“Tackling the challenge posed by climate change in the agriculture of Monsoon Asia”

Review Report

General Comments of the Evaluation Committee

The objectives of the program are very clear and relevant. All projects produced very concrete results, which are beneficial to Japan and to the international community. The quality of the academic production is very good, especially if we consider the relatively low number of researchers involved in this program. It was impressing to see that you were able to cover very different scales (field experiment, regional scale, national scale, global scale). The widespread adoption of many of its recommended mitigation and adaptation technologies and practices in Japan is commendable. The contribution of the program to the global effort on greenhouse gas (GHG) mitigation through the Intergovernmental Panel on Climate Change (IPCC), the Global Research Alliance on Agricultural Greenhouse Gases (GRA) etc. is also commendable.

Several projects were able to establish good relationships with national and international stakeholders. The willingness to develop operational solutions and tools is also a strong point of the program.

Some recommendations and suggestions are listed below;

1) Expanding the program's partnerships in target countries to include organization or entities engage in policies, programs, and operations so that there is a better outcome of its international efforts to promote GHG mitigation measures and carbon (C) sequestration. Outcomes can be better ensured if next-user partners are engaged early on in addition to research partners.
2) It seems that teaching activities and the organization of professional trainings are not a priority. However, education is key for promoting GHG mitigation strategies. The organization of trainings for professionals could be an efficient way to promote your innovations. Capacity development and governance should be also considered in future researches.
3) Your projects suffer from a lack of assessment of economic impacts of management strategies. Economic impact assessment should be considered in future works, in collaboration with groups of economists. Your projects could also benefit from the use of multicriteria analysis methods. Some projects focus on the environment, others on the production, but you don’t really analyze the tradeoffs between environmental benefits and impact on production/profitability in any project.
4) Although the impacts of pest and disease are studied in another program, published results of

yield losses due to pests and diseases could be incorporated in your own program to assess climate change impact on crop yields (see recent paper published in Science in Aug. 2018 showing an increase of 10-25% of yield loss due to insect pests). Also, weather index-based crop loss assessment should be considered in the application of the approaches, tools and outputs of the program.

5) Relationships between projects are not always very clear. Several projects partly overlap and some of them could probably merged. We could expect more collaborations between projects in the future as well because a well-grounded assumption of the modeling is very important to make the outputs useful for other users. In addition, clearer delineation of the scope and areas of collaboration/integration of the three sections (mitigation, assessment, adaptation) should be considered. Further, the program should consider integrating the climate change adaptation and mitigation research in NARO in a common framework. The current framework followed by the Institute for Agricultural Environmental Sciences, NARO is a good starting point to consider.
6) The program could benefit from the development of on-farm research activities. Some of your experiments could be carried out directly in farmers' fields, i.e., in real conditions. You could also organize workshops with farmers and collecting firms to share and discuss results of your research activities. In relation to the above-mentioned, developing a portfolio of management option that integrates mitigation, adaptation and productivity options for its target crops would be suggested. There are always cost, benefits and trade-off that are worth considering from the onset to ensure more successful upscaling.
7) From crop management portfolio to landscape, assessing the mitigation and adaptation value of the practices in integrated systems at the village and landscape level would also be suggested (e.g. climate-smart "satoyama").
8) For further improvement of the research, holistic approach with simultaneous assessment on both mitigation/adaptation in terms of sustainability could be supplemented in the future including food security, resilience, ecosystem services, disaster risk managements, etc. Further study on feedback of AgEcosystem to climate system will also greatly contribute to Numerical Weather Prediction predictability, e.g. Sub-seasonal to seasonal forecasts (S2S), Global Climate Models (GCMs) for climate change projections. It is suggested that wide application of long-range forecasts (S2S) against climate variability (extremes) with supporting sharable ICT platform for routine operation of S2S based assessments.

NARO Response to the Comments of the Evaluation Committee

Thank you for your valuable comment.

The research program of climate change in NARO has been globally headed by one program

director, under whom three theme leaders (mitigation, impact assessment, and adaptation) carry out their own research. Additionally, researchers from nine centers/institutes in NARO are participating, and we have established a system that allows them to carry out research on specific regions and crops. We also plan to further strengthen our collaboration with specialists on farm management and Life Cycle Assessment (LCA). Finally, we recognize that the dissemination of our developed technologies within and outside the country is incredibly important, and we plan to proactively establish further efforts to that end while securing outside funding. Below we describe the correspondence in each of the areas in our program.

