps agreed during the parallel sessions were as follow:

- Technical report development - Summarize chamber commonalities and methodological approaches; provide evidence-based recommendations.
- Prepare a step-by-step data handling protocol for flux processing to be included in the technical report as handout series.
- Develop annex comparing DASIG, GET, and HMR models, including their compliance with the MIRSA guidelines, advantages and limitations.

- Strengthening Community of Practice - Continue workshops as refreshers for best practices in GHG measurements; maintain peer exchange through regular monthly meetings.

Participants highlighted that the workshop served as a valuable refresher on fundamental measurement practices, often overlooked during routine operations. The session reaffirmed the importance of collective learning and the Community of Practice (CoP) as a mechanism to sustain harmonization and innovation in GHG measurement methodologies.

Fig. 11. GHG flux measurements parallel session.

B. Modeling Overview Session

Fifteen models were presented on Day 1 of the modeling parallel session (Fig. 12), with each model introduced. Ten models were identified with capabilities for CH_4 emissions (Table 3 and Annex A. Table 1), and seven sites (FACE sites in China, Japan, India, the US, the Philippines, and Brazil) were identified with high-quality datasets for model calibration and validation. The modeling team agreed on a template for minimum data requirements (e.g. CH_4, yield, soil water, nitrogen management, and climate) that will be harmonized and used for model evaluation. The management practices of focus include water, nitrogen, organic matter residue management, and varieties. The team also discussed the protocol for RIA activities. The team has established as well four main areas of collaboration moving forward with clear objectives as indicated below.

1. Model Intercomparison & Improvements

The team aim to test, compare and improve models using high-quality datasets, ensuring more reliable outputs. Thirty four global sites have been identified (Fig. 13), with seven initial sites highlighted (Japan, China, Brazil, India, U.S.–Texas, Philippines, and others). The focus is on reducing uncertainty by comparing model outputs against measured data (e.g., crop yield, GHG emissions). While initial simulations will test baseline production under current climate conditions, water management practices, and fertilizer treatments.

2. Minimum Data Requirements & Harmonization

- Clear data requirements are needed, though the minimum depends on the research question.
- Rich datasets are available, but harmonization is challenging since multiple groups use different templates.
- A balance is needed: too much burden on experimental teams may discourage participation, so collaboration on data sharing and template standardization is required.
- Metadata (units, variables, site management details) is essential.

3. Key Interventions and Research Dimensions

Innovations under study include the effects of:

- Water management (AWD, intermittent irrigation vs flooding)
- Nitrogen management
- Organic matter use
- Cultivar differences (though mechanisms are not yet fully understood)
- Current models capture water, nitrogen, and organic matter effects relatively well, but cultivar-related emissions remain difficult to simulate.

4. Scaling & Integrated Assessments

- Scaling results to regional and national levels is crucial for policy relevance.
- Stakeholder engagement is emphasized, questions must be co-created with local partners to address regional needs.
- Case studies are emerging in Bangladesh, Vietnam, India, with calls to expand to Africa and Latin America.
- Process-based models may help provide Tier 3 GHG estimates, beyond Tier 2 methods currently available.

Integration with productivity and profitability analysis is a goal, to ensure both environmental and economic perspectives are considered.

The team will be working on improving rice system GHG models by comparing them across global sites, harmonizing data requirements, integrating new management practices, and scaling results for regional assessments. The approach prioritizes high-quality data, uncertainty reduction, and collaboration with stakeholders to ensure models inform both science and policy. Strong emphasis was on involving experimenters and regional experts to expand datasets and ensure local applicability. The team has mapped as future needs the improvement of data availability in underrepresented regions (e.g., Africa) to test interventions and refine global models.

Agreed activities next steps for the team are:

- Model evaluation.
- Simulations under current and future climate scenarios for adaptation exercises, considering different water management practices.
- A Tier 3 attempt for regional estimates of emissions.
- Conduct integrated assessments of different interventions under different socio-economic and climate scenarios to evaluate their impacts, tradeoffs and synergies using the AgMIP RIA protocol.

Fig. 12. Modeling team parallel session.

Table 3. Features, objectives and applications of the different models.

