EFITA WCCA CIGR
2013 Conference
June 23-27, 2013
TORINO, ITALY
Sustainable Agriculture through ICT innovation

Prediction System for Double Cropping Optimization in Thailand

Kei Tanaka and Takuji Kiura

National Agriculture and Food Research Organization, Agricultural Research Center, Agroinformatics Division, 3-1-1 Kannondai Tsukuba Ibaraki, 305-8666, Japan.
tanaka.kei@affrc.go.jp

ABSTRACT

A research project, “Climatic Changes and the Evaluation of Their Effects on Agriculture in the Asian Monsoon Region (CAAM)” is progressing. The purposes of this project are to improve the reliability of climate prediction, and to develop the necessary information platform to design adaptation and mitigation strategies in agriculture against the predicted climatic changes in the Asia monsoon region. Sixty percent or more of the world’s population lives in the Asia monsoon region, and the effects of the predicted climate changes on the region are expected to be quite serious, since most of the countries in the region are agrarian. Our team’s central goal is to elucidate the effects of climatic changes on major crops in the Asian monsoon region by constructing an evaluation system using meteorological data and crop models. In particular, we take charge of development of a system that can simulate the cultivation under various conditions (e.g., cultivar, weather, and management).

We first surveyed the major crop models in Thailand to decide which crop model to adopt for the system. We found that the Decision Support System for Agrotechnology Transfer (DSSAT) was applied to several crops in Thailand. Next, we developed a prototype system to optimize the double cropping of rice and cassava in Thailand. This system was implemented using the Java Agricultural Model Framework (JAMF), and includes rice and cassava module of the DSSAT. As the input data for the system, solar radiation, air temperature and precipitation of 0.05 degree grid data in northeastern Thailand were prepared. This data was generated from actual data using a space interpolation method developed by Japan’s National Institute for Agro-Environmental Sciences. Each crop model was executed 365 times while the transplanting date was moved by one day each time, and the maximum yield of each crop was saved in XML files and displayed on Google Earth. The results of this system cannot be discussed yet because there are no local field data to compare and to verify the results. The comparison and verification between the results and the observation data are tasks for the coming years. The field data will be prepared by the cooperating institutes.

Keywords: Double cropping, rice, cassava, 0.05 degree grid meteorological data, northeastern Thailand, DSSAT, GRENE-ei CAAM.

<K. Tanaka>. <“Prediction System for Double Cropping Optimization in Thailand”>. EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013. The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the Internation Commission of Agricultural and Biosystems Engineering (CIGR) and of the EFITA association, and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by CIGR editorial committees; therefore, they are not to be presented as refereed publications.

1. INTRODUCTION

A Japanese research project, “Climatic Changes and the Evaluation of Their Effects on Agriculture in the Asian Monsoon Region (CAAM, 2012)” under the “Green Network of Excellence — environmental information (GRENE-ei, 2011)” program from Japan’s Ministry of Education, Culture, Sports, Science and Technology (MEXT) was started in 2011 and will be conducted until 2015. The dual purposes of this project are to improve the reliability of climate prediction and to develop the necessary information platform to design adaptation and mitigation strategies in agriculture against the predicted climatic changes in the Asia monsoon region, which encompasses Thailand, Indonesia, Philippines, and Vietnam. Sixty percent or more of the world’s population lives in the Asia monsoon region, and the effects of the predicted climate changes on the region are expected to be quite serious, since most of the countries in the region are agrarian.

