ACIAR

AgMIP The Agricultural Model Intercomparison and Improvement Project

Mitigation and Adaptation Co-Benefits Modelling Trial in Bangladesh Project

Proceedings of the MAC-B Stakeholder Roundtable

কৃষি গবেষণা

CIMMYT International Maize and Wheat Improvement Center

COLUMBIA UNIVERSITY

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Mitigation measures and Adaptation Co-Benefits Modeling Trial in Bangladesh Project

MAC-B Stakeholder Roundtable Agenda

Meeting Room, Training Complex (First Floor)
Bangladesh Rice Research Institute, Joydebpur, Gazipur
April 05, 2023
9:30-13:00 hrs. local time in Bangladesh

9:30- 10:00	Registration	
10:00-10:10	Welcome and Introductions	Tim Krupnik, Country Representative, CIMMYT-Bangladesh Erik Mencos, Columbia University
Opening Remarks		
10:10-10:20	Dr. Pratibha Singh, ACIAR Regional Manager in South Asia on behalf of Dr. Veronica Doerr (ACIAR, virtually)	
10:20-10:30	Dr. M.A. Yousuf Akhond, Director (Research), on behalf of Dr. Debasish Sarker, Director General, Bangladesh Agricultural Research Institute (BARI)	
10:30-10:40	Dr. Mohammad Khalequzzaman, Director Research, on behalf of Dr. Md. Shahjahan Kabir, Director General, Bangladesh Rice Research Institute (BRRI)	
10:40-10:55	Climate Change Challenges in Agriculture: Overview of AgMIP and MAC-B Project	Cynthia Rosenzweig (NASA/Columbia University, virtually) and Tim Krupnik (CIMMYT)
10:55-11:10	Group Photo Coffee/Tea Break	All Participants
Presentations of Findings of Research on Mitigation and Adaptation Co-Benefits		
11:10-13:00	Session Chair: Dr. Mohammad Khalequzzaman (Director of Research, Bangladesh Rice Research Institute (BRRI) Facilitator: Dr. Moin Salam, Senior Consultant, CIMMYT-BD	
11:10-11:20	Climate Team	Sonali McDermid (NYU) and Md. Bazlur Rashid (BMD)
11:20-11:45	Biophysical (Crop, GHG, Soils) Team	Tao Li (DNDC), Tek Bahadur Sapkota CIMMYT), Umme Aminun Naher (BRRI), and Apurbo Kumar Chaki (BARI)
11:45-12:10	Economics Team	Roberto Valdivia (OSU) and Md. Rajibul Alam (Ministry of Public Administration)
12:10-12:30	Presentations by BRRI Scientist on Carbon Absorption by Rice Plants and Pros and Cons of Alternate Wetting and Drying	Dr. Mofijul Islam, Senior Scientific Officer, Soil Science Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur.
12:30-13:10	Questions and Discussion	All Participants
	Stakeholder Engagement	Survey: While participants are sharing ideas, a survey link will be shared via email and on the screen with several questions on MAC-B about its potential, challenges, and recommendations. Facilitators: Sk. Ghulam Hussain (CIMMYT-BD)
13:10-13:20	Synthesis, reflections and next steps	Tim Krupnik (CIMMYT)
13:20-13:30	Wrap-Up and Closing by the Session Chair	Dr. Mohammad Khalequzzaman (Director of Research, Bangladesh Rice Research Institute (BRRI)
13:30-14:00	Lunch and Prayer	

Draft report on the MAC-B Stakeholder Roundtable

The MAC-B Stakeholder Roundtable, part of the ACIAR-funded 'Mitigation and Adaptation Co-Benefits (MAC-B) Modelling Trial in Bangladesh' project, was held on April 05, 2023, at the Training Complex of the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. Forty-six experts and scientists from different organizations in Bangladesh and abroad joined the meeting, of which 30 participated physically and 16 virtually. This hybrid event was designed to share and discuss the project's final results with the stakeholders. The half-day meeting was designed so that the stakeholders could provide feedback for improving the project's outcomes.

Welcome and Introductions by Dr. Timothy J. Krupnik (CIMMYT) and Erik Mencos (Columbia U)

Dr. Timothy J. Krupnik, Associate Director, Sustainable Agrifood Systems (SAS) Program, Asia and Country Representative (Research & Partnerships) Bangladesh, International Maize and Wheat Improvement Center (CIMMYT), and Erik Mencos, Senior Research Associate at Columbia University and AgMIP Program Manager, welcomed everyone who was participating in person and virtually in the MAC-B stakeholder Roundtable workshop. Dr. Krupnik also expressed his gratitude to the Bangladesh Rice Research Institute (BRRI) and appreciated BRRI's willingness and generosity in providing their training room and logistics to hold this event.

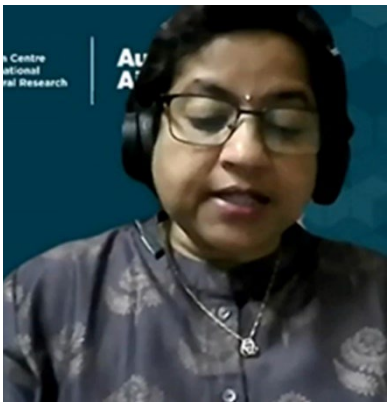
He mentioned, "I also want to appreciate everyone who has attended, I think there are more people here than we expected which is great. I know it's also very difficult to have meetings during the Ramadan period so we will try to be brief and focused on our discussions today but I want to thank everyone for giving their time and for being here in person. He then announced some small changes in the program and added that "we will have esteemed guests who will be representing and speaking from the perspective of BRRI and from BARI this morning the discussion today which is about."

At the end of his introductory remarks, Dr. Timothy said that "this effort involves a lot of Bangladeshi partners; we have contributions from groups at BRRI and BARI, for instance. It is possible to sequester carbon while simultaneously taking Bangladesh's need for adaptation measures into account. This work varies from a lot of the other research we all conduct on an experimental and field plot basis in that we used data from extremely large-scale surveys involving thousands of farmers throughout Bangladesh. We are employing data from observed farmers, which were collected from those thousands of farmers and used for modeling efforts in a variety of various places. In a nutshell, what we hope to achieve with this meeting is to share with you the modeling work that a group of multidisciplinary social and natural scientists have been doing."

Opening remarks:

Dr. Pratibha Singh on behalf of Veronica Doerr from ACIAR:

On the behalf of Veronica Doerr, ACIAR Program Manager, Dr. Pratibha Singh, ACIAR Regional Manager in South Asia from Delhi gave opening remarks. She was happy to see partners from across the globe in the workshop. She started by making a statement that "the latest IPCC synthesis emphasizes that we aren't going fast enough on either mitigation or adaptation and thus we need to urgently scale out existing technologies.



At the moment we seem to be doing too little on too many different things rather than putting enough effort into a few technologies or management or practice changes. Given this need to concentrate efforts, the IPCC also emphasizes scaling new technologies and management or practice changes that deliver both adaptation and mitigation benefits. She mentioned that "many interventions are studied separately to see if we deliver both benefits but if we study each one individually before deciding where to focus, we will be delaying significant action for too long; we need a simpler process for identifying the best bet technologies; the ones that will deliver the best balance between adaptation and mitigation benefits so we can concentrate on all the signs and action to scale out and make these new normal ways of doing things. This is what Mac-B is really all about." She requested the participants to pay attention to the way the MAC-B approach works, the way it tries to quickly provide evidence about best-bet technologies to focus on, and provide feedback on how this approach worked: was it quicker or less costly than lots of individual experiments or where the data requirements so large that it didn't really save much time and effort? Would this type of analysis convince senior decision makers to focus their efforts more and could it be used more broadly to identify where to focus in other areas not just sustainable intensification in rice. At the end of her speech, she congratulated all the partners all across the globe for this meeting and also looked forward to hearing their findings of the research.

Dr. M.A. Yousuf Akhond, Director of Research, BARI

Dr. M.A. Yousuf Akhond (Director of Research, Bangladesh Agricultural Research Institute (BARI)) made the opening remarks on behalf of the Director General of BARI, Dr. Debasish Sarker. He expressed his feelings about joining the Stakeholder's Roundtable discussion of the mitigation adaptation co-benefits modeling trial in Bangladesh. He was also very proud that his organization (BARI) has been an active part of this project and that its scientists have contributed through simulation analysis conducted by the combined model suit of the DNDC and TOA-MD economic regional farming system models. As he mentioned, Bangladesh's population has more than doubled since independence, but the country's infrastructure still needs to catch up. In his speech, he addressed that Bangladesh has also achieved significant and remarkable development and progress in agricultural production. Still, now, as in previous years, the agriculture sector is facing challenges due to rapid climate change. Bangladesh is one of the world's most vulnerable climate-affected countries. Our government policymakers and scientists are constantly working with different strategies to cope with this problem. He mentioned that the Bangladesh government is committed to two percent of its own domestic GDP to climate Finance established a National cross-sectoral Climate Change strategy and action plan and as well as emphasized climate response in its 10-year collaboration strategy with ACIAR. He said that "Our intention is to identify and transfer improvements in rise-based farming systems, but there are consequences of these only rice-based cultivation systems where we are growing in some places like consecutively three rice crops. There are some concerns have been raised from some quarters about whether to reduce this rice cultivation in Bangladesh or replace rice with some other crops, but I believe it will not be wise to replace this system with rice as rice is the major crop of the

country and we need to try to think about mitigating the problems associated with rice." According to him, this project provides a platform for scientists to evaluate those effects, and because it is modeling work, one can predict future needs and suggest to policymakers what intervention to do for the future sustainability of this system. He noticed some interventions already reported in the project, such as alternative wetting and drying, have produced significant outcomes like reducing greenhouse gas emissions with a minimal yield penalty. In addition, he thinks mechanization can be more efficient for small-scale rice planters. He also believes "there is a scope for studying intercropping which can affect greenhouse gas emissions and climate change-related effects to get complete and robust outputs. As in the workshop, the preliminary results of the models would be showing, so we still need to go further. The more input we provide, the more efficient the modeling system will be, so we need to go to more places and try to generate more data in that area so that our modeling will be accurate and it will also help us help policymakers to make better policies, and there is another area as I am a plant breeder and biotechnologist whether the plan bidders can explore that like in developing rice varieties that require less water probably and with the use of genetic engineering."

Dr. Mohammad Khalequzzaman, Director of Research, BRRI

Dr. Mohammad Khalequzzaman, Director of Research of Bangladesh Rice Research Institute (BRRI) attended and chaired the roundtable event. On the behalf of Dr. Md. Shahjahan Kabir, Director General of BRRI he read out the opening remarks. He began by saying that in this country, "Rice security" is synonymous with "Food security." Since its birth in 1970, BRRI worked hard to develop the rice sector and finally has made the country self-reliant from chronic food shortages. Bangladesh is now the 3rd in rice production in the world and the 1st in producing average yield in South Asia and similar yield as the world standard. Since independence population increased by two and half folds but rice production has increased about four folds which reflect the success story of scientists, extension agents, farmers and the pro-agriculture government. Therefore, the economy of Bangladesh is rice-centric and the development of the agricultural sector mainly depends on rice-led research and development. So, rice should be included in any policies and strategies in Bangladesh for short, medium, and long-term planning. During 2021-22, Bangladesh has produced 39.70 MT of clean rice meeting the requirements of 170 million people. If it didn't happen, millions of people would have become food refugees and would have created a global crisis. But, in reality, we have shown the courage of sheltering and feeding 1.2 million odd Rohingyas.

Despite Bangladesh being highly vulnerable to climate change and climate-induced disasters, the country contributes less than 0.35% of global emissions. Nonetheless, Bangladesh wants to actively participate in global collective action to reduce future GHG emissions. GHG emissions from rice could be reduced before it reaches the atmosphere by combining multiple approaches, i.e., efficient water management, fertilizer, variety, cropping pattern, and modification of internal spaces (limited aerenchyma). Therefore, since 2013 the scientists of the Soil Science division of BRRI have been measuring GHG emissions from rice fields. The results of various studies showed that alternate wetting and drying (AWD) irrigation significantly reduces global warming potential (GWP) by 36% compared to continuous flooding (CF) conditions.

Moreover, it reduces water use by up to 38% without a significant yield penalty, which helps reduce farmers' production costs. Therefore, AWD practice is expected to be widely adopted by farmers in the country for Boro rice cultivation. Although most of the farmers in our country are not habituated to formal AWD practice, they dry their land 2-3 times during Boro rice throughout the rice-growing season, that have an almost similar effect to AWD practice. Extrapolation of this technology in 100% of Boro area (4.8 million ha) can reduce 9 Mt CO2 eq GHG emissions from rice cultivation.

