iCassFert-NPK: The Design and Web-based Implementation of an interactive web-based approach for cassava production NPK fertilizer recommendations in Thailand

Tewin Keawmuangmoon[1*] and Attachai Jintrawet[2]

ABSTRACT: Cassava growers in Thailand are facing with fertilizer application situations on their crop, especially nitrogen (N), phosphorus (P), and potassium (K) chemical fertilizers. With the availability and computability capacity, the interactive web-based approach (iWA) provides a new way for cassava production system information collected on-site to overcome the situations. We have developed a iWA for NPK chemical fertilizer application (iCassFert-NPK) based on soil testing results, planting date, selected cassava variety, and water management options. The web-based structure and architecture of iWA was provided. We designed a total of 25 tables on SQL database on the server to store user's data. The user's data are formatted for the CSM-CROPSIM-Cassava model to simulate the response of cassava to nitrogen fertilizer management, PDSS and KDSS equations were used to estimate the amount of phosphorus and potassium fertilizer application rates. Currently, we have implemented the iWA and registered users can accessed the model simulate the response of three major cassava varieties in Thailand to management decisions in Nakhon Ratchasima province, with approximately 2 million ha of cassava planted area in Thailand. The results show that our web-based interface is well-received by users. However, further research is needed to investigate the improvement of the efficiency of NPK fertilizer application in cassava production system in the area.
Keywords: *Manihot esculata*, soil-test kit, SQL database server

Introduction

Traditional fertilizer decision-making application on a cassava field relies on historical experiences of a given cassava grower and household. These decision-making practices lead to series of consequences, i.e. over-fertilization of the cassava field, cost-overrun, and inefficient fertilizer application and un-sustainable cassava production system. In recent years, computer technology and geographic information systems technology in agricultural sciences have been widely used in fertilization research, and a various types of fertilization decision support systems or platform have been developed, for rice (Attanandana et al., 2010), maize (Attanandana et al., 1999) and lettuce (Cahn, 2012).

These decision support systems or platforms are based on an on-site and rapid soil test kit and simulation models of a given crop which are tested by a large number of field experiments. However, growers calculate fertilizer application rates using off-line databases. Lacking of the design and implementation of the online web-based platform fertilizer decision support systems prevents users to access other information such as real-time weather and soil data, leading to low adoption rate of the off-line fertilizer decision-making system.

In this paper, based on soil test kit, CSM-CROPSIM-Cassava model, Phosphorus and Potassium Decision Support System (PDSS and

[1] Center for Agricultural Resource System Research, Faculty of Agriculture Chiang Mai University
[2] Plant Science and Natural Resources Department and Center for Agricultural Resource System Research, Faculty of Agriculture Chiang Mai University
* Corresponding author: kmm.tewin@gmail.com

KDSS, respectively), we aim at designing and implementing an online web-based interface NPK fertilization decision support system. Our decision support system uses available weather and soil database and Google Map system. Our system integrates the following functions; (1) Allow users to enter NPK fertilization management decisions, including the results of soil test kit, NPK fertilization operations, cassava planting management, cassava environmental condition including weather and soil classification, (2) Access to Google Map to locate the field and retrieve soil and weather identification codes, (3) Run the CSM-CROPSIM-Cassava model, PDSS and KDSS to visualize the responses of cassava on NPK fertilizer decision making, (4) Display the results of CSM-CROPSIM-Cassava model on the Internet to promote discussion among stakeholders, experts in cassava fertilizer application, and local cooperatives.

Materials and Methods

We designed the iCassFert-NPK web-based platform for fertilizer recommendation as an interactive tool for users to access CSM-CROPSIM-Cassava simulation model, a process-oriented under the DSSAT v4.6 package (Hoogenboom et al., 2010) to simulate the response of cassava to various level of nitrogen fertilizer application and soil test kit results. Phosphorus Decision Support System (PDSS) was then used to calculate phosphorus requirement for a given nitrogen rate and a simulated cassava yield level. Finally, the Potassium Decision Support System (KDSS) was then used to calculate potassium fertilizer requirement for a given nitrogen, phosphorus rates and a simulated cassava yield level.

Web-based implementation

Figure 1 displays our design and implementation of the iCassFert-NPK web application (web app). We designed the web app for more interaction between the user and fertilizer scenarios, which requiring constant user action and reaction during a session.