Five institutions in Japan participate in this project (the Japan Agency for Marine-Earth Science and Technology [JAMSTEC], Tokyo Metropolitan University [TMU], the University of Tokyo [UT], National Agriculture and Food Research Organization/Agricultural Research Center [NARO/ARC; the authors’ affiliation], and Japan’s National Institute for Agro-Environmental Sciences [NIAES]), and together we research four subthemes:

1. The development of an agro-climatological database in the region’s developing countries (CCR1: JAMSTEC)
2. The impact of land-use/land-cover (LULC) changes on the Asian monsoon climate (CCR2: TMU)
3. The identification of climatic changes and the elucidation of their effects on agriculture based on a field survey (AER1: UT, AER2: NARO/ARC)
4. The development of an information platform to design adaptation and mitigation strategies for major crops against the predicted climatic changes (AER3: NIAES)

The NARO/ARC team researches the subtheme of “Elucidation of the effects of the climatic changes on major crops in the Asian monsoon region: Construction of an evaluation system using meteorological data and crop models.” The purpose of this subtheme is to develop an “evaluation system for major crops in the Asian monsoon region affected by climate changes” (hereinafter referred to as the evaluation system) that can simulate the growth of major crops in this region.

2. THE EVALUATION SYSTEM FOR THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

The structure of the evaluation system is shown in Figure 1. There are main three components of the system: (1) A meteorological data acquisition function, (2) crop models and a crop model execution engine that executes the models, and a parameter set

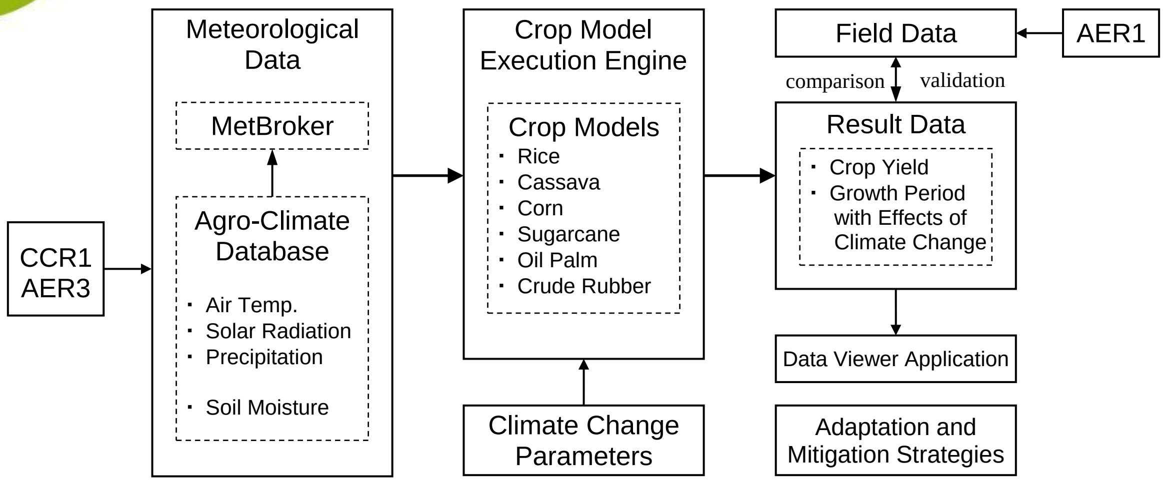


Figure 1. The structure of the evaluation system
for the effects of climate change on agriculture.

for climate change effect simulation, (3) result data with save, display, and comparison functions.

The crop model execution engine is a backbone function to execute a crop model repeatedly with conditions represented by numerical expressions. The engine can execute various crop models implemented by using a framework, JAMF (Java Agricultural Model Framework; Tanaka, 2006) by exchanging similar program parts.

A crop model (Tanaka, 1997) implemented by using JAMF acquires mainly meteorological data obtained through MetBroker (2000, Laurenson, 2002), a type of mediation software that exists between applications and databases. MetBroker can access many meteorological databases by a unified method that does not require a complex database access program. With MetBroker, a crop model can be used worldwide with meteorological databases such as those from the U.S. National Oceanic and Atmospheric Administration (NOAA) and the Global Dataset of DR and TR (GD-DR&TR) database (worldwide data in a one-degree grid) without the need to code the access program of each database. MetBroker can access a new meteorological database simply by developing a driver program. Therefore, it becomes possible for the crop model to use data in a new database that the other CAAM teams (CCR1, AER3) will construct, by obtaining the data from MetBroker.