Another study by BRRI showed that urea deep placement (UDP) significantly reduced GWP by 9% compared to broadcast prilled urea (PU). In addition, UDP saves N fertilizer use by about 25-30% and increases rice yield by about 10-15%. However, the main problem for extrapolating this technology is associated with the unavailability of briquettes on a large scale and the need for suitable applicators. To overcome this problem, BRRI already advanced rice transplanter cum fertilizer applicator. Therefore, a rice transplanter cum fertilizer applicator is expected to be widely accepted by farmers in the country for Aman and Boro rice cultivation. Extrapolation of UDP technology in 100% of cultivated area (11.6 Mha) can potentially reduce 8 Mt CO2 eq GHG emissions from rice cultivation.

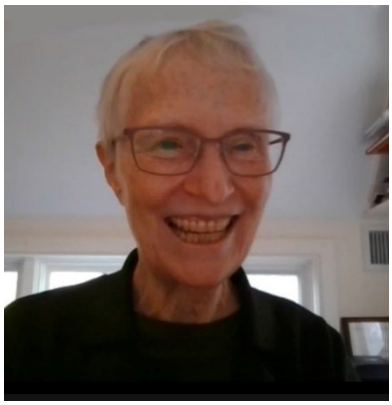
In Bangladesh, in three rice seasons, i.e., Aus, Aman, and Boro, a total of 50 Mt of rice is produced; carbon dioxide, methane, and nitrous oxide emissions are 33.3, 2.65, and 0.025 Mt, respectively. The carbon dioxide equivalent emissions of these three greenhouse gases are 106.2 Mt.

On the other hand, rice plants absorb 2200 grams of carbon dioxide per kg of rice production in the photosynthesis process. So, in total production of 50 million tons of rice, about 110 Mt of CO2 is absorbed from the atmosphere. According to the above calculations, it is clear that paddy fields absorb 3.8 (110.0-106.2) million tons more greenhouse gases from the atmosphere than emitted. Therefore, rice cultivation does not pollute; rather, it cleans the atmosphere.

He then informed the audience about other promising technologies to mitigate CH4 emissions from rice cultivation, including oxidation of CH4 and aerenchyma formation or modification. In rice roots, aerobic CH4 oxidizing bacteria (methanotrophs) consume up to 30% of CH4 before it reaches the atmosphere. Rice plants develop aerenchyma against low O2 stress in submerged conditions, which provides a channel for gaseous exchange between aerial and flooded parts. However, up to 90% of CH4 released from rice fields into the atmosphere is through aerenchyma, suggesting that aerenchyma are responsible for CH4 emission. Limited aerenchyma formation in rice plants can reduce CH4 emissions by about 27%.

In this context, BRRI is working on a plan and has taken several steps to implement it. For example, BRRI is working to develop a variety with reduced aerenchyma that can mitigate a large amount of CH4 emissions. BRRI is also working to develop a variety that can absorb a large amount of CO2. Because we know that rice is a C3 plant, as the amount of CO2 increases in the atmosphere, rice absorbs more CO2 and produces more carbohydrates resulting in an increased rice yield. To innovate more CO2-absorbing varieties, BRRI has already identified varieties from germplasm stored in BRRI Gene Bank that are more responsive to CO2 and more productive. This germplasm will be used in the future to invent more CO2-absorbing and more productive varieties. Besides, BRRI is working on nanotechnology to reduce GHG emissions from rice cultivation. He concluded by recommending that "we emphasize how to reduce GHG emissions by keeping everything in order."

Dr. Cynthia Rosenzweig (NASA/Columbia University, virtually)

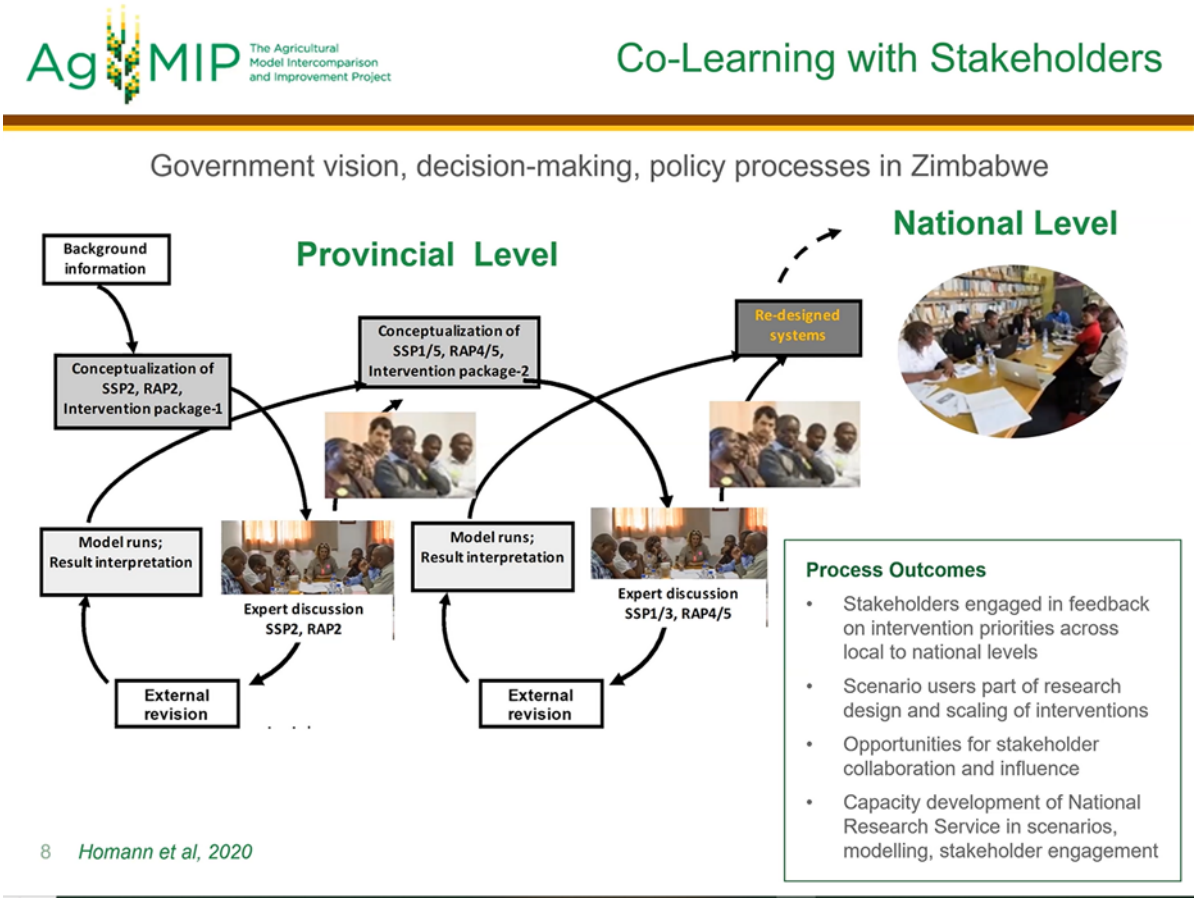


In her pre-recorded video, Dr. Cynthia Rosenzweig of NASA/Columbia University introduced herself as the Agricultural Model Intercomparison and Improvement Project (AGMIP) co-leader. She extended a warm welcome to everyone attending the stakeholder roundtable meeting.

She stated that "the MAC-B project began in September 2021, and now we are working on wrapping up the project. But before the project ends, it's crucial to get the stakeholders' feedback on its results as they stand now and thinking about next". She added that "we are a Global Network of over 1,000 agriculture, climate, and food researchers, and what we do together is as we have in this MAC-B project to convene scientifically based agricultural decision-making models and assessments of climate change to achieve local to global food security. First of all, I want to thank the project partners; it's been a great joy to work with all of my colleagues from the many Bangladesh institutions and other institutions around the world. The feedback from the stakeholders has been invaluable to the project, and we look forward to getting your last words of wisdom at the stakeholder Roundtable, so I'm going to give an overview of AgMIP." Then she talked about the AgMIP mission, which is to provide science-based agricultural decision-making models and assessments of climate change to achieve to conduct multi-model assessments, which are assessments of both the biophysical and economic sides of things.

She invited the audience to see the crop modeling results, hear about the economic impacts, and learn about the economic outcomes as well as the practices—in this case, some alternative wetting and drying and other management practices and technologies—which will prompt to consider incentives for the current and future climate conditions to create effective responses and create chances for stakeholders to participate in initiatives and have a genuine impact. One of the objectives is to establish national scale capability for scenario modeling stakeholder interaction and national adaptation strategies, to prevent a spiral of activities from the project team presenting the results and plans to the stakeholders.

Then she explained the Integrated Assessments features, including stakeholder-driven activities focused on farming systems. She then narrated the development pathways, transdisciplinary- biophysical/socio-economic modeling, multi-scale and multi-model- field, farm, regional, and global assessments, and distributional results, e.g., impacts on poverty rates. She cited an example of Co-Learning with Stakeholders from Zimbabwe. She showed how in every aspect of the process, the Stakeholders are engaged in feedback on intervention priorities across local to national levels.



Timothy J. Krupnik, Country Representative (CIMMYT-Bangladesh):

After Dr. Cynthia Rosenzweig's powerful speech, Dr. Timothy J. Krupnik (CIMMYT-Bangladesh) explained that "in terms of the emissions issues that we have focused on, this is basically the agri-food systems in Bangladesh in general; it is not specific to rice. Crop management practices may affect rice productivity and adaptation and mitigation co-benefits in Bangladesh at a large geographic scale. Compared to the global configuration of greenhouse gas emissions, Bangladesh emits a relatively small amount of greenhouse gases. And in many instances, Bangladesh is, of course, a far greater victim of climate change and of emissions that larger and more industrialized countries have mostly initiated. Several nations may benefit from what Bangladesh has accomplished in terms of producing enough rice to meet their own needs on a year-round basis. Everyone rarely benefits from a single technology or a single management practice when it comes to mitigating and adapting Bangladesh's rice production systems to climate change while also looking at the socioeconomic consequences in terms of profitability and how changes in rice production may affect men and women or different types of farmers and groups of farmers differently. We'd want to know whether you find the simulations plausible and if you believe they might assist in a direct future study, particularly the usage of younger seedlings when transplanting. Bangladesh's rice-based systems will be able to adapt while also reducing and minimizing some of the long-term effects of greenhouse gas emissions."

Talking about Key Challenges in Bangladesh Dt. Tim said, "Water is one of the most stressed resources in Bangladesh. Significant challenges are sustainable water resources management and water resources markets. Increasing vulnerability to extreme events, over-extractions, growing urban demand, climate

change, land-use changes, and environmental requirements. Bangladesh must feed a large population from declining agricultural land and water resources. Moreover, the staple food rice requires massive amounts of water and is grown under submerged conditions. Then he talked about Bangladesh MAC-B Objectives and Key Activities, touching upon the following points:

- Directly integrate stakeholder feedback into the MAC-B assessment process and co-develop feasible interventions (focused on sustainable rice management and intensification) that may generate adaptation and mitigation co-benefits
- Evaluate the effects of these interventions in current farming systems using multiple measures of mitigation, adaptation, and development benefit, including measures of greenhouse gas emissions, resilience to climate variability, farmer livelihoods, gender, and nutrition
- Evaluate the effects of the interventions on the multiple measures of benefit under future climate scenarios
- Support policy development by convening a policy-maker's round table to communicate the findings from the project and discuss policy implications for mitigation and adaptation programs
- Strengthen the capacity of all partners in using and applying AgMIP Regional Integrated Assessment methods

Presentations of Findings of Research on Mitigation and Adaptation Co-Benefits

Session Chair: Dr. Mohammad Khalequzzaman (Director of Research, Bangladesh Rice Research Institute (BRRI)

Facilitator: Dr. Moin Salam, Senior Consultant, CIMMYT-BD

Climate Team:

