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Application of Rice Disease Model for Seasonal Rice Pest Outlook in the Bicol Region

Kwang-Hyung Kim Strategic Planning Team

Seongkyu Lee Information Service Team

Christianne Michiko Aikins External Affairs Department

APCC
APEC CLIMATE CENTER

PREFACE

Agriculture is one of the sectors most vulnerable to impacts of climate variabilities, especially extreme weather and climate events. The Bicol region, which is located in the southeastern part of the country, is one of the regions in the Philippines facing this challenge due to its high exposure to typhoons, floods, intense abnormal rainfall changes, drought, and soil erosion. Under these conditions, the farming communities are unable to cope with the effects of natural disasters. Therefore, strategies are needed to build the resilience of these vulnerable farming communities.

This report was produced through a collaborative effort between the International Research Institute for Climate and Society (IRI) and the APEC Climate Center (APCC) for the 5-year Bicol Agri-Water Project (BAWP), in partnership with the Department of Agriculture Regional Field Office 5 (DA RFO-5), the University of the Philippines Los Baños Foundation, Inc (UPLBFI), and the Bicol local governments and universities. Through the project, APCC developed a decision-support tool, called the Climate-Agriculture-Modeling and Decision Tool for Diseases (CAMDT-Disease), in collaboration with IRI. The CAMDT-Disease aims to guide decision-makers in adopting appropriate disease management practices before or during the growing season based on seasonal climate forecasts, which can eventually improve crop yields for a given climatic condition. As a result of a series of capacity building and implementation activities through the project, the agricultural stakeholders in Bicol are now able to utilize seasonal climate forecast information, so that the community's quality of life is improved in terms of increased food security, protection of resource bases, lower costs, and/or better economic outcomes.

Furthermore, this publication should benefit the researchers, farmers, extension officers, and other community workers in the developed and developing countries in the APEC region who are wanting to help farmers make improved decisions, particularly around adapting to climate variability. We hope the results of this project will inspire other countries to adopt similar science-based decision support systems, climate information, and the implementation mechanisms of climate smart technologies.

Dr. **Hong-Sang Jung**
Executive Director
APEC Climate Center
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EXECUTIVE SUMMARY

The application of a rice disease model for seasonal yield loss simulation in the Bicol region, or the Bicol Rice Disease Project (BIRD), was a collaborative partnership between APCC and the International Research Institute for Climate and Society (IRI). APCC became a co-implementing partner of IRI in 2015 for the Bicol Agri-Water Project (BAWP), which aimed to improve water security in the Philippines by adopting climate decision support tools and enhance agricultural development under climate variability and change. BAWP developed climate decision support tools and enhanced agricultural development under climate variability and change. This initiative, which ran from September 2012 to September 2017, fit well with APCC's strategic plan to integrate climate products with sectoral applications such as agriculture.

APCC's main activity was to extend the Climate-Agriculture Modeling Decision Tools (CAMDT) suite, the central output of BAWP. By integrating a disease model into CAMDT, APCC has enabled the translation of climate information into potential disease risk under given seasonal climate forecasts in the Bicol region. Since crop diseases are primarily governed by climate and weather conditions under fixed management options, it is possible to predict the infection risks of crop diseases. Coupling disease components with a crop model within the CAMDT decision support tool has allowed for a more accurate reflection of real field situations where crop losses frequently take place due to the biological constraints.

Thus, making disease risk information available, coupled with a potential rice crop yield loss simulation, will enable decision-makers to develop informed farm management strategies. Such strategic decisions include short-term ones (e.g. the choice of a resistant cultivar against a high risk profile disease, seasonal scheduling of chemical and cultural

control methods, and identifying the ideal time for planting crops to minimize crop losses due to the diseases) but also decisions that do not directly pertain to disease management and yet have numerous crop health consequences (e.g. choices of the type of crop establishment, crop rotation, or cropping system).

The project had three main outcomes:

1. Capacities built for participating municipal agricultural technicians, provincial and regional level agricultural officials to manage climate risks to attain reduced losses due to pest damages at the municipal, provincial, and regional levels.
2. Improved management of agriculture systems at various scales through the validation and application of the CAMDT-Disease decision support tool. Users of the CAMDT-Disease were trained for how to utilize the disease risk information in their spray or agricultural management decisions using various farm simulation approaches.
3. Operational seasonal disease outlooks based on the APCC MME SCF strengthens APCC's experience on climate services for agricultural sector in the APEC region. This will also play a positive role for the development of future projects in the similar areas utilizing the APCC MME SCF.

CONTENTS

APPENDICES

1. PROJECT BACKGROUND

The Bicol region in the Philippines is a major river basin near the southernmost tip of Luzon. The region is extremely vulnerable to extreme or unexpected hydroclimatic events, generated by frequent typhoons and the seasonal effects of ENSO. All 6 provinces in Bicol are listed in the top 20 at risk to typhoons, out of more than 70, and the region often experiences extreme hydroclimatic conditions such as droughts and floods. This vulnerability translates to losses in agricultural productivity, which endangers the local economy as well as food security. As a primarily agrarian society, these impacts can be devastating to families, where 38% of workers are employed in the agricultural sector (CountryStat Philippines, 2013)

More recently, in 2014, the region was hit by a long dry spell and four typhoons. These weather disturbances damaged over 100,000 hectares in the Bicol region alone, resulting in a production loss of almost 250,000 metric tons - a loss valued at more than PHP 2.5 billion (US $53 million) (Philippine Department of Agriculture Regional Office No. 5, 2014). However, ongoing efforts to improve agricultural productivity have increased economic and sectoral resilience to such events and exceed rice sufficiency, arguably the most important agricultural crop in the region.

Additionally, the impacts of El Niño continue to be felt across the Pacific. It is expected to continue for as long as two years, particularly affecting food security in the region. Long-term approaches to reduce food insecurity must be found, which incorporate the effects of climate change. With long-term climate change impacts posing uncertainty in the region's agriculture sector, there is a need for 'agro-climate tools' to improve local capacities to anticipate and respond to climate risks to support Bicol's long-term food security. This project aims to increase agricultural resilience and productivity by developing a decision making tool to determine the risks of rice diseases using cutting-edge climate predictions.

APCC aims to implement practical, policy-oriented climate researches towards the APEC region countries. In this regard, BAWP aiming to improve water security by adopting climate decision support tools and enhance agricultural development under climate variability and change, fits with the APCC's strategic plan to integrate climate products with sectoral applications, with particular attention to agriculture as one of the priorities. Through a collaborative partnership between APCC and IRI, APCC decided to participate in the BAWP as a co-implementing partner of IRI. APCC's main activity regarding the BAWP was to integrate a disease modelling component into the CAMDT, so that the climate information could also be translated into a disease risk along with potential yield losses due to the predicted risks of the disease to a rice crop (Figure 1).

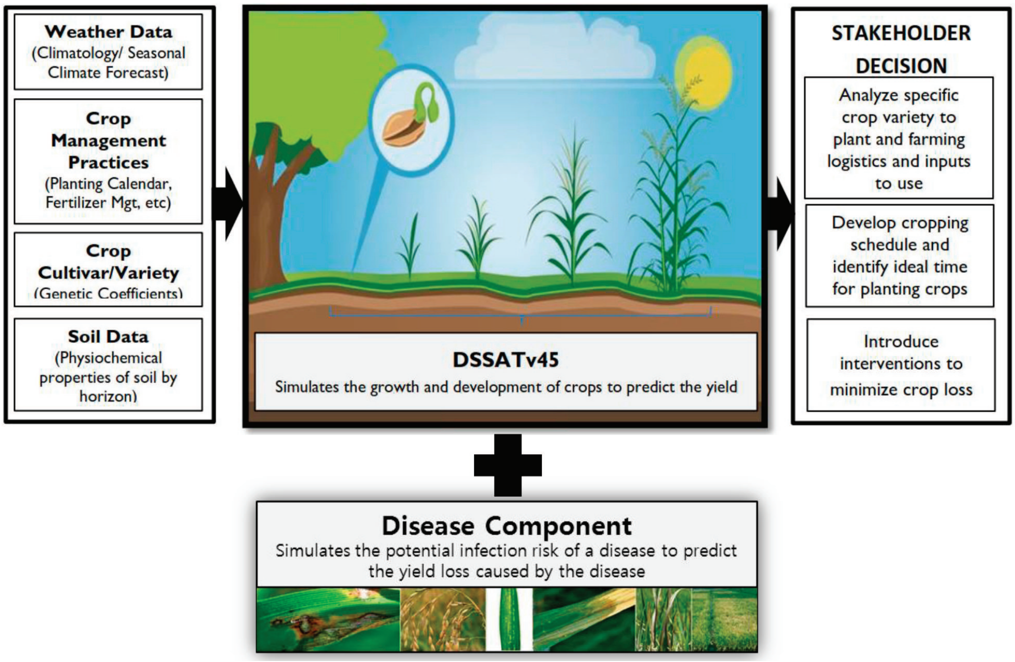

Figure 1. CAMDT-Disease work flow

The disease component of the CAMDT (CAMDT-Disease) can be used to generate potential disease risks under given seasonal climate forecasts in the Bicol region. Decision-makers can then use the risk profiles to develop their own farm management strategies. Such strategic decisions include short-term ones (e.g., the choice of a resistant cultivar against a high risk profile disease, seasonal scheduling of chemical and cultural control methods, and identifying the ideal time for planting crops to minimize crop losses due to the diseases) but also decisions that do not directly pertain to disease management and yet have numerous crop health consequences (e.g., choices of the type of crop establishment, crop rotation, or cropping system).

Crop diseases are primarily governed by climate and weather conditions. This means that with controlled or fixed management options, it is potentially possible to predict the infection risks of crop diseases. If this is the case, coupling disease components with a crop model within the CAMDT decision support tool, not just adding the disease components to the CAMDT will enhance the agricultural decision making process by stakeholders because it will more accurately reflect the real field situation where crop losses frequently take place due to the biological constraints.

1.1 Project Concept and Strategy

The initial project plan was as follows:

This study focused on rice-based agricultural systems in the Bicol region. Therefore rice diseases will be thoroughly investigated in the beginning, which is to prioritize or select target diseases among many locally-reported rice diseases. Disease prioritization will depend on its endemicity over the last 5-10 years as well as economic and social impacts in the region. The selected diseases will be subject to disease model development. Depending on availability and applicability, existing disease models can be selected or new models are developed and validated using available ground truth disease incidence data. The disease model components will subsequently be integrated into the CAMDT. The CAMDT is a suite of tools, comprised with climate data from IRI's CPT and PAGASA's seasonal climate forecasts (SCF) and a crop growth model, DSSAT v4.6. Integrating the disease component into the CAMDT may require a structural coupling of the disease component with other tools such as downscaled SCF and DSSAT model, whether it is loose or tight. Considering the structural complexity of the DSSAT model, the disease component can also be combined with more simplified rice growth models to produce actual yield losses due to damages from certain diseases.

1.2 Project Structure

Objectives:

1. To develop and integrate rice disease component into the CAMDT platform
2. To provide stakeholders in Bicol with a seasonal rice pest outlook to help their decision-making on pest management

Planned Activities

1. Initial scoping on disease epidemics in the Bicol region to select major diseases, subject to disease model development in the study
2. Examination of the APCC multi-model ensemble seasonal climate forecast over the Bicol region
3. Technical workshop I
4. Disease model development and validation
5. Model integration into the CAMDT platform
6. Technical workshop II
7. Agro advisory - Seasonal climate forecast and extension advisory

2. REPORT ON PROJECT ACTIVITIES AND FINDINGS

2.1 Initial Scoping on Disease Epidemics in the Bicol Region to Select Major Diseases, Subject to Disease Model Development in the Study

Literature review and communication with local partners was done for the initial scoping on disease epidemics and their economic and social impacts on farmers in the Bicol region. An analysis done by Hossain et al. (1995) showed that the yield losses due to agricultural disasters were 945 kg/ha during the wet season (WS) and 1,298 kg/ha for the dry season (DS) in the Philippines (Table 1). This represents 29% and 34% of total rice production combined for the WS and DS, respectively.

Table 1. Yield losses reported by farmer survey in the Philippines, 1992–94 (Hossain et al., 1995)

Characteristics	Wet Season	Dry Season
Yield at harvest (kg/ha)	3,270	3,822
Production losses (kg/ha)	945	1,298
Drought (kg/ha)	198	759
Typhoon/strong wind (kg/ha)	358	253
Floods (kg/ha)	49	27
Insect and diseases (kg/ha)	250	206
Inferior variety (kg/ha)	25	11
Lack of capital (kg/ha)	48	42
Others (kg/ha)	17	0
Expected normal yield (kg/ha)	4,215	5,120
Loss as percent of harvest (%)	28.9	34.0

As shown in Table 1, except for natural calamities such as typhoon and drought, the yield loss due to insects and diseases was the highest contributor. The yield loss accounted for by those two pests was 26% in the WS and 16% in the DS. This indicates that prevention of these losses would translate into increased rice yield. The major pests reported were tungro, stem borer, brown planthopper, sheath blight, and rice bugs.

Initial scoping on disease epidemics in the Bicol region was conducted to select major rice diseases, which were, in the next stages of study, subjected to corresponding disease model selection or new model development. The resulting disease models would then be incorporated into the CAMDT for the development of a rice disease control decision support tool using seasonal climate forecast.

Multiple interviews with local partners from DA RFO5, municipal governments, and local state universities were conducted to identify major insect pests and diseases of rice in the region and their control management practices. Key questions for the interviews included: What are the most socio-economically important pests in your area?; Which one can be managed using available control measures if the pest incidence can be predicted ahead?.

The Regional Center for Plant Protection (RCPC) under the DA RFO5 provided a long-term (more than 10 years) insect pests and diseases surveillance data collected in a provincial and municipal level. Local state universities and colleges also provided various project-related, field scale, disease incidence data for disease model development. Interviews with farmers were also conducted to find out the most problematic insect pests and diseases for their rice farming and their counteracting measures available.

Major insect and disease pests taking place in the Bicol were summarized in Figures 2 and 3, respectively, together with their occurring period within a rice cropping season. Among the insect pests reported in Bicol, rice black bug (RBB) and white stem borer (WSB) were identified as the first and second major pest concerns, followed by brown plant hopper and army worm. Crop loss caused by RBB ranged from 0% to 88%, while loss caused by WSB ranged from 14% to 65%. Most farmers experienced WSB damage at the vegetative and reproductive stages. There was an outbreak of RBB in the 1996 DS for the first time in 30 years (Torres et al., 2013). Among the disease pests, rice tungro disease (RTD) was perceived as the most important disease of the rice crop; bacterial leaf blight and sheath blight were ranked second. Crop losses due to RTD ranged from 10% to 100% based on farmers' experiences in the Bicol (based on informal interviews). Other pests were also mentioned, but it was told that their impacts on the rice yield are not significant.

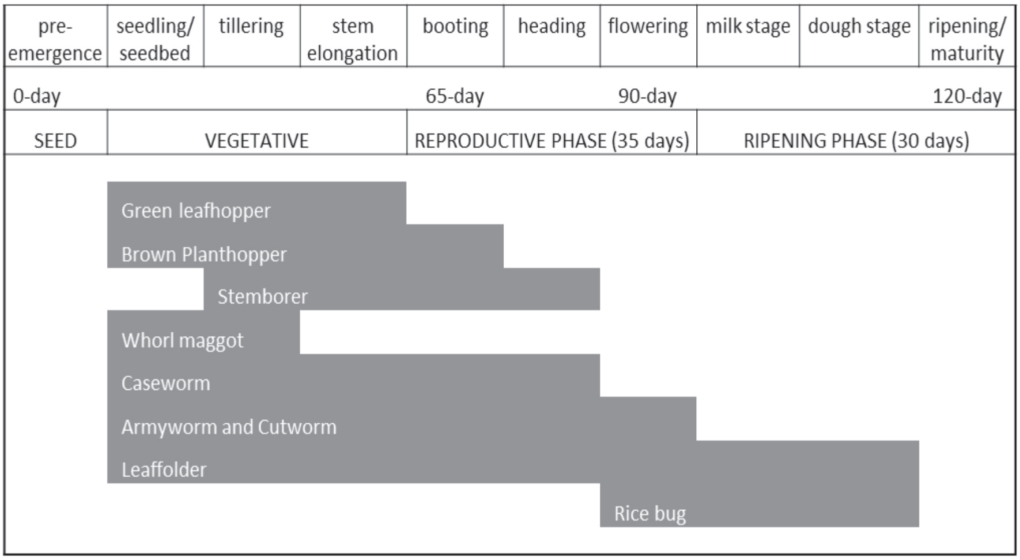

Figure 2. Major insect pest list reported in the Bicol and their occurring period within a rice cropping season.

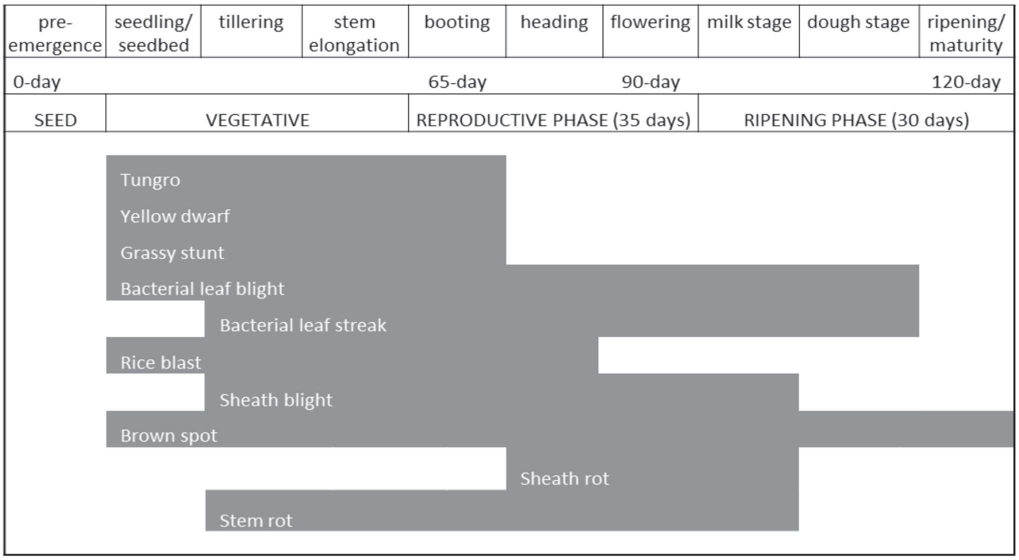

Figure 3. Major disease list reported in the Bicol and their occurring period within a rice cropping season.

During surveys, it was surprising to discover that RTD was such a priority among stakeholders in the region, with respondents citing stories of severe damage in the rice fields from RTD. In fact, Savary et al. (2000) conducted nonparametric, multivariate analysis using experimental database from 445 individual plots to find out a hierarchy of pest injuries, which provides a means of ranking rice pests with respect to their importance in terms of the potential losses they may cause. Four groups of injuries were associated with (i) low to medium yield losses; (ii) medium to high yield losses; (iii) high yield losses; (iv) medium to very high yield losses. Interestingly, tungro was not included in any of groups because it was outstanding, being associated only with very high yield losses. Therefore, they created a fifth group of injury only for tungro. Although this categorization is based on yield loss experiments, it likely indicates the huge impact of tungro in yield loss in the fields. More detailed information on RTD in the Bicol can be found in the **Appendix I**.

Based on the initial scoping results, a couple of target diseases for the modelling work were selected. The final disease list includes tungro, sheath blight, bacterial leaf blight, and brown spot. The selection of major diseases was based on the criteria of being not only economically important but also climatically influenced, which thus can be predicted by seasonal climate forecasts. Disease outbreaks largely influenced by human activities, varieties to plant, or migration from outside should be omitted from the selection process. In addition, since the modelling work requires tremendous time and effort, it was essential to narrow down the target diseases based on availability and applicability of the existing disease models.

○ Major Outputs and Outcomes

- The yield losses by insect pests and diseases accounts for almost 20% of an attainable rice yield in the Philippines, which in turn indicates effective prevention of these losses would translate into increased rice yield.
- Among the insect pests reported in Bicol, rice black bug and white stem borer were identified as the first and second major pest concerns, followed by brown plant hopper and army worm.

- Among the diseases, rice tungro disease was perceived as the most important disease of the rice crop; bacterial leaf blight and sheath blight were ranked second.
- Based on the initial scoping, tungro, sheath blight, bacterial blight, and brown spot, which are not just endemic and socioeconomically important in the region but also are feasible for a computer simulation modelling, were finally selected for subsequent modelling work.

2.2 Examination of the APCC Multi-Model Ensemble Seasonal Climate Forecast over the Bicol Region

To produce the seasonal pest outlook, seasonal climate forecast (SCF) will be used as an input variable for the pest epidemiological models. Due to fundamental variations in initial conditions as well as structural differences in the global climate models (GCM), there are inherent uncertainties in climate forecasts produced from GCMs. These uncertainties can be interpreted as either uncertainty level or a predictability skill of the climate forecast over a certain region. In fact, depending on the regions, the predictabilities of SCF are largely varied. Therefore in this study, we are going to evaluate the predictability of the APCC Multi-Model Ensemble (MME) SCF over the Bicol region. More detailed information on the examination of the APCC MME SCF over the Bicol can be found in the **Appendix II**.

The first objective was the examination of the APCC MME SCF over the Bicol region to find seasonal predictability of the forecast. This is because the accuracy of the resulting seasonal pest outlook will depend on the predictability of the SCF. The Ranked Probability Skill Scores (RPSS) for the tercile-probability SCF from 1983 to 2005 were calculated to see the seasonal variation of the APCC MME SCF's predictability. In general, SCF during the DS showed higher predictabilities than the ones for the WS in the Bicol region. Considering the fact that most recent RTDs were reported during months in the WS, this result indicates that there is an urgent need to improve the SCF skill during the WS, which can be solved with the possible development of a hybrid (statistical-dynamic) model-based prediction system over the region with collaboration with climate scientists. It is also very important to provide the uncertainty information from the climate and agriculture models when the seasonal pest outlook is provided to the stakeholders.

○ Major Outputs and Outcomes

- The APCC MME SCF was examined to find seasonal predictability of the forecast over the Bicol region.
- SCF during dry season showed higher predictabilities than the ones for wet season in the Bicol region.
- Considering the fact that most rice disease epidemics are more severe during wet season than dry season, there is an urgent need to improve the SCF skill over the wet season. Hybrid forecast system using both dynamical and statistical models will possibly have a room for improvement.

2.3 Technical Workshop I

The 4th Annual Technical BAWP Workshop: *Models and Tools for Water Agriculture and Knowledge Sharing* was held February 17-19, 2016 at the Villa Caceres Hotel, Naga City, the Philippines, co-hosted by APCC and BAWP. In many ways, though the fourth of its kind, this workshop functioned as a kick-off event for BIRD. Because of this, the outcomes were related to increased visibility and enhanced understanding of the needs of the end users.

A full workshop report may be found in the **Appendix III**.

○ Major Outputs and Outcomes

- Increased visibility of APCC research and projects in the Asia Pacific.
- Increased awareness of BIRD and its relevance.
- Enhanced relations with project partners.

- Consolidate input from stakeholders on end product.
- Discussed the functionalities of the current versions of the Knowledge Sharing Portal, WEAP-Bicol and CAMDT models and tools with project partners.
- Provided opportunity for project partners to familiarize with the models and tools for assessing and managing climate risks to agriculture and water resources.

2.4 Disease Model Development and Validation

To simulate potential disease risk for four selected diseases, an existing disease model, EPIRICE, was selected for sheath blight, bacterial blight, and brown spot simulation in the study. Since the EPIRICE was originally developed to evaluate the climate change impacts on rice diseases in the Southeast Asia including the Philippines (Savary et al., 2012), the parameters of the original EPIRICE were used in our study as was in the original study.