1) We recognize that collaboration with organizations and groups that are involved in shaping and implementing policies and plans is critical for enabling wide publicization of our developed technologies both within and outside our country. For example, as part of the international collaborative project mentioned in Project 3 below —the "Development of comprehensive rice cultivation technologies that reduce GHG emissions in Asia," (MIRSA-3)—in an effort to push the initiative towards implementation, we plan to use project meetings that will be held in different countries each year to enable opinion exchange between outreach organizations in the hosting country, producer associations, governmental branches, and more.
2) While we recognize that to spread our research results, especially our mitigation technologies, capability building is critically important, the securing a budget for it and the recruiting of staffs themselves are outstanding issues we must address to keep the activity. In 2018, at the GRA Council Meeting, an FAO workshop (Thailand), and a Capacity Building Network meeting sponsored by APEC (Chile), we conducted training on the GHG-reducing potential of the alternate wetting and drying water-saving irrigation technique (AWD). In the future, we plan to cooperate in the capacity building in target countries either through collaboration with international organizations and groups or through the acceptance of training programs mediated by Japan International Cooperation Agency, etc.
3) We recognize that evaluations of economic and environmental impacts of climate change countermeasures are important issues. As we respond in the project subheadings for each of those initiatives, economic (profitability) evaluations are often part of research for adaptation technologies. On the other hand, in our research for mitigative technologies, we have evaluated the impacts only on crop yields, but we do not consider that to be enough. In this program, we constantly consider the importance of the evaluation of the environmental impacts that come with the introduction of adaptation and mitigation measures. For example, water management practices like the GHG reduction technique of prolonging mid-season drainage (MD) and winter flooding are effective at reducing methane emissions and preserving biodiversity, respectively, but we keep in mind that their spread involves tradeoffs with an increase of cadmium

concentration in rice grains and methane emission, respectively. In the future, we will continue to take advantage of NARO's strength—the fact that it has researchers from a great variety of fields—to enhance collaborations with other programs and specialists for farm management and/or LCA. We will continue to devote ourselves to research into countermeasures to climate change, including evaluations of economic and environmental impact.

4) The increase of pest and disease damage associated with climate change is listed as one of the most important issues in agricultural climate change adaptation plan by the Japanese government. NARO is aware of its importance as well. A management support program with pest occurrence prediction models has already been implemented into the cultivation management support system introduced in Project 7. In addition, by allowing grid agricultural/meteorological data to be used in the prediction of the expansion of the distribution range of stink bugs and the predicted outbreak regions of insect-vector viral diseases, we continue to strengthen our collaboration with specialists of the pest and disease research field. Finally, we have conducted joint research with a private insurance company on weather index insurance targeting Southeast Asia (Thailand, Indonesia) using the research results of Project 5.

5) The mitigation (Projects 1-3), impact assessment (Projects 4 and 5) and adaptation technologies (Projects 6 and 7) areas each have one project leader under whom research is collaboratively carried out. Additionally, one program leader carries out progress management for each of these three sections, and information is frequently exchanged among projects. In the future, we plan to further deepen collaborations between areas and to realize the development of a crop model for both impact assessment and adaptation measures and to evaluate the impacts of our cultivation management technologies on GHG emissions.

6) Implementation of our developed technologies in society is an important issue, and for our mitigation and adaptation technologies we have engaged ourselves in the development of techniques at regional centers in NARO to make them easier for farmers to accept. In 2019, a project to verify smart farming technologies all over Japan will begin. In the project, the cultivation management support system, developed as an adaptation technology as a part of this program, is slated to be incorporated into production systems. Additionally, in the international collaboration project MIRSA-3, aiming for the coexistence of rice production and mitigation measures in Southeast Asia, we also plan to implement efforts to disseminate our technologies to producer associations and outreach organizations in the areas. When it comes to the development of adaptation and mitigation technologies, considering the tradeoff between introduction costs and benefits is only natural; however, when simultaneously considering responses to climate change, we also believe it is necessary to take on the development of cutting-edge technologies that can trigger innovation.

7) The regional application of mitigation and adaptation technologies is an important endeavor to

ensure sustainable agricultural production in the face of climate change, and we recognize it to be an important research project for us in the future. Under the Climate Change Adaptation Act established in 2018, adaptation plans are due to be formulated at the regional municipality level; we plan to make use of the research results of this program to support municipalities as they formulate their own plans.

8) The integrated, multifaceted evaluation of our adaptation and mitigation measures is something that the whole of the NARO climate change response program must be involved in, and we plan to proceed with it while asking for the opinions of NARO researchers from various fields as well as external experts. With regards to meteorological predictions that take into account the feedback of the agroecosystem to the climate system, we are undertaking research on simulating farmland climate and crop canopy microclimates, incorporating the paddy ecosystem model to the atmospheric circulation model, and are considering its application to future projections as well. And as for the movement from S2S, Project 5 is proceeding with their research examining the implementation of our models on a global scale. In Japan, the research started in 2018 on the use of second-month information of the three-month forecast provided by the Japan Meteorological Agency.

