Application of the cropping system model for determining suitable management strategies for maize in Northeast Thailand

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Abstract: Traditional way of determination of suitable crop management practices for increasing maize production involves time consuming and expensive. Dynamic crop simulation model can be an alternative option. The objectives of this study were to evaluate the performance of the CSM-CERES-Maize model and to determine suitable management practices for maize production in the Phu Pha Man district, Thailand. The observed data sets from farmer's fields located in the Phu Pha Man district were used to evaluate the model. Model simulations for different management scenarios were conducted with soil property information and historical weather data for the period from 1972 to 2003 to determine suitable management practices. Model evaluation showed a good agreement between simulated and observed seed yields. The analysis to determine suitable management practices showed that June 15 and 30 and July 15 planting dates resulted in higher simulated maize yields when compared to the other planting dates. Plant density of maize at a rate of 10 plant/m^2 gave higher seed yield than at a rate of 5 plant/m^2. Nitrogen fertilizer application at a rate of 70 kg N/ha gave the highest maize yield when compared to the rates of 0, 30 and 50 kg N/ha. This study showed that the CSM-CERES-Maize model could be a valuable tool in determining suitable management practices.

Key words: Decision Support System, CSM-CERES-Maize model, Simulation, Strategic plan

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Introduction

Phu Pha Man is a district of Khon Kaen, in the northeastern region, Thailand where the farmers commonly cultivate maize under rainfed conditions. Records from the Office of Agricultural Economics of Thailand indicate that average maize yield over the past 10 years (1994-2003) has normally been lower than the expected yields, e.g., 2,808 kg/ha. Identifying suitable crop management practices could provide valuable information for designing a strategic plan to increase maize yield. However, this process is time consuming and expensive as it may involves many years of experimental data collection.

In recent years, the Cropping System Model (CSM)-CERES-Maize has been developed to simulate vegetative and reproductive development, growth and yield as a function of crop characteristics, climatic factors, soil characteristics and crop management scenarios (Jones et al., 2003; Hoogenboom et al., 2004; Banterng et al., 2010). This model provides an alternative option to use as a decision supporting tool in identifying suitable crop management practices. However, the evaluation and application of this model in Thailand has been somewhat limited. Therefore, the objective of this study was to evaluate the performance of the CSM-CERES-Maize model and to determine suitable management practices for maize production in the Phu Pha Man district, Thailand.

Materials and Methods

Model evaluations with the inputs data from four differences farmers' fields during the rainy season in 2001 were made. The inputs data required to run the CSM-CERES-Maize model included soil property characteristics, crop managements, daily weather conditions and the cultivar coefficients (Hoogenboom et al., 2004). Soil properties included bulk density, soil texture including percent sand, silt and clay, soil moisture, organic mater, pH, total N, and exchangeable P and K. The soil fertility factor was also optimized to account for some uncertainties in soil properties that were not simulated by the model. Crop management information included planting date, plant density, and dates and rates of fertilizer and irrigation. Weather data, e.g., daily minimum and maximum temperatures, rainfall and solar radiation, were obtained from the Meteorological Department in Thailand. The cultivar coefficients for the maize cultivar CP-DK888 were based on published values for a cultivar that had similar growth and development characteristics, i.e., NS1 (Boonpradup, 2000). Observed maize yields from four different farmers' practices were also recorded during the rainy season in 2001 in the Phu Pha Man district for the cultivar CP-DK888 for different planting dates and plant densities and with and without nitrogen fertilizer application. The procedure used to evaluate the model was determined by comparing the simulated values with their corresponding observed values.

The model was also run to simulate maize yield under the soil property information for Phu Pha Man district that were obtained from the Department of Land Development in Thailand. Historical weather data for 32 years, i.e., 1972 to 2003, were obtained from the Meteorological Department in Thailand. Different management scenarios were also simulated. A rainfed condition was specified for seven planting dates in the rainy season, i.e., May 15 and 30, June 15 and 30, July 15 and 30 and August 15. Two plant population levels of 5 and 10 plants/m^2 were used. Nitrogen fertilizer was applied at rates of 0, 30, 50, and 70 kg N/ha at 20 days after planting. Commercial cultivars used for the simulation was CP-DK888.

Results and Discussion

The evaluation of the CSM-CERES-Maize model with data that were obtained from four different farmer's practices in 2001 showed that observed and simulated yields varied from 1059 to 2920 kg/ha and 1316 to 2856 kg/ha, respectively, and also showed that the model predicted reasonably well as indicated by small differences between observed and simulated seed yields, ranging from 6.40% to 14.51% of the observed values (**Table 1**). The differences between the observed and simulated seed yields were due to the crop in the actual farmers' fields would be affected by weeds, diseases and pests, and other factors which were not accounted for by the model. For overall, however, the results for model evaluation indicated that the CSM-CERES-Maize model was able to simulate yield fairly accurately for growing conditions in these farmers' fields.

