THE DEVELOPMENT OF A CASSAVA GROWTH MODEL IN THAILAND

Vinai Sarawat[1], Sukit Ratanasriwong[2], Korntong Puangprakon[1]
and Attachai Jintrawet[3]

ABSTRACT

This study was conducted at Khon Kaen Field Crops Research Center from 1996 to 1999 on four recommended cassava cultivars, namely Rayong 1, Rayong 5, Rayong 90 and Kasetsart 50 using the DSSAT-GUMCAS cassava process-oriented model. The phenology of these cassava cultivars is strongly affected by environmental factors, especially air temperature. Rayong 5 and Rayong 90 have a branching plant type, with a higher leaf appearance rate per day than those cultivars with fewer branches (Rayong 1 and Kasetsart 50). For the early rainy season planting in 1997, first branching of Rayong 90 occurred at 73 and 74 days after emergence, according to simulation and actual observation, respectively, while root dry matter yield was 6.38 and 5.69 t/ha for the simulation and actual observation, respectively. In general, the model gave close estimates on branching habit, but overestimated crop dry matter production. In the model application phase, the model was used to predict cassava yields in farmers' field in the Khon Kaen area. The results from the simulation model supported the farmers' decision to grow Rayong 90 on Satuk and Korat soil series; and Kasetsart 50 on Yasothon soil series. The potential fresh root yield of Rayong 90 was simulated to be 60.3, 51.8 and 47.2 t/ha on Satuk, Korat and Yasothon soil series, respectively, whereas that of Kasetsart 50 was simulated to be 52.8, 48.1 and 45.3 t/ha on Yasothon, Korat and Satuk soil series, respectively.

INTRODUCTION

Cassava is one of the main economic crops of Thailand. The planted area is spread all over the country, but especially in the Northeast. In 2000, the total planted area was 1.11 million ha, with a total root production of 18.75 million tonnes, with an average fresh root yield of 16.86 t/ha, which generated an export value of 20,075 million baht (OAE, 2000). Cassava is well adapted to low fertility soils and requires low inputs, which is why it has become a popular crop among resource-poor farmers. One way to improve the production efficiency is to combine suitable cultivars with good crop management for a specific area, and these new technologies need to be delivered to and adopted by farmers. There are a number of newly released cultivars, e.g. Rayong 90, Kasetsart 50, and Rayong 5. However, the current method of wide-spead testing on a regional scale is costly and not always reliable.

Nowadays, Information Technology (IT) plays an important role in the development of the country. Crop simulation models are examples of IT tools that can be used to test crop or varietal suitability and to make decisions at the farm or at the regional level. The DSSAT-GUMCAS cassava simulation model is a computer program that was developed to simulate the phenology and growth processes of cassava under the condition of different cultivars, soil, climate and management for a specific area. The application of the cassava simulation model under the Decision Support Systems for Agrotechnology

[1] Khon Kaen Field Crops Research Center, Khon Kaen, Thailand. Tel 043-246669
email: vinsar@kku.ac.th
[2] Roi-Et Field Crops Experiment Station, Roi-Et, Thailand. Tel 043-515102
email: sukit_r@hotmail.com
[3] Multiple Cropping Project, CMU, Chiang Mai, Thailand. Tel 053-221275
email: attachai@chiangmai.ac.th

Transfer (DSSAT) need four categories of input data, i.e. soil data, weather data, management data, and genetic coefficients of each cassava cultivar (Jones *et al.*, 1998). There have been no previous attempts to test the model in Thailand with Thai cassava cultivars. This paper reports the initial testing of the model in Thailand during the 1996-1999 crop years.

Data Requirement

The DSSAT-GUMCAS model operates on a daily time step basis. Matthews and Hunt (1944) described the important processes included in the model. Three growth phases are defined, i.e. 1) planting to emergence, 2) emergence to first branching (the switch to reproductive phase), and 3) first branching to maturity or final harvest (subsequent branchings may occur during this stage). The rate of vegetative development is influenced by temperature and moisture conditions, while the rate of reproductive development is influenced by both of these factors as well as by photoperiod.

The functional capabilities of DSSAT are summarized in **Figure 1.** Crop simulation models are at the center of the system. Data bases describe weather, soil, experimental details, and genotype information which are needed to apply the models to different situations.