Section 1: Mitigating global warming in agricultural fields

Project 1 Evaluation of national greenhouse gas emissions and their removal from agricultural soils

The objective of this project is clear (evaluate the national GHG mitigation potential). This project produced several scientific papers published in recognized international journals. It also led to the development of highly relevant modelling tools for calculating GHG emissions under a diversity of management strategies. The tradeoffs among SOC, CH_4 and N_2O deserve attention in the future scenario analysis. There are some recommendations and suggestions as follows;

1) Analyzing uncertainty

As an important part of the work is based on mathematical models, it will be useful to analyze the uncertainty in the model predictions. Several sources of uncertainty may reduce the reliability of the conclusions derived from model simulations; parameter values, model equations, and input variables, especially input variables related to farmers' practices collected at the regional and national scales. Sensitivity analysis is also recommended, and it could be used for ranking input factors and for identifying the most influential ones (see e.g. Lamboni et al. 2009. Field Crop Research 113, 312-320). Further, the project members may also consider adopting an ensemble modelling approach in future works in order to assess the robustness of the GHG emission simulations to model choice.

2) Refining the model

The empirical model for N_2O emission needs refinement to consider soil and crop type, probably it is better using DNDC to simulate N_2O emission from agricultural soils in the future.

3) Assessing mitigation strategies according to several criteria

The group should analyze the trade-offs between the environmental benefits of the proposed mitigation measures and their impacts on crop yields and economic profitability. If the proposed mitigation measures have negative impacts on yields and/or profitability, it is unlikely that the farmers will adopt them in the future. The project members should thus evaluate the proposed mitigation measures according to several criteria, including yields and profitability.

4) Collaborating within NARO

GCMs selected would be consistent with the other sections/projects, e.g. adaptation and assessment.

Regarding N_2O modeling, more sophisticated N fertilizer strategies should be considered. The group studied the effect of N fertilizer dose on N_2O emission, but the dates of application, the number of applications and the type of fertilizer can also influence the emissions. The optimization of the number, dates of N fertilizer application, and type of fertilizer could contribute to a reduction of GHG emission. Collaboration with other programs of NARO could be useful on this topic.

5) Collaborating internationally

The approach of combining empirical and Roth C model in computing N_2O could be shared with other countries and institutions in Asia. In addition, the results of the mitigation scenarios could provide an important guidance to the AgNDC implementation of major rice-growing countries in Asia.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Analyzing uncertainty

We find this comment highlighting the uncertainty in our GHG emission prediction and its causes quite important. We have, to date, worked on the improvement of our model as well as the accuracy of its output through the incorporation of physical and chemical research data on nationwide farmland soil and 1 km-grid weather data to analyze the uncertainty in our model. While we have been able to evaluate the model itself as a cause of the uncertainty in the output to some extent, the evaluation of the input data for our national calculations, especially the evaluation of uncertainty and the sensitivity analysis of farming activity—which you have pointed out—are important subjects for us to tackle in the future. Furthermore, it is a fact that we have far fewer types of GHG emission models comparing to climate or crop models. We

plan to incorporate the ensemble model simulation you have recommended in the future.

2) Refining the model

The current data we have is not sufficient to implement separate empirical models for soil and crop types; we need more actual measurement data of emissions. To this end, we will accelerate to store more data. As for the estimation of N_2O emissions, we are currently developing a mechanistic model to address this, independent from the statistical model.

3) Assessing mitigation strategies according to several criteria

Your comments here are incredibly important in regard to helping farmers understand the importance of efforts to reduce GHG emissions and spreading these measures across farms. We have taken them to heart as important elements of our global warming mitigation technology-related initiatives, (including Projects 2 and 3), as well as the aims of our research as a whole, (including that of adaptation measures). For example, MD —presented in Project 2—has no effect on crop yield and allows farmers to receive the government payment incentives for environmentally sustainable farming. We are currently revising our model to render it capable of evaluating the degree to which this water management technique reduces GHG emissions as part of this project.

4) Collaborating within NARO

As for our GCM, we are advancing our plans in close collaboration with Project 5, and we shall continue working in this manner. As presented in Projects 6 and 7, the use of nitrogen (N) fertilizer in paddy rice cultivation under global warming conditions necessitates a trade-off between yield and quality. The methods used to ascertain the timing and type of fertilizer applied while keeping this trade-off in mind have become a highly advanced agricultural technology. In order to achieve evaluation of GHG emissions that takes all of this into account, we will strengthen our collaborations to include other programs, as in the development of a mechanistic model, etc.

