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AN AGENT-BASED APPROACH FOR MANAGING FOOD-ENERGY-WATER SYSTEMS UNDER FUTURE CLIMATE SCENARIOS USING FEWCALC AND DSSAT: OPPORTUNITIES AND CHALLENGES FOR LOCAL DECISION-MAKERS IN THAILAND

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Thailand is one of the world's leading agricultural suppliers and has been known as the Kitchen of the World. About half of the country's total area is used for agriculture. In 2020, the agricultural sector contributed about 1.3 trillion baht to GDP, accounting for 8.64 % of GDP (Office of Agricultural Economics, 2021). The global population is expected to reach 9.1 billion by 2050. Feeding this growing population would require a substantial increase in food production to meet the global dietary demand. Increasing food production would require land, water, and energy. Even though water resources are generally thought of as renewable resources, it is dependent on parts of the water cycle and sometimes limited in daily life. Over 30% of the world's total freshwater is capped in the ground; however, surface freshwater accounts for 1.2%, which is obviously essential to all life. Nowadays, usable surface freshwater is relatively scarce due to overexploitation and pollution caused by nutrients, pathogens, and chemicals. In Thailand, groundwater becomes an important source of water in many agricultural areas. As the Thai population grows 3.3% in the last decade (National Statistical Office, 2021), food, energy, and water (FEW) demands certainly increase, causing a lack of energy supplies for food production and groundwater withdrawal, groundwater overdraft, and eventually a decline of groundwater level in many areas.

Rising global temperatures, shifting precipitation patterns, and experiencing extreme weather events are happening and currently affect all life on earth. Climate change poses intractable problems for water and food insecurity. These impacts could cause Thailand not to be on track to achieve the United Nations Sustainable Development Goals (SDGs) related to food, energy, and water: "Zero Hunger" (Goal 2), "Affordable and Clean Energy" (Goal 7), and "Clean Water and Sanitation" (Goal 6).

FEWCalc (Food-Energy-Water Calculator) is an innovative and accessible tool for farmers and decision makers (Phetheet et al., 2021a, 2021b). Here, FEWCalc's agent-based model constructed using NetLogo was designed to integrate complex systems of FEW systems. This new freeware model was developed to close critical knowledge gaps among the FEW components and relates present FEW decisions to long-term dynamics under alternative climate and production decisions. FEWCalc provides an adjustable range of options, including simulation year, crop type, crop production area, renewable energy investment, tax incentive, groundwater availability, and future climate scenarios. The first and current version of FEWCalc was tested and validated using data from Garden City, Finney County, Kansas, USA.

FEWCalc integrates crop production and irrigation water demand using outputs from a novel cropping system model called Decision Support System for Agrotechnology Transfer (DSSAT). DSSAT requires daily weather data (e.g., minimum and maximum air temperature, precipitation, and solar radiation), physical and chemical properties of soil, and crop management practices (e.g., crop cultivars, planting date, method, plant population, fertilizer application, simulation date, crop module, and irrigation and water management).

Crop simulation was based on two sets of weather data. One is 10-year historical daily data from 2008 to 2017 (base period), and the other is 81-year projected data from 2018 to 2098. Long-term climate projections were obtained from 20 downscaled General Circulation Models (GCMs), which were statistically downscaled using the Multivariate Adaptive Constructed Analogs (MACA) method. These climate projections are driven by concentration or emission scenarios of greenhouse gasses and aerosol, chemically active gases, and land use/land cover, being consistent with Representative Concentration Pathways (RCPs). In this work, RCPs 4.5 and 8.5 were chosen to represent an intermediate emission scenario with an increase of 1.1-2.6°C of global temperature by 2100 and the most warming scenario with an increase of 2.6-4.8°C, respectively.

Results show how climate change affects crop production and farm income in the Midwest USA, without effective technological advances. Income and crop productivity vary depending on the RCP scenario applied. The RCP 4.5 scenario causes a difficult financial situation for farmers, while the RCP 8.5 is considerably worse. Under this extreme climate condition, FEWCalc results illustrate that crop yield continuously losses with an increase of water use, resulting in agricultural income being worse throughout the simulation years. Due to the limited groundwater supply, the system can maintain irrigation for some years, causing crop production to drop significantly. In such circumstances, it would affect the global food and water demands in the future.