For rice tungro disease (RTD), we found a few tungro simulation models had been developed for different purposes. A spatial, stochastic, individual-based model of RTD dynamics was developed and used for a theoretical investigation of risk under different situations of vector immigration (Holt and Norton, 1993). Since then, a very similar model was developed by Ferris and Berger (1993) to compare, theoretically, virus disease dynamics under different assumptions of virus persistence in the vector. Holt and Chancellor (1996) simulated real pathosystems and considered control issues, particularly for disease management by rouging. And recently, a mathematical model of the epidemiology of RTD in the cropping system was developed to investigate the deployment of fields of a genotype expression resistance to the disease (Holt and Chancellor, 1999). Other than these process-based models, there were some regression models developed to estimate grain yield losses based on RTD incidence or green leafhopper (GLH) population at certain cropping points (Muralidharan et al., 2003; Suzuki et al., 1992).

Although there have been frequent notions about possible relations between RTD epidemics (or GLH population build-up) and climatic conditions in the literature, we could not find any climate-based epidemiological models developed for RTD in the literature we have reviewed. Therefore, a new tungro epidemiological model called *rtdSim* was developed and evaluated in our study. Detailed model development and validation work can be found in the **Appendix IV**.

During initial scoping period, data availability and proper strategies to collect the ground-truth disease incidence data were scrutinized. Through multiple channels such as literature, project reports, and kind help from local institutes (PhilRice and IRRI), ground-truth disease incidence data for tungro were collected and used to develop the *rtdSim* model.

Predicting tungro epidemics requires the use of many assumption-based, simplified model algorithms. These algorithms contain many components explaining the complex nature of the three-cornered pathosystems (virus, vector, and host) and their interactions with environmental variables (temperature and rainfall). The *rtdSim* model calculates how many rice hills are being infected with the rice tungro virus through its vector, the green leafhopper (GLH). The *rtdSim* model is divided into two linked modules: the “GLH population growth module” simulating GLH population dynamics of a complete life cycle from egg to adult stages, and their immigration from near rice paddies; and the “Infection module” simulating virus transmissions from infected rice hills to the GLH vector, and viruliferous GLH to healthy rice hills. The *rtdSim* was successfully calibrated and validated, resulting in a reasonably high level of agreement between the observed and the simulated epidemics in most cases.

○ Major Outputs and Outcomes

- A tungro epidemiological model, rtdSim, is successfully developed to simulate rice tungro disease risk in the Bicol region.
- Graphical and statistical comparisons between observed and the rtdSim-simulated tungro epidemics were made, indicating that the level of agreement between the observed and simulated epidemics was reasonably high in most cases.

- These positive results from the model development and validation encouraged to move forward for the next stage of developing climate-based epidemic early warning systems for rice pests, with SCFs as input, thus allowing better decision making in disease prevention and control in a seasonal scale.

2.5 Model Integration into the CAMDT Platform

Crop diseases are primarily governed by climate and weather conditions including temperature, precipitation, wind speed, and humidity; with controlled or fixed management options. It is, therefore, possible to predict the infection risk of crop diseases. In fact, disease forecast models have been developed to quantify the potential effects of weather on the intensity and occurrence of disease infection by pathogenic agents. This is why, to address the potential impact of disease on crop yield at a seasonal time scale, a collaborative partnership between the APEC Climate Center (APCC) and the IRI was initiated under the Bicol Agri-Water Project (BAWP) for the integration of rice disease models into the Climate Agriculture Modeling and Decision Tool (CAMDT).

Among the major insect and disease incidences occurring in Bicol, rice tungro disease, bacterial leaf blight, brown spot, and sheath blight were selected for CAMDT-Disease based on their socio-economic importance and relevant model availability. Utilizing the same work flow within the CAMDT, from the tercile seasonal climate forecast to downscaled daily weather realizations for agricultural model simulation, CAMDT-Disease enables the translation of climate information into potential disease risk under given seasonal climate forecasts. Since the CAMDT-Disease can more realistically reflect the real field situation where crop losses take place, the information it can produce adds an additional value on the use of the CAMDT as a decision support tool for the stakeholders in the Bicol region.

Readily available disease risk information, coupled with a potential rice crop yield simulation by the CAMDT, will enable decision-makers to develop informed farm management strategies. Such strategic decisions include not only short-term ones (e.g. the choice of a resistant cultivar against a high risk profile disease, seasonal scheduling of chemical and cultural control methods, and identifying the ideal time for planting crops to minimize crop losses due to diseases) but also decisions that do not directly pertain to disease management and yet have numerous crop health consequences (e.g. choices of the type of crop establishment, crop rotation, or cropping system).

CAMDT was developed by IRI in collaboration with the University of the Philippines Los Baños Foundation Incorporated (UPLBFI). It aims to guide decision-makers through user-friendly graphical interface in adopting appropriate crop and agricultural water management practices that can improve crop yields for given climatic conditions (Figure 4).

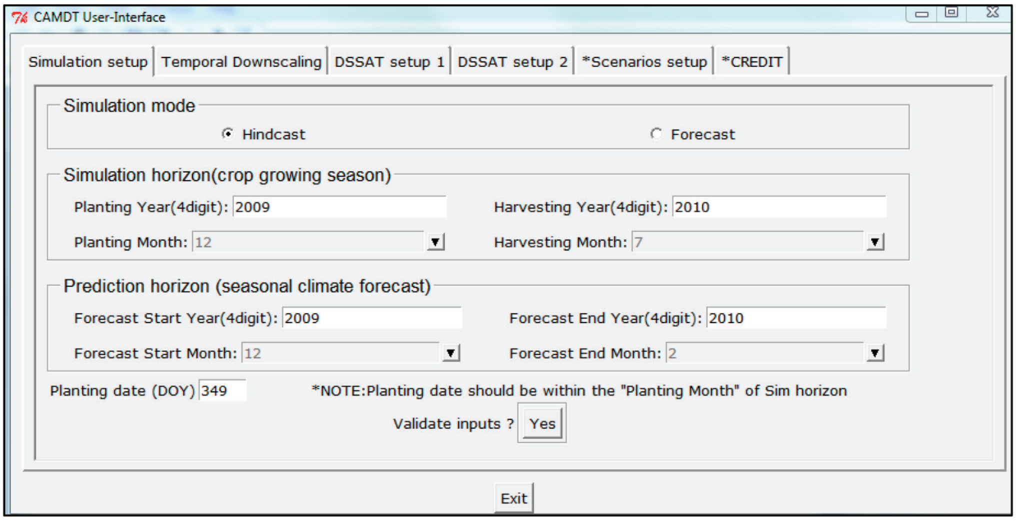

Figure 4. Graphical user interface of CAMDT

CAMDT provides a user-friendly graphical user interface (GUI) that is easy and convenient for users. Despite being a useful tool, it has limitations in expanding and maintaining its functions because it is implemented as a single source.

With the advantages of the existing CAMDT platform, the CAMDT-Disease platform, which integrates it and rice disease models, has been developed using the same development environments (Table 2). The existing CAMDT platform is referred to as CAMDT 1.0 while the new CAMDT-Disease platform is referred to as CAMDT 2.0. In the development environments, Python is used as a programming language and matplotlib library is used for plotting a variety of results that simulated by CAMDT models. Tkinter and Pmw libraries are used for GUI design in python environment, and comma-separated values (CSV) library is used to read the result data. Rice disease components are developed using R program.

Table 2. CAMDT 2.0 development environments

	Environment	Version
Operating System	Windows	Windows 10
Programming Language	Python	2.7.13
Libraries	Matplotlib	1.5.1
	Tkinter	Revision 81008
	Pmw	1.3
	CSV	1.0

We have re-designed the architecture of the CAMDT 1.0 platform to maintain and expand functions easily before integrating rice disease model into the CAMDT 1.0 platform. The package and class diagram of the new architecture of CAMDT 2.0 platform are shown in Figure 5. The packages were designed with camdt_main, process, ui, uivar, _setting, util and resources. The camdt_main package is responsible for running CAMDT 2.0 platform. The process package has classes that run the process to simulate CAMDT models and rice disease models and manages error messages. Considering the extensibility of UI, we designed the ui package with Tkinter and Pmw libraries, the uivar package to manage its input data and the _setting package to store and load user's input data on input components each UI. The util package has AutoDetectUtil, CAMDTUtil and TKinterUtil classes that provide common procedures and functions necessary to develop the CAMDT 2.0 platform. The resources package is designed to prepare for the localization of the program.

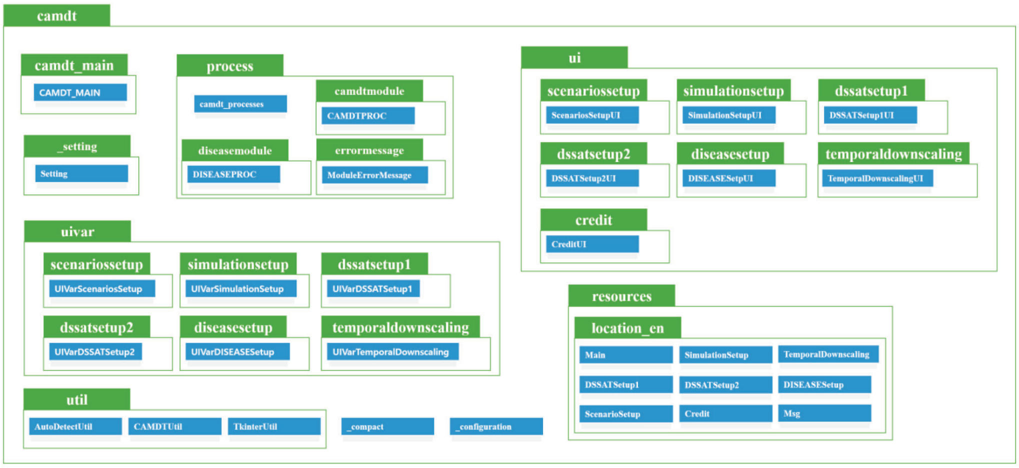

Figure 5. Package and class diagram of CAMDT 2.0

We implemented new functions and new UI, and DISEASE Setup tab for rice disease simulation using new architecture (Figure 6). The DISEASE Setup tab provides the options necessary to simulate rice disease simulation (Figure 6 (a)). The options are to enable the rice disease simulation and to set an R program path. The R program path can be not only set by user but also by automatic folder selection function to detect the path of Rscript.exe automatically using windows environment variables such as path, programfiles, etc.

Figure 6 (b) shows the scenarios setup tab of CAMDT 2.0. The scenarios setup tab provides the functions of “Run DSSAT” and “Display Outputs”. The Run DSSAT and Display buttons are to run CAMDT models and to show its results as plots, respectively. It is designed so that the rice disease models run after finishing processing of the CAMDT models in order to use the results of the CAMDT models as input data of the rice disease models. In order to simulate the rice disease models within the CAMDT platform, R program path should be set on DISEASE setup tab.

To plot the results of rice disease risk, the Display Rice Disease Risk button has been added together with existing display buttons. The rice disease model does not always run but can be executed according to the selection option (“Yes” or “No”) on DISEASE setup tab. We also added a function that copies CAMDT module files to a working directory selected by a user.

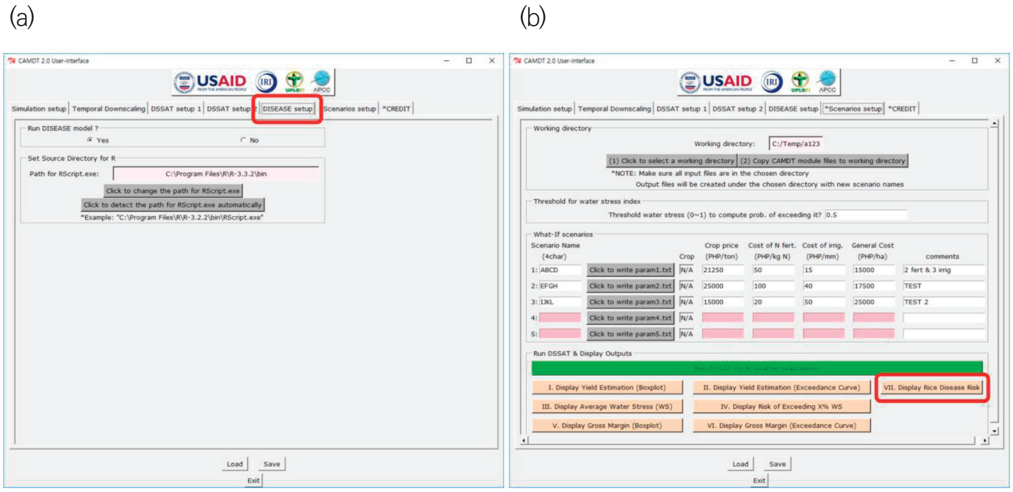

Figure 6. New functions for rice disease simulation in CAMDT 2.0: (a) DISEASE setup tab (b) Scenario setup

CAMDT 2.0 is included in the CAMDT 1.0 platform as an additional module built on the user-friendly graphical interface of the CAMDT. As the users run the CAMDT with their own "What-if" scenarios, CAMDT-Disease simultaneously generates potential risk scores for selected rice diseases under each scenario, which is solely based on climate information within the cropping season of each scenario. The resulting risk score for the rice diseases is displayed as a normalized ratio based on the 30-year average climatological risk for each disease. In this way, the users are able to estimate the relative risk level compared to last normal years in the same cropping period. This provides a grounding framework in understanding the practical implications of CAMDT-Disease outputs. High risk score leads the users to enhance field surveillance vigilance or to increase agro-chemical stock for controlling the target diseases. If the simulation is made before the cropping season, changing the rice variety to a more disease-resistant one would be another option. Rice diseases risk simulated by disease models for four rice diseases using two 'What-if' scenarios is shown in Figure 7.

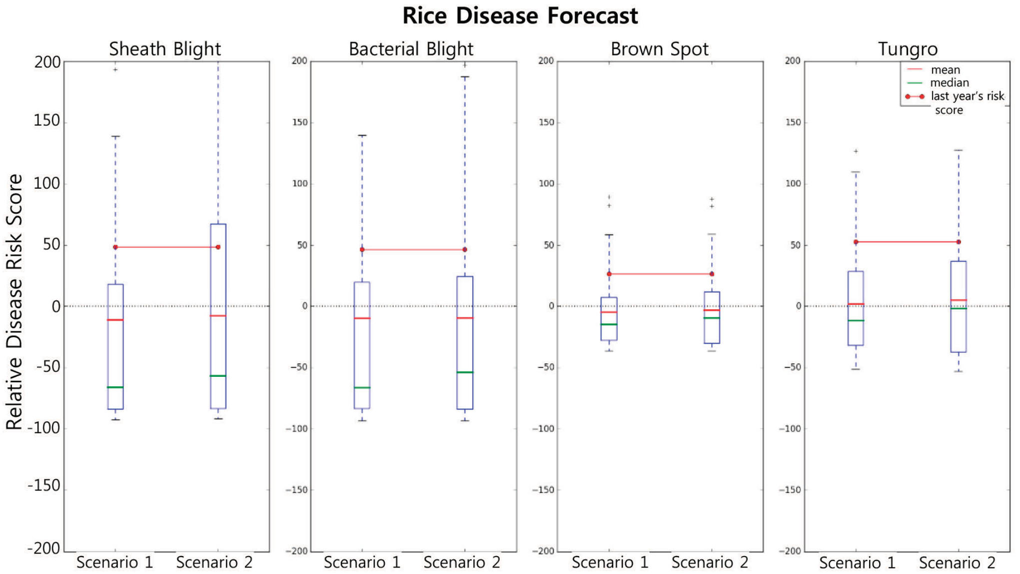

Figure 7. Rice disease risk simulated by the CAMDT 2.0 for four rice diseases by two scenarios. Note: Dotted horizontal black line is the 30-year average climatological risk level for each disease. Red dots indicate the last year's risk score, which is also relative risk scores to the 30-year average climatological risk level. The relative disease risk scores for each disease simulated with the given seasonal climate forecasts provide a seasonal pest outlook, with which agricultural stakeholders can estimate the extent of disease risk abnormality (either lower or higher compared to the past) for the upcoming cropping season.

○ Major Outputs and Outcomes

- Provided a user interface expanded from the existing user-friendly user interface to keep user experience (UX) of the existing CAMDT.
- Developed rice disease components using R program and integrated it into CAMDT platform.
- Increased user-friendly functions (e.g., saving/loading user settings, detecting R program path automatically, copying CAMDT module files into a working directory, etc.).
- Re-designed an architecture of the existing CAMDT platform to maintain and expand functions easier.

2.6 Technical Workshop II

The 5th Annual Technical BAWP Workshop: *Models and Tools for Water Agriculture and Knowledge Sharing* was held March 14-17, 2017 at the Villa Caceres Hotel, Naga City, the Philippines, co-hosted by APCC and BAWP. Final versions of the models such as Water Evaluation and Planning (WEAP) Model-Bicol, Climate-Agriculture Modeling Decision Tool (CAMDT) and Knowledge Sharing Portal and Maproom (KSPM) were presented to project partners, as well as the first version of CAMDT-Disease

Experts from IRI, Michigan State University (MSU), University of Maine, and APCC discussed the updated versions of the models and further explained how the KSPM can be more useful in operation mode. A hands on session was delivered to walk stakeholders through CAMDT-Disease, allowing for both the familiarization of the users with the model and the identification of improvements to be made. The workshop provided an opportunity for partners to be more familiarized with the climate change models and tools for assessing and managing climate risks in agriculture and water resources. The workshop was conducted in collaboration with partner agencies: IRI, APCC, Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA); Department of Agriculture Regional Field Office 5 (DARFO5) and the University of the Philippines Los Baños Foundation, Incorporated (UPLBFI).

This event also served as an avenue to officially turn-over all the decision support tools to target users for their operational use in agricultural climate risk management. On the final day of the workshop, BAWP officially turned over all its decision support tools for agricultural climate risk management such as CAMDT, WEAP, KSPM and CLEA to the project partners.

Thirty-two representatives from different partner agencies and institutions participated in this workshop. Having gained additional knowledge and skills, they are now better prepared to employ the models introduced by BAWP for adaptive climate risk management in agriculture and water resources.

A full workshop report may be found in the **Appendix V**.

Major Outputs and Outcomes

- APCC presented project and final product.
- Training held on CAMDT-Disease to run simulations and interpret results.
- Feedback from key users collected for the improvement of CAMDT-Disease.
- Strengthened connections with IRI and local organizations.
- Shared and discussed the functionalities of the final versions of the Knowledge Sharing Portal, WEAP-Bicol and CAMDT models and tools to project partners.
- Provided an opportunity for project partners to familiarize with climate change/variability and the models/tools for assessing and managing climate risks to agriculture and water resources.
- Turned over officially all the models/tools for target users for their operational uses in the future for agricultural climate risk management, excepting CAMDT-Disease (to be turned over in September 2017).

2.7 Agro Advisory - Seasonal Climate Forecast and Extension Advisory

The Seasonal Climate Forecast and Extension Advisory or CLEA is a bulletin containing a six-month climate outlook. It shows local micro-climatic rainfall data and seasonal climate forecast with corresponding agricultural extension advisories. In the Philippines, it initially covered the municipalities of Buhi and Nabua in Camarines Sur and Polangui in Albay to enhance the resiliency of farmers and the ability of their local decision makers to adapt to climate variability and change. CLEA is tailored to the local situation needs to enable farmers to minimize the effects of climate risks while maximizing opportunities of favorable weather conditions within their farming communities. It is an easy-to-read reference to help farmers adapt to "new normal" rainfall patterns.

As a decision support tool, CLEA could aid in integrating climate information in agricultural decisions as experienced in Bicol. It could help farmers improve strategic decision making in agricultural management to minimize losses and maximize yields. A two-page briefer, CLEA contains the following: 1) climate information provided by the PAGASA; 2) historical rainfall data collected from the rain gauge stations; 3) the El Niño Southern Oscillation (ENSO) Forecast and/or La Nina Watch section from the IRI-CU and PAGASA; 4) Tropical Cyclone Forecast from PAGASA; 5) the result of crop and disease simulation runs using CAMDT and CAMDT-Disease by State Universities and Colleges (SUCs); and 6) the Extension Advisory and Good Practice Options (GPOs) and advisories on ideal times for planting and harvesting, crops or varieties to plant, and crop and water management practices suitable for climate outlook, recommended by the respective Municipal Agricultural Officer and DA-RFO 5.

In the current version of CLEA, relative disease risk level compared to the past 30-year-average risk for four major rice diseases are presented as the "Seasonal Pest Outlook" with three different plantings dates: early, mid, and late. The relative disease risks (%) for each disease simulated with seasonal climate forecast provide a seasonal pest outlook, with which agricultural stakeholders can estimate the extent of disease risk abnormality (either lower or higher compared to the past) for the upcoming cropping season **(Appendix VI)**.

The seasonal pest risk information (pest outlook) on CLEA is provided to farmers before rice planting. Since this is when most important strategic decisions are made, CLEA will enable decision-makers to make informed management decisions including which diseases or insect pests to focus on to prioritize for pest management with limited resources, amount of agrochemicals needed for stocking, which crop or variety to plant, and which cropping system to adopt under the anticipated pest pressure. The longer lead time of seasonal time scales is necessary, for the majority of efficient counteracting practices require extended preparatory time for most diseases. For example, to employ proper disease control management decisions such as synchronous planting, replacing with resistant varieties, and changing cropping pattern including a fallow period in dealing with rice tungro disease, a least 3-month-lead time for the action planning would be required.

To know and understand the benefits of CLEA, farmers' meetings are now organized every month, to discuss updates, the extension advisories and good agricultural practice options (GPOs) recommended by the respective Municipal

Agricultural Offices and DA-RFO 5. This motivated farmers to adopt CLEA and benefit from it. The BAWP project partnered with provincial governments to hold a forum with 1,000 farmers in attendance where CLEA was introduced. These farmers are able to appreciate weather forecasts that can guide them in their crop choice and farm management decisions.

Major Outputs and Outcomes

- Sustainable production and use of the results from the CAMDT-Disease tool through CLEA.
- Enhanced awareness with strategic planning for disease control over the next seasons based on the Seasonal Pest Outlook on CLEA from the CAMDT-Disease.
- Enhanced skills of the local partners such as SUCs and agricultural extension workers on agriculture production in general and on weather modeling and decision support tools in particular.
- Value added information on CLEA could help farmers improve strategic and tactical decision making in agricultural management to maximize benefits and minimize any climate-related risks in the growing season.

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APPENDIX Ⅰ

Report on Disease Epidemiology and Control Management of Rice Tungro Disease

1. Rice tungro disease in the Bicol

Rice tungro disease (RTD) is a composite virus disease transmitted mainly by the green leafhopper (GLH), Nephotettix virescens (Ling, 1972). The incidences of RTD emerged as one of the most destructive rice diseases in tropical Asia shortly after the introduction of new technologies to increase the rice production in the late 1960s. Extensive planting of high-yielding cultivars and intensive use of fertilizers are particularly responsible for the population build-up of the vector population and tungro outbreaks (Ling, 1972).

Tungro affects the plant at any growth stage, most severely during the vegetative stage where symptoms are more pronounced. Leaf discoloration begins from the tip and spreads down the blade to the lower leaf portion. Leaves may also exhibit mottled or striped appearance and stunting is also evident as well as reduced tillering while flowering is delayed and consequently, incomplete maturity in the end. Panicles are small, not well exerted and are partially sterile. Grains are covered with dark brown blotches and its quality is poor. Other indications of infections are the presence of GLH adults, nymphs and eggs.