A Minimum Data Set (MDS) is required for the operation of a model destined for use in agrotechnology transfer **(Table 1).** Information for the minimum soil data set can often be obtained from soil survey publications. However, because some aspects measured during soil profile characterization (e.g. organic carbon, bulk density) may change slowly over time, particularly in the surface (plow) layer, the soil profile data may need to be supplemented with soil analysis information for the surface layer.

METHODOLOGY AND RESULTS

The testing of the cassava simulation model in Thailand from 1996 to 1999 consisted of four steps:

1. Study of growth and phenology of four cassava cultivars.
2. Calibration of genetic coefficients.
3. Model testing.
4. Model validation.

1. Study of Growth and Phenology

The experiments were planted in both the early and late rainy season at Khon Kaen Field Crops Research Center (KKFCRC) and at Roi-Et Field Crops Experiment Station, both in the Northeast of Thailand, during 1996-1999. The phenology data was taken from each individual cassava plant. For growth data, each individual plant was separated into tuberous roots, stems and leaves. The leaf area and the dry matter content of each plant part were determined at two-month intervals, while daily rainfall, maximum and minimum temperature and solar radiation were recorded year-round.

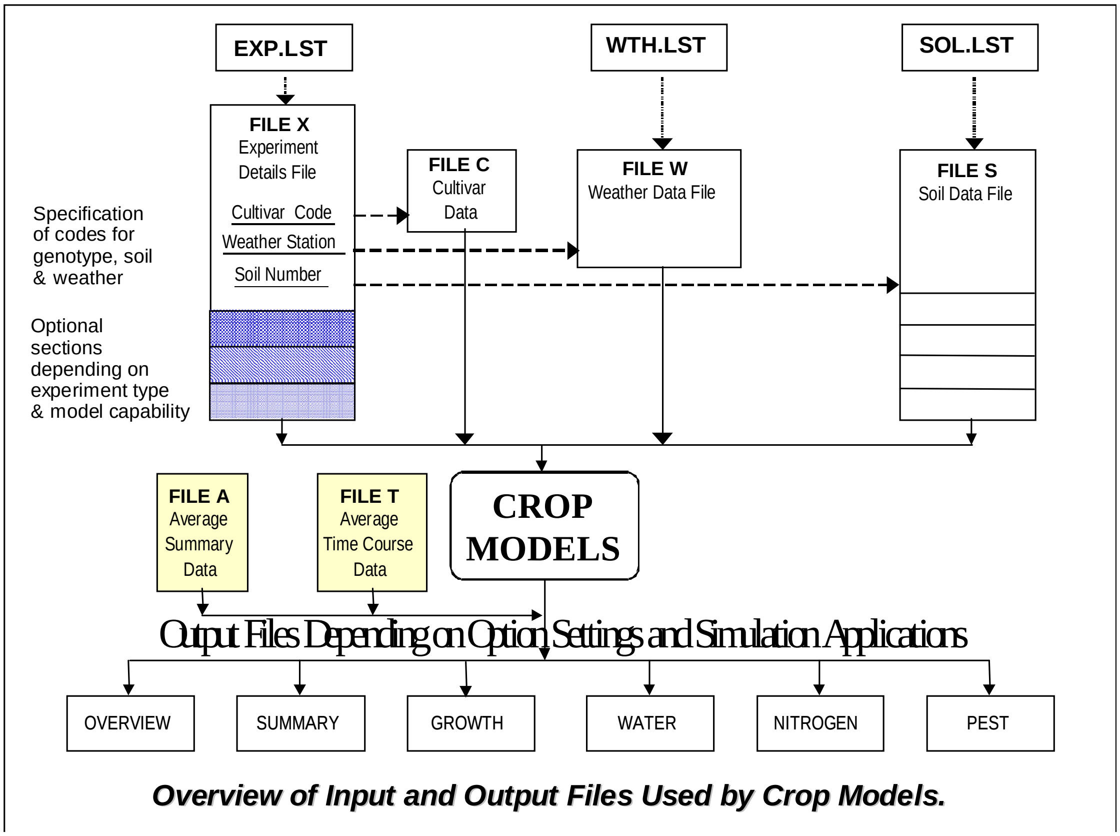

Figure 1*. The structure of a Crop Simulation Model*
Source:*Tsuji et al., 1994.*

