Review Article

Recent Evaluations and Applications of a Cassava Model in Thailand: A Review

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Abstract

Cassava is an important economic crop in Thailand. The cassava simulation model, under the Crop Simulation Model of Decision Support System for Agrotechnology Transfer package (DSSAT-CSM), has been evaluated and widely applied to simulate, evaluate and predict cassava production systems and related policy scenarios. This is the first review on the system modeling and simulation approach on cassava studies in Thailand, with an emphasis on its applications and future research directions. Various research teams were also trying to explore the site-specific technology, but still in the early stage of development. Availability of reliable data sets for model calibration and evaluation is one of the main issue that users are facing with. Therefore, future needs on the development of reliable input data sets for model testing under diverse cassava production ecosystems in Thailand are required.

Keywords: DSSAT, CSM, CROPSIM-Cassava, simulation, model, Thailand
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1. Introduction

Agricultural systems are modified natural ecosystems with complex interactions of abiotic and biotic resources and researchers are generating technical knowledge and practical solutions to maintain positive interactions and to make informed agricultural decisions. Therefore, it is imperative and need to consider the interactions of agricultural production, natural resources and human factors [1] with reliable research and practice tools. Cassava is a valuable subsistence food crop for approximately 500 million farmers [2]. In Thailand, cassava is a crop for small-scale farmers. The main planted area is in Northeastern part of Thailand. In 2017, the total cassava planted area covered 1.39 million ha and produced 27.4 million tons of fresh storage root with an averaged fresh storage root yield of 21.4 ton per ha. In the same year, various cassava products generated an export value of 92,100 million Baht [3]. Thailand has utilized cassava for chips, pellets and high value-added products including tapioca pearls, modified starch, sweeteners, organic acid, sugar alcohols and alcohols, for well-developed industry and market. These products are supplied for both local and export markets and value-chains [3].

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The importance of improving cassava productivity and the welfare of small-scale farmers regarding sustainable agricultural development is unquestioned. However, there are threats to any effectiveness of effort resulting from the complexity matters. Thus, crop simulation models can be used to test the diverse suitability and to provide decisions at the farm level to the regional level for perceiving and forecasting overall agroecosystem performance [4-5].

2. Decision Support System for Agrotechnology Transfer Model

Decision Support System for Agrotechnology Transfer (DSSAT) is a set of the application programs that consists of dynamic crop growth simulation models for over 40 crops. It is based on various tools and ranges of crops for researchers to enable an experiment for all crop from diverse weather, soil, genetics, crop management and sets of experimental and example data. [6]. It has been used for many purposes from utilities for on-farm precision crop management to regional to assess various risks. Cassava is one of the crops included in the priority list for model development. The International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) has launched this crop module to improve the transfer of technology to less developed countries [7].

In 1983, the first crop modeling workshop was held in Venezuela for a common database of the model such as input standardization and output structure. The models (programmed in FORTRAN), databases (.dbf or dBASE format) and an application program (in BASIC) were combined into a computer software called the Decision Support System for Agrotechnology Transfer (DSSAT) [8]. The first version of cassava model was launched (v2.1) in 1989; additional releases were made in 1994 (v3.0) [9], 1998 (v3.5), 2002 and 2004 (v4B), 2005 (v4.02), 2008, 2010 and 2011 (v4.5B), 2012 (v4.6) and 2017 (v4.7) [7].

2.1 Primary component of DSSAT model

The model contains the main driver program, a land unit module and modules for the primary components that make up a land unit in the cropping system. The primary modules consist of: 1) Management module, 2) Soil module, 3) Weather module, 4) Soil-plant-atmosphere module, and 5) Plant module. In the plant module, there are sub-modules such as CROPGRO (for grain legumes, vegetables, and fiber crops), CROPGRO-Perennial Forage, CERES-Maize, Sweetcorn, Rice, Sorghum, Millet, Wheat and Sugar-beet, IXIM, SUBSTOR-Potato, AROID-Taro and Tanier, YUCA-Cassava, CROPSIM-Cassava, CANEGRO-sugarcane and ALOHA-pineapple [6, 10-12].