Model Name	Version	Features/Objectives/Applications								
		Yield prediction	Climate change impact assessment	Adaptation strategy assessment	Cultivar/genotype comparison	Nutrient management simulation	Nutrient cycling modeling	Water management simulation	Carbon sequestration modeling	Greenhouse gas (GHG) emissions estimation
APSIM *(Sarkar S, et al., 2025)*	7.10	X	X	X	X	X	X	X	X	
DayCent-CABBI *(Cheng K, et al., 2013)*		X	X	X		X	X	X	X	X
DNDC *(Salas W, 2025)*	Versions 11.0 to 12.4	X				X	X	X	X	X
DNDC-Rice *(Fumoto T, et al., 2013)*	2021	X	X	X		X	X	X	X	X
DSSAT CERES-Rice *(Jones JW, et al., 2003)*	4.8.5	X	X	X	X	X	X	X	X	X
GEMRICE *(Yoshida H, Horie T, 2010)*		X	X	X	X	X				
H/H *(Hasegawa T,Horie T, 1997)*	2015	X	X	X	X	X				
InfoCrop *(Aggarwal PK, et al., 2006)*	Version 2.1	X	X	X	X	X	X	X		X
MCWLA-Rice 2.0 *(Tao F, Zhang Z, 2013)*	V2.0	X	X	X	X	X	X	X	X	X
ORCHIDEE-crop *(Wu X, et al., 2016)*		X	X	X				X	X	X
ORYZA *(Li T, et al., 2017)*	Version 4	X	X	X	X	X	X	X	X	X
RegWHCNS *(Bo Y, et al., 2025)*	2.0 v	X	X	X	X	X	X	X	X	X
RiceGrow (Tang L, et al., 2009)		X	X	X	X	X	X	X	X	X
RicePSM *Wu GW & Wilson LT, 1998)*		X	X	X	X					

RiceSM *(Scheduled for publication this year)*		X	X	X		X	X		X	X

Fig. 13. The 34 experimental sites for potential collaboration identified from a preliminary participant survey.

VI. Breakout Sessions on Priorities of Collaboration

During the afternoon session of Day 1, participants were divided into four breakout groups, each tasked with exploring opportunities for collaboration and charting possible pathways forward on four key thematic topics (Fig. 14).

The breakout group discussions highlighted common priorities across themes. These themes are summarized in Table 4, which compares how each group addressed data harmonization, key gaps, and links to farmer livelihoods.

Beyond thematic focus, the groups also developed practical work plans that outlined available resources, immediate tasks, responsibilities, collaboration strategies, required support, and anticipated challenges. These are presented in Table 5, which highlights the operational pathways for advancing rice system research, while also noting the institutional, financial, and technical barriers that need to be addressed.

Fig. 14. Breakout group discussions on collaboration opportunities, data gaps, and the need for harmonization across sites and scales.

Table 4. Breakout group results on data harmonization, key data gaps, and relevance to livelihoods.

BOG	Data Harmonization	Key Data Gaps	Relevance to Livelihoods
BOG 1 – Simulating Rice Productivity under Water Management Scenarios	Standardize AWD definitions and thresholds; align protocols for water, yield, and GHG simulations across countries; integrate irrigation and grain quality parameters.	Lack of consistent data on irrigation volumes, soil water content, rainfall, soil type, and grain quality; variable AWD thresholds complicate modeling.	Better water management (e.g., AWD) can reduce water use, maintain yields, lower GHGs, and enable access to carbon credits, supporting farmer resilience and income.
BOG 2 – Modeling and Measuring CH_4 Emissions from Paddy Fields	Establish common evaluation metrics (R^2, RMSE); harmonize minimum datasets for soil, water, crop, residues; use shared repositories with metadata and quality standards.	Missing soil data (bulk density, organic matter, C/N content), inconsistent water and weather data, limited residue management data, lack of standardized AWD definitions.	Improved methane models support credible MRV frameworks, enabling participation in carbon markets and climate policies that could benefit farmers financially.
BOG 3 – Management Interventions and Their Impact on Emissions	Standardize monitoring systems and model calibration for interventions (water, fertilizer, varieties); compile inventory of models and their applications.	Data mismatches between interventions and model requirements; limited data for crop varieties, organic amendments, and soil microbiomes; lack of regional flux networks.	Adoption of improved management practices (AWD, biochar, efficient fertilizers, better varieties) can increase yield, reduce emissions, and improve grain quality, enhancing farmer livelihoods.
BOG 4 – Scaling from Field to Region: Data Integration and Upscaling	Promote standardized data formats/units; use AI/ML to integrate remote sensing, climate, soil, and socioeconomic datasets; link GHG fluxes to management practices.	Spatial and temporal mismatches (field vs. national data, high-frequency needs); coarse soil data; limited flux network coverage; inconsistent management datasets.	Scaling integrated assessments helps design region-specific policies that balance productivity, profitability, and sustainability, ensuring that farmers benefit from both yield gains and climate incentives.