Md. Bazlur Rashid, Meteorologist, Bangladesh Meteorological Department

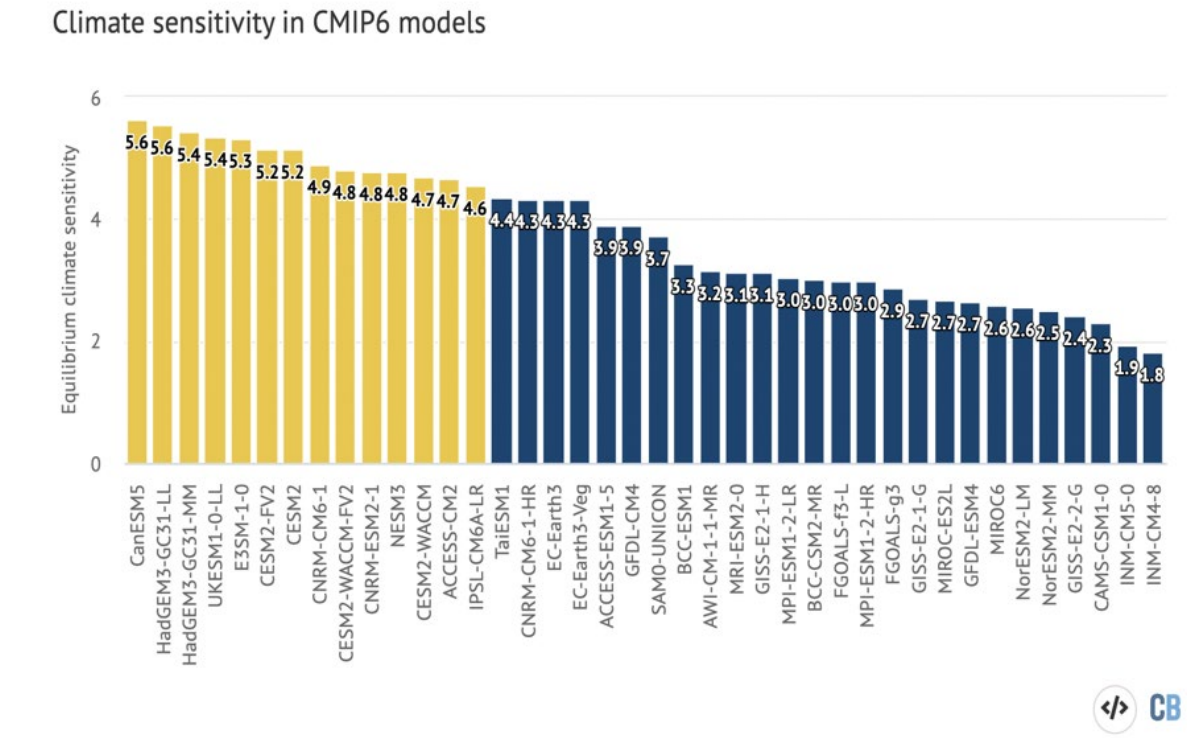
Sonali Shukla McDermid, PhD Associate Professor, New York University, USA

Sanketa Kadam, Columbia University, USA

Dr. Sonali McDermid virtually presented the climate team's activities. The information they generated has been passed to the biophysical and economic modeling teams to carry out their simulation/modeling work. The Climate Team's first objective is to provide future climate change scenarios (e.g., the 2050s, fossil-fuel development) for MAC-B assessment at the site level.

The second objective is to understand how uncertainty in these future climate scenarios and projections impacts the crop and socioeconomic outcomes, and the third objective is to consider how modeled mitigation potentials may provide feedback on the climate system. The third objective was not presented in the meeting. Dr. Sonali then added that "more of an aspect of future work that we'd like to explore a bit more. I'll walk you through now how we set up the climate data and scenarios for the crop and economic modeling assessments and so, as you might know, the latest version of the IPCC.

The Climate Team uses climate model projections from the latest Coupled Model Intercomparison Project (6), which conforms the UNFCCC Climate Reports, which have been downscaled as part of the NASA Global Daily Downscaled Projections (NEX-GDDP-CMIP6).



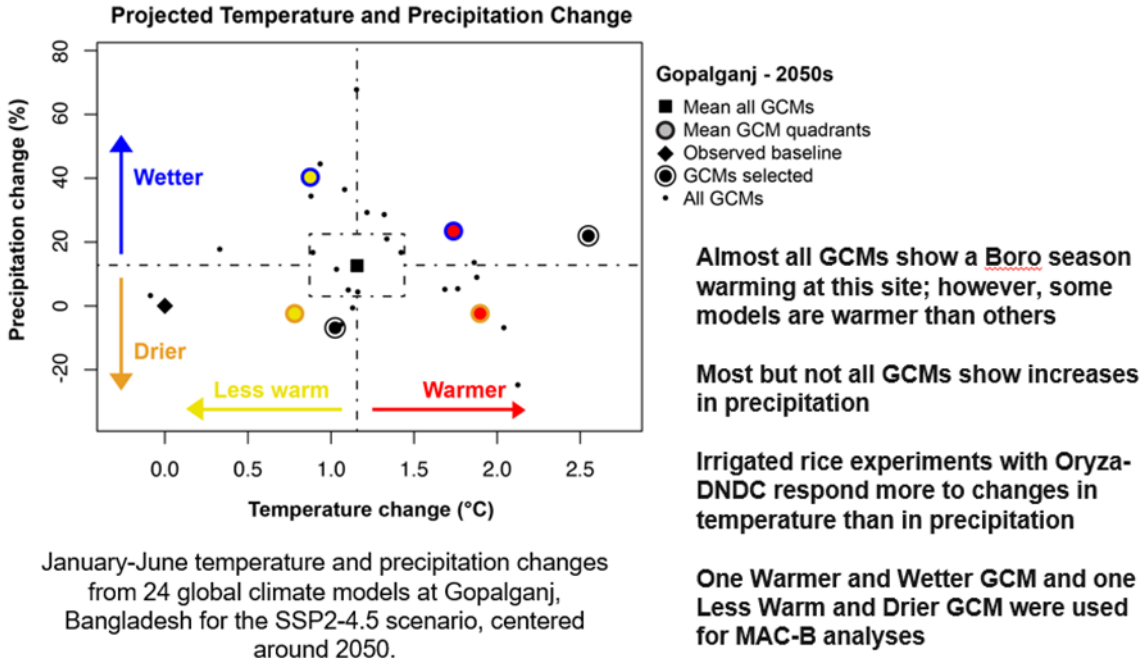
IPCC AR6

The models show climate sensitivity, so the amount of warming that they achieve for a certain amount of carbon dioxide is quite high. In other words, several of the models in this climate assessment round are hotter and hotter than what has been seen previously. So, one recommendation that has been passed down from the climate community is to be careful about using these hot models in assessments of impact because they might skew the assessment results, so they may not be representative of the physical response of the climate system and so what we have done is two things one we've still used these projections from the sixth couple model intercomparison project which informed the latest IPCC report. These models have been further downscaled from their native resolutions which are about 100 kilometers by 100 kilometers they've been downscaled to a 25 kilometer resolution data set as part of the NASA Global daily downscale projections data and then what we've done is a step further to that that down scaling we've subset the models to eliminate some of the hotter models that you're seeing here sort of the top five models in this category in order to achieve a model population or a subset that we feel is more physically representative now future work could also include some of these hotter models and in fact we did run some previous model simulations with these hotter models in order to understand the full range of sensitivity but for right now we have some physical reasons to think that the hotter models may not be representative of the kinds of changes we'd like to examine, so with this subset of models we now take another step forward to subset or select specific models for the climate scenarios we'd like to test so again we're looking for now only at an SSP2 4.5 scenario so again this is our middle range to more ambitious mitigation climate scenario but it's sort of impossible to run this many models even if we're eliminating some of them through crop and then the economic components of the project to run every

single climate model there are now about 44 climate models maybe a little bit more than that it would be rather prohibitive so we need to figure out a reasonable strategy to select just a few models that capture the range of change that we're seeing across the model space for a given climate scenario in this case SSP2 4.5.

AgMIP The Agricultural Model Intercomparison and Improvement Project

Climate Team



January-June temperature and precipitation changes from 24 global climate models at Gopalganj, Bangladesh for the SSP2-4.5 scenario, centered around 2050.

Dr. Sonali then narrated that, "We are currently driving the climatic findings from these two models via our biophysical (crop, soil and GHG emission) model inputs and then into our socioeconomic model and results. With that, I'll conclude here and answer any questions you may have about our technique, which is used at every site we have studied.

Biophysiological Team:

Dr. Tao Li, DNDC

Dr. Tek Bahadur Supkota, CIMMYT

Dr. Umme Aminur Nahar, BRRI and

Dr. Apurba Kumar Chaki, BARI

The Biophysiological Team is represented by Dr. Tao Li, a renowned modeler working at DNDC (DeNitrification DeComposition) and Dr. Tek Bahadur Supkota a greenhouse gas emission expert in working at CIMMYT Mexico and Dr. Umme Aminur Nahar a soil scientist working at BRRI and Dr. Apurba

Kumar Chaki, cropping system agronomist and crop modeler working at BARI. Dr. Apurbo Kumar Chaki on behalf on the team presented the modeling findings that highlight the benefits of both adaptation and mitigation for rice production in Bangladesh. He narrated that "We need crop management data, detailed soil profile data, and temperature data, rainfall data, thus we obtained both historical and future records for the climate modeling datasets from the climate modeling team. Before doing any scenario analysis, we went through an iterative process of model calibration to examine the uncertainties and the level of confidence in the model's predictions. As a result, we performed cultivar parameterizations. The breeds that we employed in our modeling study were two popular rice varieties, BRRI dhan28 and BRRI dhan29." We haven't really done any rotations but the economic team has done some so we have applied some new interventions of management that's the alternate wetting and drying and system of rice intensification, and we have run those simulations for 30 years in the historical climate as well as two future climate supplied by the climate modeling team.
Data used for this study were:

- **Rice yield and cropping management:** Field survey conducted in Bangladesh from 2019 to 2021;
- **Soil data:** Extracted from SoilGrid2.0 of ISRIC, and corrected by a few soil profile data from field experiments;
- **Weather:** 30-year timeseries for historical (AgMERRA 1980-2010) and future scenarios from two downscaled CMIP6 climate models for SSP2-4.5

Design of crop modeling evaluation

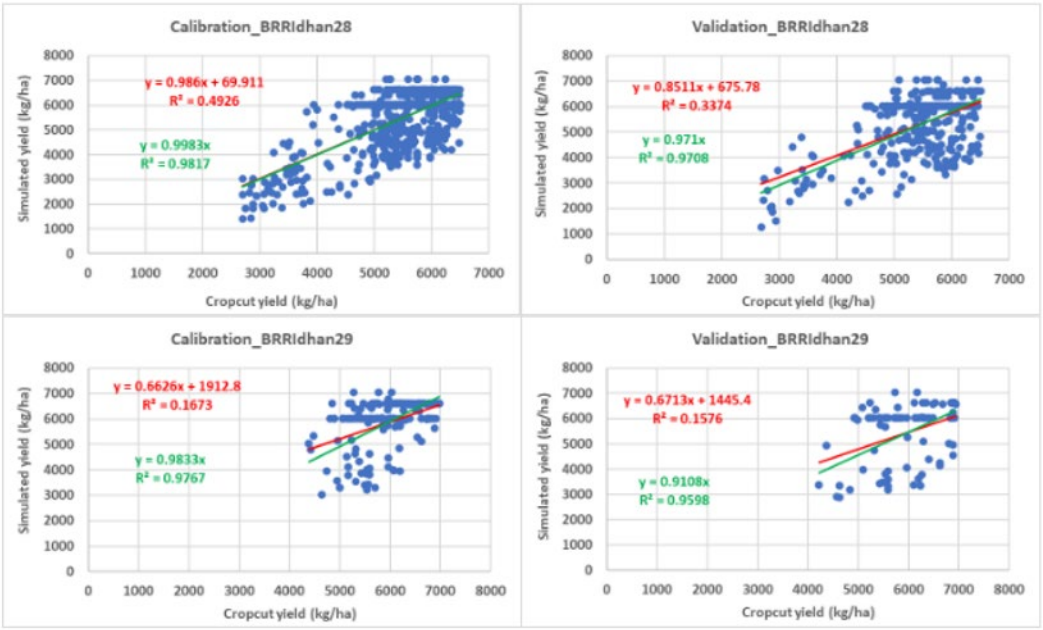
- **Model calibration and validation:**
- ***Varieties:*** BRRI dhan28 & BRRI dhan29
- ***Data sites:*** 1489 sites selected from 4427 sites of field survey from CMMIYT
- ***Calibration and validation data sites:*** Randomly split data site into 66% for calibration, 34% for validation

Model calibration and validation results

(Simulated grain yield vs. crop-cut yield in field survey)

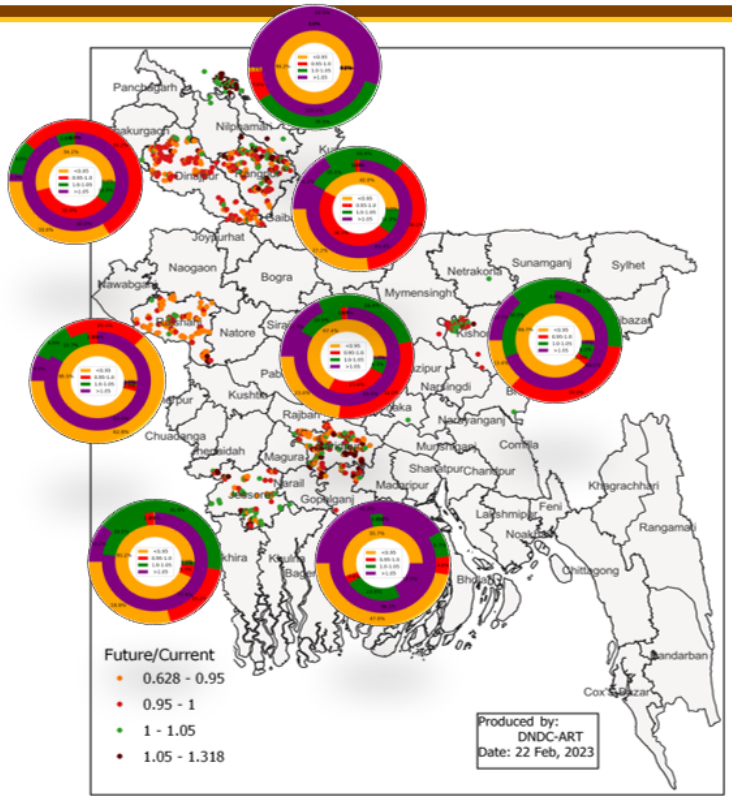
		Mean ± sd (kg/ha)		Regression		RMSE (kg/ha)	$RMSE_n$ (%)
		Survey	Simulation	Slope	R^2		
BRRI dhan28	Calibration	5545 ± 764	5537 ± 1072	0.998	0.982	764	13.8
	Validation	5524 ± 784	5377 ± 1149	0.971	0.971	953	17.3
BRRI dhan29	Calibration	5903 ± 598	5867 ± 918	0.983	0.977	907	15.4
	Validation	5951 + 715	5483 ± 1179	0.911	0.960	1238	20.8