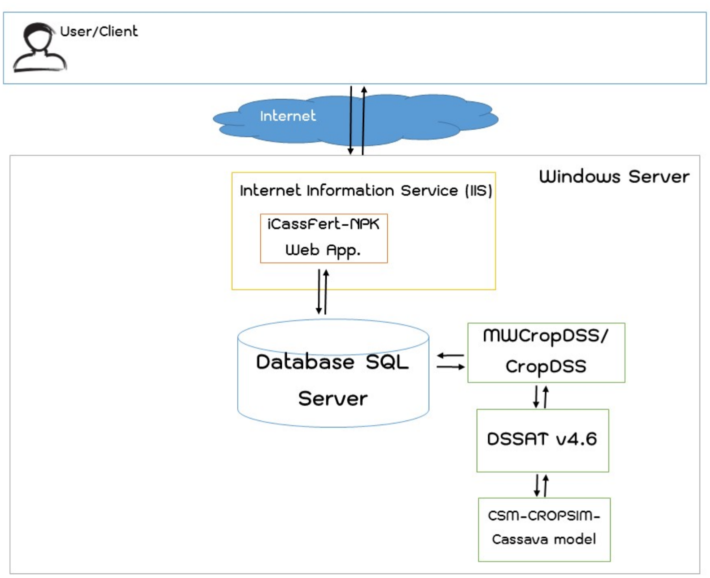

Figure 1 Structure of iCassFert-NPK.

Database on SQL server

We designed five groups of 2, 8, 3, 6, and 6 tables to store user data, spatial data, DSSAT v4.6 Beta data, cassava production project and scenario data, and CSM-CROPSIM-Cassava model simulation output data, respectively. Two tables for user's data are tb_users and tb_userlogin. The tb_users stores field locations for linking with administrative boundary and login information of a user, and the tb_userlogin stores user's code, email address, password, and user's level. A user is required to register to the system using a valid email address and iCassFert-NPK platform facilitates data input, simulation of cassava production scenarios under various project (**Figure 2**). Tables in cassava production project and scenario data group stores information of user decision-making in defining eight input variables for the CSM-CROPSIM-Cassava model to simulate the response of a selected cassava cultivar to planting and harvesting dates, plant spacing between rows, number of plants at planting and at emergence, water management, and nitrogen fertilizer application details.

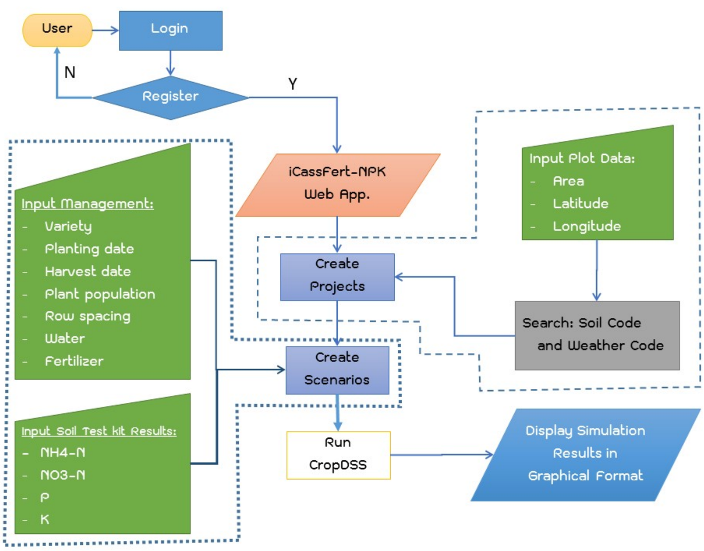

Figure 2 Schematic of user's work flow in using iCassFert-NPK web-based application.

Simulation of cassava yield response to nitrogen fertilizer

We used CSM-CROPSIM-Cassava model under the DSSAT v4.6 (Beta) package (Hoogenboom et al., 2010). The model is a process-oriented simulation model and based on the GUMCAS simulation model (Matthews and Hunt, 1994), which simulation phenology and growth variables on the daily basis. The model was evaluated in Thailand and was linked to a spatial database to simulate the effect of cassava management on cassava yield and other growth and phenology variables (Sarawat et al., 2004). For the CSM-CROPSIM-Cassava model, four inputs are required to use the model, namely; daily measured weather data between year 2000 and 2010, soil profile and soil initial conditions data, cassava genetic coefficients of nine (9) Thai cassava varieties (RY 90, RY 5, RY 1, RY 9, RY 11, KU 50, RY 7, and CMR 77) and cassava cultivation management practices. With the provided inputs, users may simulate the responses cassava on cultural practices, weather conditions, irrigation management, and nitrogen fertilizer applications.