Table 5. Key outcomes from the four Breakout Groups (BOGs), outlining available data, required actions, responsibilities, collaboration approaches, needed resources, timelines, and challenges.

BOG	What data we have?	What needs to be done?	Who will do it?	How we can work together?	Required resources/support	Timelines	Anticipated challenges
BOG 1 – Rice Productivity under Water Management	Ponding height, water table, daily weather, irrigation frequency (but often missing volumes), soil texture (0–15 cm), NPK data, yields, biomass, phenology.	Develop standardized water management datasets (AWD thresholds, irrigation, grain quality); harmonize protocols; integrate irrigation use into models.	Modelers (AgMIP) prepare templates; data providers supply datasets; rapporteur ensures quality check.	Shared repositories; direct communication between modelers and providers; co-authorship and credit agreements.	Data management tools, repository hosting, training in data use and models.	Short-term: draft terms of use/templates; medium-term: iterative harmonization.	Missing/incomplete data; labor-intensive templates; institutional restrictions; data security risks.
BOG 2 – Modeling and Measuring CH_4 Emissions	Flux measurements (chambers, eddy covariance); soil property data (inconsistent); limited water/weather monitoring; residue management records at some sites.	Harmonize AWD definitions; create minimum dataset (soil, water, weather, crop, residues); cross-validate models; build shared repository.	Flux groups, modelers (DSSAT, DNDC), regional teams for data inventories.	Open data exchange with metadata; regional partnerships; modeling group integration; public–private collaboration.	Sustained funding; coordination staff; IT support for repository and quality control.	Short-term: curate/share datasets; Medium-term: cross-validation and integration pilots; Long-term: shared repositories and AWD standardization.	Soil heterogeneity; inconsistent protocols; institutional restrictions; uncertainty in microbial impacts.
BOG 3 – Management Interventions & Emissions	Data stronger for water and fertilizer interventions; limited for crop varieties, organic amendments, microbiomes; uneven flux network coverage.	Inventory models/datasets; meta-analysis of intervention impacts; standardize monitoring; benchmark model	Regional leaders assigned; Toshi to develop metadata template; participants provide feedback and data.	Metadata-driven sharing; open-data journals; phased focus (water/fertilizer first, broader later).	Institutional support for data access; funding for coordination; journal access for reviews.	2-week metadata feedback; phased benchmarking and intervention focus.	Institutional restrictions; fragmented datasets; harmonizing units/definitions; regional coordination challenges.

		performance.					
BOG 4 – Scaling Field to Region	Remote sensing (MODIS, Landsat, Sentinel-2), climate (MERRA-2, ERA5, NCEP), soil (SoilGrids, WoSIS), crop models (DNDC, ORYZA, Daycent, RiceGrow). Regional data in India, Bangladesh, Vietnam.	Conduct regional integrated assessments; select sentinel sites; link management data with GHG fluxes; integrate economic and biophysical models.	Site leaders (India, Vietnam, Bangladesh); facilitators for climate, crop, socioeconomic modeling.	Collaborative proposals; sentinel site categorization; phased scaling (pilot → multi-model → remote sensing).	AgMIP IT revival; capacity building; funding for surveys/workshops/sprints; high-performance computing.	Start with India pilot; expand to Vietnam/Bangladesh; later include other regions.	Data heterogeneity; high monitoring cost; institutional agreements; balancing resolution vs feasibility.

All BOGs highlighted missing or inconsistent datasets (soil, water, crop, management, and socio-economic data). There was consensus on the urgent need for standardized data formats, metadata, and harmonized protocols across regions.

The participants emphasized the importance of benchmarking models, integrating multiple modeling tools, and aligning simulations with available datasets to reduce uncertainties and improve reliability.

For mitigation interventions, Alternate Wetting and Drying (AWD) emerged as a focal practice, requiring clearer definitions, thresholds, and standardization for both scientific use and for practical implementation such as in carbon credit methodology.