Tungro, which means “degenerated growth” in a Filipino dialect, has a much longer history in the Philippines. The early outbreaks of rice tungro disease in the 1940s, long before the causal organism was identified (Hibino et al 1978, 1991) in major rice-growing regions in the Philippines, reduced the overall national yield to 1.4 million metric tons annually (Serrano 1957), nearly the amount of the country’s 2008 rice import. Since then, major epidemics of tungro were recorded in the 1970s and 1980s in areas associated with intensive cultivation of early varieties recommended by the Department of Agriculture (DA) (Bajet et al., 1986; Baria, 1997). Since then, outbreaks occurred sporadically during 1993-98 (Truong et al., 1999a), affecting areas from 900 to 2,700 ha yearly in Mindanao, and in Davao del Norte alone a yield loss of almost 11 million Philippine Peso was recorded in 1993. Crop loss estimated from one outbreak case in 1993 alone reached approximately USD 400,000. In addition, about 700 ha were affected in Negros Occidental in 1998. Recent outbreaks in the past three years recorded by the DA in Cagayan Valley, Panay Island, Central Mindanao and Southern Mindanao resulted in an estimated yield loss as high as 90 percent and whatever grains left would not fetch a high price due to poor grain quality (Calleja, 2010). These huge yield losses by RTD were possible due to the nature of viral disease, a systemic infection. Based on a field survey report by Muralidharan et al. (2003), the RTD epidemic and yield losses in paddy fields are almost linearly related with each other. In other words, the yield loss can be calculated based on number of diseased hills in a linear relation. If there are 10% diseased hills, the yield loss will be approximately 10%.

Most of the affected locations commonly reported were irrigated lowlands with less pronounced DS and WS. In those areas, it is relatively dry from November to April and wet during the rest of the year, or rainfall is evenly distributed throughout the year. In most cases, RTD outbreaks were attributed to insufficient irrigation water because it prompted farmers to practice staggered planting. In fact, RTD risk in a particular field is only partly dependent on crop specific factors such as the susceptibility of the rice variety. It is also determined by area-wide factors such as the proportion of susceptible varieties, the distribution of planting dates, and the age, number and potency of inoculum sources in the locality.

The Regional Crop Protection Center (RCPC) of the Department of Agriculture-Regional Field Office 5 (DA-RFO 5) provided monthly tungro incidence records collected from 2003 to 2015 in Bicol. Monthly records for the number of municipalities and total area (ha) affected by tungro disease were displayed in Figure 1. There were four major outbreaks of RTD in terms of affected area in the Bicol: 2008 wet season (WS), 2009 dry season (DS), 2009 WS, and 2010 WS. Since 2014, there was no report of RTD incidence in the region, probably indicating unfavorable environments for RTD during 2014-16.

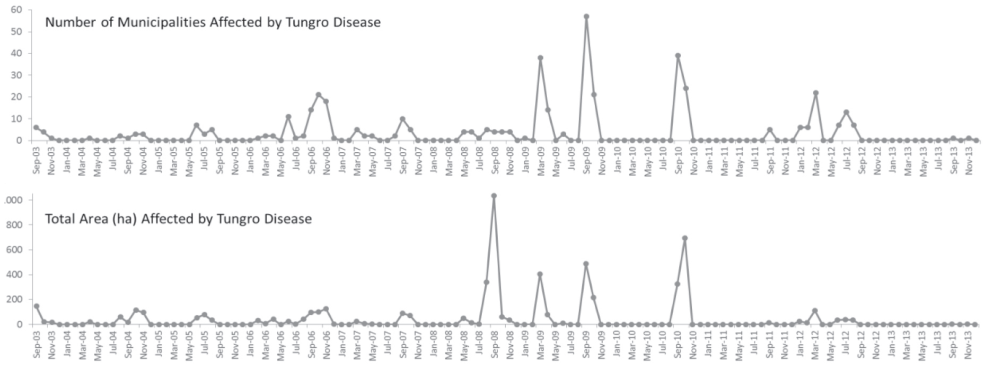

Figure 1. Tungro disease incidence records in the Bicol. Monthly records for the number of municipalities and total area affected by tungro disease were displayed for each month from 2003 to 2015. (Source: the Regional Crop Protection Center of the Department of Agriculture-Regional Field Office 5).

A number of surveys have been carried out, from which it has been possible to correlate tungro incidence with agro-ecological variables. Suzuki et al. (1992) found that almost 50% of the variation in the incidence of newly infected fields in a particular month was explained by three variables: new infections in the previous month (which are important source of inoculum), occurrence of 2-3 month old crop (which are the major source of vectors), and rainfall in the present month. Savary et al. (1993) analyzed survey data collected from three sites in the Philippines. In a non-endemic area, tungro outbreaks were mainly associated with the occurrence of infective vectors. In the two endemic areas, increasing tungro incidence was also associated with a larger number of infective vectors but the size of the leafhopper population was also important. They concluded that inoculum, as measured by infective vectors, has a greater influence on tungro outbreaks in the non-endemic than in the endemic areas. In a survey carried out in a tungro-prone locality of Southern Luzon in the Philippines, Chancellor et al. (1995) found that there are significant differences in RTD incidence related to month of planting. Crops planted late in wet or dry season suffered from very much worse tungro problems than those planted earlier. Higher tungro incidence occurred in the WS than in the DS, as already indicated in the monthly RTD records in Bicol shown in Figure 1.

It was also reported that early infection at the vegetative stage of susceptible cultivar induced severe crop losses varying from 30% to 80%. In severe cases, tungro susceptible varieties infected at an early growth stage could have as high as 100% yield loss (IRRI, 2015; Nas and Cortez, 2011). Therefore, RTD is considered as the most important factor limiting rice production by most farmers in endemic areas in the Philippines. In fact, survey results in five RTD endemic and non-endemic provinces (Albay, Davao del Norte, Davao del Sur, North Cotabato, and Laguna) during 1995-97 showed that most farmers had experienced the RTD problem (Warburton et al 1996, 1997, Truong et al, 1999b).

Currently, there are no hybrid rice varieties completely resistant to tungro. Existing resistant inbred lines are provided only as stop-gap varieties and may not yield as high as the ones farmers usually plant. However, those inbred lines usually yield more than the farmers' varieties under tungro disease pressure. So it is important to detect the disease as early as possible before transplanting in order to secure an enough lead time to be able to change rice varieties based on the early warning information.

2. Counteracting practices for tungro control

○ Government pest surveillance

Timely surveillance for tungro incidence in the fields can prevent further spread of disease and the resultant pandemic situation. Regular surveillance by farmers could be an easy option, but difficulties arise as farmers normally cannot distinguish the tungro symptoms from other physiological or viral diseases. So, in many countries, pest surveillance becomes a public service by local and/or national government agencies. Well-established surveillance system can effectively counteract the potentially huge damages from a pest epidemic within a short time.

The establishment of a surveillance and forecasting system involves setting up a practical regional system in major rice-growing areas. There is an organization and functional setup of the pest surveillance system in the RCPC of the DA-RFO 5 (Figure 2) in Bicol. A pest surveillance center operates in a municipal level.

The system is operated by an agricultural officer (Municipal IPM Coordinator) who is assisted by surveillance scouts. Each scout supervises certain area of rice paddies to detect vector numbers and tungro disease incidence, by collaborating with local farmers in many cases. Visual estimates of GLH are recorded. Visual counting permits rapid examination without subsequent laboratory work, although accuracy probably decreases as pest density increases. At times, sweep nets are also used to estimate GLH numbers. Initially, tungro incidence was assessed by symptoms. There is a field manual developed for tungro surveillance and data management for the surveillance scouts (Evangeline Trinidad, the chief of the RCPC of the DA-RFO 5, personal communication).

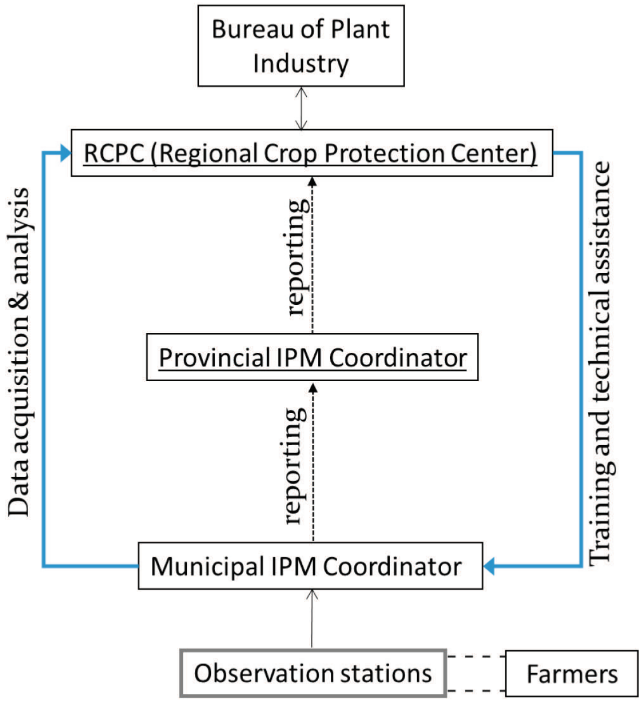

Figure 2. Diagram for the organization and functional setup of the pest surveillance system that are being operated in the DA-RFO 5 (acquired from the RCPC of the DA-RFO 5).

Data collected are examined and assessed by the municipal IPM coordinator and surveillance officers. In normal situations where insect pests and diseases are below threshold levels, farmers and extension officers are informed. This information is also displayed on notice boards at meeting places for farmers and extension staffs. If the pest situation reaches outbreak levels in extensive areas, it is reported to the provincial IPM coordinator, who then gathers all the reports from individual municipalities to develop a summary report for the RCPC office. If the situation is serious, the pest control committee is activated. The committee comprises members from the DA, the RCPC, and extension services. In addition to reviewing the pest situation in relation to field conditions and making control decisions, the committee also determines the surveillance for the period and ensures that decisions made are implemented immediately.

○ Control practice of tungro disease

Management of tungro is based on either controlling the sources of disease inoculum (infected rice hills) or controlling the vector, GLH, or both. Methods found by researchers to be effective include using resistant rice varieties and using synchronous planting, rotations, or fallow periods to remove rice plants at certain times of the year, thus removing sources of disease inoculum and preventing disease spread. In the Philippines, insecticides are widely practiced by farmers for controlling GLH, although some researchers doubt their effectiveness (Truong et al., 1999).

Rice varieties. The introduction of GLH-resistant varieties newly developed has been the central strategy of controlling RTD. However, after a few consecutive seasons of cultivation, there is a breakdown of the resistance level of the formerly resistant cultivars (Dahal et al., 1990). In fact, it appears increasingly difficult to develop a new cultivar which fully fulfils the requirements for high-yielding ability, good grain quality, and resistance against GLH. Farmers generally choose varieties they considered as suitable in terms of characteristics such as expected yield, growth duration, and tolerance level for pests. In the Philippines, it is difficult to define exactly what variety farmers are growing because they are very active in selecting their own seed. Farmers were aware of which varieties are susceptible to tungro, and a significant number are growing varieties with some resistance. A few farmers are still growing very susceptible varieties such as IR64.

Insecticide use. The level of insecticide use is four to five times higher in the Philippines compared to other rice-growing countries in Southeast Asia. The high level of insecticide use was due in large part to the introduction of black bug in the rice-growing area. This new and very visible pest is of enormous concern to farmers, who are not used to dealing with it. Tungro accounted for less than 5% of the total sprays. Although insecticides are commonly used, there seems to be a realization that insecticides are not the complete answer to tungro and cannot cure the disease (Chancllor et al., 1995; Holt et al., 1996).

Planting dates and other cultural controls. Cultural practices are the most realistic way to manage RTD because these activities are close to farmers' experiences. Large-scale synchronous rice planting combined with periodic fallow span or secondary crop planting has been proved to be the most successful strategy for tungro control (Sama et al., 1991). Correspondence analysis examining relationships between production environment variables (agroecosystem, synchrony of planting, and varieties planted) and the occurrence of rice tungro epidemics revealed that the low disease incidence was associated with synchronous planting while the high disease incidence was associated with the planting of susceptible varieties and asynchronous planting (Cabunagan et al., 2001). Even in non-endemic locations in Luzon, staggered planting increased the GLH population at later planting dates. Accordingly, the cumulative incidence of RTD also increased in late planting months (Truong et al., 1999a). In case a severe RTD infestation occurs in an endemic asynchronous planting area, it can also spread and cause serious damage even to near synchronous planting areas.

Using synchronous planting, fallows, and rotations is likely to be a greater challenge in the Philippines. In reality, it is difficult to determine the cutoff point between one cropping season and the next. For example, planting dates for the WS varied from April to September; for the DS from November to March. In fact, the irrigation water schedule was a major factor in farmers' choice of planting dates, which always requires negotiations with irrigation authorities and neighboring farmers. In fact, synchronous planting can only be achieved with sufficient irrigation water. Most farmers in irrigated lowlands in northeastern and northwestern Luzon, where DS and WS are clearly distinct, have been effectively practicing synchronous planting (Truong et al., 1999a). Planting of the first crop begins in December/January, followed by the non-rice crop/fallow period; the second begins in May/June. Irrigation water is provided only during the 4-month planting period. Farmers could produce high yields even from susceptible varieties. Alternative crops (for a rotation system) may not be possible if fields are poorly drained, and Philippine farmers have fewer alternative sources of income (other than rice), so they may be reluctant to use fallows.

Another important component of cultural practices is the broadcasting method or direct seeding. Crop establishment by direct seeding has become popular in both DS and WS in Midsayap to shorten planting time right after irrigation during land preparation. Farmers consider this method to be easier, faster, and cheaper than transplanting (Truong et al, 1999b). GLH-resistant varieties established by transplanting or direct seeding had the lowest incidence of RTD (2–12%) (Chancellor et al., 1999). Likewise, rotation of two to three GLH-resistant varieties after two to three cropping seasons and synchronous transplanting based on communal seedbed preparation were promoted.

Early warning system. An early warning system can be used together with appropriate cultural practices, which may increase the control efficiency of RTD. Developing a real-time early warning or forecasting technology in RTD-endemic, asynchronous rice planting areas needs to be done first, and then preventive actions should be prepared based on the alarming situation predicted. Lead time of the early warning system determines different control strategies that can be adopted in the given situations. In the Philippines, there is no early warning system that is operational at present.

3. Modelling tungro epidemic

Due to its vicious impacts on the rice paddies in the Southeast Asia, integrated disease management approaches were tried using various management tools. In this case, predictive epidemiological models can assist decision making over when the full range of their constituent control measures need to be deployed, when costs can be saved, and whether environmental benefits can be derived by deploying fewer measures or by non-deployment (Jones et al., 2010; Knights and Thackray, 2007; Thresh, 1986).

Holt and Norton (1993) showed the application examples of simulation modelling to improve the understanding of pest dynamics on which to base management recommendations. A spatial, stochastic, individual-based model of RTD dynamics was developed and used for a theoretical investigation of risk under different situations of vector immigration. Since then, very similar model was developed by Ferris and Berger (1993) to compare, theoretically, virus disease dynamics under different assumptions of virus persistence in the vector. Holt and Chancellor (1996) simulated real pathosystems and consider control issues, particularly for disease management by rouging. And recently, a mathematical model of the epidemiology of RTD in the cropping system was developed to investigate the deployment of fields of a genotype expression resistance to the disease (Holt and Chancellor, 1999). Other than these process-based models, there were some regression models developed to estimate grain yield losses based on RTD incidence or GLH population at certain cropping points (Muralidharan et al., 2003; Suzuki et al., 1992).

APPENDIX Ⅱ

Report on Examination of the APCC MME SCF over the Bicol Region

1. APCC MME SCF

Our study aims at producing seasonal rice pest outlook utilizing currently operational SCF information over the Bicol region. In this reason, SCF predictability over the Bicol region needed to be considered for the study. Simply we understand that high predictability of SCF may ensure more usability of the results by the users, while less usability expected if we use SCF with low predictability skill.

Since 2007, APCC is issuing deterministic and probabilistic Multi-Model Ensemble (MME) seasonal predictions for the upcoming three-month overlapping seasons, which are disseminated to APEC member economies via our website (www.apcc21.org). The operational probabilistic forecasts at APCC are seasonal forecasts in the form of tercile (any of the ordered distribution divided into three parts, each containing a third of the population)-based categorical probabilities, i.e., the probabilities of below-normal (BN), near-normal (NN), and above-normal (AN) categories (e.g., Kharin and Zwiers 2003; Boer 2005; Min et al. 2011).

To validate the prediction and measure the seasonal forecast skill, the following verification metrics are widely used not only in operational centers but also in APCC; Temporal Correlation Coefficient (TCC), Root Mean Squared Error (RMSE), Anomaly Correlation Coefficient (ACC), Brier Skill Score (BSS), Heidke Skill Score (HSS), and Ranked Probability Skill Score (RPSS).

In this section, (i) months/seasons with high performance in the precipitation prediction in Pili and (ii) the possibility and usefulness of the APCC probabilistic MME (PMME) data for the decision makings about pest management in Pili are discussed by using the PMME forecast and observational data with the RPSS method.

1.1 Data

The monthly and seasonal PMME forecast and hindcast data from APCC were used for the analysis. The data are in a 2.5×2.5 degree latitude/longitude grid format. The hindcast period is from 1983 to 2005. The lead time of the monthly data used in this study is up to 3 months from the forecasting time point.

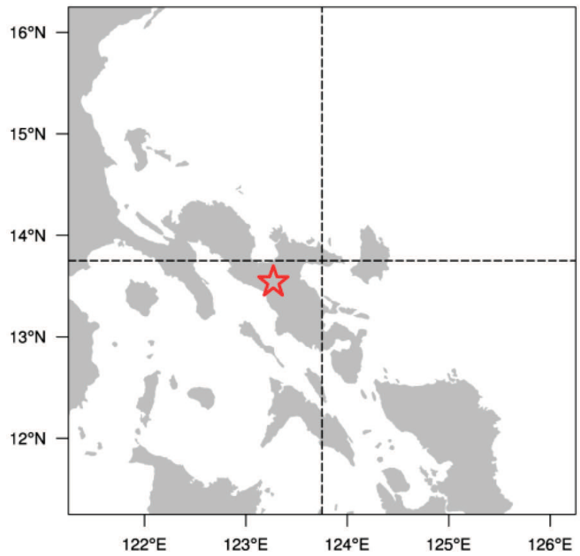

Figure 1. Map of the study area, the Bicol in the Philippines. A red star indicates Pili.

The data used for the verification of the precipitation forecast in Pili were obtained from 1) the Climate Anomaly Monitoring System and Outgoing longwave radiation Precipitation Index data (CAMS OPI; Janowiak and Xie, 1999) and 2) the Pili weather station. The CAMS OPI is a precipitation estimation technique which produces real-time monthly analyses of global precipitation. With the CAMS OPI, observations from rain gauges are merged with precipitation estimates generated using a satellite algorithm. This data set is currently used for the verification of the APCC monthly/seasonal prediction. The horizontal resolution of data is the same as that of the PMME data. The station data were obtained from the Pili weather station, which is the capital of the province of Camarines Sur in the Bicol region, the Philippines. The Pili station is located in 13.555°N in latitude and 123.270°E in longitude as shown in Figure 5. Pili is on the grid box whose center is 12.5°N in latitude and 122.5°E in longitude.

1.2 Methodology

The method used to validate the prediction skill of PMME over Pili is the ranked probability skill score (RPSS). Before RPSS is calculated, the ranked probability score (RPS) should be obtained first. The RPS is a squared measure that compares the cumulative density function (CDF) of a probabilistic forecast with the CDF of the corresponding observation over a given number of discrete probability categories in order from lowest to highest (Epstein, 1969; Murphy, 1969, 1971), as follows:

$$RPS = \frac{1}{ncat} \sum_{icat=1}^{ncat} (Pcumfcst_{icat} - Pcumobs_{icat})^2$$

where *icat* is the category number (1 for below normal, 2 for near normal, 3 for above normal), *ncat* is the number of categories (3 in a tercile-based system), *Pcumfct* is the cumulative forecast probability up to category *icat*, and *Pcumobs* is the comparable term for the cumulative observation "probability". The RPS indicates to what extent the forecasts failed to discriminate among different observed outcomes, and systematic biases of location and level of confidence. Note that the RPS is sensitive not only to the forecast probability given to the observed category, but also to the probabilities given to the other categories.

The formula for the $RPSS$ is based on the RPS of the forecasts and the RPS of the constant climatology forecasts, as follows:

$$RPSS = 1 - \frac{RPS_{fct}}{RPS_{cli}}$$

where RPS_{fct} and RPS_{cli} are the RPS for the forecast and the climatology forecast, respectively. When RPS_{fct} and RPS_{cli} are equal, $RPSS$ is zero, and when RPS_{fct} is zero, $RPSS$ reaches its maximum possible value of 1.

2. Examination of the APCC MME SCF

2.1 Precipitation in Pili

The annual and monthly average amount of precipitation in Pili was calculated from weather station data from 1979 to 2015 is 2246.9 mm and 187.2 mm (Figure 2), respectively. If we divide wet and dry seasons based on precipitation amount, the period of June to December when the monthly precipitation is over 187.2 mm should be the wet season, while the other months should be the dry season. However, it was generally known that the months from May to October are classified as the wet season and the months from November to April as the dry season. Considering that most precipitation falls from May to December, we thought it reasonable to adopt the general classification in the study as it is.

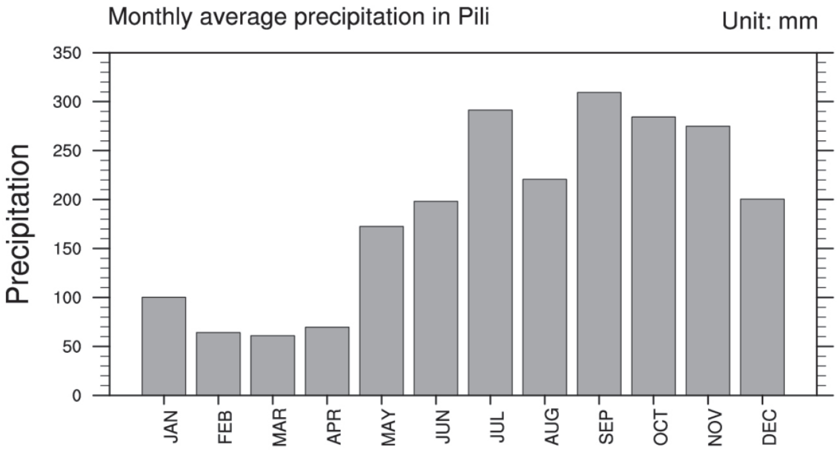

Figure 2. Monthly average precipitation in Pili.

2.2 Correlation between the CAMS OPI and the Pili weather station data

The correlation coefficients between two observational datasets, CAMS OPI and station data of Pili, are all above zero for all months and seasons during 1979 to 2015, which is the maximum available period of the two datasets (Figure 3). The highest correlation was 0.75 and 0.79 in October and OND, respectively. In addition, correlation coefficients of ten out of 12 months/seasons showed the significance of 95%. The PMME data are in a 2.5×2.5 degree latitude/longitude grid format, while the observed station data are obtained from the Pili weather station from the PAGASA. Since it is less reasonable to directly compare the observed station data with the larger grid data, we looked at observation-comparable data in a gird format, which is the CAMS OPI. To find whether the CAMS OPI can represent the Pili station data, we analyzed the correlation coefficients between CAMS OPI and the Pili station data. As shown in Figure 3, relatively high correlations were observed in most months and seasons, although the correlation was varied among months or seasons. Based on these results, we concluded that CAMS OPI can be used for the verification of the APCC MME SCFs, together with the observed precipitation data from the Pili station.

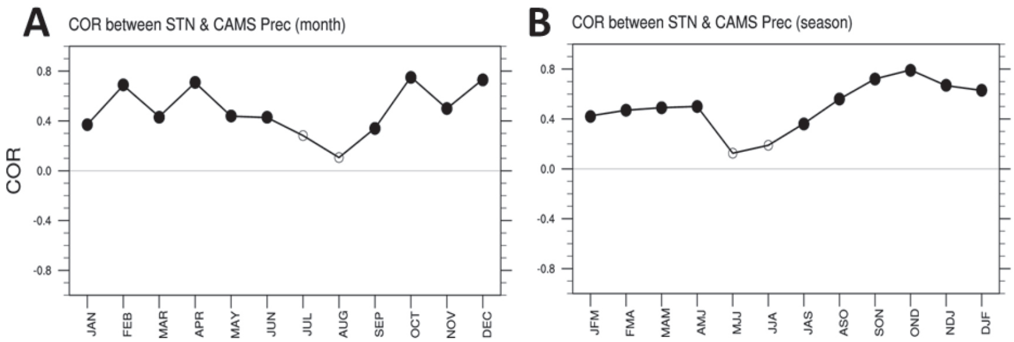

Figure 3. Correlation coefficients between (A) monthly and (B) seasonal CAMS OPI and precipitation data from the Pili station during 1979–2015. Filled circles represent coefficients with 95% significance.