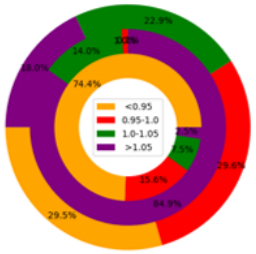
Model calibration and validation results



Results (Group 1)

– The effects of climate change



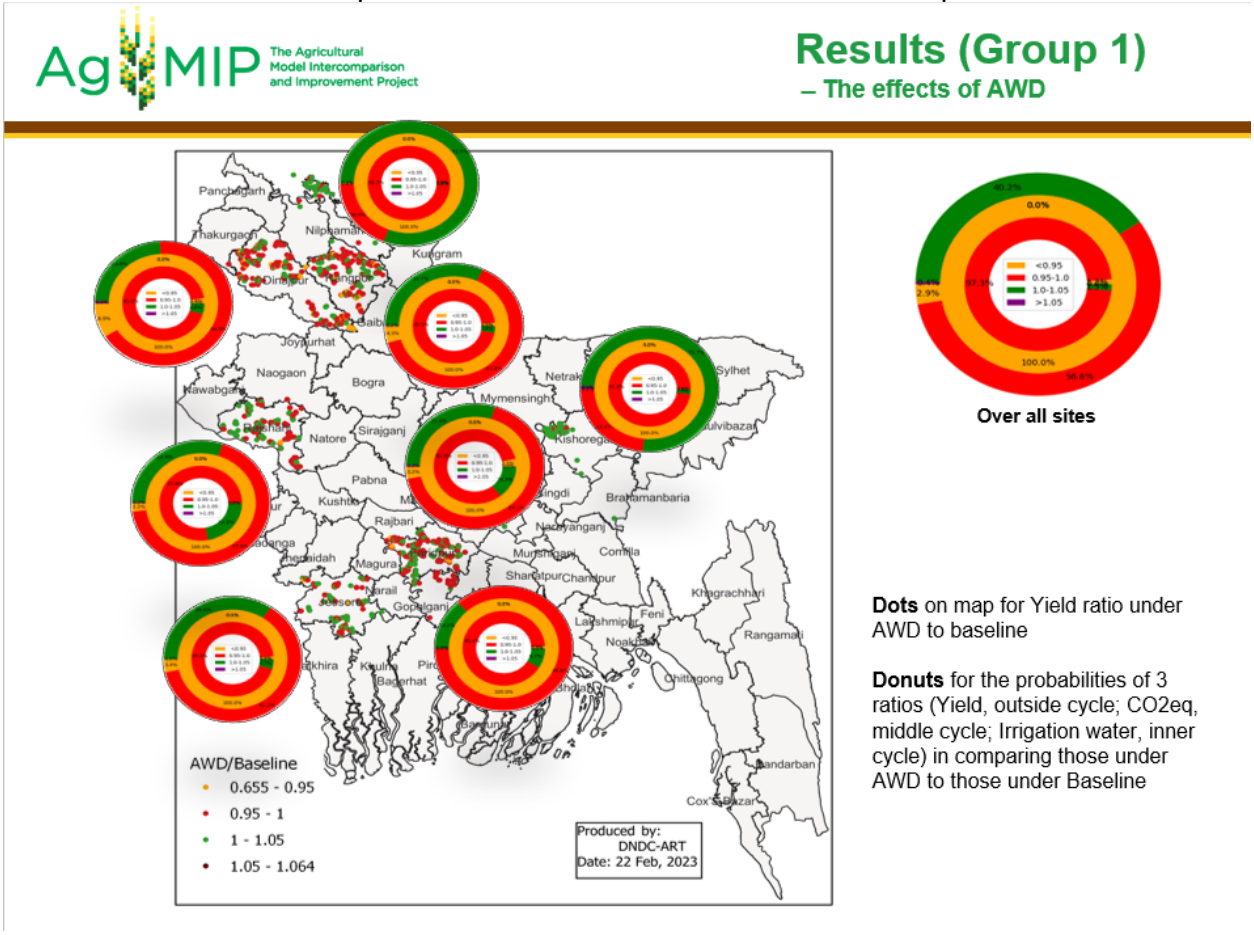


Over all sites

Dots on map for Yield ratio under future climate to the current climate

Donuts for the probabilities of 3 ratios (Yield, outside cycle; CO2eq, middle cycle; Irrigation water, inner cycle) in comparing those under future climate to those under current climate

Climate change would decrease grain yields by 1 to 7% in districts Rangpur, Dinaipur, and Rajshahi, but the yields in other districts changed insignificantly. Significant increases in CO_2 and CH_4 by up to 40%, but decreases on N_2O emission up to 7%. However, 10 to 20% increases in CO_2eq at all districts.



At the district level, the application of AWD did not remarkably change the grain yield but showed significant reductions in GHG emissions, particularly about a 50% decrease in the yield-emission indices The CO2eq decreased by more than 10% at all sites.

In conclusion Dr. Apurba said that climate change will impact yield and soil fertility, as well as increase GHG emissions if the crop management practice is not changed. AWD showed minor yield change (about 90% of sites within ± with 5% yield changes). AWD could significantly reduce CH4 emission and global warming potential of GHG emissions in all field sites under both current and future climatic conditions. One type of AWD won't be suitable for all fields, it is worth developing site-specific AWD techniques. On the other hand, SRI management increased yield, soil carbon sequestration, and also GHG emission because of the large increases in organic fertilizer application. The SRI could be optimized based on the local biophysical conditions and practical feasibility for co-benefits of yield and GHG emission.

The outcomes from this crop modeling team are unsatisfactory in terms of advantages, trade-offs, and stability of yields environmental metrics like soil organic carbon sequestration over a period of 30 years in both the historical climate and two future climates.
Presentation link:

After Dr. Apubo's presentation, Dr. Jiban Krishna Biswas asked a quick question to Dr. Apurbo, saying that two of BRRI scientists have their PhD on SRI and two published in the Field Crops journal and he has

gone through a lot of papers also BRRI result says it has no impact on yield contribution issue. He has seen an article where the author concluded SRI as a myth or in reality something like that also a controversial topic so why did you consider SRI in this simulation study where BRRI is not much interested on doing research? He added "in fact the original work of the Madagascar technique suggested SRI is good for one of the poorest soil in the world and the seedling age should be seven days old and in one square meter there should be only four seedings in fact that system will not work in our system what you are we are doing here may be the modified SRI or something like that this is nothing different from our BRRI developed system. He suggested not to use that word SRI. Even AWD, it's nothing but the system basically developed at BRRI in the 1980s, what is followed by IRRI by Dr. T.P. Tuong. Therefore, you should recognize these systems as BRRI developed systems first and also this is one of the most controversial agronomic issues so maybe what you have done it's okay. He suggested not to proceed further with this SRI technology.

Dr. Timothy Krupnik supplemented by saying, "I'm also no stranger to SRI, and I have very mixed feelings about it. I worked on SRI for three years in Africa, not in Bangladesh. Still, it's not an appropriate system for many agroecologies within Bangladesh, especially considering the labor constraints and other associated issues. The data set BRAC provided came from a study implemented by BRAC and by Cornell University that has since been published by Christopher Barrett et al., a well-known Economist working globally. He's also done some of the early papers on SRI. Let me finish Barrett; as you will know from the literature review, some of the earlier studies of SRI in Madagascar as well as those studies that were done by Moser et al. under the direction of Barrett, indicated that there were a lot of problems with the system and that it had a lot of challenges. As we know, development organizations often like to grab on topics; they like to say we are doing climate-smart agriculture, site-specific nutrient management, system of rice intensification, and they want to say that we are doing many different things. Several years ago, the data set was available if you read the papers that were published by Barrett et. al., published their work in top economic journals their results are robust but the results in my humble opinion, they do not test the effect of SRI they test the impact of training farmers on principles of good agronomic management so as exactly as you say these principles are principles of good agronomic management they are not necessarily principles of SRI when you looked at the presentation that Dr. Apurbo provided essentially the main differences in crop management that were observed by Farmers that had been trained to do SRI were AWD and increasing nutrient management there was not a substantial observation of Farmers making use of certainly single seedlings of younger seedlings or of modifying plant's geometry and spacing and plant populations which are other supposed principles of SRI so in reality what Farmers did is like if this is what SRI is meant to be in reality what BRAC achieved Farmers doing was very different and so where I would agree with you Dr Biswas is that the principles of what they did are much closer to good agronomic management principles and much further away from what SRI is in its ideal state and that's what we see in many countries where SRI is promoted that farmers apply only a few of the principles but rarely all of the principles and they apply very rarely all of their principles because they're challenging to implement and they're not always necessarily better than all of the other work so the work that Dr Latif did and teams many years ago in what 20 2005-6 no six five six five six and others that were done the those results hold still very valid right when you compare the whole set of practices Some Things Fall apart but I don't think anyone in this room would argue that in the right Landscapes alternate wetting and drying is a good thing that in principle where farmers can afford labor for access to organic matter that applying more organic matter is not a good thing so these principles hold true. Arguably in this analysis we had a lot of discussions within the team of whether we should actually call it SRI or not because again what Farmers did in the data set is very different from the ideal state of SRI they essentially attempted alternate wetting and drying and nutrient management but what you see nonetheless from the patterns that come and it actually supports your indication all this is a modeling study that was applied with an existing data set we didn't go and do a field study and ask farmers to try to practice SRI we used a data set that was available from Breck and we applied that data set and actually the results for these practices if you reflect

upon the last point that Dr. Apurbo presented are actually quite challenging to SRI and they actually indicate that there are problems with SRI practice under future climate so it actually supports I think a lot of your concerns and it supports some of the early research that was done almost 20 years ago we're getting old on SRI but nonetheless the value in this work is still looking at what is the potential implication of alternate wetting and drying and of nutrient management in the future given these issues and given the availability of that prior data set. So your concern and this concern generally is noted. It's something that we should be communicating to BRAC, who again kindly provided the data set, and to Cornell University, which kindly provided the data sets that may be in the future looking at randomized control trials around the training of farmers and things should focus much more on the principles of good Agronomy rather than applying the term as a whole.

Dr. Siraj of IRRI supplemented as the name BRAC came repeatedly. He added that the data set is also from BRAC. He was also with BRAC, worked with the SRI practices in BRAC, and conducted massive demonstration trials of the SRI technology concept or the approach in the farmers' field. Dr. Tmothy has rightly mentioned that basically on the adoption of SRI technologies, providing the training, you know, the facilities to the farmers, but I want to add something because the BRAC approach on the SRI is repeatedly we are saying that SRI it is not a technology it's an approach or methodology and the methodology BRAC followed in the name of SRI we followed three six components of SRI first one is the single seedling definitely the second one is the younger seedling it's not the seven days old seedling what Dr. Jibon mentioned. In most of BRAC's experiments, it was 18 to 20 days old seedlings, and wider spacing is not 50 by 50 cm; it was only 20 to 25 cm plant-to-plant and line-to-line spacing. Another approach is the AWD, the AWD in a real sense; what is AWD developed from IRRI the T.P. Tuong that's a different thing. Also, the AWD referred by the presenter, Dr. Apurbo, mentioned five days of draining and seven days of drying, which differs from the AWD technology. Also, this technology that IRRI developed is based on the magic pipe, so you have to consider that issue, not only the drying and wetting. The fourth component was the mechanical weeding component, and the fifth, sixth, and sixth were the organic matter applications. But Dr. Apurba said that some farmers applied 10 tons of organic matter in the soil, which is very high in the real sense. Dr. Jibon talked about Professor Moazzem, but the advocator of SRI is Norman Uphoff, Senior Advisor for the SRI International Network and Resources Center (SRI-Rice), a program at Cornell University so when he demonstrated this SRI technologies in Madagascar especially, they showed that around 40 tons of organic matter were applied in their SRI fields. Hence, these are the real things that happen in the name of SRI, and BRAC also advocated the BRRI technologies. There are three treatments one is the SRI in the name of Sri, another is the BRRI technologist and is conventional, which means we name that as the farmer's practice, but Farmers do. We found a huge difference between the SRI versus Farmers' practices, but the difference between the BRRI recommended practices and the SRI is insignificant. That needs to be also noticed here it is not significant is these technologies are the concept it is nothing new, so if you compare all these individual components like the younger seedling, it is always good. There are a lot of experiments done in BRRI also that younger selling is good. Hence, this is the practice, so what SRI is actually, that's why Dr. Timothy also mentioned in his earlier speech in the morning session that some controversial issues will arise. Hence, this is one of the controversial issues raised here, but the BRAC paper is different—the technology demonstration of what BRAC actually has done. The data set you have taken is also different, so try to understand these things before you comment.