Establishing durable data-sharing communities, supported by principles of reciprocity, co-authorship, and transparency, was prioritized. Experiences from networks such as Fluxnet and AgMIP were cited as models.

The team has then identified the following items as priorities:

- Develop a global benchmark database for rice systems that combines biophysical, management, and socioeconomic datasets.
- Standardize protocols for AWD implementation, GHG measurement, and data-sharing frameworks.
- Mobilize funding for sustained data collection, data management coordinators, and collaborative model intercomparisons.
- Establish metadata-driven mapping of datasets to identify regional strengths, gaps, and priorities.
- Pilot regional integrated assessments (starting with India) to demonstrate scalable approaches, followed by expansion to other countries.
- Strengthen cross-disciplinary collaboration between agronomists, modelers, soil scientists, and socioeconomic researchers to ensure both scientific rigor and policy relevance.

At the end of the sessions, the steering committee of the workshop has defined the below plan to sustain the work accomplished during the five days:

- The workshop will generate a technical document compiling the different team's practices that will serve as references for context dependent best practices in GHG measurements in rice.
- The workshop participants agreed to establish a community of practices in GHG measurements and modeling that will have regular/ monthly meeting. This will be an initial platform for knowledge sharing until a more formal platform is established. The team will explore the establishment as well of an AgMIP emissions data subgroup.
- With the planned position papers on policy, GHG measurements and modeling, the organizing committee of the workshop will develop an integrated project proposal that will aim to leverage the workshop participants network and expertise for capacity building in measurements and modeling and for the establishment of a framework of data, modeling and regional integrated assessment to improve baseline estimate in rice growing areas globally and for

mitigation interventions targeting guided by robust estimate of gains and co benefits at scale.

VII. Outcomes and Recommendations

The plenary and parallel sessions of the workshop have confirmed the timeliness of the initiative to address the challenges in mitigation research and efforts in rice systems. The different sessions have articulated the challenges and the existing opportunities for reducing methane emissions in rice from the standards of measurements at field level to the monitoring and assessments of co-benefits at global scale for system sustainability and resilience to climate change.

A. Main Insights and Challenges

The planned workshop outcomes include documentation on the best practices in chamber method applications and GHG flux analysis, rice model intercomparison and improvement, and policy considerations. These documents will articulate the main insights and challenges shared during the workshop that will serve as reference for researchers and practitioners in rice-growing regions across the United States and Latin America, Europe, Southeast Asia, South Asia, East Asia, and Sub-Saharan Africa.

These insights and challenges can be categorized as below:

Policy and Mitigation Context

- Rice is recognized as a significant contributor to GHG emissions, yet no ASEAN country has set specific mitigation targets for rice systems; existing commitments are usually conditional on international financing.
- Achieving the Global Methane Pledge (30% reduction by 2030) would require large-scale adoption of mitigation interventions such as for AWD estimated roughly up to 60% of rice area.
- Carbon markets are emerging with multiple schemes (compliance, voluntary, bilateral, ODA, financial institutions, scope 3), but report on success of these remains very limited.
- It is essential to quantify the impacts of GHG mitigation strategies on farmers' livelihoods and broader policy-relevant outcomes such as poverty and food security, while assessing the trade-offs among socio-economic, biophysical, and environmental dimensions.

Scientific Approaches for GHG Measurements and Modeling

- Measurement practices remain diverse, creating inconsistencies.
- Agreement was reached on the need for a unified protocol to ensure robust estimates and reduce uncertainties.
- Rice models are generally ready for climate change applications but require further development of emission modules and standardized calibration.
- Modeling offers pathways to standardize and harmonize datasets, improving usability and comparability.
- Water management processes need better representation, particularly for AWD and drainage effects on yield and GHG emissions.

- AgMIP and its rice team provide tools to integrate climate, socio-economic, and crop models for adaptation and mitigation co-benefits.
- Modeling supports uncertainty analysis, extrapolation of experimental results, and scaling from field to regional and global levels.
- There is strong potential for standardized protocols, ensemble modeling, and integration of emerging technologies (ML/AI, digital twins, genomics).