An analysis to determine suitable maize management practices showed that a plant density of 10 plant/m^2 resulted in higher yield levels than that of the density of 5 plant/m^2 (**Table 2**). Increasing the plant density can increase total biomass more than seed yield, as indicated by lower the harvest index values for the plant density of 10 plant/m^2 when compared to 5 plant/m^2. However, the plant density at a rate of 5 plant/m^2 is the recommendation by local extension for the Phu Pha Man district, but using a higher plant density such as 10 plant/m^2 could help to increase total maize production for this region. High yield levels were found for the largest amount of nitrogen fertilizer, whereas the values for harvest index were almost the same (**Table 2**). The highest yield was reached when nitrogen fertilizer was applied at a rate of 70 kg N/ha, which corresponds to the highest rate of nitrogen fertilizer recommended for maize production for the Phu Pha Man district. The mean seed yield for maize for the seven different planting dates from May 15 to August 15 under rainfed conditions ranged from 2801.6 to 3500.6 kg/ha (**Table 2**). The higher simulated mean yields in June 15, June 30 and July 15 planting dates could be attributed to a larger amount of rainfall and high solar radiation (**Figure 1**). This indicated that these three planting dates are more appropriate for maize production under rainfed condition when compared to the other planting dates.

Conclusions

This study showed the potential of the CSM-CERES-Maize model as a tool for determining suitable management practices for maize production in the Phu Pha Man district. The model simulations showed that the June 15, June 30 and July 15 planting dates are more appropriate for maize production under rainfed condition. Plant density at a rate of 10 plant/m^2 gave higher seed yield than at a rate of 5 plant/m^2. Nitrogen fertilizer application at a rate of 70 kg N/ha gave the highest maize yield when compared to the other rates.

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Table 1 Model evaluation for maize production in the Phu Pha Man district.

Planting date	Fertilizer (kg N/ha)	Plant population (plants/m^2)	Observed yield (kg/ha)	Simulated yield (kg/ha)	Difference [a] (%)
12 May 2001	0	4	1059	1316	12.79
	25	4	2494	2856	-14.51
23 May 2001	0	9	2028	2280	-12.43
	21	8	2920	2733	6.40

[a](Observed yield – Simulated yield) x 100/Observed yield

Table 2 Simulated results for maize for different management scenarios.

Management	Yield (kg/ha)[a]	Harvest Index[a]
Plant population (plants/m^2)		
5	3090.0 ± 1664 b	0.314 ± 0.10 a
10	3417.0 ± 1873 a	0.300 ± 0.10 b
N application (kg N/ha)		
0	2528.4 ± 1953 d	0.309 ± 0.11 b
30	3151.4 ± 1698 c	0.296 ± 0.10 b
50	3528.9 ± 1608 b	0.306 ± 0.09 b
70	3805.2 ± 1569 a	0.317 ± 0.09 a
Planting date		
15-May	3233.3 ± 1564 bc	0.312 ± 0.09 b
30-May	3309.0 ± 1591 b	0.315 ± 0.09 ab
15-Jun	3500.6 ± 1615 a	0.319 ± 0.08 a
30-Jun	3447.4 ± 1675 a	0.311 ± 0.08 b
15-Jul	3325.7 ± 1837 b	0.304 ± 0.10 c
30-Jul	3156.8 ± 1939 c	0.304 ± 0.12 c
15-Aug	2801.6 ± 2077 d	0.284 ± 0.13 d

[a] Value in column followed by the same letter are not significantly different at $P<0.05$ level.

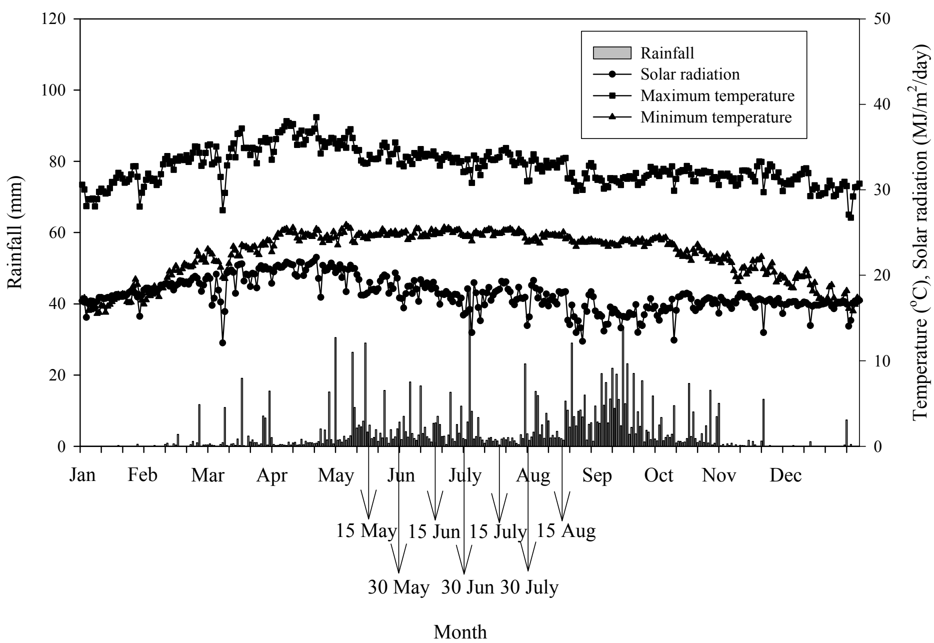

Figure 1 Daily average rainfall, maximum temperature, minimum temperature and solar radiation for the Phu Pha Man district (values averaged over 32 years from 1972 to 2003).