Agent-based modeling and simulation of integrated rice-shrimp farming in Bac Lieu province, Mekong delta, Vietnam

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Abstract

Shrimp aquaculture is economically profitable to coastal people in the Mekong Delta, Viet Nam. Nevertheless, conflicts are arising between shrimp and rice farmers from environmental and socio-economic impacts of shrimp aquaculture. For example, shrimp farming encroaches upon land previously devoted to rice cultivation.
This study aims at integrating and sharing knowledge about the rice-shrimp farming system in Bac Lieu province. Companion Modeling (ComMod) was used to involve stakeholders in the construction of a simulation model and discuss its outputs. The first stage of the modeling process consisted of role-playing game (RPG) in which farmers from two villages in the pprovince recreated their farming decisions. The process revealed diverse water and land use strategies. In the second stage, Agent-Based Modeling (ABM) used a subset of individual farming decisions to parameterize a generic model of integrated rice-shrimp farming. The initial ABM scenario spatially generated production areas and water salinity patterns similar to the ones used during the RPG sessions. This similarity is expected to convince farmers of the accuracy and value the ABM analysis and help create continued interest when requested to "validate" it by providing user feedback on its features and rules. Additional scenarios based on different sluice operators decisions, risk and economic conditions were collectively simulated and assessed.

Keywords: Agent-based Modeling, Conflict, Mekong Delta, Vietnam

Media grab

Farmers and scientists can use Agent-Based Modeling (ABM) to better understand the complexity of rice and shrimp production systems and accelerate the collective improvements in their design and management.

1. Introduction

Asian and Pacific region shrimp aquaculture contributes about 87.4 percent of cultured penaeid shrimp to global market (FAO, 2004). During the last decade, coastal zones of several Asian countries have experienced significant conversions from rice to shrimp farms, including the Mekong Delta in Viet Nam. As a consequence, traditional rice farming area in this delta decreased from 757,300 ha in 1995 to 363,400 ha in 2006, whereas shrimp farming area increased from 289,400 ha to 699,200 ha in the same period (GSO, 2006).

Bac Lieu province has experienced similar land conversion pressures. Rice and shrimp are concurrently produced as main sources of local people's income generation (Hoanh et al, 2003). Degree of integration between rice and shrimp farming rely upon farmer decisions based on interactions among biophysical and social economic factors. These interactions are often complex and difficult to understand.

The research objectives are (i) to better understand land use decisions based on interactions among water quality, risk perception and market price factors; and (ii) to provide a research process for analyzing decision making in land use that can be used for modeling and policy analysis. A participatory modeling approach namely Companion Modeling (ComMod) (Bousquet and Trebuil, 2005) is applied. In the ComMod approach, all key stakeholders who are directly or indirectly using common resources are involved into the research process through participating in the Role Playing Games (RPG). Participants contribute to the collective design of the model discuss scenarios for exploring the use of common resources and associated environmental and economic impacts. Agent-Based Modeling (ABM) helps to analyze the interactions among numerous biophysical and social economic factors that affect land use decisions. Moreover, the research process helps support all stakeholders to share experiences in land use decisions and strengthen the adaptive management capacity of local communities.

2. Model description

A conceptual model was collectively built based on available knowledge learnt from previous studies on land use changes in Bac Lieu province and a series of RPG conducted in 2006 and 2007 (Dung et al., 2007). The ABM was developed using the Common-pool Resource and Multi-Agent System (CORMAS) platform (Le Page et al., 2000) as presented in the following sections.

2.1 Spatial-temporal setting

The model is to involve households who are representative for farming actor in the province. These include five and eight households in upstream and down stream villages, respectively. Household's size is varied from 4 to seven members and the farm plots range from one to four hectares. Diversed patterns of rice-shrimp integrated, rice-shrimp integrated combining with fish and crab are main farming systems in the study site. These elements are created as spatial setting in the model.

Spatial setting is made of aggregated cells that represent different types of land uses as rice-shrimp plots, farm composing of plots and canal at the two villages (Figure 1). Cell is the smallest unit that equals to 0.5 ha. A number of cells are aggregated into a plot. A farm comprises of one to eight cells and covers from 0.5 to 4 ha of land. The weekly time step is applied in this study, and the simulation period can be run from one to five years, each year is from 1st January to 31st December.