5) Collaborating internationally

We believe our research results and developed techniques can contribute greatly to the reduction of GHG emissions in the Agriculture sectors of Asian countries. As we explain in Project 3, we continue to disseminate information and encourage technology transfer via workshops and capacity building activities made possible by consignment Projects from the Ministry of Agriculture, Forestry and Fisheries and APEC funding.

Project 2 Technical measures to mitigate greenhouse gases from agricultural fields

The project has developed various techniques to increase SOC with reducing CH_4 from rice paddy and N_2O from agricultural soils. The prolonged middle season drainage to mitigation CH_4 emission has been widely adopted, the research on reducing N_2O emission by inoculation with

Bradyrhizobium diazoefficiens in soybean fields is novel and world-leading. The contribution to IPCC national GHG inventory guidelines is unique. In addition, an impressive number of scientific papers have been published in good scientific journals in the project. There are some recommendations and suggestions as follows;

1) Interacting more with project 1

It seems that projects 1 and 2 are independent, but they address partly the same questions. Project 2 could benefit from the modelling tools produced by project 1. For example, models developed in project 1 could be used to assess N_2O emissions in the experiments carried out in project 2 – topic 3. Reciprocally, data produced by project 2 could be used to evaluate and assess the models developed in project 1.

2) Evaluating impacts on production and profitability of mitigation measures

The proposed mitigation measures may negatively impact yields and/or profitability. In this case, it is unlikely that the farmers will adopt such measures in the future. The group should thus evaluate the proposed mitigation measures according to several criteria, including yields and profitability, which are affected by pest and diseases, yield reduction and grain quality, etc.

3) Further analyses

The project conducted an interesting meta-analysis on biochar. Why not on the other topics of the projects? When possible, it is recommended using this technique more systematically in order to synthetize existing data on a diversity of mitigation measures.

In addition, LCA could be more widely applied through projects, especially being linked with footprint analysis.

4) IPCC guideline refinement

Regarding refinement of IPCC guideline, as a global leading institute in agricultural research, pros/cons of IPCC guideline can be reviewed considering the paddy-based agricultural system in Monsoon Asia.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Interacting more with project 1

As you point out, collaboration between projects is essential. There is cooperation between Projects 1 and 2. For example, field data on CH_4 emissions in paddy fields and N_2O emissions from farmland, which is being used to improve the DNDC model, has been supplied from Project 2 to Project 1. We plan to continue and advance such collaborations in the future.

2) Evaluating impacts on production and profitability of mitigation measures

As you point out, yield maintenance is critically important. This project aims to develop GHG

mitigation technologies that maintain yield and quality and improve productivity. For example, prolonging the MD period as a CH_4 reduction technique maintains the same level of yield as conventional water management practices, and we have already begun to spread this technique. We plan to continue to develop and evaluate technologies and techniques like this in the future.

3) Further analyses

We have conducted a meta-analysis (Akiyama et al., 2009) of the N_2O-reducing effects of not only biochar, but nitrification inhibitors and coated fertilizers. We plan to continue these analyses. As for the LCA, we have already made efforts with farmland application of biochar and no-till farming of cover crops, and we have recently embarked on a program for grassland application of livestock waste. Finally, we plan to advance our collaborations with other researchers with regards to a footprint analysis.

4) IPCC guideline refinement

Revision of the IPCC guidelines is currently under review by experts and governments from around the world. Two staffs from NARO have been appointed as lead authors, and they have already participated in four lead author meetings. As they respond to the comments and opinions of reviewers, they contribute to this revision which will be published in May 2019. We will strive to meet the expectations you have outlined for us here.

Project 3 Application of GHG mitigation technologies to Monsoon Asia and international cooperation

The project introduced and developed several mitigation techniques for monsoon Asian countries and has a commendable contribution to international climate change frameworks (IPCC), networks (GRA) and initiatives (4per1000, and ALTENA). The handbook of Monitoring, Reporting and Verification for GHG mitigation is very useful for many countries. Furthermore, future direction is on very right track. There are some recommendations and suggestions below.

1) Evaluating impact on economic profitability

In this project, environmental impacts and effects on yields are often evaluated and compared, but discussion on the impact of mitigation measures on profitability is almost absent. It will be useful to analyze the trade-offs between environmental benefit, production, and economic profitability.

2) Provision of more options to farmers

AWD looks as an effective technique to reduce GHG. However, in situations where water availability is not limiting, the interest of AWD for farmers is unclear. What are their incentives for implementing this technique if water in not limiting? MD may provide another option and an entry point to GHG mitigation in rice. Thus, it is recommended testing MD in these areas.

3) Assessing the actual impact of your guidelines and handbooks

The guidelines and handbooks produced by this project look very attractive, but are they used in practice? The project members should try to measure the impacts of their guidance documents.