Economics Team:

Dr. Roberto Valdivia (Oregon State University)

Dr. Md. Rajibul Alam (Ministry of Public Administration)

The Economics Team is represented by Dr. Roberto Valdivia (Oregon State University) and Dr. Md. Rajibul Alam (Ministry of Public Administration). Dr. Md. Rajibul Alam, made the presentation for the

Economics Team. The goals of economic modelling are to assess the impacts of climate change on rice-based production systems, that is, to calculate gains and losses because of climate change. Determine the proportion of households vulnerable to climate change (i.e., at risk of losing because of climate change) and estimate the impacts on socio-economic and environmental outcomes associated with climate change (gains and losses). Another goal is to assess the main advantages and trade-offs of changing the rice management system. Specifically, to determine what would happen if the rice management is switched from the conventional system to an alternative management system and determine at which point the potential adoption rates for switching from conventional rice management system to alternative rice management systems. Also, estimate the economic benefits associated with the adoption of the alternative system(s) and evaluate the trade-offs and co-benefits between socio-economic (e.g., farm net returns) and environmental outcomes (GHG emissions) due to alternative rice management systems.

In this study for economic modelling, the TOA-MD (TradeOff Analysis for Multi-Dimensional Impact Assessment) Model was used, which is a unique simulation tool for a multi-dimensional impact assessment that uses a statistical description of a heterogeneous farm population to simulate the adoption and impacts of (a) New technology (e.g., new crop variety or change in crop management) (b) Change in environmental conditions (e.g., climate change), (c) Policy interventions such as Payments for Ecosystem Services (e.g., carbon sequestration). This tool is not a farm-level model. It models distributions of outcomes (e.g., net farm returns) of a population of farms. TOA-MD is designed to simulate experiments for a population of farms using a "base" production system (System 1) and an alternative System 2. It captures the socio-economic, biophysical and environmental heterogeneity, allowing to estimate potential adoption rates and associated outcomes for adopters, non-adopters and the whole population (or for gainers and losers in the case of climate change impacts).

Then he narrated the methodology, describing the data sources for each system, plot and farm-level economic data for rice production and for other crops grown on the farm, farm household characteristics and other social data. He shared some of the important findings of the economic group highlighting the following:

Impacts of climate change and Benefits of adaptation on economic outcomes; contribution of crop returns to total farm net returns; tradeoffs and co-benefits of economic vs environmental outcomes; and economic analysis –CIMMYT data on per ha basis.

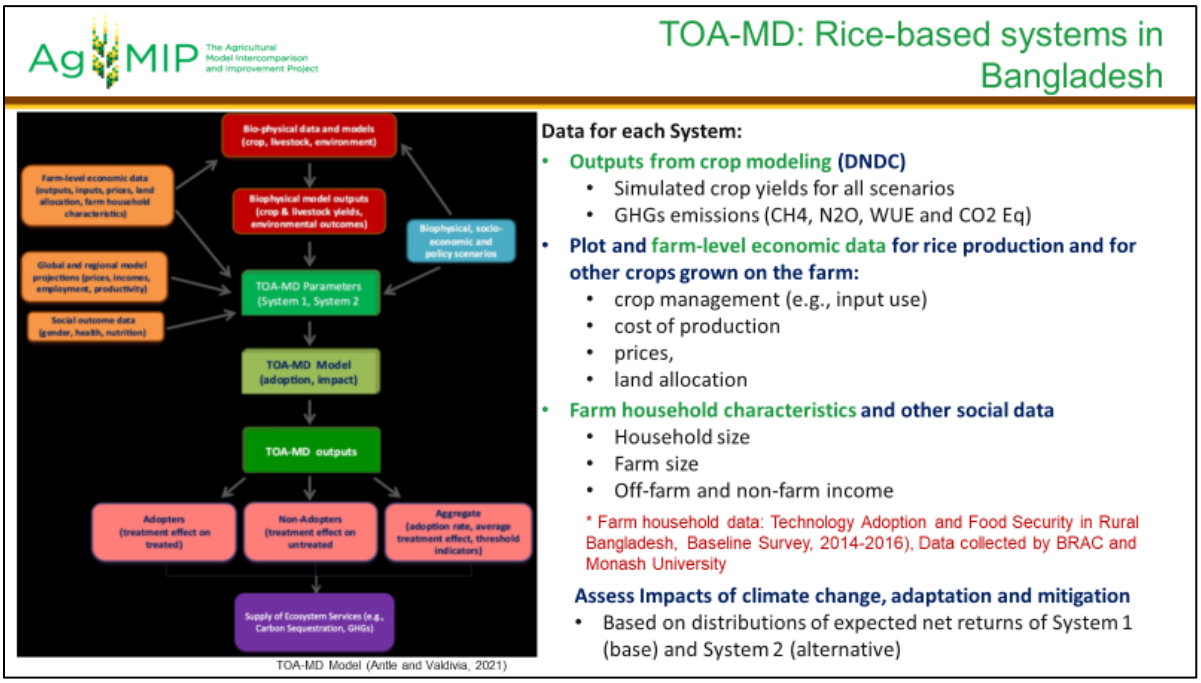
Finally, he concluded his presentation by highlighting the Tradeoffs between socio-economic and environmental outcomes:

Future hot conditions (climate XP) reduce farm net returns and increase poverty rates in most sites (there are some that gain from CC) and increase GHG emissions. However, a less warm future climate may have small positive impacts on farm income.

Adoption of Conventional AWD or SRI-AWD under current or future climate show strong reductions in GHG emissions like methane and CO2eq. N2O emissions vary across sites and farm types (small vs large). Water requirements for irrigation are reduced.

Both Conventional AWD and SRI-AWD show potential co-benefits in reducing GHG emissions and increasing income and reducing poverty rates in the region (win-win outcomes). SRI shows the larger benefits. These two systems are likely to be more resilient to CC compared to conventional continuous flood systems.

However, in practice, there are factors limit the full benefits of AWD and SRI systems (e.g., access and control to water).



TOA-MD Model (Antle and Valdivia, 2021)

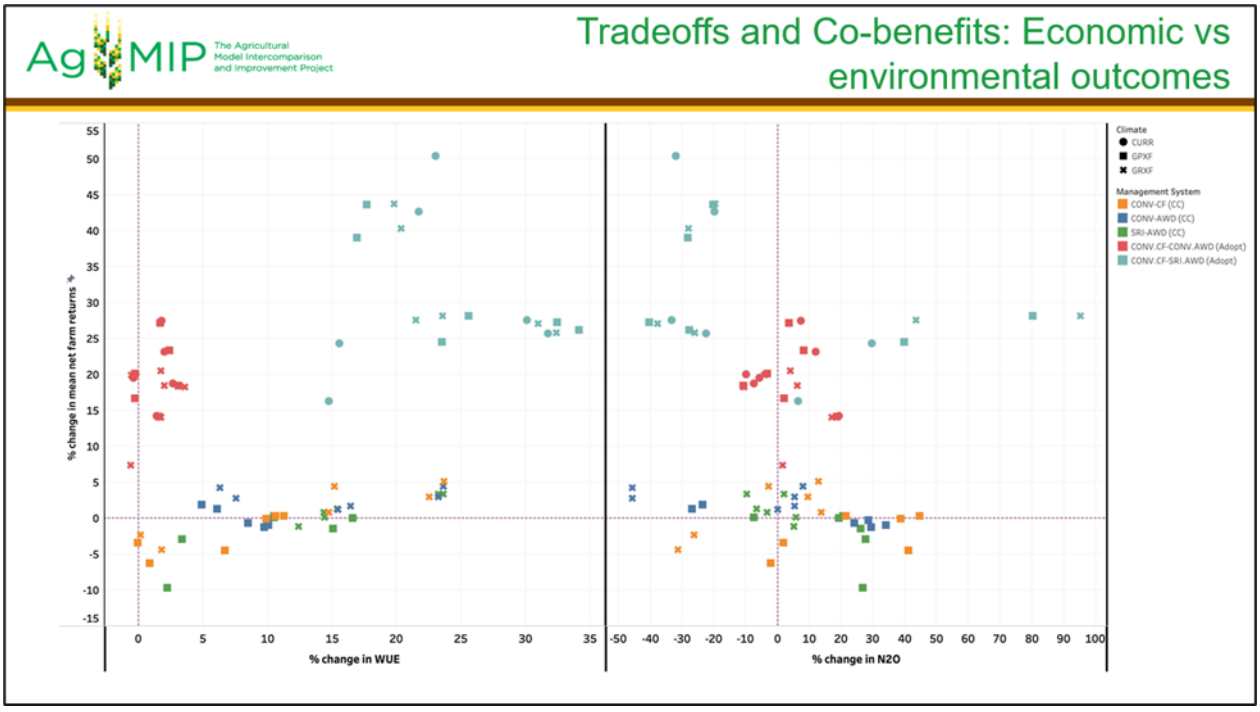
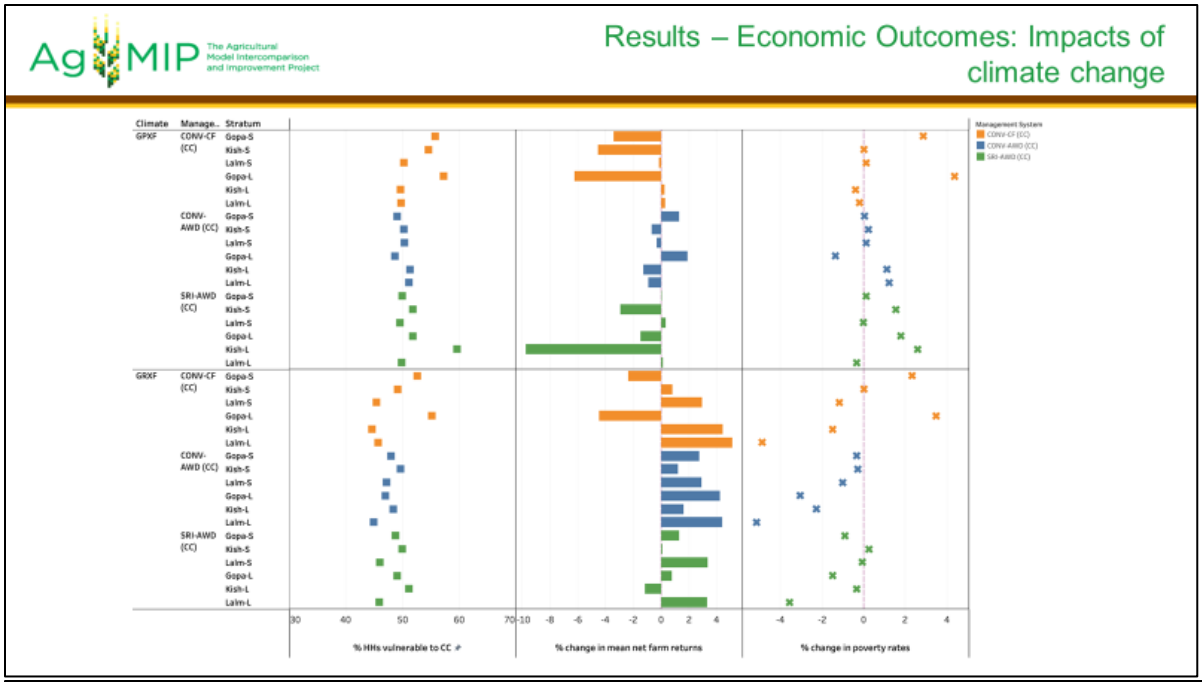
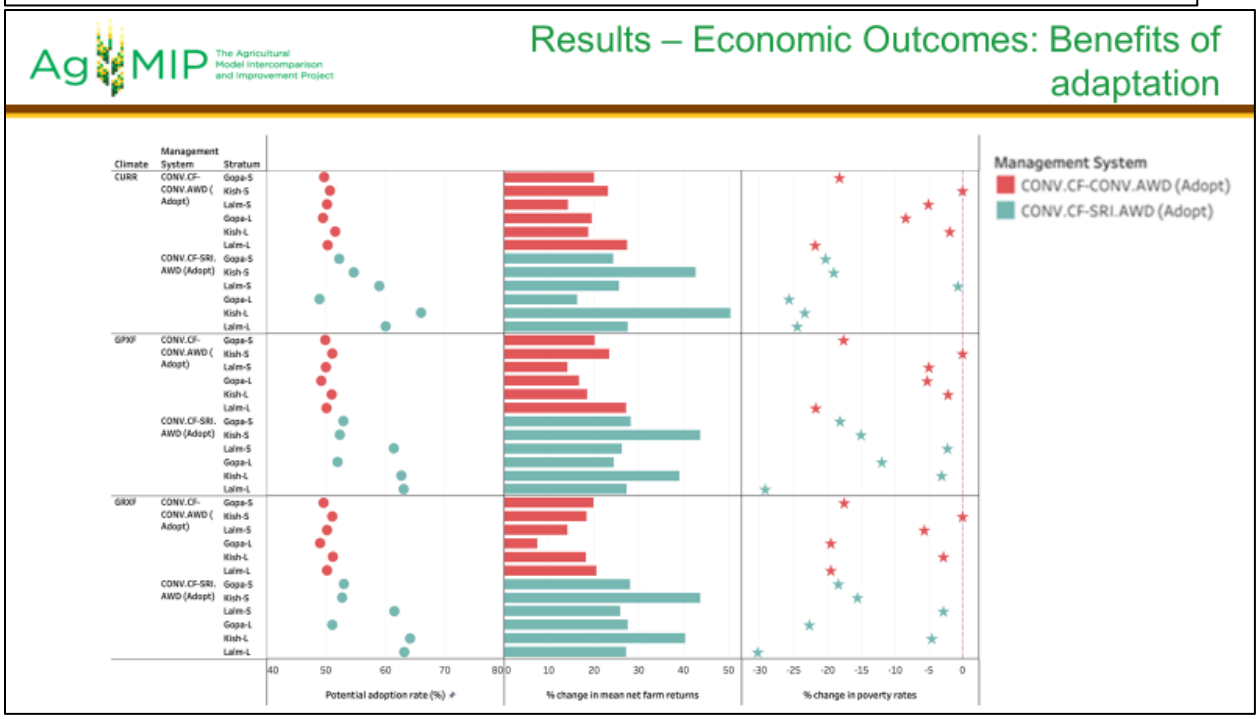