The results show that the Growing Degree Days (GDD) for the first branching date and the number of leaves per plant, rate of leaf formation as well as the dry matter content of each plant part for each cultivar for early and late planting were different. This means that the environment affected the phenology and growth of cassava. Cultivars with several branching phases, such as Rayong 5 and Rayong 90 show more variation in the number of leaves per plant during the growing season than cultivars with fewer branching phases, such as Rayong 1 and Kasetsart 50 **(Figure 2).**

Calibration of genetic coefficients

From the collected data, including soil, weather and management data, we produced FILEX (Experimental Details File), FILET (Average Time Course Data), and FILEA (Average Summary Data) for calibration of the genetic coefficients in file CSSIM980.CUL by the method of Boote (1994). The genetic coefficients can be calibrated by adjusting the output of simulated data as compared to actual data until they are acceptable.

For cassava, the genetic coefficients were separated into two parts, i.e. phenology coefficients (e.g. duration of branch phase 1, 2 and higher phases; sensitivity to photoperiod), and growth coefficients (e.g. maximum canopy photosynthesis rate; stem weight to node weight ratio; leaf number increase rate and increase period; maximum leaf area and duration to reach maximum; leaf life; leaf area at 300 days after emergence (DAE); leaf area to weight ratio; stem number, and shoot number) **(Table 2)**.

Table 1 Contents of minimum data sets for model operation.

1. Weather
   - Daily global solar radiation, maximum and minimum temperatures, precipitation
2. Soils
   - Classification using the local system and the USDA-SCS taxonomic system
   - Basic profile characteristics by soil layer: *in situ* water release curve characteristics (saturated, drainage upper limit, lower limit); bulk density, organic carbon, pH; root growth factor; drainage coefficient
3. Soil analysis
   - Surface layer measurements of bulk density, organic carbon, pH, organic nitrogen, available P and exchangeable K
4. Initial conditions
   - Previous crop, root, and nodule amounts; numbers and effectiveness of rhizobia (for nodulating crops only)
   - Water, ammonium and nitrate contents by soil layer
5. Management
   - Cultivar name and type
   - Planting date, depth and method; row spacing and direction; plant population
   - Irrigation and water management, dates, methods and amounts of depths
   - Fertilizer (inorganic) and inoculant applications
   - Residue (organic fertilizer) applications (material, depth of incorporation, amount and nutrient concentrations)
   - Chemicals (e.g. pesticide) applied
   - Tillage method
   - Environment (aerial) adjustments
   - Harvest schedule

***Source:** Adapted from Hunt and Boote, 1998.*

Model Testing

In the first stage we had to get the data on the date of planting, fertilization and harvesting as well as cultivar codes, weather station codes and soil codes to built up FILEX; the latter consisted of 16 sections, such as: experiment, cultivar treatment, planting details and simulation controls. FILEW (Weather Data File) records the daily weather from the data logger. FILES (Soil Data File) was taken from the soil database DLDSIS from the Land Development Department. The genetic coefficients (FILEC: Cultivar Data File) were compiled from stage 2. The data sets from stage 1, for instance, the dry matter from each plant part of the interval samplings, e.g. stems, leaves, and roots dry matter, including LAI, were taken to built up FILET, and the data from the final harvest e.g., dry matter from each plant parts and maximum leaf area, were taken to built up FILEA.