2.3 RPSS for hindcast

The RPSS for monthly PMME hindcast with 1-month lead time is highest compared to the RPSS with 2- and 3-month lead time for all months except for March, May, and June and the RPSS of 1- and 2-month lead time is all above zero (Figure 4A). The average RPSS of 1-month lead time is 0.172 and the scores for May, June, July, August, September, and November are lower than the average. Those months are in rainy season of Pili. Similarly, the seasonal PMME hindcast during MJJ to OND seasons also shows the RPSS below average of 0.238 (Figure 4B). The highest RPSS of 0.426 was shown in AMJ season.

The RPSS tends to decrease from April/AMJ and become below average, and then starts to increase from September/SON. This annual cycle coincides with WS and DS in Pili.

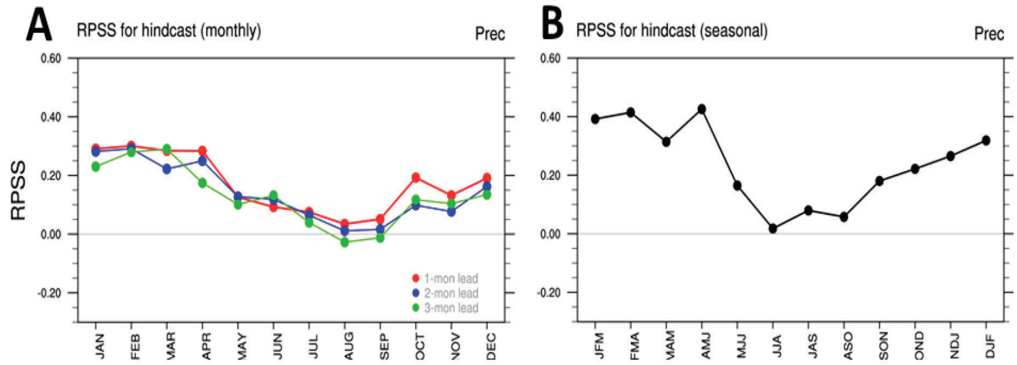

Figure 4. RPSS for (A) monthly and (B) seasonal PMME hindcast of precipitation in Pili during 1983-2005.

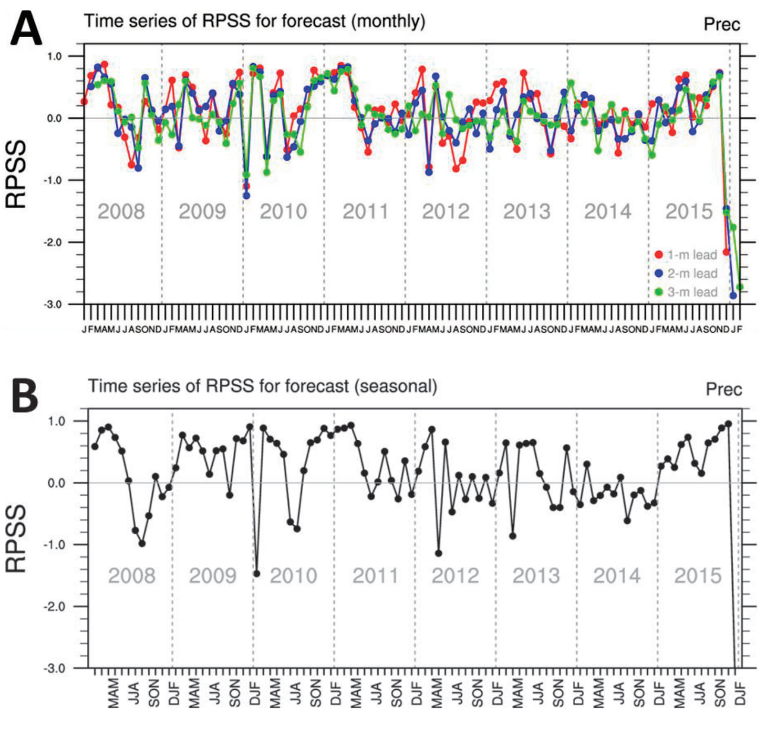

Figure 5. Time series of RPSS for (A) monthly and (B) seasonal PMME forecast of precipitation in Pili from 2008 to 2015.

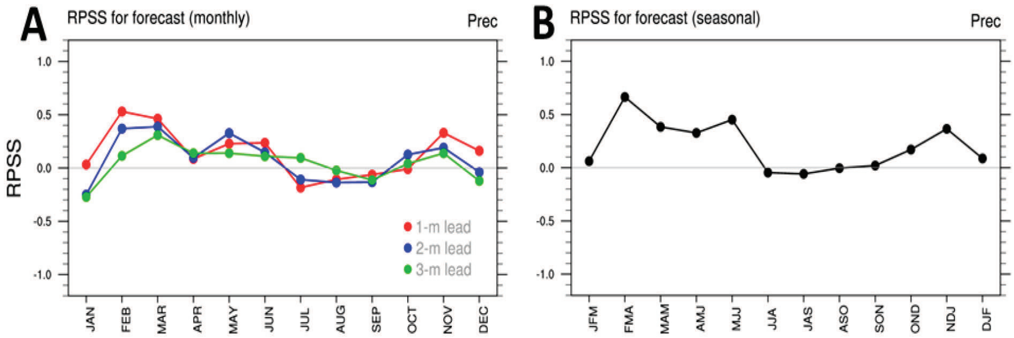

Figure 6. Average RPSS for (A) monthly and (B) seasonal PMME forecast of precipitation during 2008-2015.

2.4 RPSS for forecast

The time series of the RPSS for monthly and seasonal PMME forecast is shown in Figure 5. Most scores varies within the range from -1 to 1, but the RPSS of January and JFM in 2010 and AMJ in 2012 are below -1. There are also some severe cases showing the more strongly negative score below -2 of RPSS, which are DJF in 2015, December in 2015 with 1-month lead time, January in 2016 with 2-month lead time, and February in 2016 with 3-month lead time. The forecast period is from 2008 to 2015, total 8 years, which is shorter than the hindcast period. We assumed that this is why the distinct seasonality of the RPSS for the forecast data was not shown clear in both monthly and seasonal time series.

For comparing month-to-month and season-to-season performance of PMME forecast of precipitation in Pili, the RPSSs were averaged in each month and season, excluding the strong negative scores in December 2015, January 2016, and February 2016 to ignore the impact of them as shown in Figure 6. The RPSS for the forecast with 1-month lead time is higher than those of 2- and 3-month lead time in six months: January, February, March, June, September, and November (Figure 6A). However, the increasing trend of the RPSS with 1-month lead time during January to March and negative RPSS during July to October are similar to the trend of RPSS with 2- and 3-month lead time. The similar trend is also shown in the seasonal RPSS for PMME forecast (Figure 6B). The highest RPSS is 0.53 in February with 1-month lead time and 0.66 in FMA. The lowest RPSS is -0.27

in January with 3-month lead time and -0.06 in JAS. Except for July to October in the rainy season, the RPSS with 1-month lead time is positive during all months, and so is the RPSS in all seasons except for JJA to ASO.

3. Conclusion

The APCC MME SCF over the Bicol region was examined to find seasonal predictability of the forecast. This is because the accuracy of the resulting seasonal pest outlook will depend on the predictability of the SCF. The RPSSs for the tercile-probability SCF from 1983 to 2005 were calculated to see the seasonal variation of the APCC MME SCF's predictability. In general, SCF during the DS showed higher predictabilities than the ones for the WS in the Bicol region. Considering the fact that most recent RTDs were reported during months in the WS, this result indicates that there is an urgent need to improve the SCF skill during the WS, which can be solved with the possible development of a hybrid (statistical-dynamic) model-based prediction system over the region in a collaboration with climate scientists. It is also very important to provide the uncertainty information from the climate and agriculture models when the seasonal pest outlook is provided to the stakeholders.

APPENDIX Ⅲ

2016 Technical Workshop Report

1. Summary

- **Workshop Title**: 4th Annual Technical BAWP Workshop: Models and Tools for Water Agriculture and Knowledge Sharing
- **Related Project**: Bicol Rice Disease Project
- **Location**: Villa Caceres Hotel, Naga City, the Philippines
- **Date**: February 17-19, 2016
- **Key Partners**: International Research Institute for Climate and Society and Bicol Agri-Water Project staff

2. Project Background

The *application of a rice disease model for seasonal yield loss simulation in the Bicol region*, or the Bicol Rice Disease Project (BIRD), is a new collaborative partnership between APCC and the International Research Institute for Climate and Society (IRI). APCC has become a co-implementing partner of IRI in the Bicol Agri-Water Project (BAWP), which aims to improve water security in the Philippines by adopting climate decision support tools and enhance agricultural development under climate variability and change. BAWP is developing climate decision support tools and enhancing agricultural development under climate variability and change. This initiative, which runs from September 2012 to September 2017, fits well with APCC's strategic plan to integrate climate products with sectoral applications such as agriculture.

While BIRD mainly focuses on the integration of a disease model into the Climate-Agriculture Modelling Decision Tools (CAMDT) suite, APCC has also agreed to some monetary contributions. As set out in the agreement with IRI and the internal project proposal, APCC will support the annual Technical Workshop for 2016 and 2017, held in Naga City, the Philippines, on February 17 - 19, 2016.

Workshop Objectives

- APCC presents project and final product concept.
- Feedback collected from participants for development of disease models and future directions of the project.
- Strengthen connections with IRI and local organizations.
- Share and discuss the functionalities of the current versions of the Knowledge Sharing Portal, WEAP-Bicol and CAMDT models and tools to project partners.
- Provide opportunity for project partners to familiarize with the models and tools for assessing and managing climate risks to agriculture and water resources.
- Get feedbacks from project partners on how to improve the current versions of the models and tools for water and agriculture and how to make the Knowledge Portal more useful in operational mode.

3. Workshop Proceedings

February 17, 2016

The program proper started with an invocation given by Ms. Vina L. Peňaserada followed by the Philippine National Anthem. Next, was the roll call, where the participants from different agencies and institutions stood up as they called their names to be recognized.

On behalf of the Engr. Abelardo R. Bragas, Regional Executive Director of DARFO5, Dr. Elena B. De Los Santos, Regional Technical Director of Operations and Extension of DARFO5 gave the welcome address. She also acknowledged and welcomed the participants especially the Project Partners namely, APCC, the IRI and PAGASA.

This was followed by the Bicol Agri-Water Project update that was discussed by Dr. Agnes C. Rola, Project Director of BAWP. Next, a group photo was taken of all participants. Right after the pho-ops, Dr.Amor Ines, Assistant Professor, Michigan State University tackled the overview of the workshop activities and objectives.

PRESENTATIONS:

❖ Pest Surveillance: A tool in developing prediction models for rice

By: Evangeline C. Dela Trinidad, PhD., Chief, Integrated Laboratories Division and Regional Crop Protection Center, Dept. of Agriculture, RFO-5, San Agustin, Pili, Camarines Sur, Philippines.

- Dr. Dela Trinidad discussed the Pest Surveillance: A tool in developing prediction models for rice, she emphasised that the Agriculture plays an important role in the Philippine economy. But insects and other pests can reduce rice yields substantially in the Philippines and Asia.
- According to Dr. Dela Trinidad, periodic monitoring of pest and diseases can assist in the prediction of occurrence of plant diseases and pests, hence making it highly possible to effectively contain the spread of the diseases and pests, with eco-friendly measures at the appropriate time.
- For the Pest surveillance, data from the field were gathered through the "bantay peste" brigade and other sources like LGU's and academe, these data were verified and validated, then it was submitted for analysis. Then, the analysed data will be sent to Rice program, MAO and others.
- Dr. Dela Trinidad also discussed historical data regarding the occurrence of some pest and disease like rodents, brown plant hoppers, armyworms and rice tungro. The Department of Agriculture Regional Crop Protection Center is using Geographic Information System) for Pest Monitoring and Detection specifically for Rice Tungro Virus.
- The GIS is used in Pest Monitoring & Detection by data visualization/query; Survey data collection, management, and analysis; Risk and pathway analysis; and Change detection.
- Examples for Map of Disease and Pest of Rice were presented.
- Dr. Dela Trinidad, also presented the programs that the Department of Agriculture is presently working on to monitor the pest and diseases in the field like the PRISM project, the Community-based Plant Pest and Disease Monitoring wherein they conduct community light trapping to control Rice Black Bug.

Introduction to Modelling and Simulation of Plant Disease Epidemics

By: Avelino D. Raymundo, PhD., Chief, Professor Emeritus Crop Protection Cluster, U.P Los Banos Laguna, Philippines.

- Dr. Raymundo discussed the Modelling and Simulation of Plant Disease Epidemics. He started his discussion in showing some pictures of the effect of climate change specifically in the crops.
- According to Dr. Raymundo the occurrence of pest and diseases are associated with the Climate Change.
- Climate Change encourages more rapid pathogen development, more rapid vector development, increasing pathogen transmission and increased host susceptibility.
- He also briefly discussed the life cycle of the pest and diseases.
- Dr. Raymundo discussed the Quantitative Techniques in Epidemic Analysis, wherein he emphasized on the Disease Forecasting Network.
- The Disease Forecasting Network used Primary Tools like flow charts, historical and seasonal profiles, interaction matrices and decision trees; it also uses Secondary Tools database systems, simulation models, expert systems.
- He also discussed the Simulation Process of Abaca Bunchy Top.
- Dr. Raymundo also presented some example data generated from the model for example the map showing the location of infected plots and percent incidence of rice tungro; Figure showing the relational diagram of VIRUSIM, a rice tungro virus disease simulation model developed using STELLA 9.1.1 modeling software; and another figure Infographic of GLH life stages in relation to rice tungro infectivity.

❖ Questions and Answers:

- Dr. Amor asked if there is a current program like drown that is used for pest and diseases monitoring.
- Dr. Dela Trinidad answered that the Department of Agriculture is planning to buy one drown to monitor pest and diseases. Dr. Raymundo added that in this time of climate change it is essential for next few years.

- Dr. Antonio Payonga of BUCAF asked if now that we are experiencing Climate Change can we still consider the indigenous knowledge system in predicting pest occurrence?
- Dr. Raymundo answered that in UPLB there is a researcher who work on the indigenous techniques and effect of Climate Change. But he has no knowledge on the effect of this techniques but this should not be disregarded.

Application of rice disease model for seasonal yield loss simulation in the Bicol region

By: Kwang-Hyung Kim, PhD., Fellow Researcher of APEC Climate Center (APCC)

- Dr. Kim discussed the Application of rice disease model for seasonal yield loss simulation in the Bicol region, he emphasized that the 35%of yield loss is caused of diseases.
- Dr. Kim started the discussion with a story of a farmer taking up the Climate Field School experiencing the El Niño, the said farmer referred on the El Niño Advisory and used decision-making tool: Planting date adjustment with yield estimation in decision making. Based on the tool, the insect infestation will increases, thus the farmer cultivated early for insect control. The farmers also practice minimum tillage to protect stored soil moisture and planted half of the crop in 1 month earlier, rest was planted in the normal period. He also did not sell the grain, but he stored it for quite amount for the next market, because of the prices usually rise. As a result the said farmer is tend to have a higher income than those farmers who didn't consider the El Nino advisory, and decision support tool for disease occurrence. Practicing Climate Smart Agriculture will lead to more sustainable farming. The BAWProject is a Climate Smart Agriculture.
- Dr. Kim gives an overview on how the Bicol Rice Disease (BIRD) Project will be incorporated in the BAWP.
- The BIRD Project will develop and integrate rice disease component into the CAMDT platform; and provide users with strategic and practical information on how to utilize the seasonal disease risk information in their decision-makings though the Seasonal Rice Pest Outlook.

- He also presented the research workflow which will starts from 2016 where in Initial scoping on disease epidemics in the Bicol region will be conducted; Selection of major diseases, subject to disease model development; Collecting ground-truth disease incidence data for the target disease; and Disease model (+ yield loss simulation model) development. And for 2017 Disease model (+ yield loss simulation model) will be validated; Model will integrated into the CAMDT platform; Application of SCF downscaling methods to the CAMDT-Disease; and Scenario-based analysis to identify promising strategies using the CAMDT-Disease will be done. The activities will be extended until 2018.
- Dr. Kim showed how the Disease Component will be incorporated in the CAMDT and how the Seasonal Rice Pest Outlook will be used by farmers and decision makers.
- The following are the target Diseases for CAMDT-Disease
  - leaf blast
  - sheath blight
  - bacterial leaf blight
  - brown spot
  - Tungro Disease (with the help of Dr. Raymundo and Dr. Dela Trinidad)
- In Model Development, possibility of combining disease models with a crop growth model to simulate yield losses due to disease infestation will be explored.
- Timeline of activities to be conducted were also presented from 2015-2017.
  - The Expected Outcome is to improve management of agriculture systems at various scales. Users of the CAMDT-Disease will be trained for how to utilize the disease risk information in their spray or cultural management decisions using various farm simulation approaches.
  - Capacities built for participating municipal agricultural technicians, provincial and regional level agricultural officials to manage climate risks to attain reduced losses due to pest damages at the municipal, provincial and regional levels.

CPT Overview

Dr. Bradfield Lyon, Associate Research Scientist IRI and Associate Research Professor at University of Maine

❖ Questions:

- During the presentation of Dr. Lyon about the overview of the tool Dr. Amor asked if there is a relationship between the Typhoon and El Nino. Dr. Lyon said, "Yes" and also clarified that it is El Nino today. He noted that Typhoon can bring huge difference between El Nino now and El Nino before. He also added that it (typhoon) complicates the seasonal predictability of Bicol's Climate.
- Dr. Tony Payonga inquired about the relation of Typhoon and El Nino in the case of Mindanao. Dr. Lyon said that Typhoon rarely occur in Mindanao, and without it, the region can feel the full effect of the El Nino. Sr. Tony clarified if the condition (dryness) in Mindanao changes the weather condition in the North or the upper area of the country? Dr. Anthony Lucero explained that the typhoon tends to move northward because it develops in the central pacific which is very warm.
- Sir Arthur Estrella described that there are complexities in convincing the farmers in the region that there is El Niño because of the presence of the rain. Sir Lucero explains the effect of location i.e. we are in the eastern side and there is a western side. He added the difference between the dry spell and drought. He pointed that if the "below normal condition" that the eastern part is experiencing is different from the western part of the country.
- Dr. Elena delos Santos share her opinion about on Bicol being Typhoon prone during the period of El Nino. She said it is our advantage that typhoon occurrence on the months were El Nino is in full strength, these are the months were typhoons often occur in the region.

CAMDT

By: Dr. Eunjin Han, IRI

- After the presentation of Dr. Han about the overview if the CAMDT, Dr. Raymundo clarified about the guidelines between the stochastic and deterministic methods. Dr. Amor Ines explained that stochastic methods has parameters- a wider range or realizations while deterministic method has none and only has chunks of data. Dr. Raymundo asked if it is possible to incorporate the pest variables in the tool. Dr. Ines said yes.
- Dr. Delos Santos observed that installing and operating the CAMDT is complicated as for ordinary farmer or stakeholders. Is it possible to have a manual or e-manual for it? Dr. Han said they can provide manuals and e-manual after the model is done. Dr. Han pointed out that CAMDT cannot automatically update therefore input of data is needed.
- Dr. Foronda suggested that considering the complexities of the model, an image of the scenario that is being built can be placed.

WEAP-Bicol

By: Dr. Amor Ines, IRI

Dr. Amor Ines gave a brief overview of WEAP in both Quinale A Model and Lake Buhi Model. After the presentation, Dr. De Los Santos clarified if the air constraints-energy requirement is not included in the model where in the water used for irrigation is used to generate power. Dr. Ines said the parameter can be incorporated to the model in the future.

Dr. Tony Payonga said that in one RTD in Polangui last 2015, the council said that they want the water from Mt. Masaraga to be re-routed to Libon so that their area will not be flooded. Can WEAP help the stakeholders to do it? Dr. Ines said that they will have to ask help in evaluating the response in building the structure to be able to re-allocate the water.

Knowledge Sharing Portal

By: Mr. Remi Cousin, IRI

Mr. Cousin discussed briefly the updates on the KSP. He said that once all the models are done, the information and data will be uploaded to the KSP for the stakeholders to make use of it. For now, updated rainfall data from all the project sites must be uploaded to the server as well as meteorological data from the DA region.

There were no questions and/or suggestions after the presentation.

February 18, 2016

The second day of the workshop was devoted to hands-on learning through practical exercises. Participants were sub-divided into simultaneous training sessions. Dr. Eunjin Han led the workshop on Climate-Agriculture Modeling Decision Tools (CAMDT) with support from Dr. Kwang-Hyung Kim. WEAP was facilitated by Dr. Amor Ines from the Michigan State University.

The activities of the workshops were a combination of step-by-step demonstration and in-depth discussion coupled with practical exercises. Participants were also permitted to ask questions all throughout the workshop. They were also given take-home activities to reinforce learnings.

February 19, 2016

The last day featured final training sessions for CAMDT and WEAP, followed by presentations from participants on their mini-projects. The afternoon featured a session on CPT led by Dr. Bradfield Lyon. Dr. Cely Binoya wrapped up the workshop with a summary and closing remarks.

4. Meetings

BAWP Partners Meeting

- **Date**: February 16, 2016
- **Location**: Villa Caceres Hotel in Naga City, the Philippines
- **Purpose**: Introduce new staff and review
- **Chair**: Dr. Agnes Rola
- **Participants**:

PAGASA	1	Mr. Anthony Joseph Lucero
	2	Rusy Abastillas
UPLB	3	Dr. Avelino D. Raymundo
APCC	4	Dr. Kwang-Hyung Kim
	5	Ms. Christianne Miko Aikins
IRI-CU	6	Dr. Eunjin Han
WSU	7	Dr. Amor Ines
UM	8	Dr. Bradfield Lyon
IRI-CU	9	Mr. Remi Cousin
BAWP PI/Co-PI/Staff	10	Dr. Agnes C. Rola
	11	Dr. Elena B. Delos Santos
	12	Dr. Merlyne M. Paunlagui
	13	Ms. Dulce D. Elazegui
	14	Dr. Antonio P. Payonga
	15	Dr. Cely S. Binoya
	16	Prof. Arthur Estrella
	17	Mr. Rodel Tornilla
	18	Francis John Faderogao
	19	Edlynne Kaith R. Ravago
	20	Chrislyn Joanna P. Faulmino
	21	Sarrah D. Sambajon
	22	Annalyn I. Olaño
	23	Kim Jonah P. Bolivar
	24	Vina L. Peñaserada
	25	Edeliza B. Polo
	26	Felix L. Castañeda Jr.
	27	Karren A. Belen

Opening: Dr. Rola welcomes everyone to Naga and discusses major progress on the BAWP project.

Introductions: Each person introduced themselves and their connection to BAWP. Dr. Rola introduced new BAWP staff members and their roles.

BAWP project updates:

- Dr. Rola welcomed everyone to Naga and discusses major progress on the BAWP project
- Dr. Eunjin Han talked about progress made with CAMDT and the potential features
- Amor Ines discussed WEAP
- Dr. Kwanghyung Kim gave a brief overview of how disease modelling will be integrated into CAMDT
- Dr. Remi Cousin noted that the Knowledge Portal (KP) was not a focus of 2015, but will be as the project wraps up
- Dr. Bradfield Lyon discussed the Climate Predictability Tool (CPT) and how it will be used to assess and account for bias in the climate predictions for the Bicol region

Workshop overview: Brief overview of the upcoming workshop

Discussion on KP features: Although Dr. Rola attempted to get input from the BAWP staff, there was minimal discussion, in large part because the upcoming workshop would cover this topic.