2.2 Modes of DSSAT model operation

Different types of applications are performed by using different modes using DSSAT-CSM model. The basic mode performs the interactive sensitivity analysis and the comparison of simulated and observed field data. A second mode of operation simulate crops to evaluate the effects of uncertain weather conditions and to provide information for decision by using a number of years of weather under the same soil initial conditions. A third mode operates the simulation of crop rotations over a number of years, and soil conditions for cropping system management. A fourth mode simulates for precision agriculture, land use management or other spatial-based applications [6]. It was consequently developed to generate plausible predictions for practical options to improve productivity and farm performance [11].

2.3 Minimum data set

A crop simulation model under DSSAT package needs the minimum data set for model calibration and evaluation, following the standard of input and output file structure such as data for site, weather, soil and crop management [5]. The calibration phase was based on time-series and end-of-season samplings of crop developmental stages, biomass of cassava plant parts collected from well-designed field experiments. Field observations required for this phase are the date of key cassava phenological stages, including branching dates and storage root yield. The genetic coefficients of a given cassava variety were derived using GENCALC or GLUE utilities. The evaluation phase requires four minimum data set, namely; 1) Weather data during the growing season, 2) Site soil profile and soil surface data, 3) Crop management data, and 4) Observed data from the field experiment [12]. Thus, these data sets should not have been used for the previous calibration but should represent the complete array of environments and crop sequences for which model has to be performed [6], for example, from different planting dates, years, water and nitrogen management practices.

2.4 Benefit of DSSAT model

All levels of agricultural decision making need the relevant information to collectively handle with the demands of agricultural products that are increasing rapidly. The traditional research methods and dissemination of information are not sufficient to generate new knowledge to meet these needs. The applications of crop simulation models under DSSAT package to a research program can provide a number of advantages such as identification of knowledge gaps, generation and testing of hypotheses and an aid to the specific experiments, determination of the sensitivity of a system, provision of a medium for better cooperation between researchers in different disciplines and bringing all stakeholders to solve common problems in a given situation [13].

3. Development of CROPSIM-Cassava application in Thailand

In Thailand, crop model has been used to develop for site-specific recommendations of fertilizer management for small holder farmers growing crops such as rice, cassava, maize and sugarcane. Cassava is an important economic crop that can adapt well in poor fertile soil, requires low inputs and it is a famous crop for smallholder farmers [6]. Improving crop productivity focuses on choosing suitable cassava cultivar and applying good cultural practices for a given site and area as well as to maintain the certain cassava production capacity have been done over time. The development of the cassava model has been applied in some key issues in Thailand. Here we presented three applications related to its applications.

3.1 Genetic coefficient (GC)

The application of DSSAT model on cassava has been used in both research institute and university such as Department of Agriculture, Kasetsart University, and Khon Kaen University. The DSSAT-cassava simulation model, called "GUMCAS" [14-15], was first used in Thailand. It was applied to study growth, phenology and the estimation of genetic coefficients in four cassava cultivars, namely; Rayong 1, Rayong 5, Rayong 90 and Kasetsart 50. Subsequently, the derived GCs were applied to calibrate and evaluate the model. The result showed that the model gave a reasonable prediction of phenology, the first branching date and storage root dry matter yield for Rayong 90 cassava variety. However, the model overestimated yield of Rayong 90 and Rayong 5 cassava variety. In the application phase, the model provided site-specific variety recommendation. Rayong 90 is suitable to plant on Satuk and Korat soil series and Kasetsart 50 for Yasothon soil series [16-18, 8]. The modification of Mcol-1648GC data was set to evaluate growth and yield of three cassava cultivars, namely; Rayong 9, Kasetsart 50 and Huay Bong 80 in early and late dry season. The model provided good simulations of growth and yield. In addition, it provided a fair prediction for mid rainy planting dates [19].

3.2 Climate change

The DSSAT model and Geographic Information System (GIS) were applied to understand the impact of global warming on cassava production areas throughout the country during 1980-2099, using the CropDSS 1.0 shell. The result showed that cassava yield was decreased by 43% from 1980s (based year period). In addition, there was the fluctuation in temporal and spatial of the future climate system by 33%. Consequently, cassava yield was also much affected by climate change scenarios under the study [20].