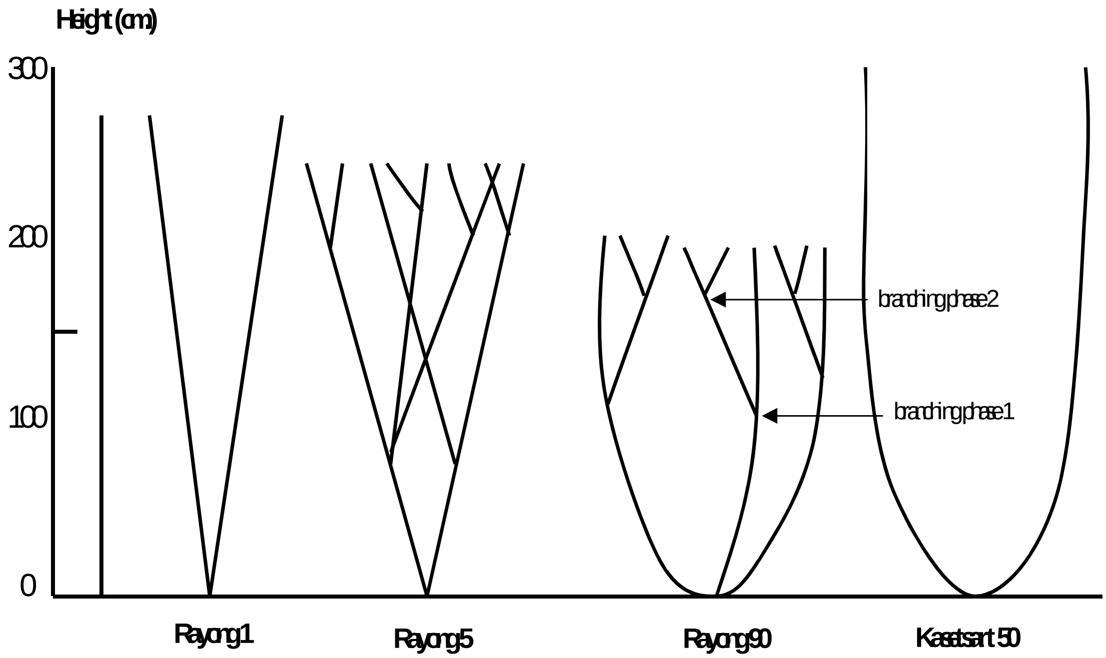

***Figure 2**. Branching habit of four cassava cultivars.*
Source: *Adapted from Oka et al., 1987.*

To test the model, the simulated data on duration of first branching and dry root yield were compared with the observed data during the year 1996-1999 at KKFCRC by 1:1 line graph (Jongkaewwatana, 1995), and the dispersion of simulated and observed data by the Root Mean Square Error Statistic (RMSE).

The results from phenology showed that the model gave a reasonable estimation of the first branching date, especially in Rayong 90 which occurred at 73 and 74 days after emergence, according to the simulation and actual observation, respectively, while root dry matter yield was 6.38 and 5.69 t/ha for the simulation and actual observation, respectively **(Figure 3)**.

Model Validation

Fresh yields of two cassava cultivars, Rayong 5 and Rayong 90, from the Regional Yield Trails at Rayong, Mahasarakham, and Khon Kaen Field Crops Research Centers during 1991-1995 seasons were compared with simulated data from the cassava model that used data sets of weather and soil from each site. The simulated and observed data was compared by the 1:1 line graph method (Jongkaewwatana, 1995).

The results showed that most of the simulated yield data were higher than the observed values in all locations. The simulated yields of both cultivars were highest at Mahasarakham. Rayong 90 gave a simulated yield of 79.3 t/ha, while the observed data was

39.1 t/ha. Rayong 5 gave the highest simulated yield of 63.5 t/ha compared with the observed yield of 40.4 t/ha **(Figure 4)**.

Table 2. Example of parameters in cultivar data file (FILEC).

*CASSAVA GENOTYPE COEFFICIENTS - CSSIM980 MODEL

Most phase durations are expressed in 'biological' days (Bday); these are equivalent to chronological days at the optimum temperature and daylength, and with no water or nutrient limitations.

DUB1 Duration of branch 1 phase (Bday germination to first branch)
DUBR Duration of branch 2 and greater phases (Bday between branches)
DESP Development, sensitivity to photoperiod (h-1) (0=insensitive)
PHCX Photosynthesis, canopy, maximum rate (g dm m-2 d-1)
S#PE Stem number per plant at emergence (#)
S#FX Shoot no per fork, maximum (#)
S#PX Shoot no per plant, maximum (#)
SWNX Stem weight to node weight ratio (fr)
L#IS Leaf number, increase rate, standard (leaves(shoot-1) Bday-1)
L#IP Leaf number, increase period (Bday after emergence)
LALX Leaf area, maximum (cm2 leaf-1)
LAXA Leaf area, maximum, age at which reached (Bday after emergence)
LAL3 Leaf area, 300 days after emergence (cm2 leaf-1)
LAWS Leaf area to weight ratio, standard (cm2 g-1)
LFLI Leaf life (Day)