Figure . Tradeoffs between socio-economic and environmental outcomes





Guest Presentation:

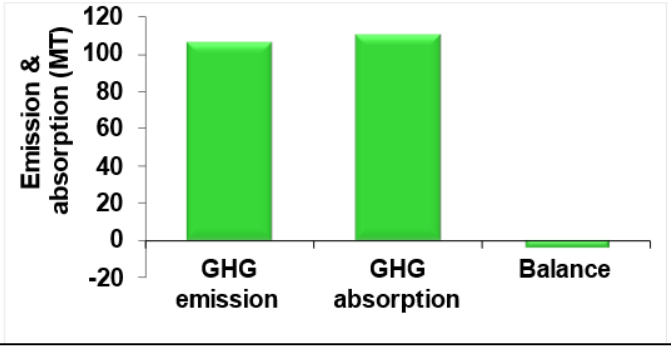
Dr. S.M. Mofijul Islam, Senior Scientific Officer, BRRI

Dr. S.M. Mofijul Islam, Senior Scientific Officer, Soil Science Division of the Bangladesh Rice Research Institute (BRRI) made a guest presentation titled Alternate Wetting and Drying and Carbon Absorption by Rice Plant. He informed the audience that this presentation does not belong to MAC-B project activities this is the activities of Soil Science Division of BRRI with

direct field measurement data. He started by saying that some national and international media are attempting to attribute massive methane emissions to rice cultivation. Last year, a prominent international media outlet published a report on methane emissions in Bangladesh, claiming that Bangladesh is a major source of methane emissions and identifying three sources: rice fields, gas fields, and landfills. But the big question is that these types of sources are available in our neighboring countries, such as India, China, and Pakistan, and they have personally identified Bangladesh, so now is the time to address this issue in case our food security be compromised. Food security is directly or indirectly correlated with rice security; Bangladesh is self-sufficient in rice; however, we face multiple biotic and abiotic challenges, such as an increase in climate sensitivity and the occurrence of natural disasters. For this reason, we must produce more rice on less land in order to feed the expanding population. Nonetheless, rice cultivation has been identified as a significant anthropogenic source of greenhouse gas emissions. Likewise, rice cultivation consumes a comparable quantity of carbon dioxide, and the balance is nearly zero or occasionally positive or negative.

Emission vs Absorption

GHG	Emission (kg/t rice)	Emission (kg/ 50 Mt)	Emission (Mt)	CO_2 eq (Mt)	CO_2 absorption (kg/t rice)	absor ption (MT)
CO_2	665	33,250,000,000	33.25	33.25	2200	110
CH_4	53	2650,000,000	2.65	66.25		
N_2O	0.5	25,000,000	0.025	6.625		
				106.125		



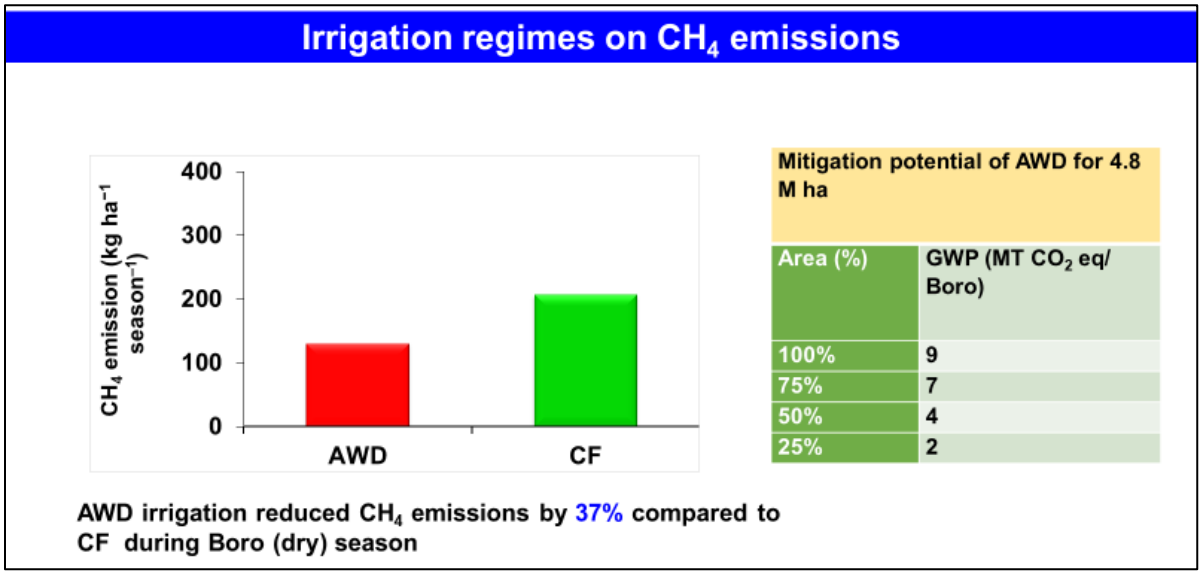
Source: Haque et al., (unpublished data)

Although we have some popular technologies but we could not get any carbon credit by using this technology wetting and drying and urea deep placement. So we have to raise this issue in the global climate sense from now the some features of major greenhouse gases everybody knows the issue so it is better to skip this presentation this slide

He then explained why AWD is so much popular in South Asian countries. because it improves water use efficiency and saves 25 to 30 fuel cost. It does not decrease rice yield rather it increases. AWD increases fertilizer use efficiency particularly sulfur and zinc. It improves rice root morphology and physiology, it enhances soil uerase activity and increases oxygen concentration in the soil also increase nitrogen content in the rhizosphere soil because of maintaining some aerobic spell. Finally, it is carbon friendly technology due to significantly reduce global warming potential compared to conventional practice.

Using closed gas chamber technique, Gas sample was collected using a 50 ml air-tight syringe with a 3-way stop cock once a week at 15 min intervals (0,15 and 30 min). Gas concentration was measured using GC Analyzer (Shimadzu GC-2014, Japan). Emission rates was determined from the slope of the linear

regression curves of CH4 and N2O concentration against the chamber closer time and expressed as mg m-2 d-1. Then he talked about effect irrigation regime on methane emission, AWD irrigation significantly reduced cumulative methane emission by 37 percent compared to continuous flooding irrigation. If AWD technology adopted in 4.8 Mha in boro rice area about 9 Mt carbon dioxide equivalent could be mitigated if we extrapolate this technology at least in 50% boro area mitigate about 4 Mt carbon dioxide equivalent GHG emission during season boro season.



To conclude his deliberation, he said that AWD practice showed comparable rice yield with CF irrigation under safe AWD principle and AWD irrigation reduced about 37% GWP over CF condition. Rice cultivation consumes more CO2 than is emitted. Therefore, rice cultivation does not pollute rather it clean the atmosphere.

Stakeholder engagement and discussion:

With the permission of the chairperson, Dr. Jatish Biswas actually, I like to talk regarding the presentation of Dr. Apurbo Chaki. They are using the DNDC model, and they have calibrated and validated the result, but what I have seen is that the calibration result was almost around 15 percent error, so I think they should recalibrate the model before validation because you know the DNDC model is very much sensitive to organic carbon and soil texture so please take care of those issues; otherwise it will be a misleading one. Dr. Apurbo thanked Dr. Jatish for his question and replied by saying, "I think the normalized RMS, if you see the survey data, there is high variability in the grain yield, as well the normalized RMS for the calibration dataset was around 15 percent considering the high volume of data we believe that the normalized RMS of 15 percent is within the acceptable range for any model calibration and validation for grain yield to go for the scenario analysis. The data is not like the experimental data sets, so there is very high variability in soil texture, management, and estimated grain yield.

Dr. Jatish said, "So I think 15 % of a normalized RMS, we believe that's the acceptable range, but to go for the scenario analysis, that's okay what I wanted to mean to meet DNDC model to organic matter content, yes and texture they look especially the clay content so you can divide the country based on soil texture it will give more robust result than as a whole. Dr. Apurba thanked Dr. Jatish and agreed to consider his suggestions.

Dr. Asaduzzaman, who could not join the meeting physically, asked a relevant question based upon the last two presentations directed to Dr. Roberto, in particular, to potentially respond to the question because his question is about the interface of modeling and policy and markets and what these things mean for these systems. so the question that Dr. Asad also asked why AWD which is known for so many years has not been accepted by farmers whereas the answer lies in the nature of water markets in which no matter what water is applied, the farmer has to pay the same price by water area which was discussed in the last presentation and is a very valid point. Hence, he asks where the incentive is he also asked SRI is not practical as it involves co-management by farmers as a group. Dr. Timthy added, "I assume that he's assuming that this is around the management of seed beds or of organic matter management and that group management is hardly practical in the context of Bangladesh, so the suggestion that he brought is that modeling should include water market characteristics or perhaps assumptions around cooperative management by communities and he asks if this has been done or could be done in economic modeling.

Dr. Roberto gave it a short clue to answer the many aspects there, and he said, "I totally agree. I mean, sometimes, even though we try to represent reality with our models, that was a comment at the beginning. I think you said the team right simulation service simulations and depending what you enter as input decides what you what we get as outputs; the approach that we follow will it's basically trying to link climate, crop in some cases livestock modeling and economics as an integrated approach to assess what would happen with farming systems if they have let's say a shock it could be climate change could be a new technology a new probability and of course there are things that we cannot model like in the crop models have some issues for example incorporating pests and diseases to predict yields so there is some bias there likewise, in economic modeling there are also teams that we cannot model like human behavior although there is now a exciting branch of the economics looking at behavioral economics and how behavior may influence adoption for example but there are things that we cannot model or incorporate in a model approach like the ones we are doing so aspects for example as whether farmers have access or control to water right it's things that are difficult to model we can make assumptions and in terms of what does that represent and how farmers use water or irrigations whether they have access to irrigation things like that but other aspects in terms of factors that may limit or what we call barriers to adoption might be difficult to incorporate in some cases so the way that we like to interpret this kind of results is what we are showing is a potential adoption rate where we may not include all the barriers or limitations for adoption but this approach is one of the few that exists that predicts a

potential adoption rate which is based on expected returns so basically we have a base system that produces expected returns to farmers so farmer say with my current system let's say I earn 100 per hectare and then with a new system the Spectator tool says you are going to get 120 dollars so farmers make that rational choice that okay I'm gonna be better off with that new system so we adopt and that's the process that we follow to estimate a potential adoption rate on a population of farms but I agree there are some factors that limit that that adoption and in some cases we can do other types of analysis like a market analysis in terms of water right in some case we've done a life cycle analysis where we go further in terms looking at the value chain to see how things improve how what are the feedbacks in terms of prices and to create an incentive for farmers but the basic approach is that looking at those distributions of expected returns in system one we call system one and system two and not only that but this approach also allow us to look at what are the consequences of that adoption process meaning we have in a population of farms now we have adopters and what are the potential outcomes for each one of those meaning those may emit more greenhouse gases those systems system one and those the system two may emit less greenhouse gases and then in the aggregate these will be different as well so we can model that with this approach and I think this is what we can provide to to policy makers to see. You have this management system or you have this new technology this needs new crop variety and this is the potential

adoption rate and these are the potential sequences or impacts and then we can identify; but what are the barriers for adoption and then that's where we can put investments on how we change that how we remove those barriers with the modeling we can do many other things like put subsidies put taxes look at sensitivities in terms of investments that farmers would have to do those kind of things but those outputs should be helpful to decision makers to look at so this new technology or this new management or these new crop variety shows that a potential for benefits or to benefit farmers, a population of farmers so let's identify what are the next steps what are the barriers for adoption and invest on those that's the kind of information that we want to provide and likewise with climate change we know that there will be gainers and losers but then trying to identify adaptation strategies for decision makers to invest on or create the incentives like markets for example for farmers to adopt those adaptation strategies so that's the kind of information that we want to provide with this this project. I wonder if that answers the question.