Because the resulting data generated by the evaluation system will be saved in XML format, several types of display applications will be available to meet users' requirements. In addition, the accuracy of the evaluation system will be able verifiable by comparing the result data and the cultivating data that the AER1 team will observe.

<**C0256**>
<K. Tanaka>. <"Prediction System for Double Cropping Optimization in Thailand">. EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

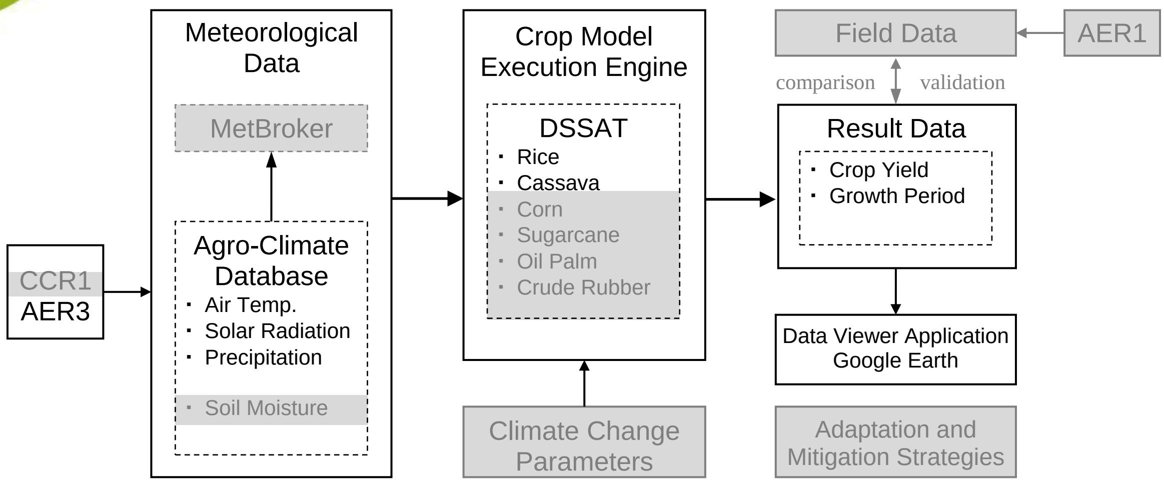


Figure 2. The structure of the prediction system for double cropping optimization.

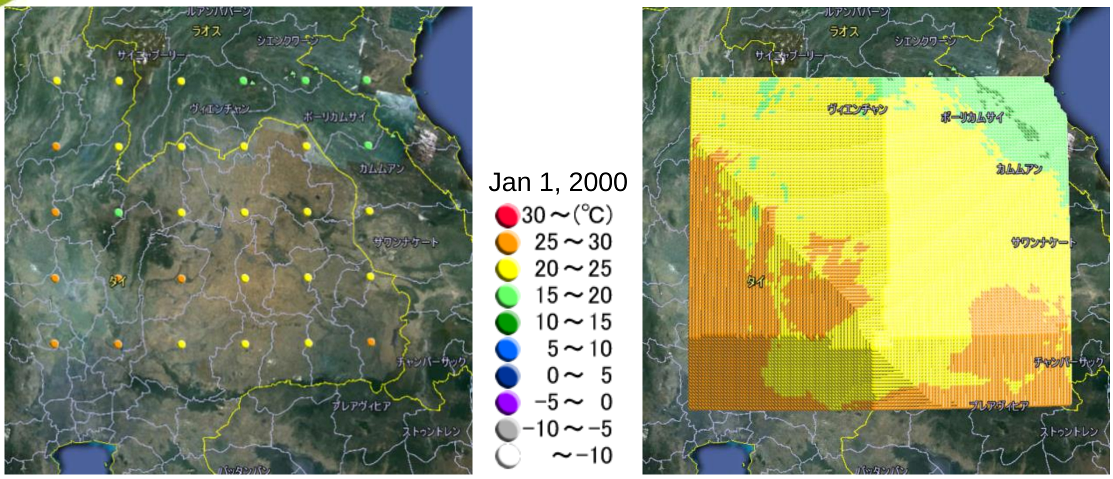
3. PREDICTION SYSTEM TO OPTIMIZE THE DOUBLE CROPPING OF RICE AND CASSAVA IN THAILAND