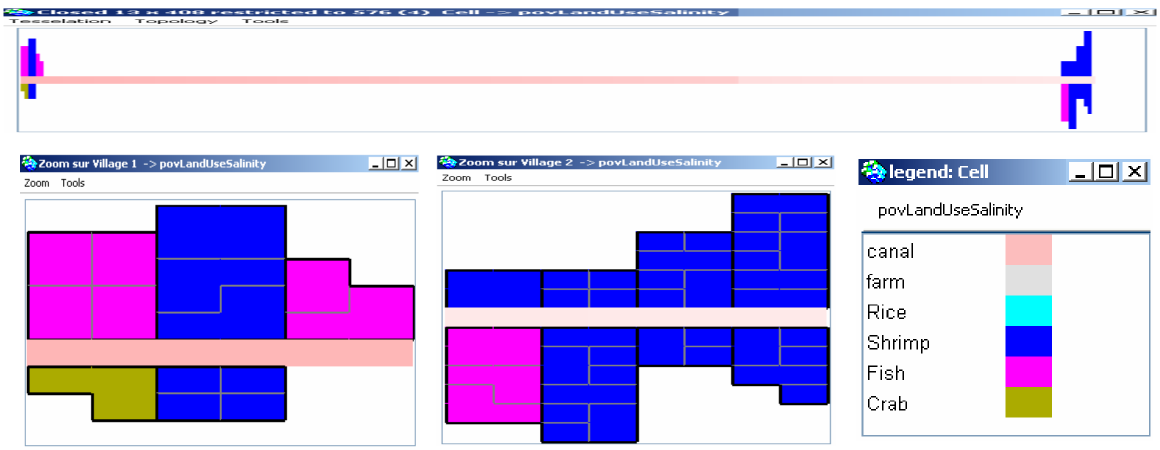


Figure 1: Spatial setting represents different land use types at two villages, downstream (left), and upstream (right) in the study area

2.2 Overview of model structure

Three components of the model, the water, production and social modules, and their relationships are presented in a class diagram using Unified Modeling Language (UML) (Wuyts, 2004/2005) (Fig. 2). The water module is the core component of the model since it links the farm activities that is managed by the household in the social module with the plot that is occupies by the crop in the production module.

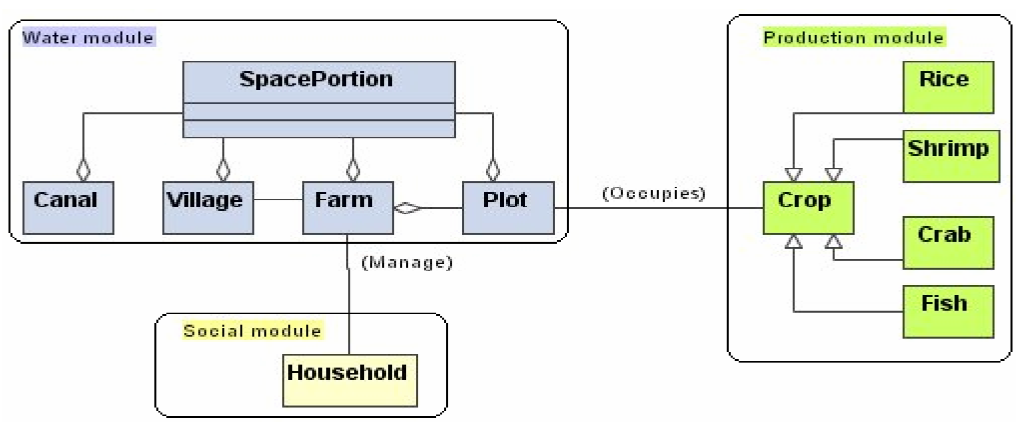


Figure 2: Class diagram of model's structure in UML.

2.3 Water module

Water is a key factor to provide salinity seasonally for rice and other aquatic species to be grown in the farms. It is built into a separate module in which a super class entitled SpacePortion aggregates four classes of canal, village, farm and plot. The functions of these classes are:

- Canal: carry water for rice crop and other aquatic species' requirement. An important attribute of the canal is the state (opened or closed) of sluice connected to the canal that controls the salinity in the farm.
- Village: contain the farm and the canal, two main spatial entities of the model.
- Plot: where rice and other aquatic species are cultivated.
- Farm: aggregated by plots, the farm can be considered as a core class where the crops in the production module are produced and the household in the social module can implement its management strategy.

2.4 Production module;

Production module is composed of four classes: shrimp, rice, fish and crab. These are the products for income generation. Their key attributes and operation method are briefly described as follows:

- Shrimp: the highest value product. Its main attributes are shrimp stock, risk of shrimp disease, harvesting time, harvesting method (partial or full harvest). Shrimp's attributes are affected by water quality regarding timing and salinity degree.
- Rice: the second product in term of importance in the study area. Its main attributes are growing duration and yield response to degree of salinization of the soil where saline water has been kept in dry season for shrimp culture. .
- Fish: can be combined into shrimp or rice crops as an additional income source. Its main attribute are fish stock and weight of individual to be harvested. It can be stocked with a wide range of salinity either in dry or rainy season.
- Crab: crab can be combined into shrimp crop in brackish or fresh water condition. However, crab is more preferred to raise in down stream village of Phong Thanh. Similar to fish, its main attributes are crab stock and weight of individual to be harvested.