Field Trial and MOA Discussion with DA RFO 5

- **Date**: February 19, 2016
- **Location**: Villa Caceres Hotel in Naga City, the Philippines
- **Purpose**: Discuss field trial details and MOA
- **Chair**: Dr. Kwanghyung Kim
- **Participants**: Dr. Avelino Raymundo (an emeritus professor of UPLB in the Philippines, a plant epidemiologist), Dr. Evangeline Trinidad (a chief of the Integrated Laboratory Division of the DA RFO 5, Bicol), Dr. Elena Delos Santos (Regional Technical Director of the DA RFO 5, Bicol), Dr. Kwanghyung Kim (APCC), and Christianne Miko Aikins (APCC)

Details about field trial for data collection were discussed.

1) Two trial sites were selected: Polangi and DA experimental plot in Pili. Trial site should be near AWS location, so that it can get weather data. Trial site should be within a major rice cultivation area and be included in the BAWP study sites. Polangi was selected due to a good maintenance of the AWS by the municipality and it is known as an endemic site for the tungro disease every year. Another site is an experimental plot within the DA station (Pili). There is an AWS in Pili, maintained by PAGASA. And Dr. Trinidad said that there are always large amount of inoculum sources of the tungro disease existing there, thus the disease infestation should be always assured. And because it is near the RCPC office, data collection is easy. Farms in Polangi will be rented from the owner, with a conditional contract that all products from the farms will belong to the owner at the end of trial.

2) Trial protocol was designed: For each site, two trial farms will be selected. Within each trial farm, four replicate plots will be separated. Each replicate plot needs to be distant to each other and the size of plot will be 100 hills x 100 hills, total 10,000 hills per a replicate plot. A rice cultivar susceptible to the tungro disease will be selected by Dr. Trinidad's recommendation. Data collection will be conducted once a week from 15 days after transplanting until 8 weeks after

transplanting. All managements including fertilizer, agrochemical spray, weeding will be conducted following regular farming protocol, except for insecticide spray. The insecticide spray is prohibited during the trial period (for 8 weeks from transplanting). Data collection will be done by a new staff at RCPC under Dr. Trinidad's supervision. The new staff hired for the project should have a basic knowledge and experience on tungro disease and be capable of distinguish the typical symptom of tungro disease from other similar symptoms by nutrient deficiency or disease/pest damages. The level of training will be the first priority when hiring the staff for the trial. Dr. Raymundo will act as a resource person for the trial and help to analyze the data for the model development and validation.

3) Trial period was discussed: Transplanting will be done from late May to early June. Contracting with the owners of the trial farms need to be done beforehand. Trials can be repeated based on this first trial results (based on the extent of epidemics) in around September or October.

MOA) An MOA will be created, which will act as a formal contract between DA RFO 5 and APCC. While a draft of the MOA has already been developed, the details of the field trial must be finalized and financial estimates created before the MOA can be finalized.

5. Outcomes

In many ways, this workshop functions as a kick-off event for BIRD. Because of this, the expected outcomes are related to increased visibility and enhanced understanding of the needs of the end users. These include:

- Increased visibility of APCC research and projects in the Asia Pacific.
- Increased awareness of BIRD and its relevance.
- Enhanced relations with project partners.
- Consolidate input from stakeholders on end product.

APPENDIX Ⅳ

Report on Development of a Rice Tungro Epidemiological Model for Seasonal Pest Risk Prediction in the Philippines

1. Introduction

Insect and disease pests are amongst the most notable yield-reducing factors in most rice-growing areas, especially in the Philippines. An analysis by Hossain et al. (1995) showed that rice pests accounted for 26% and 16% of yield losses in the wet and dry seasons of the 1990s, respectively, after controlling for calamities such as typhoon and drought. Major pests reported were rice tungro, stem borer, brown planthopper, and rice bugs. Among them, tungro is very common among farms in the region and inflicts severe damage on rice fields (Warburton et al., 1996; 1997). In fact, Savary et al. (2000) conducted nonparametric, multivariate analysis using an experimental database from 445 individual plots to establish a hierarchy of pest injuries, which provides a means of ranking rice pests with respect to their importance given the potential losses they may cause. Four groups of injuries were associated with low to medium, medium to high, high, and medium to very high yield losses. Interestingly, because it was associated only with extremely high yield losses, tungro was placed in its own category, indicating the large influence of tungro on yield losses in fields.

Rice tungro disease (RTD) is a composite virus disease transmitted mainly by the green leafhopper (GLH), *Nephotettix virescens* (Ling, 1972). RTD affects the plant at all growth stages, but most severely during the vegetative stage wherein symptoms are more pronounced (Dasgupta et al., 2015). Leaf discoloration begins from the tip and spreads down the blade to the lower leaf portion, followed by stunting, reduced tillering, delayed flowering, and consequently, incomplete maturity at the end. Grains are covered with dark brown blotches and their quality is poor. Another indication of infection is the presence of GLH adults, nymphs, and eggs.

RTD has a very long history in the Philippines. In the 1940s, long before the causal organism had been identified in major rice-growing regions in the Philippines (Hibino et al. 1978, 1991), the early outbreaks of rice tungro disease reduced the overall national yield to 1.4 million metric tons annually (Serrano 1957). Since then, major epidemics of tungro have been recorded in areas associated with extensive planting of high-yielding cultivars, staggered planting, and intensive use of fertilizers, which were responsible for the build-up of the vector population and for the tungro outbreaks (Bajet et al., 1986; Baria, 1997; Calleja, 2010; Ling, 1972; Truong et al., 1999b). In severe cases, tungro-susceptible varieties infected at an early growth stage could have yield losses as high as 100% (IRRI, 2015; Nas and Cortez, 2011). These severe yield losses by RTD occur because the nature of viral disease involves a systemic infection (, resulting in total crop failure of diseased plants?). Based on a field survey report by Muralidharan et al. (2003), the RTD epidemic and yield losses in paddy fields are almost linearly correlated with each other. In other words, yield loss can be calculated based on the number of diseased hills, i.e., should 10% of hills be diseased, an approximate 10% yield loss is anticipated.

A number of surveys have been carried out to correlate tungro incidence with agro-ecological variables. Suzuki et al. (1992) found that almost 50% of the variation in the incidence of newly infected fields during a particular month was explained by three variables: new infections in the previous month (which are an important source of inoculum), occurrence of a 2- to 3-month old crop (which is the major source of vectors), and rainfall in the present month. Savary et al. (1993) analyzed survey data collected from one non-endemic site and two endemic sites in the Philippines. They concluded that an inoculum, as measured by viruliferous vectors, has a greater influence on tungro outbreaks in the non-endemic areas than in the endemic areas. In a survey carried out in a tungro-prone locality of Southern Luzon in the Philippines, Chancellor et al. (1995) found that there are significant differences in RTD incidence related to the month of planting. Crops planted late in either the wet or the dry season suffered from considerably more severe tungro problems than did those planted earlier.

In the Philippines, management of RTD generally involves controlling the sources of disease inoculum (infected rice hills), controlling the vector (GLH), or both. In particular, insecticides are widely applied by farmers for controlling GLH, although some researchers doubt their effectiveness (Chancellor et al., 1995; Holt et al., 1996; Truong et al., 1999a). Integrated pest management (IPM) has been found to include effective strategies such as using resistant rice varieties and using synchronous planting, rotations, or fallow periods to remove rice plants that are sources of disease inoculum and thus prevent disease spread (Cabunagan et al., 2001; Chancellor et al., 1999; Dahal et al., 1990; Hibino et al., 1987; Sama et al., 1991). However, decisions for those strategies used in IPM need to be made before planting. In this regard, employing a seasonal pest outlook (a predicted risk for rice pest epidemics in the coming months), which uses predictive epidemiological models and seasonal climate forecasts, in conjunction with current cultural practices may increase the efficacy of RTD control.

Thus far, some epidemiological models for RTD have been developed and used to assist in making decisions on deployment timing of various control measures, when costs can be saved, and whether environmental benefits can be derived by deploying fewer measures or by non-deployment (Jones et al., 2010; Knights and Thackray, 2007; Thresh, 1986). Holt and Norton (1993) showed examples of applying simulation modeling to improve the understanding of pest dynamics, and of how to make management recommendations based on these models. A spatial, stochastic, individual-based model of RTD dynamics was developed and used for a theoretical investigation of risk under different situations of vector immigration. Since then, a very similar model was developed by Ferriss and Berger (1993) to theoretically compare virus disease dynamics under different assumptions of virus persistence in the vector. Holt and Chancellor (1996) simulated real pathosystems and considered control issues, particularly for disease management by rouging. Recently, a mathematical model of RTD epidemiology in the cropping system was developed to investigate the deployment of fields of a genotype expressing resistance to the disease (Holt and Chancellor, 1999). Apart from these process-based models, some regression models have been developed to estimate grain yield losses based on RTD incidence or GLH populations at certain cropping points (Muralidharan et al., 2003; Suzuki et al., 1992). Although there have been numerous hypotheses about possible relationships between RTD epidemics (or GLH population build-up) and climatic conditions, we could not find any climate-based epidemiological models for RTD in the literature we reviewed.

The present study involves intensive modeling work for RTD epidemiology and its relationship with climate factors, aiming at producing a seasonal tungro outlook by integrating seasonal climate forecasts and the tungro epidemiological model in the future. In this study, we develop and evaluate a tungro epidemiological model called *rtdSim* using historical tungro incidence data and weather data collected in the Philippines. A series of model parameterization steps with calibration were performed, followed by validation against available observed incidence data for tungro. The Bicol region of the Philippines was selected as a case study region for model evaluation and a potential applicability test for making predictions about seasonal tungro epidemics using the *rtdSim* model.

2. Model Development and Evaluation

The tungro epidemiological model developed in this study was named rtdSim (rice tungro disease Simulation) and was created in the R programming language. It calculates how many rice hills are infected with rice tungro virus through its vector, green leafhopper (GLH), based on climate condition over the simulation area. The rtdSim model is divided into two linked modules. The “GLH population growth module” simulates GLH population dynamics of a complete life cycle from egg to adult stages and immigration movement from near rice paddies (Figure 1), and the “Infection module” simulates virus transmissions from infected rice hills to the GLH vector and viruliferous GLH to healthy rice hills during rice cropping, determining the daily ratio of total infected hills as a final simulation result (Figure 2).

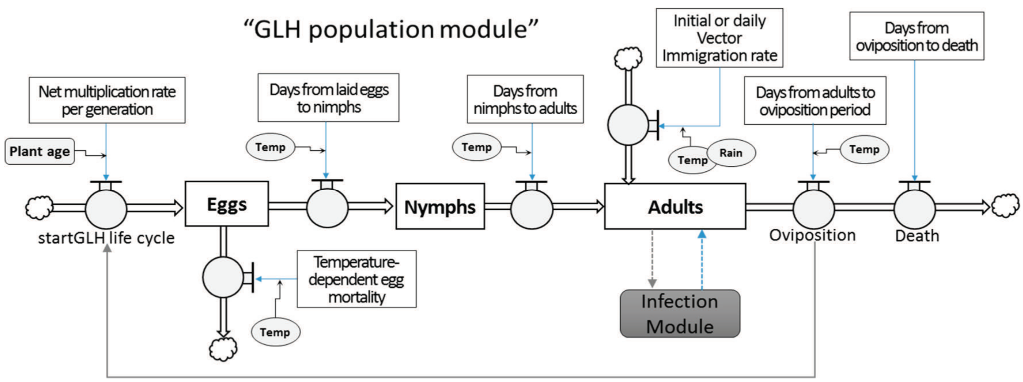

Figure 1. Schematic diagram of the GLH population module in the rtdSim model.

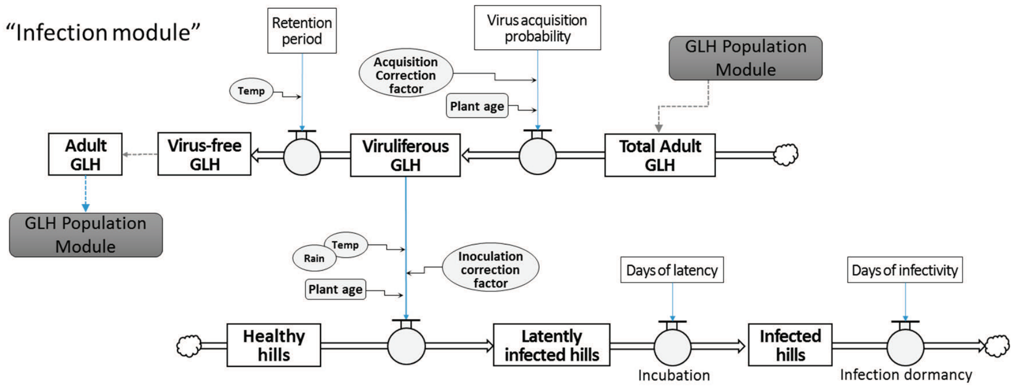

Figure 2. Schematic diagram of the Infection module in the rtdSim model.

The Model simulation had a daily time-step for vector development from birth to death, oviposition, immigration from near rice paddies, virus acquisition from infected plants, and virus inoculation to healthy plants. The GLH population growth module generates a record for each vector, containing information on its age, gender, virus infectivity status, and virus retention period. With the Infection module, the rtdSim model simulates the spread of tungro virus within a square grid of 324 rice hills containing a rice variety susceptible to the virus and the vector GLH. The size of the grid was adopted from a rice tungro simulation model developed in a previous study (Holt and Chancellor, 1996). The rice hills (an entire plant) represent sites (i.e., entities that may become infectious when occupied by the pathogen), and thus, a model grid contains 324 sites in this case. During model simulation, infected hills result in disease incidence at the plant level (% hills infected out of a total of 324 hills). The sequence of events in the model algorithm was adopted from the study by Holt and Chancellor (1996) and modified as detailed in Table 1.

VECTOR POPULATION GROWTH

To perfectly simulate GLH population dynamics, it would be necessary to integrate data on the fecundity rate (the number of eggs that a single female can lay in its lifetime) and oviposition rate (the number of days for which she can deposit her eggs) of the GLH, female-to-male ratio, transit times for different growth stages (the number of days it takes to develop from one stage to another), and mortality rates due to predation or unfavorable environmental conditions. However, insufficient information is currently available on these factors, limiting the possibility of a detailed understanding of all the biological and physiological mechanisms of GLH development.

Table 1. The *rtdSim* model algorithm.

A. Initial set up 1. Construct an array of rice hill records containing uninfected, newly transplanted 324 hills (initial rice age = 0 days after transplanting) 2. Construct an array ready to store the green leafhopper (GLH) records containing age, gender, virus infectivity status, and virus retention period information. 3. Estimate the number of initial GLH immigrants: (a) Determine whether it is wet season or dry season to define the seasonal start date (May 1 for the wet season, Nov 1 for the dry season); (b) Calculate growing degree days (base temperature = 13.86 °C) accumulated from the start date of each season until the transplanting date to determine the number of generations of GLH; (c) Using mean temperature and rain frequency (total rainy days of more than 10 mm/day rainfall) from the start date of each season until the transplanting date, estimate the number of initial GLH immigrants (d) Allocate the gender, age, and virus infectivity of each immigrant at random
B. The following steps are repeated daily 1. Update the age of the rice plant, of each GLH and the duration of the period since each infection was initiated: (a) increment the age of each rice hill by 1 day; (b) increment the duration of the period since initial infection of any infected rice hills; (c) increment the age of each GLH by 1 day (daily temperature-dependent adjustment applied). If the maximum age is exceeded remove the GLH. 2. GLH oviposition: (a) check the age of the rice crop; (b) for each GLH, check whether it is female and weather its age is appropriate for oviposition – if it is, initiate a number of new individual eggs with an age 0, the number being dependent upon rice crop age (before and after 30 DAP). 3. GLH immigration: (a) determine the number arriving that day using temperature and rainfall functions and virus infectivity based on acquisition possibility; (b) allocate the gender and age of each immigrant at random. 4. Virus transmission: (a) for each GLH adult, check whether viruliferous and, if so, the time elapsed since acquisition, if it still virus free, determine whether it acquires virus based on acquisition probability and acquisition correction factor; (b) determine whether each viruliferous GLH loses virus using retention function; (c) determine for currently viruliferous GLH whether it inoculates virus into healthy hills based on inoculation rate and inoculation correction factor.

In this study, the population dynamics of GLH were therefore simplified to enable model development. Simplification approaches have been used by many previous RTD modeling studies (Holt and Chancellor, 1996, 1999; Holt and Norton, 1993) and we adopted their core concepts in the study. Rather than distinguishing separate fecundity, oviposition, and mortality rates of each growth stage, we specified a common generation multiplication rate considering all of the above factors. For this reason, a reduced rate of oviposition was applied, considering the absence of subsequent mortality. Based on the results from Cook & Perfect (1989), a plant age-dependent oviposition rate was applied; there was a higher rate during the first GLH generation (before 30 days after transplanting (DAT) and a lower rate during the second and subsequent generations (after 30 DAT). This assumption was successfully applied in a spatial, stochastic RTD simulation model developed by Holt and Chancellor (1996).

In highly asynchronous rice planting areas, such as most rice paddies in the Philippines, GLH populations in paddy fields grow from G0 (0^{th} generation immigrated from near rice paddies) to G1 (1^{st} generation developed from eggs laid by G0), but sharply drop shortly thereafter since most G1 adults emigrate without leaving G2 eggs (Widiarta et al., 1990). Suzuki et al. (1992) also showed that the nymphal mortality and adult loss was low in paddy fields transplanted in the transition seasons, suggesting that areal population growth of GLH is the result of active invasion of GLH adults to young paddy fields. It is highly possible that the survival rate of their progeny is higher on young rice plants than old plants. Nevertheless, it is also known that the mortality rate is relatively higher in earlier growth stages of GLH (Palis et al., 1984). Therefore, we decided to consider the temperature-dependent mortality of GLH eggs by utilizing data from Palis et al. (1984). Daily mean temperature was used as a major driving variable for the laid egg mortality. Although there are estimated periods (days) for each stage (from egg to egg hatching, 1^{st} to 5^{th} instars, and then adult GLH), it is also highly variable based on environmental conditions and other unknown factors. Based on the simplification rule, we also used average values of transit periods from a growth stage to the next.

Holt et al. (1996) indicated that the number of immigrants and the temperature during the growing season are the main driving variables determining GLH population size. In order to determine the number of immigrants entering the crop, we developed two different algorithms: one for initial immigration at the transplanting date and another for daily immigration after the transplanting date.

The rtdSim model starts by estimating the initial population of GLH adults when it starts the day=0 simulation. To determine the number of initial GLH immigrants, we utilized the past weather information from the start date of that particular season to the planting date. In the Philippines, there are two separate seasons: the wet (May–Oct) and dry (Nov–Apr) seasons, although there is rainfall variation among regions. Each season, a rice cropping is generally practiced in a very asynchronous manner (nearly a 4-month transplanting period stretched within a season). Nevertheless, there are clear seasonal patterns of transplanting dates for each season (data obtained from the Department of Agriculture, the Philippines). Previous studies showed there is a typical monthly GLH population fluctuation within each season (Suzuki et al., 1992; Othman et al., 1999): a gradual increase in the GLH population from the start of season and a sharp decrease towards the end of the season. This GLH population distribution within a season is very similar to that of transplanting timing within a season, which indicates that the timing of transplanting within a season determines the potential GLH population built in surrounding paddies. In other words, the GLH population immigrating from near paddies is has a close relationship to the extent of the GLH population at the time of transplanting date. To simulate this, we developed an algorithm to determine the number of initial GLH immigrants. The algorithm calculates the number of GLH generations from the season start date to the transplanting date, assuming the number of generations represents the number of initial GLH immigrants. In the algorithm, the number of GLH generations is solely affected by temperature and rainfall during the calculating period.

First, growing degree days (GDD) were calculated using daily mean temperature. GDD are useful for studying the phenology of insect populations and predicting the occurrence of certain pests in the field (Eckenrode and Chapman, 1972). It is thus possible to calculate the heat energy required to complete a given stage or the entire life cycle of an insect using GDD. Valle et al. (1986) estimated a thermal constant (K) as 469.48 in day-degrees for the entire life span of N. virescens (a tungro-mediating GLH in the Philippines), with the base temperature of 13.86°C. Based on the GDD accumulation, the number of GLH generations could be estimated.

Second, rainfall frequency (the number of rainy days over a certain amount of rainfall) was calculated. We assumed that heavy rainfall directly affects vector migration by inhibiting the vector flight in the air. In fact, Dasgupta et al. (2015) reported that the population of GLH was low during heavy monsoon rains. In the Philippines, data analysis from light traps showed that monthly rainfall higher than 250 mm or lower than 100 mm gradually decreased the population of GLH (Truong et al., 1999a), indicating that even dry conditions, as well as heavy rainfall, suppress vector flight. Therefore, adjusting the rainfall function affecting GLH migration will be crucial when calibrating the rtdSim model. Based on the rainfall frequency, a rain index affecting the initial GLH immigrants was determined.

Lastly, mean temperature from the season start date to the transplanting date was used to determine a temperature index affecting the initial GLH immigrants. Temperature-dependent life span estimates result from the experiments by Ling and Tiongco (1977) and were used to determine the temperature effect function. Together with the number of GLH generations calculated from GDD, both the rain and the temperature index were used as adjusting factors in determining the number of initial GLH immigrants.

GLH migration from nearby rice paddies was also simulated in the model on a daily basis right after transplanting. The daily number of immigrants moving into the simulation grid of the model was determined based on daily weather conditions, similar to the algorithm for the initial immigration at the transplanting date, except for the GDD function. Daily mean temperature and daily rainfall were used in the algorithm to determine the daily migration rate of GLH.

VIRUS TRANSMISSION

The transmission of a virus involves the virus, the vector, the plant, and environmental conditions. Six steps are involved in the transmission of a virus from an infected plant to a healthy plant by an insect vector, according to Ling and Tiongco (1976): 1) A virus-free insect moves to an infected plant showing disease symptoms, 2) The insect feeds (acquisition feeding) and acquires the virus, becoming viruliferous (infective), 3) After a latent period, if any, the insect becomes capable of infecting healthy plants. 5) The viruliferous insect feeds on the healthy plant (inoculation feeding), inoculating it with the virus. 6) The inoculated plant develops disease symptoms. With these six steps, virus transmission is completed.

We tried to include all these essential steps in the Infection module of the rtdSim model. Each transmission step was affected by environmental conditions, if there are references to support. The Infection module has an algorithm calculating viruliferous GLH out of the total susceptible GLH population. It assumes that only the adult stage after adult molt can be involved in the virus transmission activity. The viruliferous GLH was computed using the formula: Viruliferous GLH = Total susceptible adult GLH * Virus acquisition probability * Acquisition correction factor, where the virus acquisition probability is the probability rate of the tungro virus acquisition by the vector from feeding an infected plant, and the acquisition correction factor is the proportion of the number of infected plants to the total number of plants in the simulation grid. Although the virus transmission rates were known to be affected by temperature (Ling and Tiongco, 1976), in the present study, we did not consider the temperature effect in order to make the algorithm simple.

The infected GLH was assumed to continue affecting the rice field until it reached a retention time, which is the time for which a virus is retained by an insect vector. The retention time was determined within a predefined retention period (5–8 days) based on mean temperature of the day and was chosen randomly: higher temperature reduces retention time toward 5 days while lower temperature toward 8 days. Temperature-dependent retention times of viruses inside a vector were reported previously (Ling and Tiongco, 1976). Even after its loss of virus, the virus-free vector can be infected again until its death.