We developed a prototype system to optimize the double cropping of rice and cassava in Thailand (Figure 2) as the mid-term result of the CAAM project. The system is an extended version of the "simulator for the cultivation possibility of rice" (DIAS, 2011, Tanaka, 2011) developed for the Data Integration and Analysis System (DIAS, 2006) project, and it is a part of the "evaluation system for the effects of climate change on agriculture" (Figure 1). The gray parts in Figure 2 are not implemented functions.

In our survey of major crop models in Thailand, we found that the Decision Support System for Agrotechnology Transfer (DSSAT 2004, Jones *et al.*, 1998, 2003) was applied to several crops in Thailand. Enhancement of the educational system in Thailand and the maintenance of crops and soil databases are the main reasons for the spread of the DSSAT to Thailand. This system includes rice (Singh *et al.*, 1993) and cassava (Matthews *et al.*, 1994) modules of the DSSAT (version 4.5 for Linux). The default configuration (i.e., cultivar, dates, and amounts of fertilizer and irrigation) was used to execute, because the local cultivating data are not currently available.

The prediction system for the DIAS uses one-degree grid data (only for land, about 15,000 points) whose distance between points is 100 km (Figure 3, left). This resolution was adequate because the system simulates conditions all over the world. The evaluation system for GRENE simulates conditions in the Asia monsoon region, and therefore it requires higher-resolution meteorological data. As the input data for the system, the solar radiation, air temperature and precipitation of 0.05-degree grid data (w 100 × h 120 = 12,000 points, center point coordinates: 16°30′N, 103°00′E) whose distance between points is 5 km in northeastern Thailand (Figure 3, right) were prepared. These data were generated using a spatial interpolation method by NIAES from actual data observed by the TMD (Meteorological Department of Thailand) and NOAA.

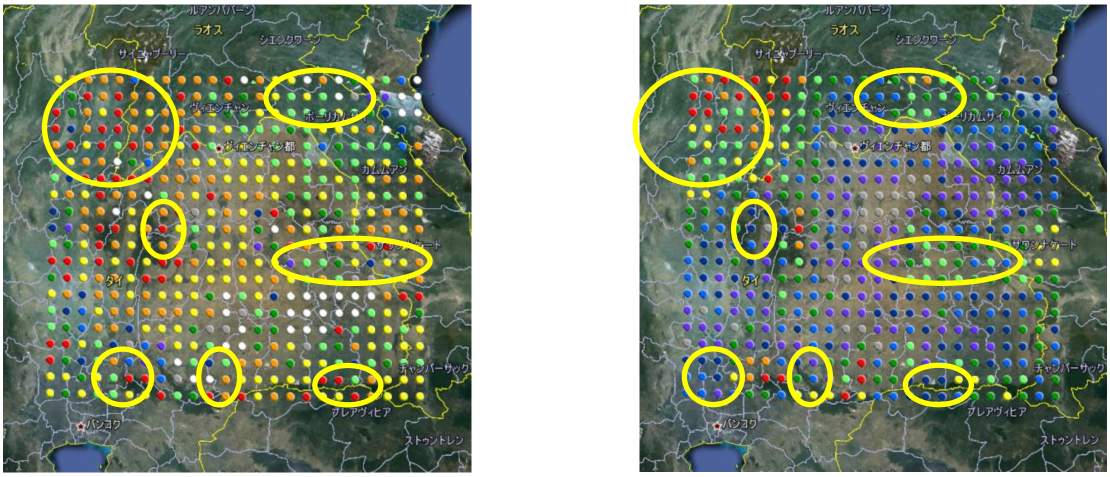
<**C0256**>
<K. Tanaka>. <"Prediction System for Double Cropping Optimization in Thailand">. EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.



1 degree (100km) grid (DIAS)

0.05 degree (5km) grid (CAAM)

Figure 3. The points of meteorological grid data displayed on a map.



