25th International Congress on Modelling and Simulation, Darwin, NT, Australia, 9 to 14 July 2023
mssanz.org.au/modsim2023

An agent-based model for sustainable agricultural development in the Upper Mekong Delta of Vietnam

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Abstract: The Upper Mekong River Delta of Vietnam (Upper VMD) is an agricultural region prone to flooding from the upstream Mekong River. In addition to market drivers, the agricultural systems are driven by changes in the hydrological regime due to flood dynamics and dyke construction. Over time, a wide network of manmade canals and dykes have been built to prevent flooding, allowing farmers to cultivate two or three short-term high-yielding variety rice crops per year, the dominant crop in the region. However, full dyke systems and intensive rice cultivation have made the Upper VMD lose its flood retention capacity. The excessive use of chemical inputs has magnified soil degradation and water pollution, and rice farmers' income remains low due to low prices and increasing production costs. Under these changing socio-economic and biophysical conditions, the Vietnam government and scholars have been advocating for removing the third crop of rice and diversifying into low dyke-based agricultural systems. This involves switching back to flood-based crops (floating rice, lotus, fishery, etc.) and making use of their flood retention and regulation abilities (GOV, 2020). This raises the questions of (1) whether this pathway is possible given the existing full dyke systems and flood uncertainties under the impacts of climate change and upstream developments; and (2) what factors can manipulate to drive the sustainable and flood-adaptive pathway.

This study aims to answer these questions by adopting an agent-based model to simulate farmers' crop choice decisions over time in Phu Huu commune, the upstream deep-flood area of An Giang province. The model investigated the changes in crop area through simulations up to the year 2030 and identified the influencing factors. Various socio-economic and biophysical factors were integrated into the model through a Belief-Desire-Intention architecture. The model was built in Matlab R2019b (version 9.7.0.1216025) and had three modules: (1) Module 1-Farmer agents, (2) Module 2-Land use, and (3) Module 3-Socio-economic and biophysical context. Calibration was undertaken using observed data from 2011 to 2016. Simulations were conducted for 2017–2030 under a business-as-usual (BAU) scenario and four alternative scenarios at different flood levels and rice prices. Sensitivity analyses were conducted for parameters of interest (e.g. perception of environmental sustainability, knowledge of flood-based crops, financial capacity, labour requirement and risk preferences) to determine the robustness of the findings to changes in the modelled values and the key drivers of change.

The results showed that under all scenarios, farmers had the tendency to reduce triple rice areas; however, they would shift quickly to other high-dyke based farming systems with higher income as the main driver, especially fruits, instead of flood-based crops as recommended. Under the BAU scenario, the area of fruits would increase considerably from 7.8% at the beginning of the simulated period to 23.5% of the total land area in 2030. This shift was accelerated in the scenarios where low floods were projected to happen more frequently and slowed down in the scenarios where high rice prices were assumed. Meanwhile, the area of flood-based crops only fluctuated around 1% (0.87%–1.3%) of the total land area under all scenarios. Sensitivity results showed that better perception, knowledge, and preference for risk would stimulate farmers to shift to flood-based crops. On the other hand, higher mechanisation levels of other crops, better perception and possessing a risk-seeking preference would facilitate shifts out of triple rice monoculture systems.

Simulations highlighted that farmers' expansion of fruit areas and reluctance to shift to flood-based crops would challenge the government's strategy for more flood-adaptive agriculture. This demonstrated that definitive steps should be taken as a matter of urgency before a projected new, hard-to-reverse situation occurs in the upstream VMD. Policy designs should respect both natural and market regulations, take into consideration the farmers' risk preferences, enhance perception and knowledge, and increase levels of mechanisation.

REFERENCES

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Keywords: *Climate change adaptation, flood-based crops, perception, labour, risk preferences*