Viruliferous GLH can inoculate virus into healthy plants using the inoculation algorithm. Infected plants (hills) were computed using the formula: Infected hills = Viruliferous GLH × Inoculation correction factor × Inoculation rate, where the Inoculation correction factor refers to the proportion of the number of healthy plants to the total number of plants in the simulation grid. The inoculation rate

(Rc) is again computed using the formula: Rc = baseRc × RcA × RcT × RcR, where the baseRc refers to the inoculation probability (which is the probability rate of tungro virus transmission from a viruliferous vector to a new healthy plant while feeding), the RcA refers to the plant age effect, the RcT refers to the temperature effect, and the RcR refers to the rain effect.

Plant age affects the inoculation rate of viruliferous GLH. Plants are most susceptible between 7 and 30 days post-transplanting, and beyond this period, their susceptibility decreases (Suzuki et al., 1992; Widiarta, 1999). Temperature and rain are also important factors affecting the inoculation rate as shown in previous studies (Ling and Tiongco, 1976; 1977; Shivanna et al., 2011; Truong et al., 1999a). Healthy plants inoculated by viruliferous GLHs get infected based on the inoculation rate and the number of infected GLH. Once the plants are infected, they become latently infected for a latent period (7 days), and eventually become infectious plants with visible symptoms. Once the plants become infectious, they can transmit the virus into sucking GLHs.

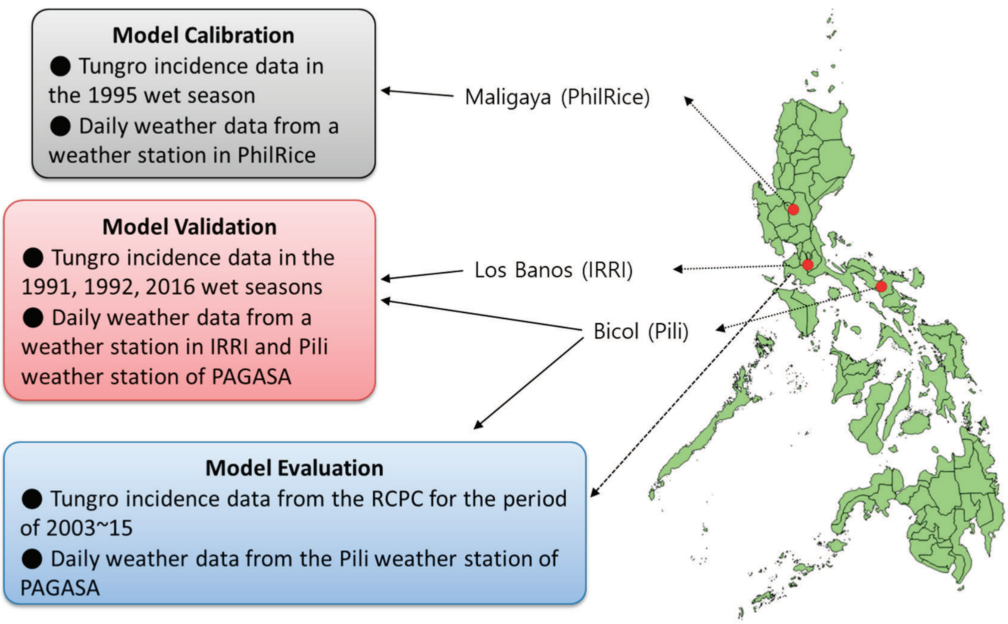

Figure 3. A map for the sites where tungro incidence data and weather data were collected for model calibration, validation, and evaluation in the study.

MODEL CALIBRATION

The calibration of the rtdSim model to fine-tune the parameters was conducted using observed ground-truth disease incidence data and weather data obtained from a local research institute in the Philippines. Data for a tungro test plot (planting date = July 15) in Maligaya, Central Luzon, during the 1995 WS were used for the model calibration (Figure 3). The approach adopted was to set each parameter value within a reasonable range to obtain a simulated disease incidence similar to that observed. Variable values estimated from previous studies in the fields or in the laboratories, such as environment and plant age effects, mostly remained unchanged, while variables showing strong locality or high variability, such as acquisition probability and inoculation probability, were prioritized for the calibration.

Changing either the acquisition probability or the inoculation probability could directly scale the simulated disease incidence to the observed disease incidence in the model calibration process. Initial vector acquisition and inoculation probabilities were estimated from a previous study (Holt and Chancellor, 1996). Subsequently, we arbitrarily chose to change the probability values until reasonable correspondence between the simulated and the observed was made, resulting in 0.16 of the acquisition probability and 0.18 of the inoculation probability. The fit of the model to both sets of data was improved by changing both probabilities based on the assumptions about the decline in virus transmission rates with increasing plant age, in line with plant aging and its effect on plant resistance to tungro (Narayanasamy, 1972). During calibration, we reduced acquisition probability to the 30% of its initial value after 30 DAT and also reduced inoculation rates by using a plant aging function, which fixed an over-estimation problem of the simulated disease incidence during the latter half of the 60-day simulation. Lastly, it was clear that vector population growth was better represented by assuming a more drastic reduction in multiplication rate as the season progresses. During the first GLH generation (before 30 DAT), the net multiplication rate per generation was assumed to be eight; in the second and subsequent generations (after 30 DAT), this was reduced to two.

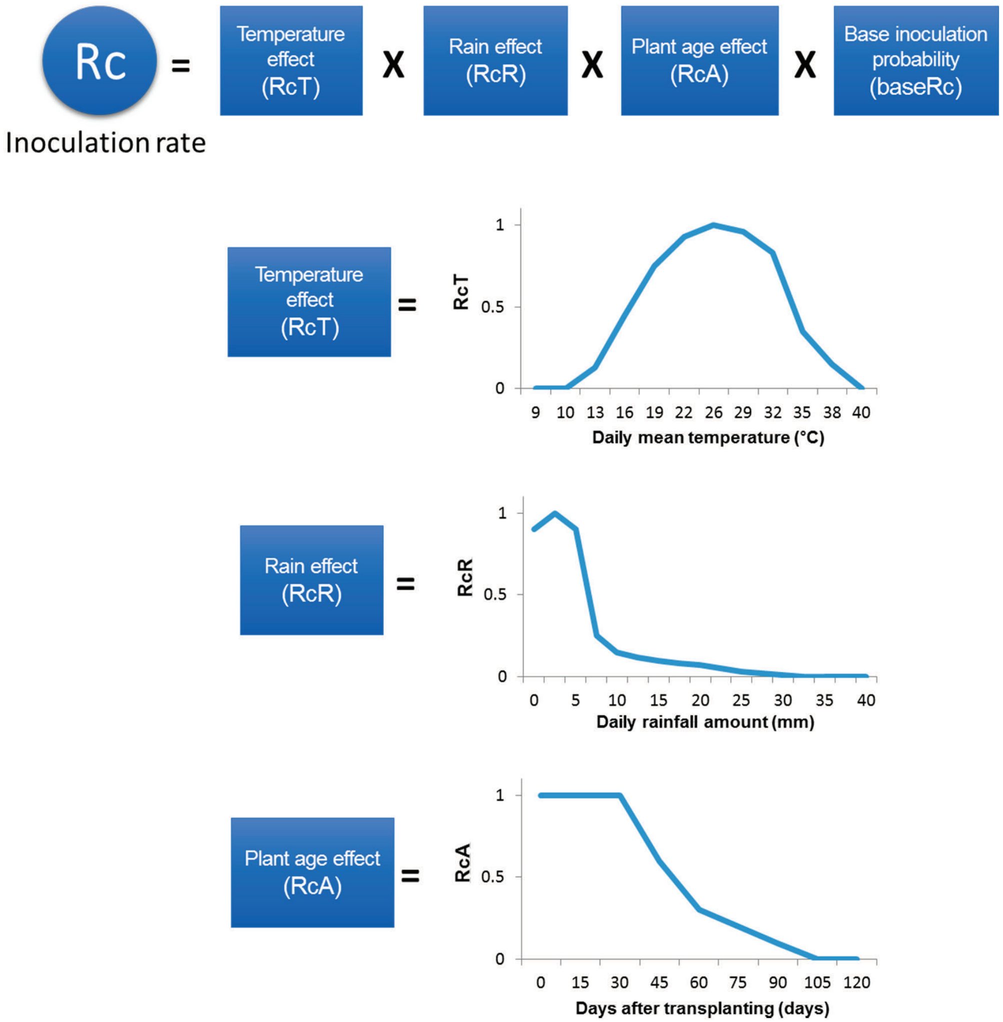

Figure 4. Temperature, rain, and plant age effect functions that determine the inoculation rate of the virus into plant in the Infection module of the rtdSim model.

In detail, calibration was made in determining the inoculation rate (Rc), where the inoculation probability (baseRc), the temperature effect (RcT), the rain effect (RcR), and the plant age effect (RcA) are multiplied (Figure 4). Initial RcT and RcR functions were first estimated based on the studies on optimal temperature for the infective capacity of GLH (Ling and Tiongco, 1976; 1977) and rainfall effect on GLH (Truong et al. 1999a), respectively, and were further elaborated through fitting the simulated to the observed in the model calibration. We also reflected the early stage susceptibility of plants to RTD (Suzuki et al., 1992) by reducing the RcA after 30 DAT as shown in Figure 4.

Since it was reported in previous studies that there are always large variation in the number of GLH immigrants (Chancellor, 1995; Holt et al., 1995), we assumed that first, the immigration occurs every day starting from transplanting date, but the number of daily immigrants is adjusted based on temperature and rain functions. The initial population of GLH immigrants was estimated by utilizing the past weather information from the start date of the season to the planting date. Temperature-dependent GDDs were first used to get a base number of initial vector immigrants (baseGLH). As already explained in the previous section, "VECTOR POPULATION GROWTH" in 2. Model Development and Evaluation, the temperature effect and rain frequency effect functions were first derived from the works of Ling and Tiongco (1977), and Dasgupta et al. (2015) and Truong et al. (1999a), respectively, and were further adjusted based on the tungro test plot data collected in Maligaya in the 1995 WS. Final number of initial GLH immigrants were calculated by multiplying the temperature effect (Init.effT) and the rain frequency effect (Init.effRF) to the baseGLH as shown in Figure 5.

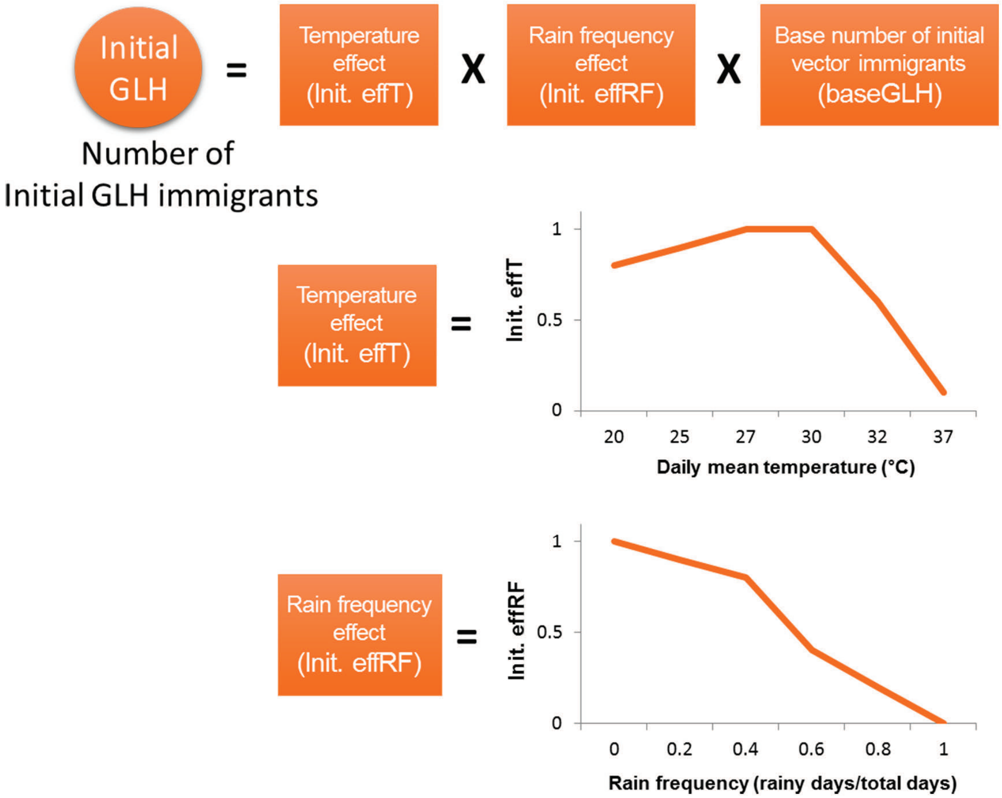

Figure 5. Temperature and rain frequency effect functions that determine the number of initial GLH immigrants in the GLH population module of the rtdSim model.

MODEL VALIDATION

The rtdSim model was subsequently validated using disease incidence data collected from three plots (planting date = July 1) in Los Baños during two WSs in 1991 and 1992 by the International Rice Research Institute (IRRI), and weather data from a weather station installed near the IRRI test plot. Additional validation was made using a disease incidence data collected in three rice paddies (planting date = May 15) near the synoptic weather station of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) in Pili, Bicol. Model validation was carried out to determine whether there is good agreement between the observed ground truth data and the potential epidemics simulated by the rtdSim model. Simulated outputs for disease epidemics were based on changes in disease incidence with time (daily percentage of the total infected hills over all the hills). Graphic comparisons were made by plotting the observed and simulated disease progress curves together. This technique was used to subjectively evaluate the goodness of fit and to determine whether the rtdSim model is sufficiently accurate for its intended purpose. The intended purpose determines the level of performance criteria for model validation. If the model is intended to simulate the temporal changes of disease incidence, it will need to accurately fit with the observed disease progress curve. However, if the model attempts to simulate relative disease risk based on total diseased area or peak incidence level, the performance criteria should be different. In the present study, we consider the model valid if the simulated peak disease incidence fits with the observed peak disease incidence.

MODEL EVALUATION

Simulated disease incidence results were compared with the ground truth data collected in Bicol. Monthly tungro incidence data of the municipalities in Bicol, the Philippines, have been accumulated by pest observers of the Regional Crop Protection Center (RCPC) of the Department of Agriculture-Regional Field Office 5 (DA-RFO 5), which include municipal-level location and infected area information. As there is only one synoptic weather station of PAGASA in Pili, it was necessary to only use ground truth data gathered near to the Pili weather station. Therefore, we combined all RTD incidence data from 10 municipalities around the Pili weather station: Pili, Canaman, Minalabac, Bula, Baao, Ocampo, Calabanga, Bombon, Naga City, and Milaor. Owing to the limited data, we combined only the monthly RTD incidence data from September to October, which corresponds to the simulation period (July-August) with the transplanting date of July 1. This is because there is a lag time of approximately one month between the actual incidence time when the epidemics in the field occurred and the reporting time when the collected incidence data were reported to RCPC by the agriculturists of each municipality. Therefore, we applied the one-month lag time when we compared the simulated and observed incidence results.

For the model evaluation, simulation of the *rtdSim* model and statistical analysis were conducted. Briefly, the transplanting date was set as July 1 and the model simulated for 60 days using the weather data from the Pili weather station. Daily weather data (temperature and rain) from May to September for each year were used to run the model. The correlation coefficient was calculated by analyzing the observed and simulated disease incidence data over the period of 2002-13 (12 years). For the statistical analysis, we used the area under the disease progress curve (AUDPC) as the simulation result. The AUDPC (% days) was calculated by accumulating the daily disease severity (%) for the entire simulation period (days), providing information about the dynamics of disease development and an assessment of disease intensity.

The final evaluation of the model to examine its potential applicability for making predictions about seasonal pests was performed to find significant relations between simulated results and climate conditions during the simulation period. We simulated the model using the historical weather data (1976-2013) of the Pili weather station with the transplanting date of July 1. Climate variables such as mean temperature, accumulated rain, and the number of rainy days with more than 10 mm/day (rain frequency) were calculated for the period of June-August for each year. Regression analyses were conducted with the simulation results and each one of the climate variables to find any statistically significant relations.

SENSITIVITY TEST

Sensitivity tests were conducted using the RTD incidence data in the 1995 WS and daily weather data, which was used for the model calibration as the reference data for the sensitivity test. The sensitivities of the rtdSim model were analyzed for five variables, including two weather variables (daily mean temperature and precipitation), transplanting date, and virus acquisition and inoculation probabilities. By changing the values of a variable in the model with the other variables held constant at reference conditions (or original parameter values), the responses of the model were analyzed. The levels for the test were determined by estimating the overall range of each variable for the future period based on observed past records.

As a result, 10 levels of temperature deviations, ±1, ±2, ±3, ±4, and ±5 ˚C from daily mean temperatures and rainfall deviations, ±2, ±4, ±6, ±8, and ±10 mm from daily rainfall were compared with respective reference variables. Because it is difficult to change rainfall frequency, we only made changes in the rainfall amount on rainy days. If daily rainfall became a negative value by subtracting a larger value than the reference rainfall amount, it was considered to be 0 mm. Twelve levels of virus acquisition and inoculation probabilities in between 0.03 and 0.36 at 0.03-intervals were applied. In addition, transplanting dates within 15-day intervals from 1 May to 15 May, 1 June, 15 June, 1 July, 15 July, 1 August, 15 August, 1 September, and 15 September were used as input values for the sensitivity tests.

3. Results and Discussion

3.1 Tungro epidemiological model

A tungro epidemiological model was developed through a series of parameterization and calibration processes. The *rtdSim* model has two separate modules explaining vector growth and virus transmission. With the two separate modules, the model not only simulates insect vector development dynamics, but also simulates plant infection by viruliferous vectors based on biologically plausible conditions of environment (temperature and rainfall). As a result of the model calibration with an observed RTD incidence data, a few important parameters such as virus transmission probabilities have been successfully calibrated. The calibration resulted in a relatively accurate fit between the simulated and observed disease progress curves, as shown in Figure 5. The *rtdSim* model closely followed the temporal increase of the observed disease incidence and the peak incidence level at 60 DAP. The slight over-estimation during early days was simulated by the model even after calibration. The disease onset day can be set to make a better fit, as shown in a previous study (Holt and Chancellor, 1996). Because very complicated factors affect the onset day, it is highly variable in the field situation. Therefore, we did not set the onset day in the model. Table 2 shows the parameter variables finally set for the *rtdSim* model through parameterization and calibration.

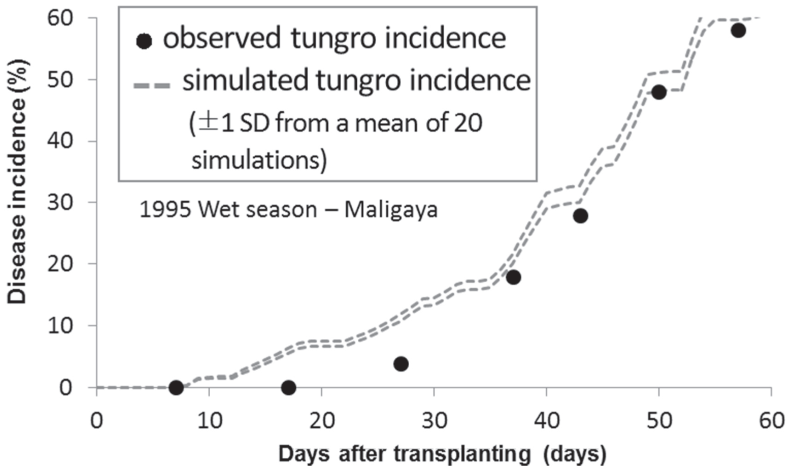

Figure 6. Comparison of the simulated disease incidence by the calibrated rtdSim model (dotted gray line, -- indicates ± 1 SD from a mean of 20 simulations) and the observed disease incidence in Maligaya in the 1995 wet season (black dots).

To examine the *rtdSim* model's overall performance in vector population dynamics and virus acquisition, we plotted temporal changes in the number of total nymph and adult GLHs, and the number of viruliferous GLHs and the ratio of viruliferous GLHs over total adult GLHs. As shown in Figure 6, the population for each stage increased exponentially, although at different time points, owing to each stage's own development period. It can be assumed that G0 immigrants played an important role in the establishment of G1 generation in the paddies, leading to the subsequent exponential increase in G1 nymphs and adults at around 30 and 40 DAP, respectively. Increased adult GLHs and infected hills resulted in an increasing number of viruliferous GLH, which is significantly related to the increase in disease incidence in the field. As previous studies have indicated, the G1 GLHs act as the main factor responsible for most of the RTD incidence increases observed in the field. As Aryawan et al. (1993) and Widiarta et al. (1990) showed in their field surveys, the *rtdSim* model also simulated that adult density increased from the immigrant generation to the first generation and sharply decreased to the second generation. Based on these results, we confirmed that the *rtdSim* model could simulate the vector population dynamics and the virus acquisition pattern of GLH, in a way similar to that described in previous studies.

Table 2. Parameter and driving variable definitions with values used in the *rtdSim* model.

Parameter	Definition	Value
Vector Population Dynamics		
v1	Age of eggs at hatching (days)	9
v2	Age at adult molt (days)	25
v3	Age at first oviposition (days)	31
v4	Age at last oviposition (days)	35
v5	Age at death of vectors (days)	37
v6	Net multiplication rate per generation	8 (before 30 DAT) or 2 (After 30 DAT)
v7	Vector development rate based on temperature	Gradual increase from 20 to 37 ˚C
Virus Transmission		
r	Retention period of virus inside vector (days)	Random (5:6) or random (7:8)
baseRc	Inoculation probability of virus from vector to plant	0.18
RcA	Plant age effect on inoculation probability	Gradual fall after 30 DAP
RcT	Temperature effect on inoculation probability	Optimum: 25 ˚C

Parameter	Definition	Value
RcR	Rain effect on inoculation probability	Optimum: around 2.5 mm/day, but drastic fall with heavy rain
t	Acquisition probability of virus from infected plant to vector	0.16 (before 30 DAT) or 0.05 (after 30 DAT)
l	Latent period of disease symptom in plant (days)	7
Vector Immigration		
baseGLH	Base number of initial vector immigrants	100
Init.effT	Temperature effect on initial vector immigrants	Optimum: 25–31 °C
Init.effRF	Rain frequency effect on initial vector immigrants	Optimum: 0 rainy days with more than 5 mm
Mid.effT	Temperature effect on daily vector immigrants after transplanting date	Optimum: 25–31 °C
Mid.effR	Rain effect on daily vector immigrants after transplanting date	Optimum: around 2.5 mm/day, but drastic fall with heavy rain over 10 mm/day
Model Simulation		
Sites	Total number of rice hills within the simulation grid (hills)	324
ACF	Acquisition correction factor	Number of infected hills per number of total hills (*Sites*)
ICF	Inoculation correction factor	Number of healthy hills per number of total hills (*Sites*)
Duration	Simulation duration (days)	60

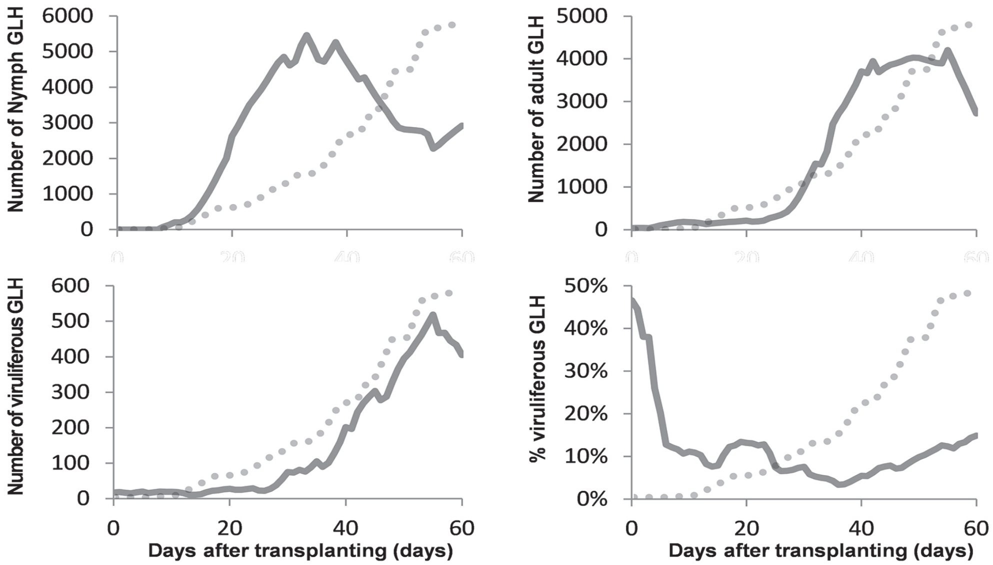

Figure 7. Simulated number of nymph, adult, and viruliferous GLHs and the ratio of viruliferous GLH (number of viruliferous GLHs / number of adult GLHs) (gray solid lines), generated as a result of calibration simulation in Figure 6. Gray dots indicate the simulated disease incidence.