Rice (transplanting date: Aug 1, max cultivation period: 4 months)

Cassava (starting date: Dec 1, harvest date: Jul 15)

Figure 4. Results of the prediction system for double cropping optimization.

Each crop model was executed 365 times while the transplanting date was moved by one day each time, and the yield and growing period of each crop were recorded. Those data were summarized to maximum yield data and displayed on Google Earth (Figure 4). The left side of Figure 4 is the rice grain yield, with the transplanting date August 1 and maximum cultivation period of 4 months. The right side of Figure 4 is the cassava yield, with the starting date December 1 and harvest date July 15. In the regions enclosed in the yellow circle, the yields of rice and cassava are more than other regions. These dates and periods were set based on the cropping calendar in northeastern Thailand (Figure 5). The evaluation equation was decided based on such conditions.

<**C0256**>
<K. Tanaka>. <“Prediction System for Double Cropping Optimization in Thailand”>. EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

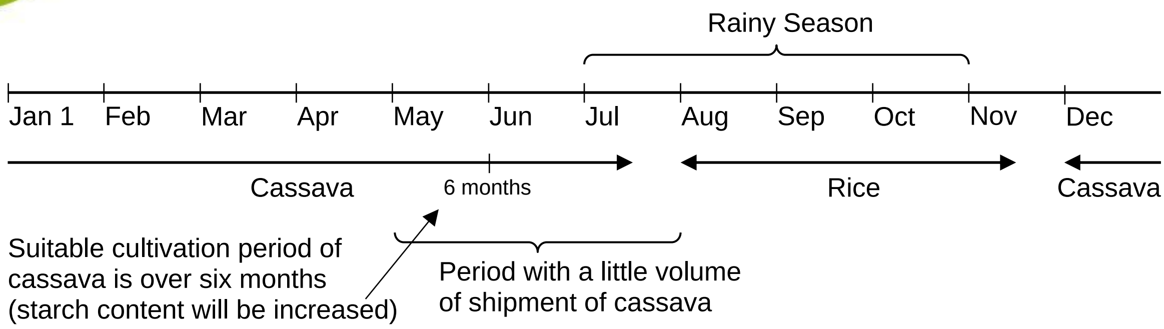


Figure 5: Clopping calendar in northeastern Thailand

- The harvest day of rice is not over the end of November, because cassava should be planted in December.
- A higher rice grain yield is better.
- The harvest day of cassava is between May and July.
- A higher cassava yield is better.

4. RESULTS AND FUTURE PLAN

The results of this system cannot be discussed yet, because there are no local field data to compare and to verify the results. The comparison and verification between the results and the observation data are the next tasks for this year and next year. The field data and more wide-ranging meteorological data will be prepared by the cooperating institutes.

About 30 sec were required to execute one point, and thus it took 4 days or more for the calculation of 12,000 points. The crop model execution should shorten the processing time by improving the execution method. Multithreading is an effective acceleration technique because the calculation of the crop model for each point is independent. The server in which the system is installed has 8 cores/16 threads CPU, and therefore about ten times speed-up can be expected.

The NARO/ARC team’s research is proceeding based on a five-year research plan. In 2011, we surveyed the major crop models used in Thailand to embed them in the evaluation system and to execute them. We found that the DSSAT was applied to several crops (rice, cassava, maze, sugarcane, etc.) in Thailand.

In 2012, the JAMF was improved to enable the use of field observation data (meteorological data, soil moisture data, etc.), and to execute the DSSAT.

In 2012–2013, a prototype of the evaluation system was constructed. The simulation of the growth of major crops will be performed under various conditions (e.g., cultivar, weather, and management), and the climate change effect will be shown.

In 2013–2014, the accuracy of the prototype system will be improved by comparing the results of the evaluation system and the cultivating data that other teams will obtain in local fields.

In 2015, the evaluation system will be implemented as a Web application and deployed to the DIAS server. These applications will have good operability and visibility so that not only researchers but also administrative officers and farmers can use them.