Estimation of cassava yield response to phosphorus fertilizer

The ability to estimate phosphorus fertilizer requirement for cassava to meet its critical levels throughout the growing cycle for one year is critical to achieve sustainable cassava production system in rainfed conditions in Thailand. PDSS was developed by Yost et al. (2011) to facilitate estimation of phosphorus requirement as follows;

$$P_{req} = \frac{P_{CL} - P_0}{PBC} + 0.8 \times PBC \times P_{uptake} \times 0.8 \times \frac{1}{2} Placement \times App\ depth \qquad \text{---------------} [1]$$

Where:

P_{CL} = P critical level of the crop using a specific extractants

P_0 = Initial, measured soil level of P using a specific extractant

PBC = Phosphorus Buffer Coefficient using a specific extractant

P_{uptake} = Yield of crop component removed * P content of the removed tissue

App depth = Depth to which the P fertilizer is incorporated

Placement = A factor that represents the relative efficiency of localized placement in reducing the P fertilizer requirement

Estimation of cassava yield response to potassium fertilizer

Yost and Attanandana (2006) developed an equation for predicting potassium fertilizer application for maize in various soils in the tropics using cases from Thailand as follows;

$$K_{req} = \left[\frac{K_{CL} - K_0}{BC_K} \times B.D. \times Placement \times App\,depth \right] + K_{uptake} \qquad \text{---------------} [2]$$

Where:

K_{req} = the amount of fertilizer K that is needed to restore the soil K supply such that crop yields were maximum.

K_{CL} = the level of soil K needed to ensure that maximum growth and productivity occurred

K_0 = the measured level of soil K.

BC_K = the soil buffer coefficient, i.e. the reactivity of the soil to added K, using the same extractant as Ksoil.

B.D. = Soil bulk density (specific gravity), i.e. the weight of soil per unit volume

App depth = the intended depth of incorporation of the fertilizer K in cm.

Placement = A fraction that represents the relative benefit from application to a fraction of the soil volume at the specified depth to be fertilized.

K_{uptake} = Biomass removed (the amount of crop bio product that is expected to be regularly removed from the field) * K content of the biomass (the K content of the portions of the crop that will be removed from the field).

Results and Discussion

Inputs for NPK response simulation

The iCassFert-NPK web-based interface allow users to login to his/her account and create and a new project and define new production scenarios or modify the existing ones. The important step is the production scenarios definition for a given cassava production plot in particular season. Soil test kit results are required for the estimation of initiate values of soil nitrogen (N), phosphorus (P), and potassium (K) levels for the simulations by CSM-CROPSIM-Cassava model. Our design and web-based implementation also enable user to enter eight crucial input variables for the model, namely; cassava cultivar to be planted, planting and harvesting dates, plant spacing between rows, number of plants at planting and at emergence, water management, and nitrogen fertilizer application details (**Figure 3**).

Outputs of NPK response simulation

The iCassFert-NPK web-based interface was designed to provide two options for a user to view the results of the response of cassava to application of nitrogen fertilizer decision-making, viewing one cassava production scenario on a graphic display and comparing several scenarios on graphical display (**Figure 4**). The total crop biomass is used as an input for the PDSS and KDSS to estimate the response of cassava to various phosphorus and potassium chemical fertilizer.