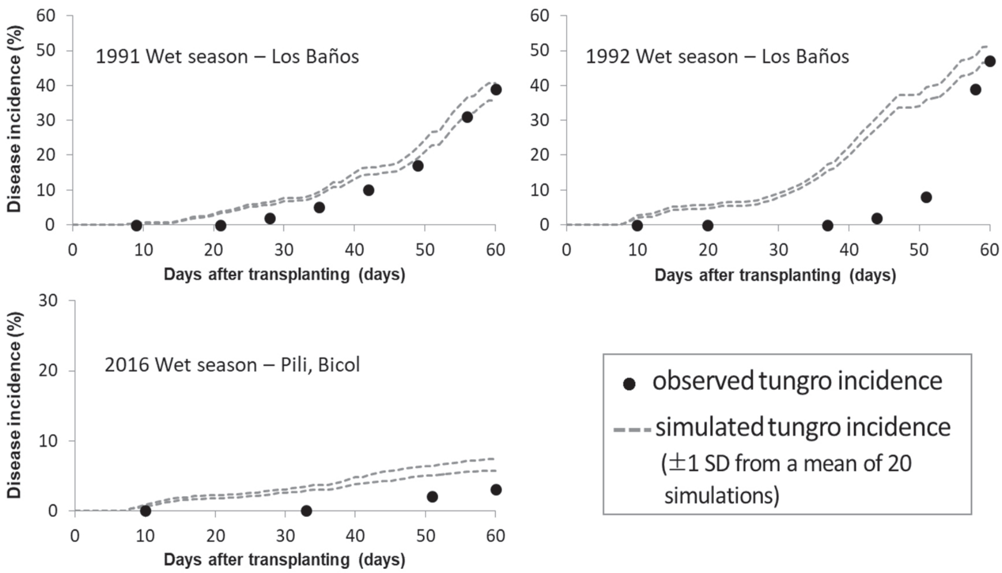

Figure 8. Simulated disease incidences (gray dotted lines, -- indicates ± 1 SD from a mean of 20 simulations), compared with observed disease incidences (black dots) on the IRRI experimental farm in Los Baños in the wet seasons of 1991 and 1992 and on the rice paddies in Pili, Bicol in the wet season of 2016.

With model calibration using ground truth field conditions, this study demonstrated that the model could be used to predict tungro incidence in rice paddies in the Philippines. However, it is important to note that limitations remain as the driving variables (in this case, the population dynamics of viruliferous GLH and inoculation rates) could only be estimated using key assumptions. This need for estimation is common to several other models of annual crop insect pests and means that a detailed curve fitting cannot be justified. With data sets from only two seasons used for calibration, some parameter values were adjusted in the study. This is an important consideration when exploring the broader applicability of conclusions derived from the model. Adjustment of some parameters may be warranted by the fact that the initial estimates were based on laboratory studies under the ideal conditions for transmission; in the field, the situation is likely to be different. In the case of plant age effects on transmission, no other model parameter had the same effect of changing late season disease progress without altering dynamics earlier in the season. A similar argument applies to changing the effect of plant age on vector population growth using the net multiplication rate. That the model results are very sensitive to changes in parameter values, as shown by the sensitivity tests, supports the generality of conclusions.

In this study, we introduced an algorithm to determine initial GLH population based on the GLH population development estimation since the start date of WS, May 1. In other words, it was presumed that the RTD incidence level was closely associated with the population build-up of GLH until the point the transplanting take place. This association was confirmed by previous studies where results indicate that vector population increase was at least one of the most important factors causing RTD increase (Suzuki et al., 1992; Aryawan et al., unpublished). Suzuki et al. (1992) indicated that tungro infections in rice paddy fields reached the highest peak on average in 6 weeks after transplanting, when the first generation adults of GLH are generally most abundant. It was also recognized that increasing migratory activities of the first generation adults accounted for the population build-up in the near paddies.

Outbreaks of RTD are triggered by the sporadic occurrence of severely infected paddy fields caused by the initial GLH immigrants (Suzuki et al., 1992). This was confirmed by the fact that the proportion of viruliferous GLH sharply increased as the percentage of infected hills exceeded a certain level at the late stage of the simulation. It is thus recommended the first special surveillance for RTD to be carried out shortly after transplanting. Suitable sites for the surveillance are the RTD-endemic locations from which RTD spread frequently in the past and the locations where tungro incidences were reported recently.

3.2 Comparison with field observation

Simulations with the rtdSim model were conducted to compare the simulated disease incidences with those from field observations. Figure 8 shows the fit of the model to the disease incidence data for the WSs of 1991 and 1992 in Los Baños, and for the WS of 2016 in Pili. The stochastic representation of vector development dynamics and virus retention period leads to variation between simulations. The range of variation is indicated in Figure 8 by lines plotted one standard deviation on either side of the mean of 20 simulations. A comparison between the simulation results and the observed RTD incidence data in the 1991 WS showed a fairly accurate fit. Temporal disease progress curves showed a similar increasing pattern, and both peak disease incidences at 60 DAP were almost the same. However, in the 1992 WS, the rtdSim model simulated disease progress curves that over-estimated the observed epidemic on most of the days. This is probably because the model algorithms could not detect some abiotic or biotic factors that prevented early onset of the RTD, resulting in staggered development of disease. In fact, the observed incidence showed very radical changes right after 40 DAP, owing to an unknown reason. Nevertheless, the model was successful in finding the peak incidence level observed in the field, although we cannot conclude whether this was coincidental. Simulating the realistic peak incidence level is very important, because it is closely related to the final yield loss observed in the fields (Muralidharan et al., 2003). In addition, the simulation results for the 2016 WS slightly over-estimated the observed epidemic, but the weak epidemics and very slow progress of the disease curve in the field condition were well simulated by the model. In fact, the year 2016 was recorded one of the lowest historical incidences of tungro in the region (RCPC, personal communication).

The rtdSim model was developed with the objective of applying it to seasonal pest risk prediction in the Bicol region. Therefore, it was necessary to examine whether it performed reasonably well against disease incidence cases reported in the region. To examine this, we graphically compared the RTD simulations by the model with available ground truth data collected by pest observers of the RCPC of the DA-RFO 5 in Bicol. Figure 9 indicates that the rtdSim model was not efficient at simulating the relative level of high/low profiles of the observed incidence data (diseased areas each year). From 2002 to 2008, highly over-estimated disease incidences were simulated by the model; the same holds true for the 2012-2013 period. Although the quality of the crude ground truth data obtained cannot be guaranteed, to be useful to farmers the model cannot over-estimate actual disease risk. Nevertheless, the comparison with the observed data in the incidence area in Bicol indicated that the model results could be used to at least predict the relative interannual risk variation rather than the absolute magnitude of the risk.

Validation results using observed RTD data showed that the set of parameter values calibrated from comparison of the model with available data appeared to work well in simulating the RTD epidemic. For our purposes, a model is considered valid if the simulated peak disease incidence fits with the observed peak disease incidence, as this gives critical insight to yield losses. The *rtdSim* model, with peak incidence levels comparable to the observed ones in both cases, fits the chosen criteria and is thus valid. However, it is important to note that the model failed to simulate the exact time-series changes in disease incidence in one of the validations (the 1992 WS), indicating that the *rtdSim* model requires further validation with additional ground truth data in the future. In particular, more data with temporal disease progress would need to be gathered for the purpose.

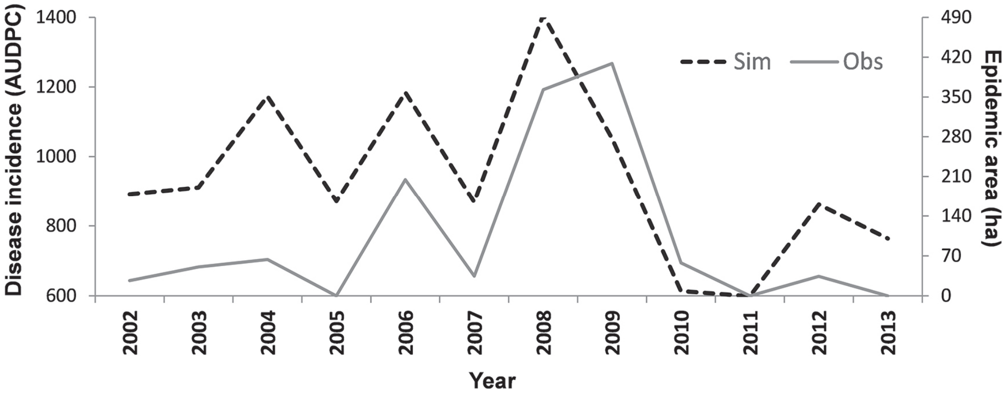

Figure 9. Comparison of observed disease incidence (total epidemic area, gray solid line) in the municipalities around Pili and simulated disease incidence (Black dotted line), the area under disease progress curve (AUDPC, % days), by the rtdSim model for the period of 2002-2013. Temporal correlation coefficient: 0.70.

3.3 Sensitivity test

Sensitivity analyses of the rtdSim model highlighted the effects of changing weather variables on model outputs. The reference weather condition for the ground truth RTD incidence monitored at a rice test plot in Maligaya, Central Luzon in the 1995 WS are shown in Figure 10, with separate weather data for pre-cropping season and cropping season. The climate conditions exhibited typical WS features, with frequent precipitation from May to mid-September. Mean temperatures were 28.3 and 26.9 °C, accumulated rainfall amounts were 757.7 and 682.3 mm, and rainfall frequencies of more than 10 mm/day were 20 and 21 days, respectively, for the pre-cropping and cropping seasons.

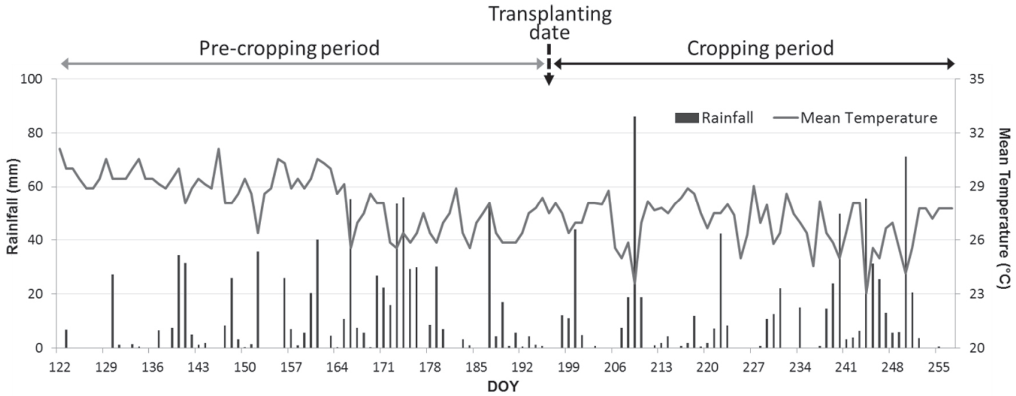

Figure 10. Sensitivity tests for the rtdSim model. Sensitivity to (A) temperature and rainfall, (B) transplanting date, (C) acquisition probability and inoculation probability were examined. Disease incidence with reference weather condition was indicated with arrows for each test. Reference weather condition for the 1995 wet season was from a weather station installed in the experimental station in Maligaya.

Table 3. Parameter/variable ranges for sensitivity tests

Parameter/variable	Values
Temperature	−5 ~ +5 ˚C (1 ˚C interval)
Rain	−10 ~ +10 mm (2-mm interval)
Acquisition and Inoculation Probabilities	0.03 ~ 0.36 (0.03 interval)
Transplanting date	May 1 ~ Sep 15 (15-day interval)

Responses of the rtdSim model to the ranges of temperature, rainfall, and transplanting date were plotted (Figure 11A and B). Changes in each variable in either direction resulted in increasing or decreasing dynamics of the simulation results. In all tests, higher disease incidences than the reference condition were simulated within the range of each variable. Thus, it may be interpreted that the reference climate condition for each variable is not optimal for the maximum disease incidence simulated from the epidemiological algorithms in the model.

Temperature changes within the test range dramatically affected the rtdSim output from 295 AUDPC to 1653 AUDPC, indicating that the model is sensitive to temperature changes. A temperature approximately 2 ˚C higher than the reference temperature resulted in peak disease incidence. In contrast, a completely different response to rainfall was observed. Continuous decline in disease incidence was simulated with the increase in rainfall amount, indicating that higher rainfall during the rainy days led to disease suppression. It can also be noted that the disease incidence under the reference weather condition already suggests rainfall-attributed disease suppression.

The responses to transplanting date are consistent with the observations of previous studies (Holt and chancellor, 1997; Truong et al., 1999b; Hasanuddin et al., 1999), wherein late transplanting causes higher RTD risk in an asynchronous cropping area. For example, Savary et al. (1993) used historical survey data to characterize planting date, cropping season, vector population, and proportion of viruliferous vectors, for their contribution in the variation of RTD incidence. One of their conclusions indicated that higher RTD incidence is associated with late planting date. Nevertheless, toward the end of season, changes in transplanting date had fewer effects on the model results (Figure 11B), probably because fewer young plants were available for new RTD infection at that time of the season.

Owing to the lack of detailed experimental evidence, the largest errors were expected to be in those parameter estimates associated with virus transmission. Vector infectivity was also highly variable; therefore, the sensitivity test focused on these factors (Figure 11C). Two variables, for virus acquisition probability and inoculation probability, were varied independently. The results showed that the final disease incidence in the simulations was influenced dramatically by both transmission rates: higher transmission rates led to higher disease incidence.

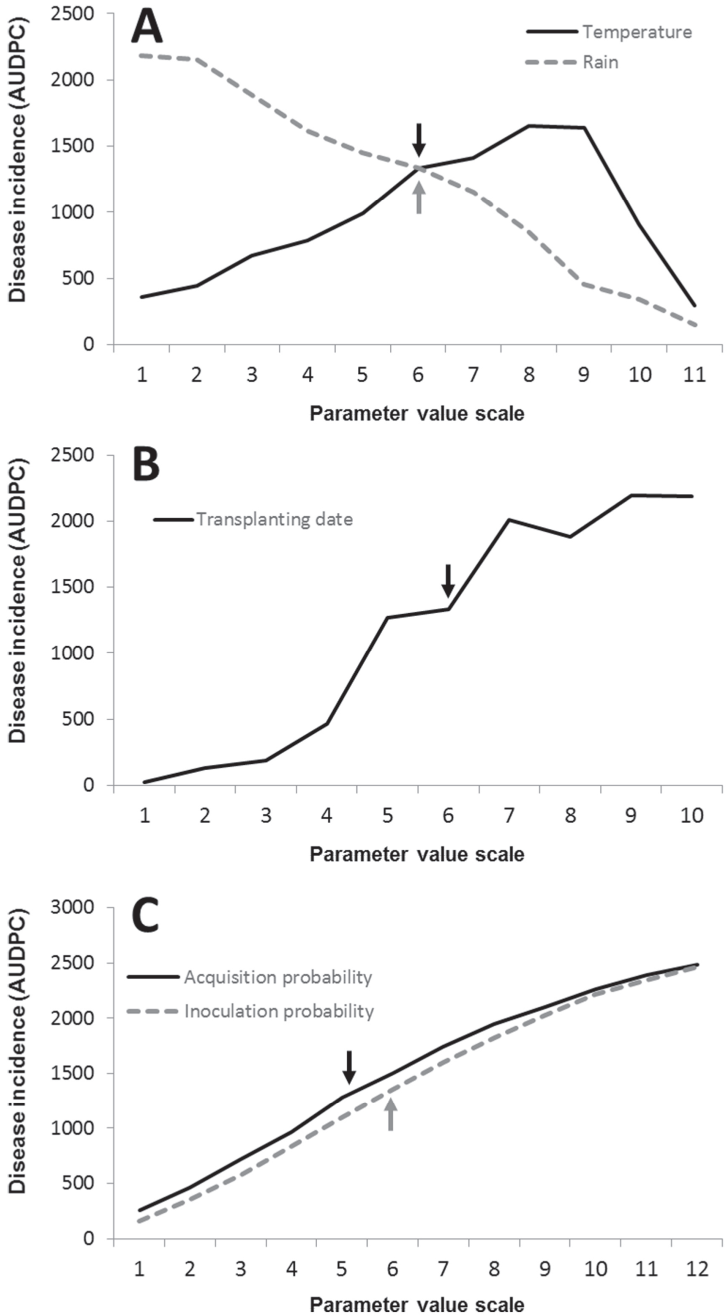

Figure 11. Sensitivity tests for the rtdSim model. Sensitivity to (A) temperature and rainfall, (B) transplanting date, (C) acquisition probability and inoculation probability were examined. Disease incidence with reference weather condition was indicated with arrows for each test. Reference weather condition for the 1995 wet season was from a weather station installed in the experimental station in Maligaya.

3.4 Potential applicability of the rtdSim model for the seasonal tungro outlook production

The seasonal tungro outlook will be produced by simulating the rtdSim model using SCF as an input variable. Currently seasonal mean values of temperature and rainfall over the upcoming three months are available from the SCF. To examine whether the rtdSim simulation is sensitive to the seasonal variations of the temperature and rainfall SCFs, we first simulated the model using observed daily weather data in the Bicol region over 38 years, and then we extracted seasonal means of each climate variable over the simulation period and analyzed them in relation to the model simulation results. As shown in Figure 12, the rtdSim model simulated clear inter-annual variation in disease incidences based on climate conditions, in particular, accumulated rainfall, corresponding to the simulation period. In fact, regression analyses using mean temperature, accumulated rainfall, and rainfall frequency (more than 10 mm/day) for the June-August period indicated the reason as well (Figure 13). Among the climate variables, accumulated rainfall resulted in the highest R2, followed by rainfall frequency and mean temperature. In particular, no correlative changes were shown in simulated disease incidence as the mean temperature varied between 27.5 and 29 ˚C. Based on this result, we understand the accumulated rainfall during this three-month period to have higher explanatory power in predicting the simulated RTD incidence among climate variables. Nevertheless, it is also obvious that rest of the variations in the simulated RTD incidence could be explained by the model algorithms for other climate variables for different periods.

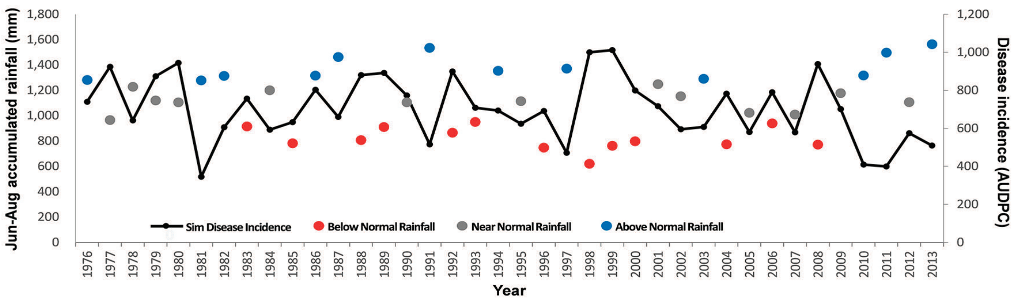

Figure 12. Simulated disease incidence by the rtdSim model using weather data from the Pili station for the period of 1976-2013. Daily simulated disease incidence was converted into the area under disease progress curve (AUDPC). Accumulated rainfall for Jun-August were divided into three categories, below normal, near normal, above normal, mimicking tercile-probability seasonal climate forecast, and displayed together with the simulated disease incidence.

APCC is issuing probabilistic multi-model ensemble SCFs for the upcoming three-month overlapping seasons in the form of tercile-based categorical probabilities. Based on this information, we divided the accumulated rainfall for June-August into three terciles: first 33.3% as below normal (BN) rainfall, second 33.3% as near normal (NN) rainfall, and last 33.3% as above normal (AN) rainfall. In addition, the categories of the accumulated rainfall for each year were displayed on the graph with the simulated disease incidences (Figure 12). In many years with AN rainfall, relatively low disease incidences were shown, while high disease incidences were shown mainly in the years with BN rainfall.

Table 4 summarizes the rtdSim-simulated disease incidence categorized by three separate periods (dry, normal, and wet years) based on the accumulated rainfall in the period of June-August. Based on average values of accumulated rainfall and simulated disease incidences for each period, we could estimate that the accumulated rainfall is highly correlated with the simulated disease incidence, suggesting that the rtdSim model can be used to predict RTD risk with the tercile probability SCFs in the region.

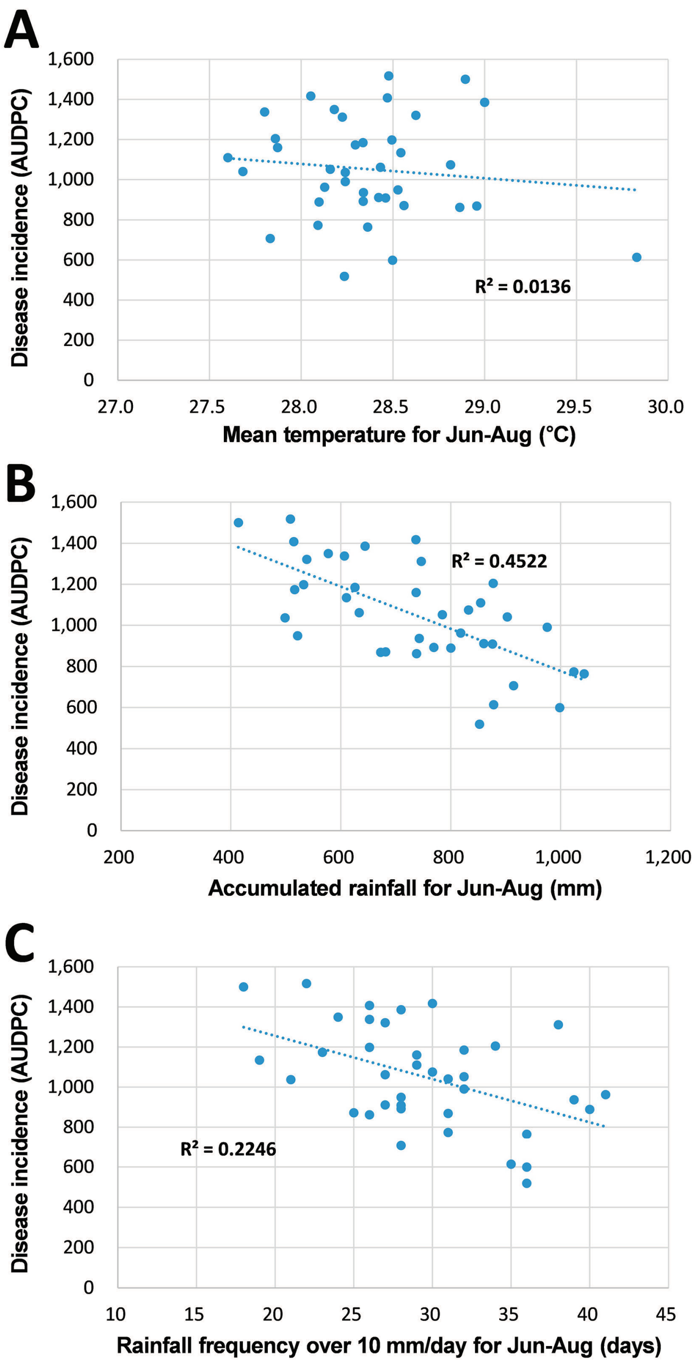

Figure 13. Regression plots for the relation of the simulated disease incidence (AUDPC) and climate variables (mean temperature, accumulated rainfall, rainfall frequency over 10 mm/day) for Jun-Aug. Trend lines were displayed together with R squares for each regression.

