A multi-agent model to help managing rainfall variability in the rainfed lowland rice ecosystem of northeast Thailand

The problem

•The drought-prone rainfed lowland rice (RLR) environment of lower northeast Thailand is characterized by high rainfall variability associated with coarse-textured soil conditions, which lead to low rice yields (1.8 t ha^{-1}).
•Past efforts to alleviate water stress in RLR (varietal improvement, irrigation, soil compaction, etc.) had limited impact.
•An understanding of water users' needs and existing patterns of water use is required to improve the current situation.

Research objectives

•To understand dynamically the interaction between water resource availability and water use in the RLR ecosystem.
•To develop a simulation tool based on multi-agent systems (MAS) to explore this interaction.
•To identify pathways to mitigate drought problems in RLR at the catchment scale

Approach and methodology

•Identify and understand decision-making rules associated with water use through on-farm surveys.
•Integrate present knowledge (natural and anthropic phenomena) in a MAS model to create an environment in which the main factors involved in farmers' decision-marking processes are realistically represented.
•Use the Common-Pool Resources and MAS (CORMAS) platform to implement the model.
•Analyze system dynamics, especially the variation in water availability in time and space, through simulations.

The study site

•Surveys and field observations were conducted in seven villages within the Huay Bua sub-watershed (75 km^2) of the Lam Dom Yai River (Fig. 1).
•Since the late eighties, the promotion of small farm ponds (600 to 2,400 m^3) helps farmers to alleviate the effect of dry spells and to stabilize RLR production.

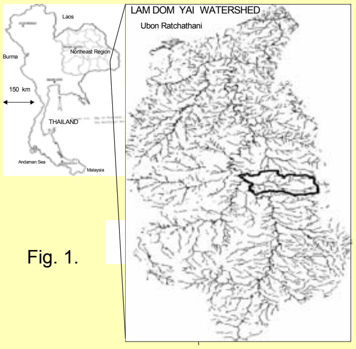
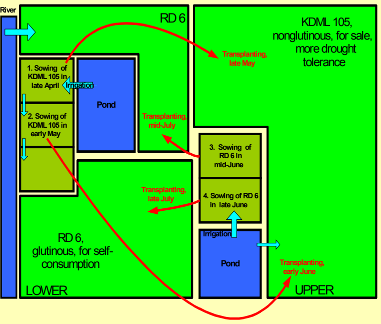


Fig. 1.

Understanding decision-making rules governing water use

Fig. 2.



•Survey results point to two main water uses in RLR:
  - ➢During land preparation,
  - ➢For supplementary irrigation of nurseries and paddy fields.

•Factors taken into account by farmers to decide their water-use practices vary:
  - ➢In space: soil type, plot position on the toposequence, access to water resources;
  - ➢In time: soil moisture, rainfall intensity, volume of water available;
  - ➢In both time and space: rice varieties and farmers' habits.

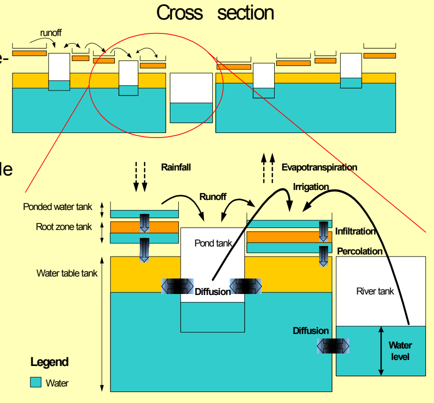
•These determine the date, location, and frequency of water uses (Fig. 2).

MAS modeling for knowledge integration

•A time step and a spatial unit are defined:
  - ➢A daily basis is compatible with rainfall data and the one-year maximum length of simulations.
  - ➢The spatial unit is the RLR field as important decisions regarding water use are made at this level.