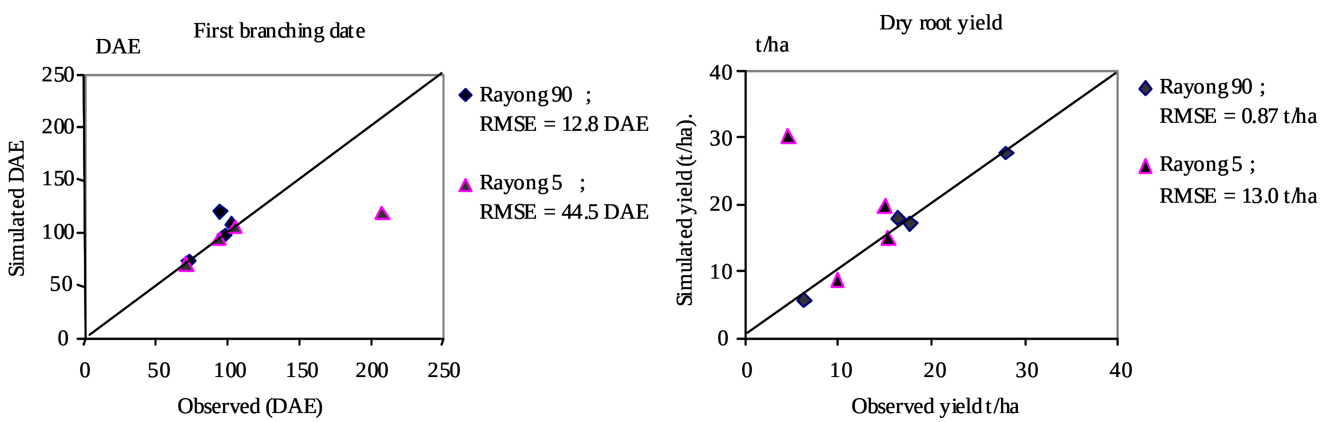

Figure 3. *Days after emergence (DAE) to first branching (left) and dry root yield (right) of simulated and observed data of Rayong 90 and Rayong 5 during 4 years (1996-1999) at Khon Kaen FCRC. RMSE = root mean square error statistic.*