2.5 Social module

The module is composed of one single class of household, an active agent that would have a number of attributes and do several operation methods. Its main attributes are village code, farm size, income and cost for production. Other attributes to present inputs of labor and fertilizer in rice and shrimp production can be temporary ignored due to its minor contributions in decision making regarding salinity change in the model. Three key operation methods of farm are to initial the household income status, to produce crops and to harvest products.

2.6 Sequence of activities

At present the model simply includes only one active agent (the household) that can make decisions on crop production, but more active agents as sluice operator, middleman for buy products… will be added. The sequence activities performed in the model are as follows:

- Setting salinity of water in the canal: monthly salinity is dependent on the sluice operation. In the model there are three patterns of salinity variations corresponding to three sluice operation schedules selected by the sluice operator and villagers living in the two villages (Figure 3).

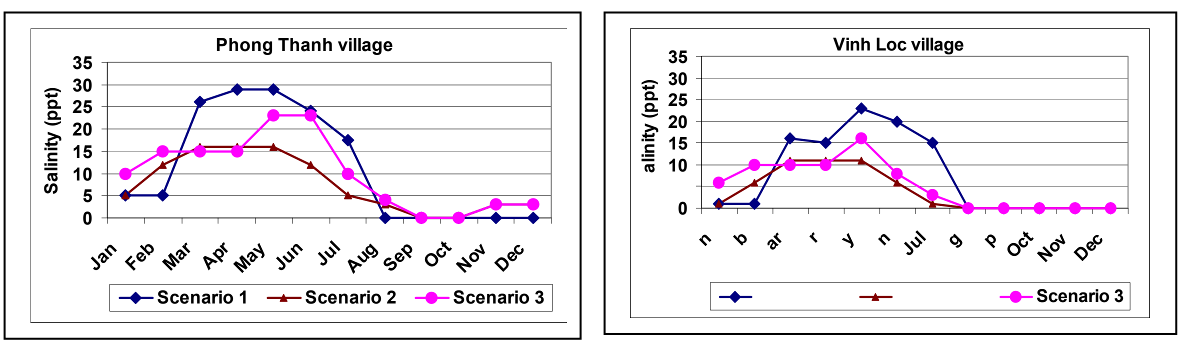
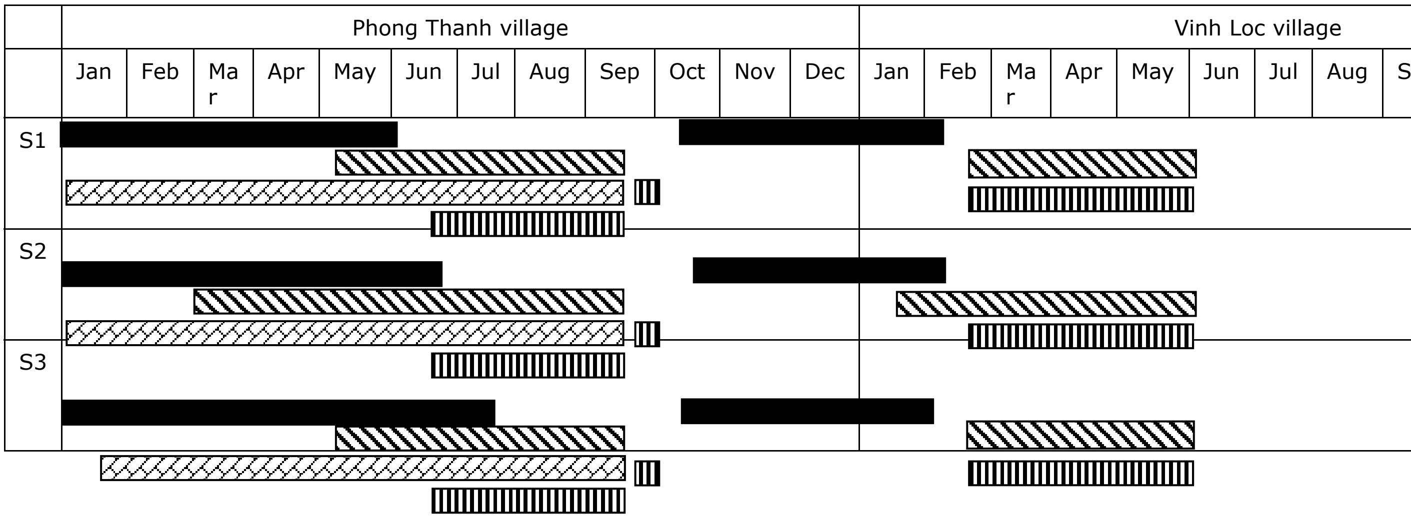


Figure 3: Saline water schemes by scenarios of three different sluice operators

- Producing crops: four major products and their timing are presented as the followings
  - Shrimp is the first crop started at the beginning of the year. Whenever salinity is higher than 5 ppt, usually in November in previous year, shrimp seed can be stocked. Since intensive shrimp farming with high inputs is not sustainable, hence not encouraged, extensive or improved extensive shrimp farming with maximum density of 4 seeds per square meter is practiced.