4) Scenario analysis approach developed in Project 1

The Mitigation scenarios in project 1 can be useful here. How about if the dry season crop is high N consuming like onion, garlic, pepper, tobacco, and other vegetables? How about if AWD or MD in rice production is applied after the wet season CF rice? The rainfed rice consortium that IRRI implemented in the 90s' may provide some useful information on nitrate leaching in groundwater rice-based cropping systems.

5) International collaboration

To attain a greater outcome, the project may want to consider expanding partnership with national organization engage in policies and programs, and the private sector in addition to research organizations. In addition, the project may want to assess portfolios of practices like 1M5R in Vietnam, PalayCheck in the Philippines, and RICM in Indonesia and recommend modifications or adjustments that will help realize the future thrust of the project i.e. reducing the total emissions (converted to CO_2) of CH_4 and N_2O by 30% with maintaining the present yield status in monsoon Asia. The project may want to look into location-specific portfolios integrating GHG reducing and C sequestering practices. Further, the project members may also consider organizing international training sessions associated with the publications of their guidance documents. Training sessions can indeed be useful to explain guidance principles to stakeholders.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Evaluating impact on economic profitability

As you have observed, it is important for us to expand our indices of harvest yield and productivity to include economic profitability. Furthermore, with regards to benefit to the environment, we feel that by introducing the viewpoint of the LCA, we can strengthen both of the indices we have been using and explain with greater clarity the real-world significance of the technologies we have developed. On the contrary, adding these elements to our operation will require additional resources, particularly human resources (economists, LCA specialists, etc.). Pursuant to the future achievement of these goals, we plan to consider collaborations with other programs and organizations.

2) Provision of more options to farmers

(1) In some parts of Asia that enjoy access to abundant water, the introduction of AWD has

led to both reductions in GHG emissions and increases in yield. By targeting regions where yield is expected to increase, it can be an incentive for farmers. (2) MD is thought to be 80–90% as effective as AWD in reducing GHG emissions. Therefore, it would be quite meaningful for it to also be available as an option for farmers with little reason to conserve water. We plan to incorporate this fact into future research projects.

3) Assessing the actual impact of your guidelines and handbooks

We are currently in the stage of publicizing our guidelines and handbooks to policymakers, researchers, and farmers via a variety of different channels and events. Evaluation of the impacts of these guides is a task we plan to become fully involved in in the future. Furthermore, in 2018, we worked on the dissemination of our guidelines and handbooks at a Council Meeting of GRA, at a workshop organized by the FAO, and in other venues.

GRA Council Meeting: https://globalresearchalliance.org/e/2018-council-meeting-berlin/

Workshop: https://faounfcccagworkshop.wixsite.com/faoricelandscape

4) Scenario analysis approach developed in Project 1

We are currently moving forward with our activities in close collaboration with Project 1. For example, long-term estimates of the effect of GHG reduction made by a mathematical model developed in Project 1 have become a pillar of the MIRSA-3 Project, an international collaboration project which subject is paddy fields in Southeast Asia. In this manner, we plan to use the results of Project 1 in the future for specific cases like the ones you have brought to our attention.

5) International collaboration

We understand the importance of collaboration with national organizations that engage in policymaking and with the civil sector, and as described specifically in 3) above, currently we proactively present our work to councils, etc. on which various national policymakers sit. We have also kept ourselves abreast of the efforts of other nations, and while we have focused our research primarily at the intersections of these efforts in the past, we plan to advance our research on the specific approaches of each country and region and acquaint ourselves with the social dividends of new technology and findings. Nevertheless, a comprehensive evaluation of the specific approaches of these countries and regions is a bit more than NARO can handle alone. We plan to examine the possibility of working together with the research organizations that participate in the international MIRSA-3 Project which began in 2018. With regards to “training sessions”, in addition to the workshop mentioned in 3), in November 2018 we held capacity-building activities using APEC funds and in collaboration with the Chilean Institute of Agricultural Research.

Section 2: Assessing the impacts of climate change on crop production

Project 4 Experimental evaluation and modeling of the response in rice to increasing CO_2 and temperature

This group established the first rice Free-Air Carbon dioxide Enrichment (FACE) in the world and was able to conduct experiments to analyze the effects of temperature and CO_2 on both rice yield and rice grain quality. The results are very interesting and were published in major scientific journals. Further, the team was also able to develop strong international collaborations, and to organize several international events. The plans are ambitious and challenging but very important. Several recommendations and suggestions are listed below;

1) Further data analysis

Compare your own experimental assessment of CO_2 effect with other types of assessment obtained from yield time series (for example, by distinguishing dry versus wet years. See e.g. McGrath and Lobell 2011).

Assess the capabilities of various N fertilizer strategies to compensate for the negative effects of elevated CO_2 on grain N content.