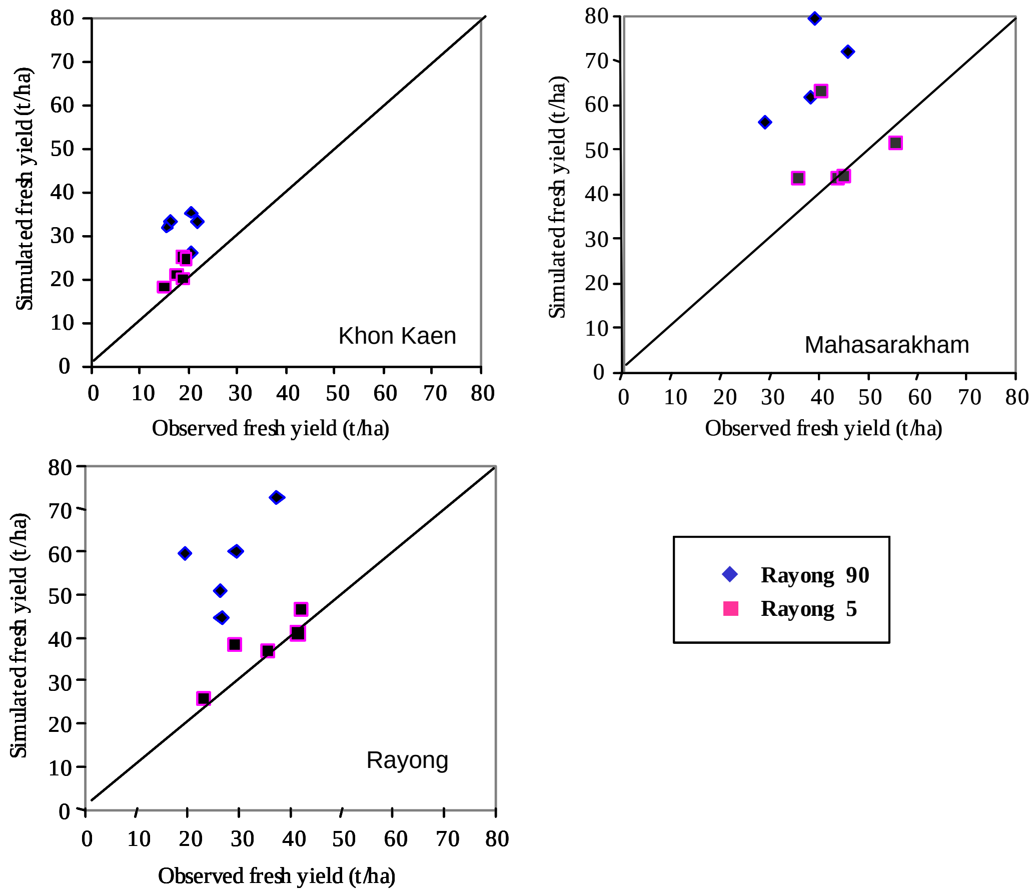

Figure 4. *Fresh root yield of simulated and observed data of Rayong 90 and Rayong 5 during 5 years (1991-1995) of Regional Yield Trials at three locations.*

Model Application

The Climatic Zone Map was taken from the study of climatic zones in the Northeast of Thailand (KKU-FORD Cropping Systems Project, 1982). There are four climatic zones in the Khon Kaen area, which can be differentiated by amount of rainfall, which ranges from 800 to 1,400 mm per year. Soil data were taken from the study of soil series digital base map (Promburom *et al*., 2002). The two cassava cultivars, Rayong 90 and Kasetsart 50, were simulated on the Oxic Paleustults great group, with fine loamy texture, namely soil series Satuk (Suk), Korat (Kt), and Yasothon (Yt) (Thai Land Development Department).

The results indicate that the potential fresh root yields of Rayong 90 were simulated to be 60.3, 51.8 and 47.2 t/ha on Satuk, Korat and Yasothon soil series, respectively, whereas those of Kasetsart 50 were simulated to be 52.8, 48.1 and 45.3 t/ha on Yasothon, Korat and Satuk soil series, respectively **(Figure 5)**. This means that Rayong 90 is expected to produce higher yields than Kasetsart 50 on Satuk and Korat soil series, while Kasetsart 50 may produce higher yields on the Yasothon soil series. This information may be useful for farmers to make their decision about the most suitable cultivar for a specific area.

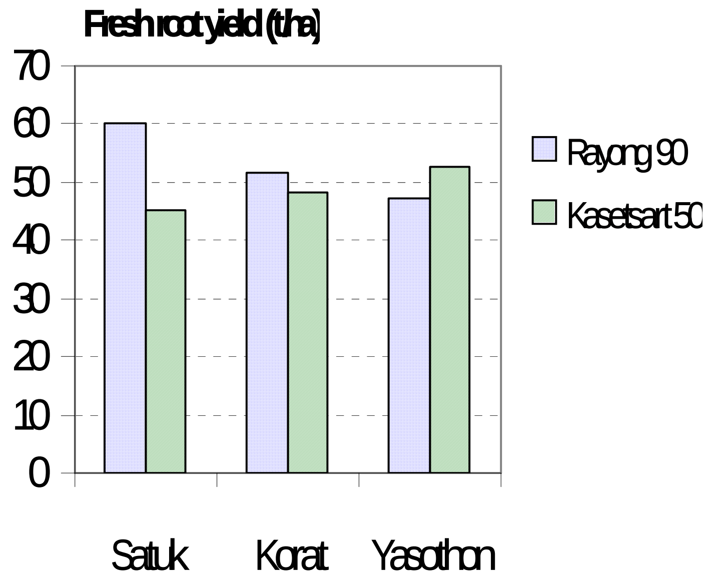

Figure 5. *Yield potential from the cassava simulation model of Rayong 90 and Kasetsart 50 on different soil series.*

CONCLUSIONS

The DSSAT-GUMCAS model was tested against data sets generated from four widely used cassava cultivars during 1996-1999 in Khon Kaen. The model gave a good estimation of phenology, but overestimated the growth and yield of all cultivars. Further testing and development of the model in Thailand should be continued in a network of researchers, both at the national and at the international level. Currently, the model deals with carbon and water balances of cassava production systems, while nitrogen and other nutrients are not part of the model. The model may have great potential to be used as a tool in dealing with large-scale planning issues for linking between farm and policy levels.

It is clear that the development and testing of Agricultural Decision Support Systems based on a simulation model for cassava production in Thailand is still in its early stage. None of the existing institutions has the resources or the expertise to develop this system alone; thus researchers must work together. A formal network of crop model evaluators should be established to link various individuals and institutions, both inside and outside Thailand to make improvements in the model.

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