Data Gaps

- Current data collection is designed for food security, not mitigation.
- The baseline concept is flawed: unintentional AWD adoption and straw management variability are not accounted for.
- National inventories lack systematic, reliable, and validated data for calibration/validation.
- Data availability and quality remains the largest barrier - sharing, standardization, and coordinated calibration/validation efforts are crucial.
- Examples like IRRI's farm survey + RS framework show pathways to link farm-level data with district/regional assessments.
- Data sharing remains a sensitive issue due to ownership and access concerns.
- AgMIP's FAIRER principles (Findable, Accessible, Interoperable, Reusable, Ethical, Responsible reuse) provide a stronger framework than the basic FAIR approach.

Scaling assessment

- The limited understanding and quantification of variability of rice ecosystems and the heterogeneity of management practices, and varieties that introduce wide variability in emissions and mitigation potential. This has impact on the Baseline validity in rice that is currently undermined by widespread unreported AWD and straw management practices.
- Limited robustness of Monitoring and Verification tool: Tier 1 and 2 approaches carry large uncertainties, requiring transparent reporting of these and shared understanding of their limits.
- Data scarcity as there is no clear incentives, protocols, or benefit-sharing mechanisms for data collection and sharing among stakeholders either for national actors or private entities.
- Knowledge gaps in research and in modeling such for instance representation of ratoon crops, grain quality (e.g., arsenic, starch, and chalkiness), SOC variability, and pest/disease interactions.

B. Actionable Next Steps

The different discussions raised from the different sessions have suggested the below recommendations for the team to leverage and to address moving forwards:

- Implement a unified GHG measurement protocol across teams to reduce inconsistencies. These can contribute to addressing verification challenges by standardizing emission factors and stratification methods.
- Create data-sharing platforms with clear benefit-sharing mechanisms and opportunities for governments, researchers, and local stakeholders. Use of such platform can be used to update baselines as these need to be redefined to

reflect actual practices (e.g., unintentional AWD, straw management). It is important to move beyond FAIR to FAIRER for this platform embedding ethical and responsible reuse into all data initiatives. And as data became available, opportunities to leverage advanced technologies in RS, AI/ML, genomics and other will offer opportunities to scale mitigation and adaptation interventions with confidence and sustainable impact.
- Promote long-term studies combining measurements and modeling that will ensure closer integration between modelers and experimentalists which can improve both field experiment design and model performance.
- Expand capacity building in GHG flux measurement, crop modeling, and integrated assessment approaches. A structured training and mentorship program will help harmonize methods across regions, strengthen technical expertise, and support the next generation of researchers in applying these tools to policy-relevant questions.
- These initiatives can encourage cooperation across regions, disciplines and sectors that will ensure data access, availability and trust with future efforts focusing data-driven model intercomparison, and MRV/NDC alignment for broader, policy-relevant applications.

VIII. Conclusion

The 5-day workshop achieved its main objective: establishing a community of practice that can be used as a platform for knowledge exchange, capacity building, and collaboration development. By bringing together GHG measurement experts and modelers, the workshop has created an opportunity for dialogue between these two disciplines and established the key gaps that may offer opportunities for effective collaboration, such as the development of a common ontology and the establishment of minimum data requirements. As a first example, a data template was developed to evaluate data availability for model applications that will be used to create a repository of metadata of available data that the participants of the workshop will be ready to share for crop model evaluations. The roadmap below was identified for the integration of both efforts in measurements and in modeling GHG quantification for baseline, predictions, and mitigation from field to regional assessments.

Agreed Actions

- Technical report on narratives for commonalties among practices
- Position papers on Measurements, Modeling, and Impact and Policy
- Regular monthly meeting for sustaining impact
- Activities plan in a year’s time - East Asia AgMIP Nov 2026, Global early 2027, IRC 2027

GMH Commitment

- Support for a core group to keep and bring people together
- Catalyze existing opportunities and funding
- Seed fund for proposal development

Roles and Responsibilities

- Dr. Hasegawa for the modeling - Modeling different pathways for low emissions rice
- Roberto for the RIA - Co-roasting funding- Building the scientist network towards shared goals - Google docs for proposal development and seed funding for proposal development
- Ando for the GHG data - Robust GHG data, sharing data and capacity building sustaining the discussion

Priority Objectives

- Publication and sharing of the workshop outputs
- Capacity building for GHG measurements and modeling
- Proactive engagement in initiatives to support national capacity for mitigation data collection, harmonization and different countries GHG inventory for UNFCCC reporting aiming for robust baseline update across rice growing regions and targeted interventions for mitigation and adaptation co benefits

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X. Annexes

A. Summary of Models

Table 1. Summary of the models presented during the Modeling Parallel Session, including their CH_4 emission capabilities.