Combine your data with those obtained in other FACE experiments and even maybe with those obtained in field warming experiments. (See e.g. Zhao et al. 2016, Nature Plants 3, 16202).

2) Further experiments

The soil biogeochemistry under FACE condition deserves attention.

Researchers should be aware of potential feedback mechanisms between agroeco/climate systems while conducting research projects.

Side effect of infrared radiation on leaf temperature might be significantly higher than expected, which may cause extremely high evapotranspiration from leaves.

3) Geographical prediction

It may be good to identify the areas where higher temperature and higher CO_2 will be beneficial and areas where the same will have a negative effect.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

We are grateful for your exceedingly constructive compliments. We receive them respectfully, and plan to put them to use in future research endeavors and international collaborations.

1) Further data analysis

Thank you for your suggestions. We are in complete agreement with the opinion of the reviewers: yield records from long-term field trials are as valuable as data obtained in environmental manipulation experiments. They mutually complement each other and make our ability to predict crop responses to environmental changes more robust. We plan to use multiple

data sources and our crop model to implement a meta-analysis to compare our results. Furthermore, using data from long-term field trials, we have already begun to analyze the various factors that affect rice yield.

Further, we recognize that, as the reviewers point out, N is the most important factor for changing crop response to the environment. We are conducting experiments on how the effects of CO_2 concentration on yield and quality change depending on the amount and timing of N fertilization. While N fertilization methods can positively affect yield and quality, we cannot ignore the interaction between N and cultivar. Explaining the interaction among CO_2 concentration, N, and cultivar is vital in the development of adaptation technologies and has become one of our primary research themes.

The idea of combining our FACE and T-FACE (FACE plus temperature manipulations) experiment results with those of field warming experiments is an interesting one, and we would like to begin a collaboration aimed at implementing a meta-analysis soon.

2) Further experiments

As you point out, the soil biogeochemistry in FACE or temperature control experiments is certainly crucial to understand the potential feedback interactions between the agroecosystem and the climate system. At present, we use C stable-isotope to quantify the C flow in the soil-plant-atmosphere system. We are also aware of the importance of microclimates under climate change, and we are currently conducting research on heat and water balance in canopies under high CO_2 concentrations using cultivars with significantly different canopy structure and physiological traits.

As pointed out by the reviewers, we are aware that infrared heating greatly increases the vapor pressure deficit at the leaf surface. We wish to combine data from this experiment with data from experiments using other heating methods plus long-term field trials to create more robust predictions of crop responses to climate changes.

3) Geographical prediction

Thank you for your comment. Crops respond non-linearly to temperature and high CO_2 concentrations; we therefore expect the effects of climate change to vary by region and year. Crop growth simulation models have the potential to provide the only practical answer to this question, but the uncertainty of these simulation models is still a concern. Through international collaboration, we wish to construct an ensemble model capable of elucidating regional differences.

Project 5 Climate change risk assessment of crop production at country and global Scales

The project developed downloadable climate scenarios with high resolution, the resulting dataset are used widely in Japan. They simulated the growth, yield and quality of rice in various climate

change scenarios using the H/H model, also described possible pathways of global food production under various climate and socio-economic assumptions using multi-type numerical crop models. The scientific production of this project is of high quality. Some recommendations and suggestions are listed below;

1) Further data analysis

It will be interesting to compare your projections of future crop productions with projections of future food/feed demands. You will then be able to estimate food/feed balances and then analyze risk of deficit.

2) Technical improvement

The project team should consider using niche modelling techniques to explore the consequences of climate change on cultivated areas. As an alternative, the team could develop collaborations with groups of people working on this topic.

S2S will be a promising tool/information for early warning on weather/climate extremes originated from climate variability.

3) Further evaluation of the climate change impacts

The analysis of impact of climate on rice quality is very interesting, but it seems that large scale predictions were done for rice yield only, not for rice quality. It would be interesting to forecast rice quality in addition to rice yields.

As climate change is expected to have a strong influence on pest and disease incidence and severity in the future, the project team should develop collaboration with scientists specialized in this scientific field.

In the future, it could be interesting for you to work on a larger number of crop species, especially on crop species with high economic added values, like fruits and vegetables.

4) Improvement for practical use

For the municipal adaptation plans, can your model integrate high-resolution data (local risk maps, local knowledge, local land use maps, infrastructure, topography etc.)? This will make the adaptation plan more realistic and practical for field application.

The project should consider how to make these models more practical for use in formulating policies, programs and operations by integrating other high-resolution data and ground validated information, e.g. support adaptation measures in Project 6.

The project will also benefit using the approaches and outputs of projects 1 and 4.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Further data analysis

On the day of our presentation, we referred to some simple hypotheses in previous research on food demand. However, in collaboration with other organizations, we are currently conducting research on food demand and on risks of starvation and nutritional deficiencies from the perspectives of human health, based on shared socioeconomic pathways scenarios.