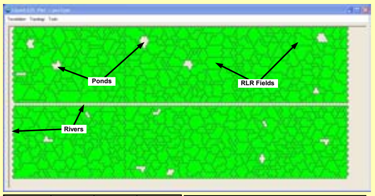
•The model structure relies on hydrologic entities whose dimensions, spatial organization, and functioning are based on field surveys and GIS data (Fig. 3).

Fig. 3.



•The model grid (5,000 cells) represents 50 ha of diverse soil, water, and crop situations of the Huay Bua sub-watershed (Fig. 4).
•Decision-making rules are represented by predetermined functions:
  - ➢*Irrigation function*: pumps water from ponds or rivers and transfers it to RLR nurseries or fields when root-zone moisture content has dropped below the water-stress threshold.
  - ➢*Assess water-stress function*: at each time step, it calculates the proportion of water-stressed RLR fields that cannot be irrigated.

Fig. 4.



Surface (m^2)	minimal	average	maximal
RLR field	200	800	1600
Ponds	200	420	800

In the model	Quantity	Number of cells	
		minimal	maximal
RLR field	625	1	16
Ponds	15	2	8

Average density of ponds : 3 ponds for 10 ha of RLR fields

•The model is verified by running simple scenarios with predictable behaviors. Figure 5 displays interactions between evapotranspiration functions and water in ponded-water and root-zone tanks.

Fig. 6.

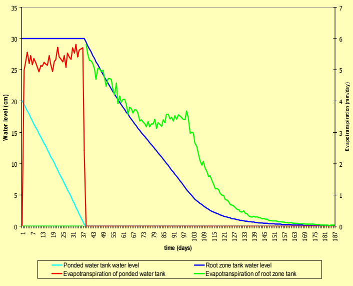
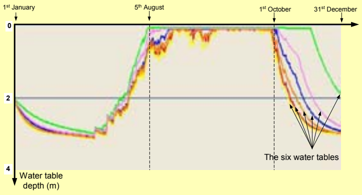


Fig. 5.

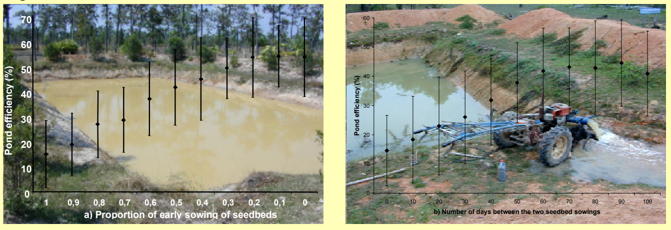


•It is calibrated to avoid unrealistic behaviors. A normal climatic year (rainfall and evapotranspiration) is simulated and water transfers between tanks are readjusted to make the water-table variations coherent with empirical data (Fig. 6).

Exploring scenarios

•Assessing the efficiency of ponds to decrease the proportion of water-stressed fields during dry spells is a critical question. Pond efficiency is measured by comparing the proportion of water-stressed nurseries/fields with and without ponds.
•Simulations are run based on 27 years of actual climatic data. For each year, several simulations are made for varying periods between the two sowing dates of RLR nurseries and different proportions of early sown seedbeds (Fig. 7).

Fig. 7.



Results and discussion

•Ponds have a limited volume of stored rain water at the beginning of the rainy season and are more efficient later in the year.
•Pond efficiency is stable when the period separating two seedbed sowings is longer than two months. Below this threshold, it is possible that the ponds are not completely refilled.
•Pond efficiency is also limited by farmers' strategy to maximize the length of the vegetative phase of RLR commercial cultivars through early sowing of KDML 105 nurseries.
•Groundwater could be an additional source to meet water needs in the early part of the cropping season. We already observe more and more wells in the area.

Perspectives

•We will present this prototype model to local farmers for social validation and identification of key questions to be explored with this tool.
•We will add autonomous agents in the model to make decisions on water use and cooperative behavior.
•In particular, we will assess the possibility of improving the management of underexploited collective ponds and groundwater.

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