Model Name	Version	Contact Name	Email	Institution	Reference DOI	Features/Objectives/Applications	Crop Processes Simulated	Gas Exchange Simulated	Soil Processes Simulated
APSIM	7.10	Sukamal Sarkar	sukamal.sarkar@gm.rkmvu.ac.in	Ramakrishna Mission Vivekananda Educational and Research Institute	https://doi.org/10.1016/j.envsoft.2021.105239 https://doi.org/10.1016/j.agsy.2025.104473	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Cultivar/genotype comparison;Nutrient management simulation;Nutrient cycling modeling;Water manatement simulation;Carbon sequestration modeling;	Phenological development;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;	CO2;CH4;H2O;	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification and nitrification;
DayCent-CABBI		Naoya Takeda	n3.takeda@qut.edu.au	Queensland University of Technology	https://doi.org/10.1016/j.geoderma.2024.116851 https://doi.org/10.1016/j.ecolmodel.2013.04.003	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Nutrient management simulation;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Carbon sequestration modeling	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;Product quality;Transpiration;Architecture of above-ground organs;Architecture of below-ground organs	CO2;H2O;CH4;N2O;NH3	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;CH4 production ;CH4 oxidation;Denitrification and nitrification;Nutrient volatilization;Organic matter decomposition;Nutrient leaching;Soil erosion
DNDC	Versions 11.0 to 12.4	Bill Salas	bill@regrow.ag	Regrow Agriculture	https://doi.org/10.19103/AS.2025.0155.09	Greenhouse gas (GHG) eimissions estimation ;Carbon sequestration modeling;Yield prediction;Water manatement simulation;Nutrient management simulation;Nutrient cycling	Phenological development;Respiration;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;Transpiration	CO2;H2O;CH4;N2O;NH3;NO	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification

						modeling			and nitrification;Nutrient volatilization
DNDC-Rice	2021	Tamon Fumoto	fumoto.tamon877@naro.go.jp	National Agriculture and Food Research Organization (NARO)	https://doi.org/10.2480/agrmet.69.3.11	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Nutrient management simulation;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Carbon sequestration modeling	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Nutrient uptake and partitioning;Yield formation;Transpiration	CO2;CH4;N2O;NH3	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification and nitrification
DSSAT CERES-Rice	4.8.5	Upendra Singh	usingh@ifdc.org	International Fertilizer Development Center	https://dx.doi.org/10.19103/AS.2019.0061.10 ; https://doi.org/10.1016/S1161-0301(02)00107-7	Yield prediction;Climate change impact assessment;Nutrient management simulation;Cultivar/genotype comparison;Adaptation strategy assessment;Water manatement simulation;Nutrient cycling modeling;Carbon sequestration modeling;Greenhouse gas (GHG) eimissions estimation	Phenological development;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation	CO2;CH4;H2O;N2O;NH3	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;Denitrification and nitrification;Nutrient volatilization
GEMRICE		Hiroe Yoshida	yoshida.hiroe457@naro.go.jp	National Agriculture and Food Research Organization (NARO)	https://doi.org/10.1016/j.fcr.2010.02.007	Nutrient management simulation;Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Cultivar/genotype comparison;	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Architecture of above-ground organs;Nutrient uptake and partitioning;Yield formation;Product quality;	CO2;	Nutrient mineralization ;N loss from the system;