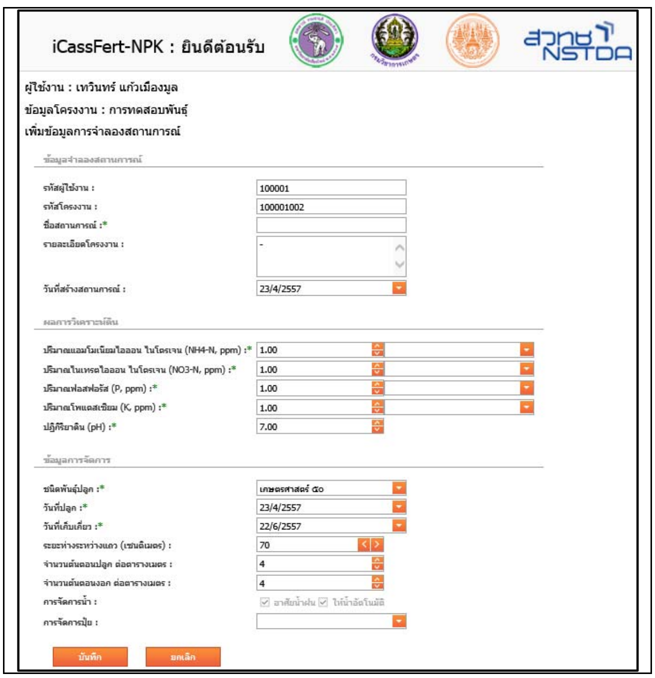

Figure 3 Cassava production scenario CGI for user to enter soil test kit results, define cassava cultural practices which is then used for the CSM-CROPSIM-Cassava model under DSSAT 4.6 Beta.

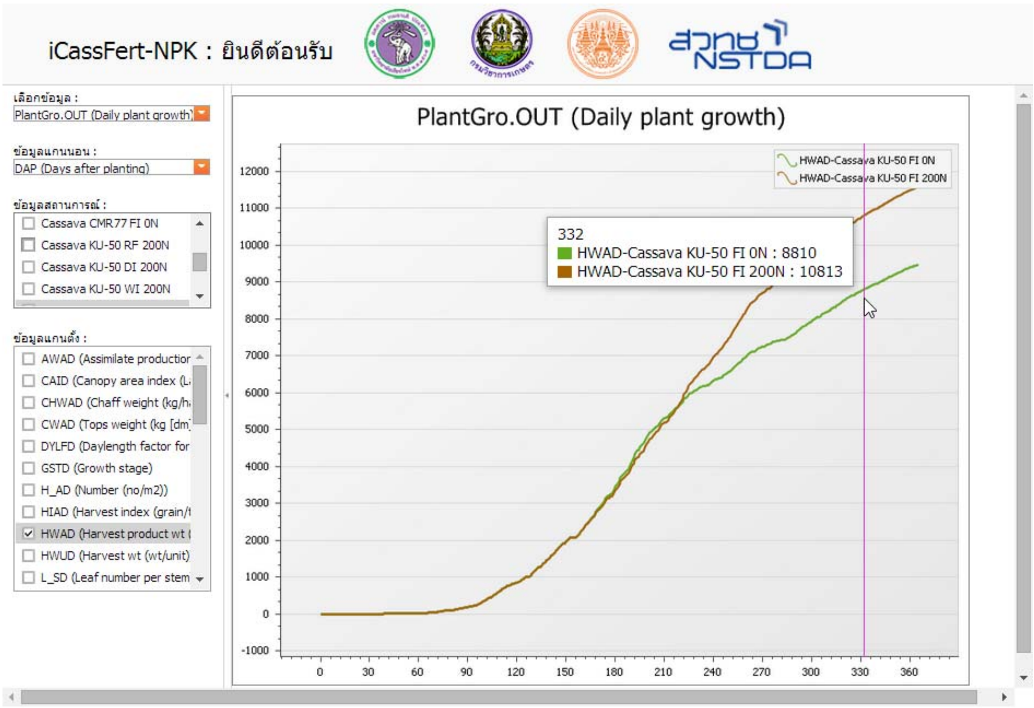

Figure 4 CGI for displaying simulation output variables from planting to harvesting.

Conclusion and Suggestions

The iCassFert-NPK web-based decision support system for fertilizer application platform described in this paper take into account various types of cassava grower's inputs that influence cassava NPK fertilizer decision making. User can access the iCassFert-NPK platform at this URL: http://carsr.agri.cmu.ac.th/projects/iCassFert-NPK, registration using a valid email address is required. We also realized several limitations of the WWW, for example when user is interacting with data over the Internet may cause delays in download the data set and connection errors. The web-based app and interface has several advantages to overcome the weakness of the current fertilizer application method and allow interaction between cassava growers and fertilizer experts. Firstly, soil test kit allow rapid a reliable test results that were used as inputs for the CSM-CROPSIM-Cassava model to simulate the response of cassava to nitrogen fertilization application decision-making. Secondly, we design a web-based and practical platform for users, with Thai language interface. Basic information and database for NPK fertilizer decision-making are all integrated into our platform, i.e. real-time daily weather data, link of Google map to soil and weather station identification codes, algorithms to calculate initiate conditions for the simulation model. Thirdly, and finally, we consider the user's friendliness of the interface, which lead to a practical hardware and software architecture for NPK fertilizer recommendation in cassava production system in Thailand and may be modified for other ASEAN member states.

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