3.3 Site-specific technology

The application of DSSAT-Gumcas model for the assessment of site-specific technology was done on seven cassava cultivars, namely; Rayong 5, Rayong 90, Rayong 7, Rayong 72, Rayong 9, Rayong 11 and Kasetsart 50. The model can predict the storage root yield of those cassava cultivars depending on the conditions of each tested site based on climate, soil series and planting season and the model can be used as a tool to provide information of site-specific production options [4, 21]. The calibration of Kasetsart 50 for selected Thai cassava production conditions to determine nitrogen requirements of cassava, and to evaluate the requirements, the minimum data set of GC was used. The model gave good estimation of first branching, top root weight, dry root yield, leaf area index (LAI) and harvested root N concentration. The model gave reasonable prediction of dry root yield in the range from 0 to 250 kg N ha^{-1}. The rate of nitrogen that greater than 300 kg N ha^{-1} gave low yield, which was not adequately predicted from developed GC data set [22]. The determination of the optimum N fertilizer rate in representative soils of Thailand for cassava, namely; Satuk (Suk), Pak Chong (Pc), Ban Bueng (Bbg) and Don Chedi (DC) soil series, showed the maximum cassava storage root yield could be obtained with the application of urea at the rate of 187.5 kg ha^{-1} and gave significant net revenue increased ranging from 54 to 211%. In addition, the prediction on the relationships of physiological characteristics and storage root yield of three cassava cultivars, namely; Rayong 9, Rayong 11 and Kasetsart 50 under three N fertilizer rates was 46.9, 90.0 and 133.2 kg N ha^{-1}, respectively. The result showed that higher N rates resulted in a higher positive effect of N fertilizer application on cassava growth [23-24]. The variation of soil properties and weather conditions in each region could result in the difference of response to N fertilizer application and maximum fresh root yield [19].

4. General Discussion

Crop simulation model can help researchers from various disciplines to co-develop hypotheses for improving crop management options by making appropriate decisions, developing improved cultural practices and management strategies. It can also be used to support the planning process to link the implementing agencies and policy levels for sustainable cassava consumption and production. There are needs for researcher to use modeling approach as an integrated research method of the mainstream methods to develop appropriate crop production technologies with cassava farmers in various production situations [2, 16-17].

The calibration and evaluation work of cassava model in Thailand was in the early stage. The genetic coefficients of major cassava varieties can be estimated from data sets generated from well-designed and well-equipped field experiments. The future development of application of the CSM-cassava model in Thailand requires careful and long-term policy to carry out model calibration and evaluation, which depends on the development of reliable data sets, following the DSSAT's field manuals, to improve model performances. In turn, these efforts facilitate the model's users to analyze various practices under diverse cassava ecosystems for optimizing practices, resources and profit [25-26]. However, budget allocation for long-term research strategy planning and implementation, research infrastructure and researcher networks are urgently required for driving the development and implementation of the cassava model in Thailand. In addition, farmer participatory research (FPR) approach, including all stakeholders in the cassava supply and demand value chain, should also be incorporated to provide opportunity for effective adoption of appropriate and economically technologies [27].

Recently, there is a requirement to predict the impacts and risks of various changes such as climate change, regional technologies changes, natural resources degradation and agriculture sustainability [28]. So, the need for policies to develop adaptive strategies for handling future risks under the Sufficiency Economy Philosophy (SEP) is required, which stresses the middle path of agricultural resource utilization as an overriding principle for all Thai people. SEP calls for national development and administration to temporally and spatially modernize in line with the forces of globalization for Sustainable Development Goals (SDGs) in 2030 [29]. Therefore, policy makers and implementing agencies should integrate the modeling approach and geographic information systems, which are essential tools for decision-makers to account for the spatial dimension of vast cassava production ecosystems in Thailand. These approaches allow greater number of production and consumption options at different levels to be evaluated and implemented for the improvement of cassava production and consumption systems as well as livelihood of communities.

5. Conclusions

The applications of crop simulation models in Thailand, especially cassava model, were expanding in various issues including (i) improve cassava productivity with site-specific recommendations, (ii) evaluate impacts, vulnerability and adaptation to climate change. The understandings of agricultural system situations and solving these concerns require integration and quantification of knowledge at the whole system level. There is a need to reorganize our research teams and resources to implement system simulation and modeling approach to develop the cassava model as an integral component of cassava research strategy in Thailand to support small-scale cassava farmers. This is crucial, considering that these tools are progressively needed to ensure that agricultural crop, in particular cassava, will reach the food demands and will environmentally and economically sustainable in the near future.

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