H/H	2015	Toshihiro Hasegawa	hasegawa.toshihiro633@naro.go.jp	National Agriculture and Food Research Organization (NARO)	https://doi.org/10.1007/978-94-017-0754-1_17 https://doi.org/10.3354/cr01320	Adaptation strategy assessment;Yield prediction;Climate change impact assessment;Cultivar/genotype comparison;Nutrient management simulation	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;Product quality	CO2	Soil temperature dynamics;Nutrient mineralization
InfoCrop	Version 2.1	Arti Bhatia	artibhatia.iari@gmail.com; artibhatia@icar.org.in	ICAR-Indian Agricultural Research Institute	https://doi.org/10.1016/j.agsy.2005.08.001	Yield prediction;Climate change impact assessment;Nutrient management simulation;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Adaptation strategy assessment;	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;Transpiration;greenhouse gas emission, soil C and Nitrogen;	CO2;CH4;N2O;NH3;	Organic matter decomposition;CH4 production ;Denitrification and nitrification;Nutrient volatilization;Nutrient mineralization ;Soil water movement;Soil temperature dynamics;Nutrient immobilization;CH4 oxidation;Nutrient leaching;
MCWLA-Rice 2.0	V2.0	Fulu Tao	taofl@igsnrr.ac.cn	Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences	https://doi.org/10.1175/JAMC-D-12-0100.1	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Cultivar/genotype comparison;Nutrient management simulation;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Carbon sequestration modeling;	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Nutrient uptake and partitioning;Yield formation;Transpiration;	CO2;CH4;N2O;	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification and nitrification;
ORCHIDEE-crop		Xuhui Wang	xuhui.wang@pku.edu.cn	Peking University	Wang X (2015) Response of China's rice ecosystem to environmental change based on development, parameterization and application of ORCHIDEE-crop	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Carbon	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;Transpiration	CO2;H2O;N2O	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient leaching;Organic matter decomposition;Denitrification and nitrification

					model	sequestration modeling;Biophysical process modeling			
ORYZA	Version 4	Tao Li	t.li@cgiar.org	International Rice Research Institute	https://doi.org/10.1016/j.agrformet.2017.02.025	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Cultivar/genotype comparison;Nutrient management simulation;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Carbon sequestration modeling;Organic and slow-release fertilizering, crop residue return and mulching, the effects of inhibitors and biochar on GHG emission, complex AWD scheme for all type of AWD;	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Nutrient uptake and partitioning;Yield formation;Transpiration;Abiotic stress, rice ratoon, ;	CO2;H2O;CH4;N2O;NH3;	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification and nitrification;Nutrient volatilization;
RegWHCNS	2.0 v	Hao Liang	haoliang@hhu.edu.cn	Hohai University	https://doi.org/10.1016/j.agsy.2021.103528 https://doi.org/10.5194/gmd-18-3799-2025	Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Yield prediction;Adaptation strategy assessment;Climate change impact assessment;Water manatement simulation;Nutrient management simulation;Cultivar/genotype comparison;Carbon sequestration modeling;	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Architecture of above-ground organs;Nutrient uptake and partitioning;Yield formation;Product quality;Transpiration;	CO2;H2O;CH4;N2O;NH3;	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification and nitrification;Nutrient volatilization;

RiceGrow		Liujun Xiao	liujunxiao@njau.edu.cn	Nanjing Agricultural University	https://doi.org/10.1016/j.njas.2009.12.003; 10.1016/j.agrformet.2025.110452	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Cultivar/genotype comparison;Nutrient management simulation;Water manatement simulation;Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Carbon sequestration modeling	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Architecture of above-ground organs;Nutrient uptake and partitioning;Yield formation;Product quality;Transpiration	CO2;H2O;CH4;N2O	Soil water movement;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;CH4 production ;CH4 oxidation;Denitrification and nitrification
RicePSM		Lloyd T. (Ted) Wilson	lt-wilson@aesrg.tamu.edu	Texas A&M University	https://doi.org/10.1016/S0308-521X(97)00070-X	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Cultivar/genotype comparison;Pest and disease dynamics;	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Architecture of above-ground organs;Nutrient uptake and partitioning;Yield formation;Product quality;Transpiration;	CO2;	Soil water movement;
RiceSM		Xianguan Chen	1069335668@qq.com	Fujian Agriculture and Forestry University	Scheduled for publication this year.	Yield prediction;Climate change impact assessment;Adaptation strategy assessment;Nutrient management simulation;Greenhouse gas (GHG) eimissions estimation ;Nutrient cycling modeling;Carbon sequestration modeling	Phenological development;Leaf and canopy photosynthesis;Respiration;Biomass accumulation and partitioning;Architecture of below-ground organs;Architecture of above-ground organs;Nutrient uptake and partitioning;Yield formation;Transpiration	CO2;N2O	Soil water movement;Soil temperature dynamics;Nutrient mineralization ;Nutrient immobilization;Nutrient leaching;Organic matter decomposition;Denitrification and nitrification;Nutrient volatilization

B. List of Participants

Table 2. Complete list of speakers and participants of the workshop.

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C. Workshop Materials

Program and PowerPoint Presentations (**LINK**)