Strategic management of RTD has been implemented in some countries through government-controlled programs, such as rotating cultivars with different degrees of resistance. Planting dates were also manipulated in an attempt to avoid peak GLH numbers coinciding with the crop growth stage that is the most vulnerable to tungro infection. This also resulted in synchronizing planting to produce more definite breaks between crop seasons. In general, it will only be beneficial for farmers to adopt such measures if the risk of tungro occurrence is clearly sufficiently high to outweigh the various disadvantages in adopting these practices. In this regard, early warning based on seasonal pest outlook might allow farmers and extension specialists to collaborate in assessing and managing the risk, thereby allowing a timely switch to resistant varieties or modification of planting dates in order to reduce carry-over of inoculum between crops.

5. Conclusions

Issues associated with sustainable crop production have gained considerable importance in recent decades, as a result of global population growth and increased demand for agricultural products, occurring in the context of climate change. The present study addressed one of these critical issues from the perspective of crop health management, specifically targeting the risk of rice pest epidemics. Although considerable progress has been made in estimating and quantifying such risks and in characterizing the distribution and variability of risk across agricultural areas, environmental conditions, and crop management strategies over the past years (Júnior et al., 2008; Luo et al., 1998; Savary et al., 2006), our study aimed at measuring the seasonal-scale risk for seasonal-scale management options.

Seasonal pest risk prediction provides risk information measured by environmental conditions, thus it involves rice pest epidemiological models and seasonal climate forecast. When it provides timely and accurate forecasts, agricultural stakeholders can utilize the outlook information to inform their crop management strategies in a seasonal scale. On a governmental level, the seasonal pest risk prediction can be used for the implementation of national-level disaster preparedness plans. As a first step to predict the seasonal rice pest risk in the target region, we developed a tungro epidemiological model, the *rtdSim* model, to simulate RTD risk. The *rtdSim* was calibrated and validated against available observed incidence data for tungro. Comparisons between the observed and simulated tungro epidemics were made graphically and statistically, and it was revealed that the level of agreement between the observed and simulated epidemics was reasonably high in most cases, although more validation with more ground truth incidence data from the fields over subsequent years is required.

The present study highlights the potential for developing climate-based epidemic early warning systems for rice pests, with SCFs as input, thus allowing better decision-making and prevention on a seasonal scale. To reach the intended goal of a functional seasonal pest outlook, additional work such as SCF downscaling, the development of a decision support system linking climate information to rice pest epidemiological models, and the application of the seasonal pest risk prediction to integrated pest management will be undertaken next year. Through this study, we also realized there remain enormous challenges in this complex, multidisciplinary work, limiting the active and effective use of the *rtdSim* model in predicting the seasonal tungro outbreak. The identified limitations include the failure to allow for non-climatic confounding factors in modeling, insufficient calibration and validation due to limited ground-truth data, and seasonal low predictability of the SCF in the region (PAGASA website: http://www.pagasa.dost.gov.ph/).

Due to the probabilistic nature of SCF information, it is important to avoid interpreting or evaluating outputs from a deterministic viewpoint. In other words, a highly accurate forecast does not preclude the possibility of it being wrong for a particular season. This means that we cannot rely solely on the seasonal pest outlook, owing to uncertainties that the information carries. This is why a seamless approach for RTD management is necessary, integrating different information at different timescales. Starting from the seasonal pest outlook, stakeholders can prepare seasonal management strategies. If a sub-seasonal forecast is possible, it allows the confirmation of some seasonal-scale strategies, as well as the designing of additional sub-seasonal management strategies. Using a short-term weather forecast, short-term risk information can be used to directly manage the RTD on the fields, such as chemical spraying and surveillance. Vector population and disease symptoms in relation to weather factors are continuously monitored for earlier intervention of possible RTD spread.

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APPENDIX V

2017 Technical Workshop Report

1. Summary

- **Workshop Title:** 5th Annual Technical BAWP Workshop: Models and Tools for Water Agriculture and Knowledge Sharing
- **Related Project:** Bicol Rice Disease Project (September 2015 – September 2017)
- **Location:** Villa Caceres Hotel, Naga City, the Philippines
- **Date:** March 14 (Tuesday) – 17 (Friday), 2017
- **Key Partners:** International Research Institute for Climate and Society (IRI) and Bicol Agri-Water Project staff (BAWP)

2. Background and Purpose

Project Background

The *application of a rice disease model for seasonal yield loss simulation in the Bicol region*, or the APCC Bicol Rice Disease Project (BIRD), is a collaborative partnership between APCC and the International Research Institute for Climate and Society (IRI). In 2015, APCC became a co-implementing partner of IRI in the Bicol Agri-Water Project (BAWP), which aims to improve water security in the Bicol region of the Philippines by adopting climate decision support tools and enhance agricultural development under climate variability and change. BAWP is developing climate decision support tools and enhancing agricultural development under climate variability and change. BIRD, which runs from September 2012 to September 2017, fits well with APCC's strategic plan to integrate climate products with sectoral applications such as agriculture.

While BIRD mainly focuses on the integration of a disease model into the Climate-Agriculture Modelling Decision Tools (CAMDT) suite, called CAMDT-Disease, APCC has also supported the 2016 and 2017 BAWP Technical Workshops. This served as the final event for BAWP, as the project has now ended. APCC's BIRD, however, will continue into September 2017, until the completion of the CAMDT-Disease component.

Event Overview

From March 14-17, 2017, BAWP conducted its 5th and final technical workshop on models and tools for water, agriculture and knowledge sharing in Naga City, Camarines Sur. Final versions of the models such as Water Evaluation and Planning (WEAP) Model-Bicol, Climate-Agriculture Modeling Decision Tool (CAMDT) and Knowledge Sharing Portal and Maproom (KSPM) were presented to project partners.

Experts from IRI, Michigan State University (MSU), University of Maine, and APCC discussed the updated versions of the models and further explained how the KSPM can be more useful in operation mode. A hands on session was delivered to walk stakeholders through CAMDT-Disease, allowing for both the familiarization of the users with the model as well as the identification of improvements to be made. The workshop provided an opportunity for partners to be more familiarized with the climate change models and tools for assessing and managing climate risks in agriculture and water resources. The workshop was conducted in collaboration with partner agencies: IRI, APCC, Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA); Department of Agriculture Regional Field Office 5 (DARFO5) and the University of the Philippines Los Baños Foundation, Incorporated (UPLBFI).

This event also served as an avenue to officially turn-over all the decision support tools to target users for their operational use in agricultural climate risk management. On the final day of the workshop, BAWP officially turned over all its decision support tools for agricultural climate risk management such as CAMDT, WEAP, KSPM and CLEA to the project partners.

Thirty-two representatives from different partner agencies and institutions participated in this workshop. Having gained additional knowledge and skills, they are now better prepared to employ the models introduced by BAWP for adaptive climate risk management in agriculture and water resources.

Results

- APCC presented project and final product.
- Training held on CAMDT-Disease to run simulations and interpret results.

- Feedback from key users collected for the improvement of CAMDT-Disease.
- Strengthened connections with IRI and local organizations.
- Shared and discussed the functionalities of the final versions of the Knowledge Sharing Portal, WEAP-Bicol and CAMDT models and tools to project partners.
- Provided an opportunity for project partners to familiarize with climate change/variability and the models/tools for assessing and managing climate risks to agriculture and water resources.
- Turned over officially all the models/tools for target users for their operational uses in the future for agricultural climate risk management, excepting CAMDT-Disease (to be turned over in September 2017).

3. Acronyms

APCC	-	APEC Climate Center
BAWP	-	Bicol Agri-Water Project
BIRD	-	Bicol Rice Disease
BUCAF	-	Bicol University College of Agriculture and Forestry
CAMDT	-	Climate - Agriculture Modeling Decision Tool
CBSUA	-	Central Bicol State University of Agriculture
CPT	-	Climate Predictability Tool
DARFO 5	-	Department of Agriculture - Regional Field Office 5
IRI	-	International Research Institute for Climate and Society at Columbia University
KSPM	-	Knowledge Sharing Portal and Maproom
MLGU-BUHI	-	Municipal Local Government Unit of Buhi
NIA-ALBAY	-	National Irrigation Administration, Albay
NIA-RIIS	-	National Irrigation Administration -Rinconada Integrated Irrigation System
NPC -BBWAT	-	National Power Corporation - Buhi Barit Watershed
PAGASA	-	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PLGU-ALBAY	-	Provincial Local Government Unit of Albay
USAID	-	United State Agency for International Development
UPLB	-	University of the Philippines Los Baños
UPLBFI	-	University of the Philippines Los Baños, Foundation Inc.
WEAP	-	Water Evaluation and Planning

4. Program of Workshop Activities

Time	Details	Presenter
Tuesday 14 March 2017		
12:00-1:00	Registration	BAWP Secretariat
1:00-1:30	Opening Program	BAWP Secretariat
1:30-2:00	BAWP Project Updates	**Dr. Cely S. Binoya** *Co-PI* BAWP
2:00-2:30	Overview of the Workshop activities and Objectives	**Dr. Amor Ines** *Assistant Professor* Michigan State University
2:30-4:30	Overview/review of Climate Change (CC) scenarios, CAMDT, Water Evaluation and Planning System (WEAP), BAWP Knowledge Sharing Portal and Maprooms (KSPM)	**Dr. Eunjin Han** *Research Scientist* IRI-Columbia University **Dr. Bradfield Lyon** *Associate Research Professor* University of Maine **Dr. Amor Ines** *Assistant Professor* Michigan State University **Mr. Remi Cousin** *Senior Staff Associate* IRI-Columbia University
4:30-5:00	Climate-Agriculture Modelling Decision Tools with Disease component (CAMDT-Disease)	**Dr. Kwang-Hyung Kim** *Research Fellow* APEC Climate Center
Wednesday 15 March 2017		
8:00-9:00	CC scenario Vector Autoregression-simulation	**Dr. Bradfield Lyon** *Associate Research Professor* University of Maine
9:00-10:00	Practical Exercise: How to download needed inputs to WEAP from KSPM	**Mr. Remi Cousin** *Senior Staff Assoc.*, IRI
10:00-11:00	Practical Exercise: New version of WEAP (*linking with new CC)* both for CBuhi and Quinali A watershed	**Dr. Eunjin Han** *Research Scientist* IRI-Columbia University **Dr. Amor Ines** *Assistant Professor* Michigan State University

Time	Details	Presenter
11:00-12:00	Practical Exercise: Collection of WEAP outputs for KSPM	**Mr. Remi Cousin** *Senior Staff Assoc.,* IRI
12:00-1:00	*Lunch*	
1:00-2:50	Practical Exercise: How to download needed inputs to CAMDT from KSPM	**Mr. Remi Cousin** *Senior Staff Assoc.,* IRI
	Practical Exercise: CAMDT scenario exercises & discussion	**Dr. Eunjin Han** *Research Scientist* IRI-Columbia University
2:50-3:20	*Break*	
3:20-4:50	Practical Exercise: Applying CC to Decision Support System for Agrotechnology Transfer (DSSAT) for long-term scale decision making & discussion	**Dr. Amor Ines** *Assistant Professor* Michigan State University
4:50 - 5:00	Practical Exercise: Collection of CAMDT outputs for KSPM	**Mr. Remi Cousin** *Senior Staff Assoc.,* IRI
Thursday 16 March 2017		
9:00-9:10	Introduction to APEC Climate Centre	**Ms. Christianne Miko Aikins** *Project Manager* APEC Climate Center
9:10-12:00	Practical Exercise: CAMDT-Disease; Disease models in CAMDT-Disease and model validation	**Dr. Kwang-Hyung Kim** *Research Fellow* APEC Climate Center **Dr. Seongkyu Lee** *Research Fellow* APEC Climate Center
12:00-1:00	*Lunch*	
1:00-3:00	Presentation of new Maprooms since last year (*Rainfall and Water Balance Monitoring driven by local stations)* Presentation of WEAP Maproom interpreting results of previous day session	**Mr. Remi Cousin** *Senior Staff Assoc.,* IRI
3:00-3:30	Presentation of CAMDT Maproom interpreting results of previous day session	
3:30-5:00	Open Discussion	
Friday 17 March 2017		
8:00-8:30	Registration	
8:30-8:40	Welcome Remarks	**Mr. Rodel P. Tornilla** *Co-PI* BAWP

Time	Details	Presenter
8:40-8:50	Message	**Mr. Eric Schaeffer** Chief Finance Officer USAID/Philippines
8:50-9:00	Presentation of CLEA	**Mr. Francis Faderogao** *Project Associate* BAWP
9:00-9:15	Response from Project Partners	LGU Project Partners
9:15-9:25	Presentation of the models	**Dr. Amor Ines** *Co-PI* BAWP
9:25-9:30	Turnover of the Models	Project Partners
9:30-9:40	Response from Project Partners	SUC Project Partners
9:40-9:45	Pledge of Commitment	All
9:45-10:00	Group Photo	All
10:00-11:30	Free Discussion	
11:30-12:30	*Lunch*	
1:00-3:00	BAWP Partners meeting	BAWP, PAGASA, UPLBFI DA RFO 5, IRI, and APCC

5. Event

Workshop

In addition to an overview of project activities and successes by key BAWP staff, including the project co-PIs Dr. Cely S. Binoya and Mr. Rodel P. Tornilla, a number of presentations and hands-on workshops were given by experts on various aspects of the tools in the CAMDT suite.

Dr. Amor Ines, Assistant Professor from the University of Michigan, discussed the overview and objectives of the workshop. He assured the partners that the work of the team will not end when the models are turned over to the local partners but only the beginning. Dr. Bradfield Lyon, Associate Professor from University of Maine, presented the overview of the climate change scenarios for the Bicol Region in near term climate change scenarios and near term climate projections. He discussed the data and methodology used in obtaining plausible climate change scenarios over the Bicol region.

Dr. Eunjin Han, Research Scientist from IRI-Columbia University, gave an overview on CAMDT and the improvements that the team made. She also explained why risk management is in seasonal scale and the role of the crop models. Dr. Han specified that the tool is not difficult to use if the concept behind it will be much realized. Later in the week she gave a full hands-on workshop.

Dr. Amor Ines also went through the Water Evaluation and Planning (WEAP) model. WEAP is free/low cost software developed largely by SEI and operates on a basic principle of water balance. It is comprehensive, flexible and user-friendly framework for integrated water resources planning and policy analysis. He also shared the improvements that the team made for the WEAP- Buhi and WEAP Quinal A.

Mr. Remi Cousin, Senior Staff Associate from IRI, presented the updated Knowledge Sharing Portal and Maproom (KSPM). New data, tab and information were added including WEAP Data, CAMDT Data and the Rainfall Data that the Rainfall Data Collectors collected from Nabua, Buhi and Polangui. He also added that a tab for the Climate Forecast and Extension Advisory can be viewed at the portal.

Lastly, Dr. Kwang-Hyung Kim, Research Fellow from APCC, presented the overview of the application of rice disease model for seasonal rice pest outlook in the Bicol region. He showed that rice yields reduce substantially with the occurrence rice pests and diseases. He also discussed the factors affecting rice pest occurrence and coping mechanisms. He also shared that they conducted scoping on disease epidemics in the Bicol region. He said that thorough investigation and monitoring was done by the team to come up with the improvements of the model.

Turn-Over Ceremony

The Bicol Agri-Water Project (BAWP) officially turned over all its decision support tools for agricultural climate risk management such as Climate-Agriculture Modeling Decision Tools (CAMDT), Water Evaluation and Assessment Planning (WEAP), Knowledge Sharing Portal and Maproom (KSPM) and Climate Forecast and Extension Advisory (CLEA) to its project partners in Bicol, namely; Philippine Atmospheric, Geophysical and Astronomical Services Administration 5 (PAGASA 5), Department of Agriculture Regional Field Office 5 (DARFO5) Central Bicol State University (CBSUA), Bicol University of Agriculture and Forestry (BUCAF), National Power Corporation - Buhi-Barit Watershed (NPC-BBWAT), National Irrigation Association- Riconada Integrated Irrigation System (NIA-RIIS), NIA-Albay, Department of Environment and Natural Resources 5 (DENR 5), and to the Local Government Units of Nabua and Buhi in Camarines Sur and Polangui in Albay, last March 17, 2017 held at Villa Caceres Hotel, Naga City.

The models and tools have been developed and customized by the experts from International Research Institute for Climate and Society of Columbia University (IRI), Michigan State University (MSU), University of Maine and APEC Climate Center (APCC). Each decision support tools covered an aspect that could enhance the capabilities of the institutions and stakeholders for assessing and managing climate risks to agriculture and water resources. It also ensures that decision-makers and researchers can access the data and other information from the models online which can broaden the scope of their science-based decision making. Ultimately, these models and tools will help better equip the agricultural extension workers and communities in reducing their vulnerability to climate-change and allowing them to better manage and plan climate risk in agriculture and water resources.

Outcomes

At the end of the workshop, participants were more knowledgeable on the BAWP models and tools provided and to be more ready to utilize them for climate risk management in agriculture and water resources.

Since this is the last Technical Workshop under the BAWP project (2012-2017), this workshop functions as a final event for the delivery of the products from the BIRD by APCC. Because of this, the outcomes are related to increased familiarity and usability of the CAMDT-Disease by the end users. These include:

- Critical feedback collected for the improvement of CAMDT-Disease.
- Key users are familiarized with and trained on the use of CAMDT-Disease.

- Increased visibility of APCC research and projects in the Asia Pacific.
- Increased awareness of BIRD and its relevance to the region.
- Enhanced relations with project partners.
- Consolidate input from stakeholders on end product.

APPENDIX Ⅵ

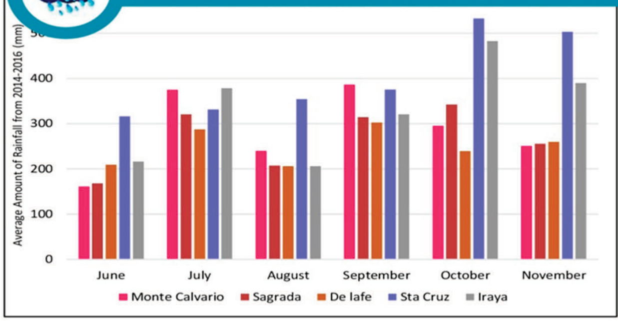
Sample Climate Forecast and Extension Advisory

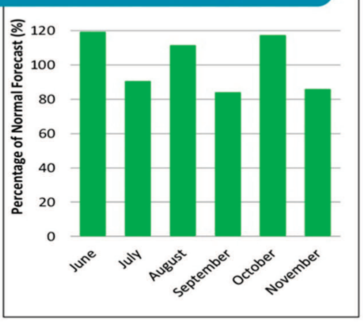
USAID FROM THE AMERICAN PEOPLE — APCC APEC CLIMATE CENTER — IRI — UPLBFI

CLIMATE FORECAST AND EXTENSION ADVISORY

JUNE 2017–NOVEMBER 2017 (CLEA 5-31-2017_WET SEASON_BUHI, CAMARINES SUR)

RAINFALL COLLECTED, (MM) & FORECAST RAINFALL, (%)





Average Rainfall Data for Year 2014 - 2016

The variability of rainfall within the Municipality of Buhi was observed between the actual rainfall collected through raingauges by Rainfall Data Collectors in five barangays. Barangay Sta. Cruz had the highest amount of rainfall received for the quarter. Upward trend of the rainfall was observed from June and continued at the succeeding months.

Rainfall Forecast for Jun-Nov 2017

Near normal rainfall forecast condition is expected for the whole quarter with the highest percentage of normal in the month of June and the lowest in the month of September.

FORECAST 2017 — WAY BELOW NORMAL < 40% — BELOW NORMAL 41% - 80% — NEAR NORMAL 81% - 120% — ABOVE NORMAL > 120%

EL NINO SOUTHERN OSCILLATION (ENSO) & LA NINA WATCH

The province of Camarines Sur is now on ENSO neutral condition that would be present on the month of June. The province may experience weak El Niño (~76% chance) in the month of May, June and July.

TROPICAL CYCLONES FORECAST

There's a probability of 9 to 14 tropical cyclones that can develop or enter in the Philippine Area of Responsibility (PAR). The breakdown are as follows: June – 1 or 2; July – 2 or 3; August – 2 to 4; September – 2 or 4; October – 1 to 3; and November – 1 or 2.

IMPACT OUTLOOK

The predominant "near normal" forecasted rainfall would be beneficial particularly on the rainfed areas and ideal for land cultivation and crop establishment specifically for lowland rice and upland crops. Early planting is suggested to avoid the high probability of extreme rainfall events (typhoons, etc) in the middle of the quarter that may cause floods and landslide. Wet condition may cause disease and pest outbreak in crops and increased respiratory diseases and parasitism in livestock and poultry.

CLIMATE AGRICULTURE MODELING DECISION TOOL

PILI, CAMARINES SUR STATION

Fertilizer Application*	Date of Planting**	PSBRc 82 (Inbred) Neutral Years Mean (Yield of Rice)	Neutral Years ±stdev	PAGASA (JJA, 2017) Mean (Yield of Rice)	PAGASA (JJA, 2017) ±stdev
No Fertilizer	Early	**3.28%**	14.26%	**13.27%**	9.95%
	Mid	-0.55%	19.27%	4.03%	17.00%
	Late	-1.06%	21.49%	4.29%	19.85%
(2) Two Fertilizer Application	Early	**3.14%**	6.13%	**8.99%**	5.52%
	Mid	0.00%	8.57%	5.16%	6.77%
	Late	-0.52%	13.56%	4.22%	9.95%
(3) Three Fertilizer Application	Early	**2.84%**	5.04%	**7.83%**	5.89%
	Mid	0.65%	6.10%	4.42%	4.93%
	Late	-1.47%	10.57%	6.40%	5.62%

*Fertilizer: Urea (46N-0P-0K); **Early-planting (Jun. 1); Mid- planting (Jun. 15); Late-planting (Jun. 30)*

Based on the results of **CAMDT** for the inbred (PSBRc 82) rice variety, it is recommended for an early planting (**June 1, 2017**) which shows the optimal yield of rice for the three scenarios on the fertilizer application, both in *Neutral Years* datasets and in the *PAGASA's Seasonal Climate Forecast (SCF)* relative to historical average yield.

Based on the **Seasonal Pest Outlook**, the lowest risk of the below-mentioned diseases for sheath blight, bacterial blight, brown spot and tungro diseases were also observed at the early planting date (**June 1, 2017**).

Seasonal Pest Outlook***

Planting Date**	Sheath Blight	Bacterial Blight	Brown Spot	Tungro Disease
Early	**83.8%**	**6.7%**	**45.7%**	**0.2%**
Mid	123.5%	79.0%	79.0%	45.6%
Late	125.6%	81.4%	81.4%	7.9%

**Relative risk level compared to the past 30-year-average risk for each diseases*

NOTES, REMINDERS & REFERENCES: 1. For more information, please visit this link: www.pagasa.dost.gov.ph/index.ph/climate/climate-outlook-forum; 2. Monthly updates on recommended GPO's will be issued upon the availability of recent developments of the climate outlook. For more information, please visit this link: https://bicol.gov.ph/seasonal_climate_outlook; 3. This is a two page briefer of climate information for the Bicol Agri-Water Project and this is for discussion purposes only. Views herein are made in consultation with PAGASA, DARFO5, IRI-CU, UPLBFI and APCC.

【Research Team】

Kwang-Hyung Kim, Research Fellow

Seongkyu Lee, Research Fellow

Christianne Michiko Aikins, International Project Manager

Research Report 2017-11

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