Dr. Asad thanked Dr. Roberto for trying to explain, in broad terms, I do not contest much of the scientific evidence for or against AWD or SRI or the various types of organic management and all these kinds of things; I do not contest that. Still, after all, when we present the evidence to a policymaker, he would be asking. Hence, what shall I do? The answer lies very simply, a popular idea, but AWD or SRI in the context of Bangladesh he will those who know the water market here; the irrigation water market is basically private water market with shallow tubewells as the main equipment, and the payment is by area; you provide me water for the whole season-- I pay you this amount for so much of area no matter what. So I have no incentive to conserve water because I have already paid the water seller. So the best solution that can be if you want to minimize or lower water use through AWD, of course, training and demonstration and all of these you will have to be there, no doubt about it and when we talk to the Upazila Agriculture Officer (field level extension) or even some of the farmers some they do know about AWD but the next question is so why shall we have to pay the same amount at the end of the season. Hence, what do they do are they don't bother about it? Now if we tell them that okay, you have to pay, say some less money if you want to lower your water use, okay he agreed but the water seller would not agree because then his income ffalls so how can we compensate, I mean there are instances in Latin America and some other places in China and also in some places in India where there are things called payment for ecosystem services, if you conserve water that's a kind of ecosystem service and under this climate change scenario whatever various SSPs and RCPs whichever you look at it conserving water is a major issue because that becomes problematic in most places so if you do that if you compensate the water sellar in some way or other why you would do that had to be found out and though the name seems exotic payment for ecosystem services in Bangladesh we do actually practice that in case of fishery you see in case of Hilsa fishry and now the week or about two weeks all the fishermen would refrain from catching Hilsa fish and for that they are paid in kind so much of water so much of edible oil and so much of other things. However, there are management problems with that, but in principle, that is already accepted and practiced in Bangladesh, so something like this will have to be done in the case of AWD. SRI is a different ball game altogether because it's not simply seedbed but for water management, the levels of the various fields will have to be at the same level or things like that. So that's why SRI becomes more difficult in the farming community, but AWD certainly can be done if you can provide the proper incentive, and that's what I am telling you about. If we provide the incentive, what would be the result? If we don't provide the incentive, what would be the result? If we can put that up to the policymakers, they would be interested in it.

Dr. Roberto agreed completely with what Dr. Asad said. In fact, when he visited Bangladesh in September last year, Dr. Ghulam Hussain took him to visit some farms and talked to one farmer that had tried different managements, including SRI and AWD. He said, for example, concerning AWD he would like to

have AWD, but the problem is that he didn't have control over water. So the water is one of the issues. Dr. Roberto said, but for example, Dr. Hussain told me that there is a project that they're working on ways to improve these conditions in some parts of Bangladesh in terms of the market water and but that's the kind of conversation that we need to have, and that's where these model results hopefully will help to see benefits and trade-offs between different types of management and not just rice there are other crops. In the slide that Rajibul presented one of the first slides showed that for most of these farms, rice contributes to farm income between 35 in some cases, it's a little bit more but in average it's 35 to 40 percent, but then they have wheat, pulses, maize other crops. So we also need to be aware of that, and regarding ecosystem services, that's also been done in some places. By the way, our modeling approach, our economic model, can estimate the potential also the potential economics of ecosystem services in a region. Hence, I agree with your statement. Thank you, anybody, in-house.

Dr. Faruque made some comments on all of the presentations adding, "I can realize that AWD is the solution for methane emission or GHG emission; Dr. Mofijul Islam has already shown in his presentation that in the AWD system, there are some problems that mean there is some barrier due to that this type of technology not accepted at farmers level so far. Although I have less knowledge of rice farming regarding methane emission, rice growth stages might have some influence on methane emission; maybe at the booting or flowering stages, rice emits higher methane. AWD follows throughout the growth stages of the crop, so if there is some data on the methane emission by the growth stage of rice, then that would be helpful for us as researchers. Besides, varietal selection might have some genetic potential, and the variety those are less responsible for methane emission. In the morning session, Dr. Khalequzzaman mentioned some technology that may be in the pipeline of BRRI. They are working on reducing air and aerenchyma cells in rice plants, so this type of attempt may be helpful for future respiratory development, which will be fit for the future climates and reduce methane emission so the AWD system is already established through all of the presentations that it is a promising technology so as a research organization how could BRRI can take the initiative to resolve those barriers like pricing of the irrigation water or like that so in that: cases may be BRRI may take initiative to the responsible authority or resolve these issues.

Dr. Sohela Akhter thanked the MAC-B team for taking the time demanding-project and thanked all the presenters for the valuable project findings. Then she made some suggestions; "as I understand the project will primarily focus on mitigation and adaptation for benefits of sustainable boro rice management, I would suggest a few more simulation options to study in the future, maybe in the next phase of the project or the feature project like considering simulating cropping systems that are boro - transplanted aman or wheat – mung bean- transplanted aman rice or mustard-boro-t. aman rice, rather than focusing on a single rice crop as we cultivate several cereal crops for food and nutrition security, consider intensifying the rice-based system that will ensure nutrition security and be good for soil health, like the rice pulse system. As the simulation modeling requires advanced knowledge and skill, I would appreciate it if the project also focuses on capacity building of Bangladeshi scientists through training Ph.D. post-doc etc.

Professor Adbul Kader, National Senior Lead Agronomist, FAO, thanked all the presenters for their nice presentation and congratulated them for their wonderful work; at the same time, He thanked the organizer for organizing this wonderful event. He then added that "We understand that under these current climate change context, this workshop is concerned about the issues which are the result of greenhouse gas emission, and we are concerned about our cropping systems and how these cropping systems or farming systems are contributing to GHG emission and particularly with this project what I understood in this modeling trial we would like to make some future initiative so that we can take proper agronomic management practices for our crops by having these core benefits of yield increase, maybe

water use efficiency, fertilizer use efficiency, and also at the same time very notably by minimizing the greenhouse gas emission.

I have a few very quick questions. So first one is whether you considered not the amount of precipitation but the pattern of the precipitation, like the changes like erratic rainfall that we are experiencing in Bangladesh, and this is very critical impacting agricultural systems, so I would request that you can consider this issue. The second question is to Dr. Apurbo and also with this socio-economic study in both the cases, you have shown that this alternate AWD and also SRI you compared all the time with continuous flooding. I am wondering what you mean by continuous flooding and do we have continuous flooding in the farmers' fields; to my understanding probably, this is not the practice in the farmer's fields, at least in the majority of the fields, except in low-lying areas you get continuous flooding but in the other areas like you consider during February, March, and April when you don't have any rainfall people even they cry for irrigation water. It would be better if you considered the farmer's practice and as far as I know the farmers practice during the boro season in many areas this is not continuous flooding so when you compare this one, please consider that thing and another point is like in some cases you have shown that in case of methane and nitrous oxide emission, there is huge variability among the sides so did you look at what are the reasons because of this high variability among this, is it only because of the treatments you used or there are some other factors like agroecological factors or soil factors which can influence this one. So this is my concern about this study otherwise this is wonderful.

He thanked Dr. Mofijul Islam for his nice work and presentation and congratulated him for his wonderful publications. He added, "You have shown that with this AWD technology, we can tremendously minimize the greenhouse gas emission in rice; that is a very good answer for the people talking about the negative effect of rice cultivation in greenhouse gas emission. Then he asked, did you ever compare GHG emission in the case of rice to other crops so that one may argue that it's not only rice; rice is much better than some other crops?

Finally, he said we heard about many technologies, and these are very effective in terms of yield benefit in terms of water efficiency and some other things; maybe the GHG emission, but now we need to think about how to get these technologies into the field so that farmers adopt it and they accept it then only we will get those benefits.

Dr. Ashraf, Professor of Animal Nutrition at Veterinary and Animal Science University and a member of the GRA who came from New Zealand last two years back, commented that the MAC-B project is a flagship project of GRA; we know that there are a lot of technologies which can reduce the greenhouse gas emission, but the problem is that the policy level implementation. So I would like to request all of the Authority regarding this project that we need to collaborate with the policy level people and make the rules and regulations as an Act for the farmer's level; otherwise, it is very difficult to implement this type of technology in the field level, and it is it would be very difficult to minimize the methane or greenhouse gas emission. I request the Authority that you collaborate with the policy level people and DAE or other stakeholders.

Synthesis, reflections and next steps

The Session chair requested Dr. Timothy Krupnik to reflect on the roundtable and the way forward. Dr. Timothy started by saying, "Well, I think that's a lot to respond to all very good comments; it's impossible to address the depths and breadth of comments the last two colleagues provided. Although I think particularly the last point is valid and around the importance of actually fostering approaches that move this work into actual use, perhaps through collaborations with extension or policy and so on, which is duly noted. This MAC- B project was essentially a small pilot project, and this work was done over, I think,

in practice less than 15 months, 12 months, give or take, intensively again with existing rice-based data sets that we had from the field; hence the focus on rice. The points that were raised with respect to modeling cropping systems by two colleagues I think are very valid and very important; we did not address that though in this preliminary work, but it is important to note that yes, indeed, if you want to adapt and save water and if you're going to mitigate against greenhouse gas emissions then potentially looking at options to shift into alternative crops and away from rice may be something that is worth investigating in further studies and has a solid justification and approach notwithstanding that must also be balanced with respect to the very valid preoccupation that we have in Bangladesh of maintaining national food security and stocks of rice that is very important politically and needs to be recognized.

A few comments were made with respect to the perhaps unusual climatic conditions that we're experiencing right now, and I've also noticed this over the last few years; what the work has done, however, has focused on current conditions based upon existing models that simulate current conditions and also futuristic conditions looking very far into the future. Although these issues concerning intense precipitation events are important and worth addressing, that is again duly noted. I want to make just one last comment, though, which I think is an important observation; again, I commented earlier that I've never met a farmer who says I am an AWD farmer, nor have I met a farmer who says I am a urea deep placement farmer or an SRI farmer or any other of the categories that we as researchers often place on farmers. I do think that in a number of locations in Bangladesh we have AWD as being applied but not because farmers want it but because of logistic problems and failures in how water is distributed to farmers and when they are able to access water that however is not alternate it's not what I guess I should say is scientific alternate wetting and drying as has been researched by colleagues at BRRI and that a range of different international institutes that approach is around the strategic reduction of water to the crop at particular times when rice is phenologically less susceptible to water stress and that means primarily during the vegetative stage and before booting and that is it's a precision approach to water management and not necessarily a reflection of just overall drought but having said that in the model comparisons, we did choose to go with an assumption around continuous flooding which is at least from a farmer's perspective. I think, in many cases, what Boro farmers would prefer to have but your point around the feasibility of that in practice and the problems around water distribution. I think are very noted and important but I do want to distinguish that importantly and I think our colleagues from BRRI will agree that a lack of water does not mean alternate wetting and drying these are two different things; alternate wedding and drying is a well-managed system of water and irrigation frequency but not drought and not a lack of water. So I've again said more than I promised that I would, and I also recognize that it's Ramadan and we're 30 minutes over schedule, so I want to move us towards completion. I hope that this was useful and certainly, by the debate and the discussions that we've had, we've managed to do one thing that's important in science, and that is to stimulate your critiques and your comments and your suggestions and to get all of the participants to think and to give a range of important suggestions around what could be done next.