- Crab is the second crop started in a year, but only at Phong Thanh village near the sluice because salinity of at least 5 ppt from 4 to 6 months is needed for crab growth.
- Fish is the third crop to be considered in a year. Fish can be grown in low salinity or in fresh water condition, which is available mostly from June to December in both Phong Thanh and Vinh Loc villages.
- Rice crop is started after September annually when salinity is lower than 4 ppt. Rice is produced in the entire upstream village (Vinh Loc) whereas it is seldom practiced in the downstream village (Phong Thanh).



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S: scenario shrimp

Table 1: Values and source of parameters used in the modules of ABM model

Module	Attri-butes	Explanation	Range of values	Unit	Source
Spatial	Salinity	Water salinity	0 - 29	ppt	CPWF PN#10
	Area	Farm size of a household	0.5 - 4	ha	Gallop et al., 2003
Production	Stock amount	Shrimp density	10,000 – 40,000	Seeds /ha	Interview with farmers (2006)
		Crab density	200 – 1,000	Seeds /ha	
	Risk	Shrimp dead due to disease	30 - 80	%	Key Informant Interview (2006)
	Survival rate	Rate of shrimp survived	65 - 72	%	
		Rate of crab survived	50 - 80	%	
	Weight	Weight of harvested shrimp	0.022 – 0.067	Kg	Interview with farmers (2007)
		Weight of harvested crab	0.3 – 0.5	Kg	
	Yield	Rice yield per ha	3,000 – 5,500	Kg	
		Fish yield per ha	500 – 1,000	Kg	
	Price	Market price of shrimp	50,000 – 120,000	VND/kg	http://www.vneconomy.vn (26/09/2006)
		Market price of rice	2,250 – 3,500	VND/kg	http://www.vneconomy.vn (17/11/2006)
		Market price of fish	4,000 – 6,000	VND/kg	Interview with farmers (2007)
		Market price of crab	120,000 – 200,000	VND/kg	Interview with farmers (2007)

Note: 1 US$ is approximately equivalent to 16,000 VN in 2008.

- Harvesting crops
  - Shrimp can be harvested after 14 weeks from stocking date. Shrimp survival rate is ranged from 65% to 72% of initial population at harvesting time. However, there is a risk of 30% to 80% of shrimp died due to disease. There are two harvesting methods: (i) full harvesting (all shrimp are

harvested at one time), and (ii) partial harvesting (only big shrimp is harvested). The full harvesting is applied by 20% of households. Shrimp is a most valuable product in the study area with price ranged from 50,000 to 120,000 VND/kg.

- Crab can be harvested after 4 to 6 months from stocking date. Survival rate of crab is high, from 50% to 80% of initial population. Depending on harvesting time, farmers can sell crab at a highest price of 200,000 VND/kg.
- Fish crop can last from 18 to 22 weeks. Risk due to disease is minor. Fish yield can be varied from 500 to 1,000 kg/ha, but price is not high, from 4,000 to 6,000 VND/kg. So, fish is a popular crop to provide additional income to other crops.
- Rice in Phong Thanh is harvested in December, 3.5 months after sowing. However, in Vinh Loc rice can be harvested later, up to January. Market price of rice is relatively stable, from 3,000 to 5,500 VND/kg, depending on variety and quality.

The model has been collectively built based on available knowledge collected from secondary data, group meeting with local stakeholders and RPGs with farmers. At each time step land use change in each farm is displayed in the spatial interface (Figure 1). These changes are consistent with results of land used patterns under the two scenarios of early and late salinity intake into the system selected by players at the RPGs in 2006 and 2007. At present more technical parameters such as production cost, price of product return and risk of shrimp disease, new operation methods attributed to the new active agents (sluice operator, middleman) are included into the model. These will be tested for analyzing more complex land use decision under various scenarios such as variation in prices of products and of inputs for production.

3. Conclusions and perspective

This ABM prototype can display the spatial settings and present the impacts on production due to changes in water salinity similar to what farmers were practiced during the RPG sessions. Various scenarios based on different sluice operations, risk perception and economic conditions could be collectively simulated and assessed by stakeholders. More active agents will be added to reflect the complexity in land use decision in selecting production systems at two extremes of the canal with different salinity conditions.

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