The simulation under climate variability produces negative impacts on SDG 2 (Zero Hunger) and SDG 6 (Clean Water and Sanitation). However, the outcomes also present that renewable energy development would reduce farmers' reliance on agricultural production. This leads to achieving SDG 7 (Affordable and Clean Energy). Consequently, farmers tend to use less water for crop production when they achieve financial security, with positive impacts on SDG 6 (Clean Water and Sanitation). In addition, some farmers prefer to continue agricultural activities with supports from clean energy. This would ultimately lead to reducing adverse impacts on SDG 2 (Zero Hunger).

Climate change will have a global impact affecting many countries including Thailand. FEWCalc agent-based model can be modified using data in Thailand to better enable its abilities to help tackle climate issues locally. As stated earlier, Thailand is one of the world's leading food exporters, which causes its economy to be vulnerable to climate change. Hence, policymakers are responsible for being aware of upcoming issues and implementing suitable policy decisions.

Keywords: Climate projection; Agent-based model; Decision making

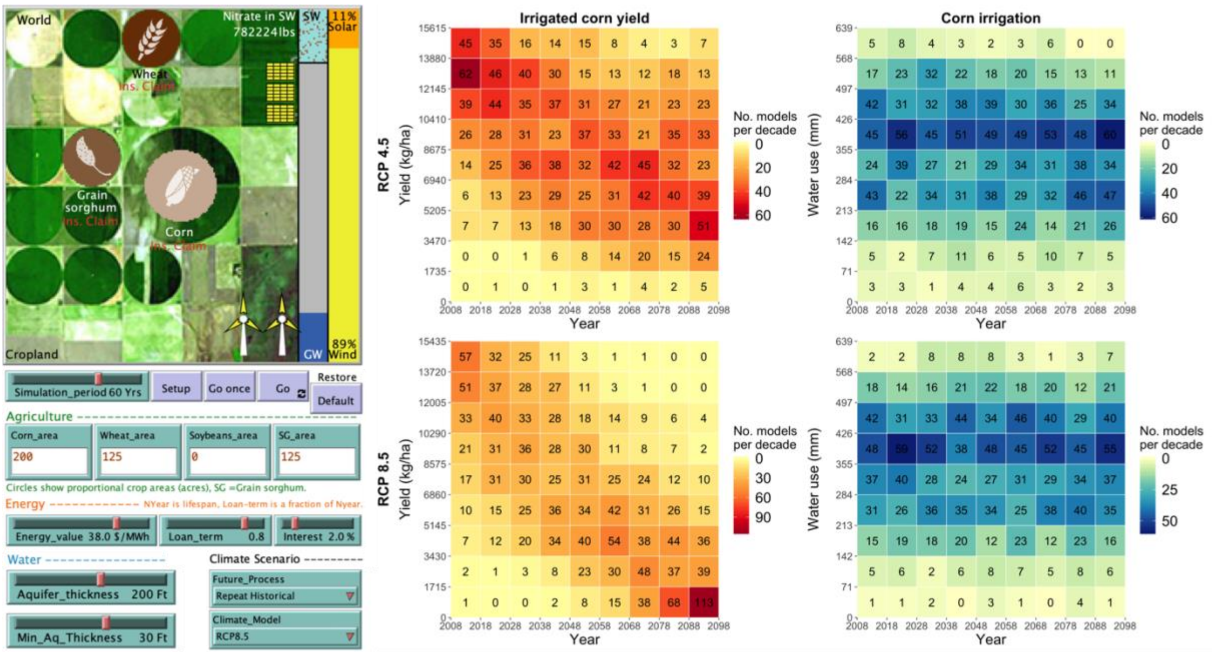

Fig. 1. (Left) An interface of FEWCalc NetLogo with some user-defined parameters. (Right) Heatmaps of DSSAT irrigated corn yield (in kg/ha) and irrigation water demand (in mm), showing the decreasing trend of crop yield and changes in water use over time. The calculation is based on the 20 individual GCMs under the RCPs 4.5 (upper) and 8.5 (lower) from 2008 to 2098.

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