I think we've also been successful in indicating that, generally, there's an interest in seeing work like this continue and this is something we will very happily take back to our colleagues at ACIAR and suggest for potential work moving into additional projects and around again looking at a cropping systems-based approach and not just a rice-based approach that also needs to be linked very well to policy is what will we do next the team of scientists that were involved in this work this again these are preliminary results we are writing it up currently into a report that will be made public after ACIAR's approval that report I hope will also find its way in streamline form into the peer-reviewed literature but also will be distributed to all of you and to colleagues that are interested in seeing the results of this work communicated in simple form and easy to understand formats for policymakers. Moving us to a conclusion, I want to thank everybody for staying and giving your comments and heartfelt debate. Science only moves forward if we

disagree with each other and we challenge each other around the data that are shown. It's always positive when we have discussions such as this and modeling in particular because it is about scenarios really, the importance of modeling is to stimulate discussion. I think we've been successful in stimulating discussion and debate here and we'll take that in terms of the next steps and bring this information back to ACIAR. I'm assuming Dr. Pratibha is still listening and that there is an interest in this work I'd like to thank again our colleagues at BRRI for hosting this today and I'd like to thank also our colleagues at BARI and at BRRI and that have generally been involved in this work I'd like to thank Dr. Apurbo and Rajibul for their work in engaging and I'd like to also thank Sonali and Roberto and Eric and others who are with Columbia University with NASA with NYU and with Oregon State University also for engaging in this work with that I think we can say we will close and keep you informed if there are next steps and I will pass for the formal final closing to our colleagues from BRRI.

Wrap-Up and Closing by the Session Chair

Dr. Khalequzzaman, as the session chairperson, thanked all the presenters who presented virtually and physically here and those who attended the roundtable. He added, "Actually, they all made various informative presentations and mostly the model-based result which needs to be validated, and they rightly mentioned *that these are simulation outputs of these models. Therefore, we need to find out what is the simulation study about and see the confidence level of the predictions. It should be more than 95 percent;* this model is perfect or can be applied in future implications. The other thing that Dr. Kader said about precipitation sometimes increasing and warmer and cooler that pattern is fine, but for the most part, the precipitation also increases; that's my concern how it's predicted these; I don't know that's whether models are defective or need to be checked or whether it really predicted these things and other things the agriculture sector. Dr. Timothy said 21.5 percent contribution comes from the agriculture sector, but our findings at BRRI say it is 14 percent; it's almost all right for rice. The most important thing in our case is food security; we do not want to lose in any situation, and we don't want our country to face any food insecurity. We must ensure output security anyway; that's why whatever we think are applying, we must also think about rice security, not only food security alone, but our rice security.

If rice security becomes wrong, then our political security also be unstable, so we must think about the security of rice. In this Workshop we discussed many mitigation options, including AWD, which is a nice technology; everybody knows these things, but the reality is that Dr. Mofijul mentioned some social problems and some adaptation problems. There are other technology like urea deep placement also that reduce greenhouse gas emissions and other things also; we look through the advancements like low water consuming variety as well as the low carbon dioxide emitting and high temperature tolerant varieties we are trying to develop, we are searching this germplasm for these things, and we got some of those. Develop a variety with reduced aerenchyma that can mitigate a large amount of CH4 emissions. We hope to find a suitable variety to mitigate the GHG emission, developing high-yielding varieties with these special characteristics, and anyway, I should conclude here.

Finally, the results shared here are very interesting and impressive, but it needs to convince the main policymakers so that they support these issues. In my sense, this meeting is not enough to find the solution to everything, and we need further long-term commitment with higher policymakers. Finally, I should thank the organizers for selecting BRRI as the venue and the participant from home and abroad, CIMMYT, Columbia University, New York University, Oregon State University and other partner organizations, for sharing your knowledge and experience. Thank you very much, everybody, for your patience in hearing. I should say this is the end of this Roundtable meeting. Thank you very much.

List of Participants

MAC-B Stakeholder Roundtable Workshop

Wednesday, April 05, 2023
Meeting Room, Training Complex (First Floor)
Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh

Sl	Name, Designation, Organization	Email	Phone Number	Physically/ Virtually present
1.	Dr. Pratibha Singh, Regional Manager in South Asia, Australian Center for International Agricultural Research (ACIAR)	Pratibha.Singh@aciar.gov.au		Virtually
2.	Ms. Chetali Chhabra, Assistant Manager, Australian Center for International Agricultural Research (ACIAR)	chetali.chhabra@aciar.gov.au		Virtually
3.	Erik A Mencos Contreras, AgMIP Project Coordinator, Center for Climate Systems Research, Columbia University	eam2215@columbia.edu		Virtually
4.	Mr. Md. Abeed Hossain Chowdhury, Project Manager, Crop Zoning Project, Bangladesh Agricultural Research Council (BARC)	abeedchowdhury@gmail.com	01819686449	Virtually
5.	Dr. AFM Tariqul Islam, Principal Scientific Officer, Agricultural Engineering Unit Bangladesh Agricultural Research Council (BARC)	tariqul.islam@barc.gov.bd	01727700625	Virtually
6.	Dr. Sohela Akter, Director (TCRC), Bangladesh Agricultural Research Institute (BARI)	dir.tcrc@bari.gov.bd	01922242737	Physically
7.	Dr. Faruque Ahmed, Principal Scientific Officer, Plant Physiology Division, Bangladesh Agricultural Research Institute (BARI)	faruquebari@gmail.com	01911760503	Physically
8.	Dr. Golam Wahed Sarker, Consultant, Water conservation project, Bangladesh Agricultural Research Institute (BARI)	gwsarker@gmail.com	01715077893	Physically
9.	Dr. M.A. Yousuf Akhond, Director (Research), Bangladesh Agricultural Research Institute (BARI)	a_akhond@hotmail.com	01715000633	Physically

Sl	Name, Designation, Organization	Email	Phone Number	Physically/ Virtually present
10.	Apurbo Kumar Chaki, Scientific Officer, Bangladesh Agricultural Research Institute (BARI)	a.chaki@vqnet.av	01705338306	Physically
11.	Dr. Md. Mazharul Anwar, Chief Scientific Officer, On-Farm Division, Bangladesh Agricultural Research Institute (BARI)	anwar-sci.bari@gmail.com	01916847240	Physically
12.	Dr. Mohammed Asaduzzaman, Professorial fellow at Bangladesh Institute of Development Studies	asaduzzaman.m@gmail.com	01711595066	Virtually
13.	Dr. Md. Abdul Mannan, Meteorologist, Bangladesh Meteorological Department	mannan_u2003@yahoo.co.in	01715199017	Virtually
14.	Md. Bazlur Rashid, Meteorologist, Strom Warning Centre, Bangladesh Meteorological Department	Email: bazlur.rashid76Sgmail.com ;	0 1716-762472	Physically
15.	Ms. Nayma Baten, Meteorologist, Bangladesh Meteorological Department	shuvra.swc@gmail.com	01727226853	Virtually
16.	Tausif Ahmed Qurashi, Senior Program Manager Climate Change Programme, Bangladesh Rural Advancement Committee (BRAC)	tausif.qurashi@brac.net	1730347052	Physically
17.	Dr. Mohammad Khalequzzaman, Director Research, Bangladesh Rice Research Institute (BRRI), Joyebpur, Gazipur-1701	Email: zamanmk64@yahoo.co.uk, directorresearchbrri@yahoo.com, dr@brri.gov.bd.	01715752595	Physically
18.	Dr. S.M. Mofijul Islam, Senior Scientific Officer, Soil Science Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur.	mislambrri@gmail.com	01718160966	Physically
19.	Dr. Md Sazzadur Rahman, Principal Scientific Officer, Plant Pathology Division, Bangladesh Rice Research Institute (BRRI)	sazzad_73@yahoo.com; sazzadur.phys@brri.gov.bd	01722210429	Physically
20.	Dr.Umme Aminun Naher, Principle Scientific Officer, Bangladesh Rice Research Institute (BRRI), Joyebpur, Gazipur-1701	Email: naher39@gmail.com; uanahar.soil@brri.gov.bd	01913151914	Physically
21.	Dr. Aminul Islam, Head and Chief Scientific Officer(CSO), Soil Science Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur	Email: aminbrri@gmail.com	01843998570	Physically

Sl	Name, Designation, Organization	Email	Phone Number	Physically/ Virtually present
22.	Md. Saiful Islam, Principal Scientific Officer & Head, Agricultural Economics, , Bangladesh Rice Research Institute (BRRI), Joyebpur, Gazipur-1701	saiful.econ@brri.gov.bd; msislamecon@yahoo.com	01912540640	Physically
23.	Dr. Md. Shahadat Hossain, Chief Scientific Officer (CSO) and Head, Training division, Bangladesh Rice Research Institute (BRRI),	sahadat-brri@yahoo.com	01718363685	Physically
24.	Dr. A.T.M. Sakhawat Hosain, Principle Scientific Officer, Soil Science, Bangladesh Rice Research Institute (BRRI)	sakhawatbrri@gmail.com	01718261858	Physically
25.	Niaz Md. Farhat Rahman, Principle Scientific Officer, BRRI	niaz.sust@gmail.com	01912700606	Physically
26.	Dr. Md Abdul Latif, Chief Scientific Officer (CSO) and Head, Plant Pathology Division, BRRI	alatif1965@yahoo.com; latif.path@brri.gov.bd	01715034094	Physically
27.	Md. Amiruzzaman, Computer assistant, Bangladesh Rice Research Institute (BRRI)	mdzaman06@gmail.com	01911676832	Physically
28.	Dr. Akbar Hossain, Senior Scientific Officer, Bangladesh Wheat and Maize Research Institute, Dinajpur	akbarhossainwrc@gmail.com	01713163381	Virtually
29.	Mr. Ahmmed Zulfiqar Rahaman, Hydrologist and Climate Change Expert, Climate Change and Disaster Management Division, CEGIS	azrahaman@cegisbd.com; azr.wre@gmail.com;	01534902612	Virtually
30.	Tamim Al Hossain, Climate Change and Disaster Management Division, CEGIS	cetamim@gmail.com	01912-807760	Virtually
31.	Dr. Md. Zahidul Haque, Senior Agriculturist, Centre for Environmental and Geographic Information Services (CEGIS)	Md. Zahidul Haque <haque0609@gmail.com>	01718640609	Virtually
32.	Dr. Timothy J Krupnik, Associate Director, Sustainable Agrifood Systems (SAS) Program, Asia, CIMMYT	t.krupnik@cgiar.org	01755568938	Physically
33.	Dr. Sk Ghulam Hussain, Senior Consultant, CIMMYT-Bangladesh	g.hussain@cgiar.org	0 1715885608	Physically
34.	Dr. Moin U. Salam, Senior Consultant, CIMMYT-Bangladesh	moinsalam1@gmail.com	01855871938	Physically
35.	Md. Washiq Faisal, Research Associate, CIMMYT-Bangladesh	m.faisal@cgiar.org	0 1740603385	Physically

Sl	Name, Designation, Organization	Email	Phone Number	Physically/ Virtually present
36.	Ms. Fahmida Khanam, Assistant Research Associate, CIMMYT-Bangladesh	f.khanam@cgiar.org	01713409446	Physically
37.	Mr. Mustafa Kamal, GIS & Remote Sensing Specialist, SAS, CIMMYT-Bangladesh	m.kamal@cgiar.org	1717425006	Virtually
38.	Radia Rowshan, Communication, CIMMYT-Bangladesh	radia3094@gmail.com		Physically
39.	Professor Adbul Kader, National Senior Lead Agronomist, FAO	md.kader@fao.org	1724828058	Physically
40.	Dr Sirajul Islam, Chief of Party – Business and Private Sector Development, IRRI-Bangladesh	sirajul.islam@northsouth.edu	01817640355	Physically
41.	Md. Ashraf Ali, Manager-Project Coordination, IRRI-Bangladesh	m.a.ali@irri.org	1714400411	Physically
42.	Dr. Nathu Ram Sarker, Director, Krishi Gobeshona Foundation	sarkernr62@yahoo.com	1711733119	Virtually
43.	Dr. Jiban Krishna Biswas, Executive Director, Krishi Gobeshona Foundation Former Director General, BRRI	biswas.jiban@gmail.com	01711960349	Physically
44.	Dr. Md. Rajibul Alam Ministry of Public Administration	rajibulalam.1828@gmail.com	01886262533	Physically
45.	Dr. Sonali McDermid, Assistant Professor of Environmental Studies, New York University.	sps246@nyu.edu		Virtually
46.	Dr. Roberto Valdivia, Oregon State University AgMIP Regional Economics Co-Leader Oregon State University, USA	Roberto.Valdivia@oregonstate.edu		Virtually

Abbreviations

ACIAR		Australian Center for International Agricultural Research
AgMIP		Agricultural Model Intercomparison and Improvement Project
BARC		Bangladesh Agricultural Research Council
BARI		Bangladesh Agricultural Research Institute
BIDS		Bangladesh Institute of Development Studies
BMD		Bangladesh Meteorology Department
BRAC		Bangladesh Rural Advancement Committee
BRRI		Bangladesh Rice Research Institute
BWMRI		Bangladesh Wheat and Maize Research Institute
CEGIS		Center for Environmental and Geographic Information Service
CIMMYT-BD		International Maize and Wheat Improvement Center

FAO		Food and Agriculture Organization of the United Nations
IRRI		International Rice Research Institute
KGF		Krishi Gobeshona Foundation
MoPA		Ministry of Public Administration
NYU		New York University
OSU		Oregon State University