Combining Agent Based Modelling and Role Playing to develop sustainable shrimp farming

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Abstract

This paper presents a research where a Role Playing Game (RPG) and Agent Based Model (ABM) were combined to study and foster a social learning across shrimp farmers in the Mekong Delta of Vietnam. The objective was to seek an improvement in awareness about the effects farming decisions have on environment sustainability in the region. The ABM is used to simulate farm-level decision-making and to evaluate the effects different scenarios have on key parameters related to the shrimp farming system. Role Playing Game was used to collect and validate data as well as to raise awareness. The first analyses done show that the effects of the RPG as a social learning intervention does not seem to be very strong. Data collected at two with an exit survey suggests weak effects directly after a playing session. For the ABM the business as usual scenario has been implemented which shows a slow decline in single intensive and improved extensive types of shrimp farming and an increase in hybrid systems combining integrated mangrove shrimp farming with more intensive types.

Keywords: Agent Based Modelling; Role Playing Games; Participatory Modelling
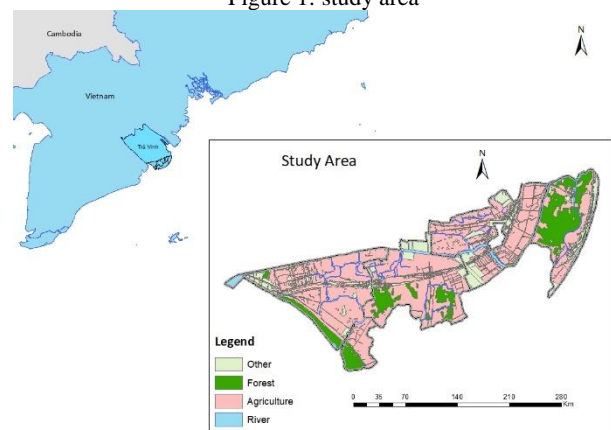
1 Introduction

Agent Based Modelling (ABM) is widely used as a method to explore and understand complex adaptive systems such as found in land use change (Antona *et al.*, 2002; Parker *et al.*, 2002; Matthews *et al.*, 2007; Rodela *et al.*, 2017). Increasingly ABM models are combined with participatory methods to stimulate social learning. Participatory modelling, or companion modelling approaches, are applied to help stakeholders and other actors to exchange knowledge and explore alternative solutions (D'Aquino *et al.*, 2003; Guyot and Honiden, 2006; Salvini *et al.*, 2016). This paper reports on the ongoing development of a role playing game (RPG) and an ABM to support sustainable development of shrimp farming in the Mekong Delta of Vietnam.

2 Context

In the Mekong Delta shrimp farming is a dominant aquaculture system accounting for 20% of the aquaculture products in 2015. The tendency to intensify shrimp farming leads to increasing pressure on the sustainability of the area. Risk of disease as well as environment pollution and cutting of mangrove forest leads to a degradation of the coastal protection and marine biodiversity. To mitigate these effects, the Vietnamese government and the local authorities promotes mixed, or integrated mangrove-shrimp systems in which farmers maintain at least 40% of their area under mangrove

cover (Phuong et.al. in press). At present there is limited understanding of farmers' willingness to shift to, or maintain, integrated mangrove-shrimp systems as well as there is limited understanding of policymakers' opinion about the feasibility and the effects that current policy measures have. Our study focus on four communes within the Tra Vinh Province in the Mekong delta of Vietnam (Long Vinh, Long Khanh, Truong Long Hoa, and Long Toan) (Figure 1).

Figure 1: study area

The Tra Vinh Province covers 234116 ha. The Aquaculture in Tra Vinh province is divided into two types: fresh water and brackish water shrimp farming. The brackish water area

occupied 25,648 ha, approximately 83% total aquaculture areas (General Statistical Office, 2015).