2) Technical improvement

As part of the global research of this project, to date we have worked to introduce various model-based techniques. Niche modeling is thought to be useful in the climate-based evaluation of suitable cultivation regions for specific crops. However, future changes in cultivated land area will be affected by changes in land use due to climate and socioeconomic factors, meaning that we must consult experts as to whether or not these models can be adapted to this project.

With regards to early warnings, we are continuing our yield prediction research that uses down-scaled S2S values with international organizations, and we plan to release a practically applicable version in the next few years. And, as mentioned in 4) below, we also plan to use it in tropical island countries to help them adapt to climate change.

3) Further evaluation of the climate change impacts

We are currently in the middle of analysis and modeling our large-scale evaluations of rice quality. And as for some rice varieties, an end is in sight for our modeling for evaluation and future projection. In the future, we plan to adapt the model to varieties currently in use and in raising. In collaboration with researchers of pest and disease, we are applying for research funds to carry out integrative modeling. Finally, with regards to fruit trees, Project 6 is primarily leading the charge on the research front, and this project is collaborating mainly from the perspective of climate projection. We have employed similar approaches for research assessing the impacts of climate change on wheat, soybeans, vegetables, feed crops, and other crops.

4) Improvement for practical use

We understand you are pointing out that integration of high-resolution risk-assessment models that evaluate geography, land use, infrastructure, and other variables is important for more realistic adaptation measures at the municipal level. This research project has, to date, formed cross-disciplinary research groups for the assessment of climatic environment change caused by cultivation abandonment and its impacts on rice and horticultural crops, as well as for the research on changes in water resources and environments due to extreme precipitation, and facilitated repeated discussions with legislative figures. In the future, in order to achieve more practical and policy-based goals, we plan to work very closely with Projects 4, 6, and 7.

Further, it is at the focus of our preliminary study to integrate weather early-warning systems that employ ICT technology to resource recycling systems that consider land use to conserve underground water resources and fertilizer in Pacific island countries, where farming relies on rainwater. With regards to these endeavors, we will continue to advance our collaborations with

Project 6, Project 1, and other regional research centers in NARO.

Section 3: Adaptation to various influences of climate change on agriculture

Project 6 Development and implementation of adaptation measures for climate change effect on crop production in Japan

This group was able to produce practical solutions to address several important agricultural issues in Japan. The results are relevant on a practical point of view. The group produced numerous scientific and technical papers, and also several patents. Some recommendations and suggestions are listed below;

1) Assessing the environmental impacts

The group should assess the environmental impacts of the proposed countermeasures, especially those based on fertilization (see your works done on rice and fruit). You should evaluate the proposed management strategies according to several environmental criteria (e.g., N_2O emissions).

2) Assessing the reliability of your maps of suitable cropping areas

The maps of suitable areas produced by this group are very interesting, but it will be useful to analyze the uncertainty of the proposed maps. As several niche modelling techniques are available, the group could use several of these techniques and compare the resulting maps in order to assess the robustness of their conclusions.

3) Improvement for practical use

Further refinement and analysis of the cost and benefit will be useful in enhancing the upscaling of the adaptation practices.

For top dressing recommendation- how much additional N will be optimal and practical for application without compromising the other quality trains like protein and amylose content, gel consistency, gelatinization temperature, etc.? How about changes of planting dates and use of shorter/longer duration varieties?

Regarding the adaptation of fruit production to climate change, in order to make the future crop suitability projection practical and useful for field level planning and implantation (e.g. suitable areas for fruit trees), it will be good to integrate data from field validated by horticulturist, soil scientist, pest management expert for specific crops/trees.

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Assessing the environmental impacts

As explained for Projects 1 and 2, we are aware that we must keep side effects of adaptation

and mitigative measures at the forefront of our minds at all times.

In the cultivation of paddy rice, applying N fertilizer under non-submerged conditions or draining paddy water with high N concentration cause concerningly high levels of N_2O flux. Such phenomena are noticeable overseas where the N fertilization level is considerably higher than in Japan. However, at the standard fertilization levels in Japan, application of fertilizer under submerged conditions does not change N_2O emission amounts appreciably. Of course, we understand that there is a need to discuss the tradeoff between cultivation management techniques to climate change adaptation and increases in N_2O emissions.

In terms of global warming countermeasures for fruit trees, reductions in the use of N and accumulation of soil organic matter are known to be effective. These methods reduce the damage from the global warming and are also effective in the reduction of GHGs. At present, we are advancing our examination into their ability to reduce global warming-related damage, but our next step will be to evaluate the environmental impact of adaptation measures such as these.