5. CONCLUSION

We introduced the "evaluation system for the effects of climate change on agriculture," which is our team's development goal in the GRENE-ei CAAM project. The evaluation system will be developed to elucidate the effects of the climatic changes on major crops in the Asian monsoon region. Our main research products developed in former projects, JAMF and MetBroker, will be used to develop the evaluation system.

Next, we introduced the "prediction system to optimize double cropping of rice and cassava" that is a part of the evaluation system. This system includes the rice and cassava modules of the DSSAT that are major crop models in Thailand. The input data for the system, i.e., solar radiation, air temperature and precipitation of 0.05-degree grid data (12,000 points) of northeastern Thailand generated by the NIAES were prepared. A more detailed simulation was made possible by using these data. The range and period of gird data will be expanded in the future.

It took 4 days or more to complete the calculation of all points, and the computing time will continue to increase as the area of meteorological data expands. The crop model execution should thus shorten the computing time by improving the execution method. Multithreading is an effective acceleration technique, because the calculation of the crop model of each point is independent.

We also hope to provide an engineer and an administrative officer in each country who will obtain the information infrastructure necessary to design climate-change adaptation and mitigation strategies in agriculture by presenting detailed predictions of climate-change effects on farm products based on reliable future climate change.

6. ACKNOWLEDGEMENT

This study was financially supported by the Japanese research project "Climatic Changes and Evaluation of Their Effects on Agriculture in the Asian Monsoon Region (CAAM)" under the "Green Network of Excellence — environmental information (GRENE-ei)" program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan.

---

7. REFERENCES

CAAM. 2012. GRENE-ei CAAM, http://grene.agrid.org/

DIAS. 2006. Data Integration and Analysis System. http://www.editoria.u-tokyo.ac.jp/dias/english/

DIAS. 2010. Simulator for Cultivation Possibility of Rice. http://dias.tkl.iis.u-tokyo.ac.jp/simriw/

DSSAT. 2004. Decision Support System for Agrotechnology Transfer. http://dssat.net/

GRENE-ei. 2011. Green Network of Excellence — environmental information, http://grene.jp/english/

Jones, J.W., G.Y. Tsuji, G. Hoogenboom, L.A. Hunt, P.K. Thornton, P.W. Wilkens, D.T. Imamura, W.T. Bowen, and U. Singh. 1998. Decision support system for agrotechnology transfer: DSSAT v3. In *Understanding Options for Agricultural Production*, eds. G.Y. Tsuji, G. Hoogenboom, and P.K. Thornton, Eds. Kluwer Academic Publishers, Dordrecht, the Netherlands, 129-156, ISBN0-7923-4833-8.

Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie. 2003. The DSSAT cropping system model. *European Journal of Agronomy* 18(3-4):235-265, doi:10.1016/S1161-0301(02)00107-7.

Laurenson, M.R., A. Otsuka, and S. Ninomiya. 2002. Developing Agricultural Models Using MetBroker *Mediation Software. Journal of Agricultural Meteorology* 58(1):1-9.

Matthews, R. B., and L. A. Hunt. 1994. GUMCAS: a model describing the growth of cassava (*Manihot esculenta L. Crantz*). *Field Crops Research* 36:69-84.

MetBroker. 2000. http://www.agmodel.org/projects/metbroker.html.

Singh, U., J. T. Ritchie, and D. C. Godwin. 1993. A User’s Guide to CERES Rice - V2.10. International Fertilizer Development Center; Muscle Shoals, AL.

Tanaka K. 1997. Crop growth and pest prediction models by Java http://cse.naro.affrc.go.jp/ketanaka/model/

Tanaka, Kei. 2006. A Java Framework for Developing a Plant Growth and Disease Prediction Model, *Agricultural Information Research* 15:183-194. (in Japanese).

Tanaka, Kei, Takuji Kiura, Masahiko Sugimura, Seishi Ninomiya, Masaru Mizoguchi (2011) Tool for Predicting the Possibility of Rice Cultivation using SIMRIW, *Agricultural Information Research* 20:1-12. (in Japanese).