2) Assessing the reliability of your maps of suitable cropping areas

With regards to the uncertainty associated with our future map of cultivation suitability, at present we are engaged in the development of probability maps using multiple climate scenarios. As for the robustness of our conclusions, we plan to evaluate them in the context of in-field tests of our developed technologies so that the conclusions can be used to refine these technologies. Furthermore, we have considered the uncertainty of our cultivation suitability model possesses and would like to consult with specialists first on the possibility of introduction of niche modeling techniques.

3) Improvement for practical use

The global warming countermeasure technologies and techniques introduced in this section are currently being tested —including cost-effectiveness analyses—in the field in various regions throughout Japan. Several of these technologies have been fitted into the early-warning/cultivation management support systems developed in Project 7, and we plan to further advance the spread of these techniques.

Applying N fertilizers to rice at panicle initiation stage to avoid the damage caused by high temperatures has already been shown to not significantly increase the brown rice protein content that negatively affect eating quality. At present, we are developing a model for brown rice protein, and in the future, we plan to further clarify the relationship between top-dressing and protein content. However, amylose content is known to be affected by variety and maturation stage. Gel consistency is enhanced by the improvements in quality associated with top-dressing. Late varieties are currently being promoted in each regional block as a countermeasure technology to avoid grain-filling under the high-temperature environment.

Actually, large-scale rice farmers, increasing in Japan, use multiple varieties with different maturity types to distribute their labors.

The suitability map we are currently developing for fruit trees evaluates risks caused by future climate change, and will be used at first in decision-making regarding replanting and selecting of different cultivars. Of course, as you point out, when expanding its use to other regions and in order to improve its usability, we must take into account soil conditions, cultivation technologies, types of pests and diseases and their occurrence, and other factors.

Project 7 Agricultural decision support systems to reduce weather and climate risks by utilizing high-resolution gridded meteorological data

The group developed a useful high-resolution gridded meteorological data system which delivers datasets on demand, and simulation models for crop growth were developed. Based on these, decision support systems for crop management to reduce weather and climate risks were established. The group made a very good technical description of their decision support systems but didn't really explain who the users of the proposed systems will be. It is a bit unclear how the proposed tools will be used in practice. The quality of the scientific publications is very good, and the proposed tools look promising, but the business model didn't seem fully clear. Regarding the future research plans, it is important to pursue them. Some recommendations and suggestions are listed below;

1) Precisely defining the business model

Who are the users? How many people will use this system? Which decisions could be taken based on your systems? What are the potential benefits for the users? Do the farmers/machine manufacturers need to pay to get access to your systems? Do they want to pay? How much?

2) Considering major environmental issues

It will be useful to address major environmental issues, which are not limited to GHGs emission, in your systems. You should consider including the models produced by project 1 in your tools, in terms of GHGs.

3) Collaboration among projects

The project will benefit with closer collaboration with Project 6. There are synergies in the 3 adaptation projects (Project 5, 6, 7).

The rating is: **A – good quality and minor revision needed.**

NARO Response to the Comments of the Evaluation Committee

1) Precisely defining the business model

While the final user is the producer, with regards to delivering information and encouraging

decision-making, there are multiple possible routes, each with different business models, including the following: 1) direct utilization of the system by large-scale producers and dissemination leaders; 2) provision to farmers via agriculture management systems offered by ICT companies, and; 3) provision of developmental know-how when the Japan Agricultural Cooperatives / prefectural governments construct an independent system for farmers. With regards to the producers, whom we consider to be our final users, we are currently targeting those that possess over 10 ha of cropland (approximately 20,000). As for the billing system, it is a matter to be considered in a future project. We are currently advancing discussions between NARO and companies by way of a data-use consortium that private businesses participate in.

In order to reflect the needs of producers in the system, we have gone through a process involving various research meetings, outreach activities, and on-farm experiments, and we plan to continue them in the future.

2) Considering major environmental issues

We have continued construction and management of an agricultural data collaboration platform called WAGRI, a cloud service that enables sharing of multiple different kinds of agriculture-related information, which is run by NARO. We are currently formulating a platform that combines, by user request, agricultural management support information with GHG emission evaluations developed by Project 1.

3) Collaboration among projects

Projects 6 and 7 have proceeded in an integrated fashion since the beginning, and many researchers have been associated with both projects. The organization of both of these projects reflects the importance of their synergy, something pointed out in your comment as well. As a result, the technologies we have developed as global warming countermeasures (Project 6) that were deemed to increase usability via implementation into our information system, can be immediately put into the content development workflow (Project 7). We are also carrying out collaborative research with regards to the development of crop growth models required by future projection systems for the effects of global warming (Project 5) and current development of adaptation technologies (Project 7).