3 Participatory modelling approach

The approach presented here includes the coupling of a RPG and an ABM. The goal of the RPG is two folded:
- be used as a tool to promote social learning across communities and so contribute to raise awareness amongst shrimp farmers about the effect current shrimp farming practices have and about the benefits more sustainable types of farming could have;
- be used as means to collect data, and further insight, on decision-making of individual farmers to fine-tune the ABM.

The ABM serves the main goal to communicate to policy makers the effects of policies on farmers' shrimp farming practices so to better understand the potential effects of measures on the overall quality of the agricultural and ecological systems in the Mekong Delta

To develop the RPG and ABM a socio-economic farmer survey including questionnaires and face to face interviews amongst 132 farmers was held in May 2016. The survey focused on social networks, climatic conditions and shrimp farming practices. Purposive sampling was used to select farmers selection and it was sought to talk to those who have experience with the various farming systems currently present in the region.

3.1 Social Learning and Role Playing

Based on the interviews held during the survey a first version of an analogue role playing game has been developed. This game was commented upon by experts in gaming and participatory techniques during a workshop, and tested during sessions with students of Can Tho University. Additionally, a selected group of farmers who played the game offered their comments on the RPG during a workshop organized jointly with policy makers and scientist of Can Tho University and Wageningen University. Based on outcomes of this evaluation and tests the game has been revised into a final version.

To measure the effect of RPG, and ways it triggers, social learning a longitudinal set-up has been put in place. This includes repeated observation of social learning effects over a 3 years period across 3 groups of farmers: 1) farmers who never played the game, 2) farmers who played once and 3) farmers who played the RPG 3 times. Semi-structured questionnaires were used to collect data about aspects of interest. Until now 2 game playing sessions have been organised and will be reported upon in this paper.
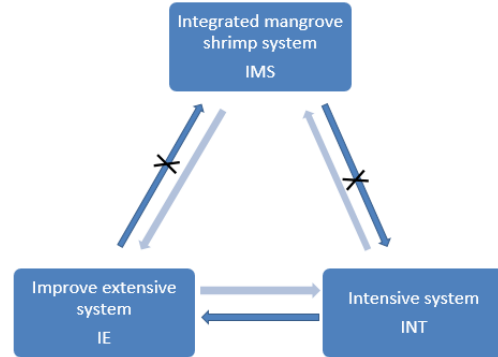
3.2 Agent Based Model

Parallel to the RPG sessions an ABM has been implemented to simulate the effects of the decision-making by individual farmers on the (spatial) distribution of the shrimp farming systems as well as the consequences for shrimp production, environmental quality, and social-economic situation of the area.

From the survey and RPGs it showed that farmers basically shift between three system: intensive farming systems (INT),

improved extensive systems (IE), and integrated mangrove systems (IMS). It appeared that in practice the majority of the farmers only decide to invest in more intensive systems while shifting to lower intensity systems such as IE and IMS rarely occur. Figure 2 shows the most occurring shifts.

Figure 2: potential shifts between farming systems.

Individual farmers are represented as agents having attributes related to their capital, loan, family size, labor size, second income, and risk taking behavior. At the beginning of the simulation each farmer and farm is initialized using data collected from the socio-economic survey complemented with formal statistics on market prices and shrimp production etc.

Each cycle of the model indicates one month. Each month there is a probability of disease (white spot) which is determined by the type of farming system and the type of shrimp (Figure 3). If a farm is hit by a disease it will, loose on production. Depending on the investment capacity of the agents, its plot size and current system, a farmer might have the ability to shift to another system. Besides an ability to shift agents have a willingness to shift which depends on the individual characteristic of the agent for example regarding their risk taking behavior. The latter is currently simply implemented as a potential based on the farmer-survey and interviews but will be replaced by a behavioural model based on the Consumat framework (Jager and Janssen, 2012)(Jager *et al.*, 2000).

The ABM model is implemented in GAMA an agent based development platform specifically designed for spatial ABMs (Grignard *et al.*, 2013). It provides various views on the system. Currently the land use change is monitored as well as the number of agents that shift, the area occupied by the various farming systems, and the change in productivity and average income of the farmers.

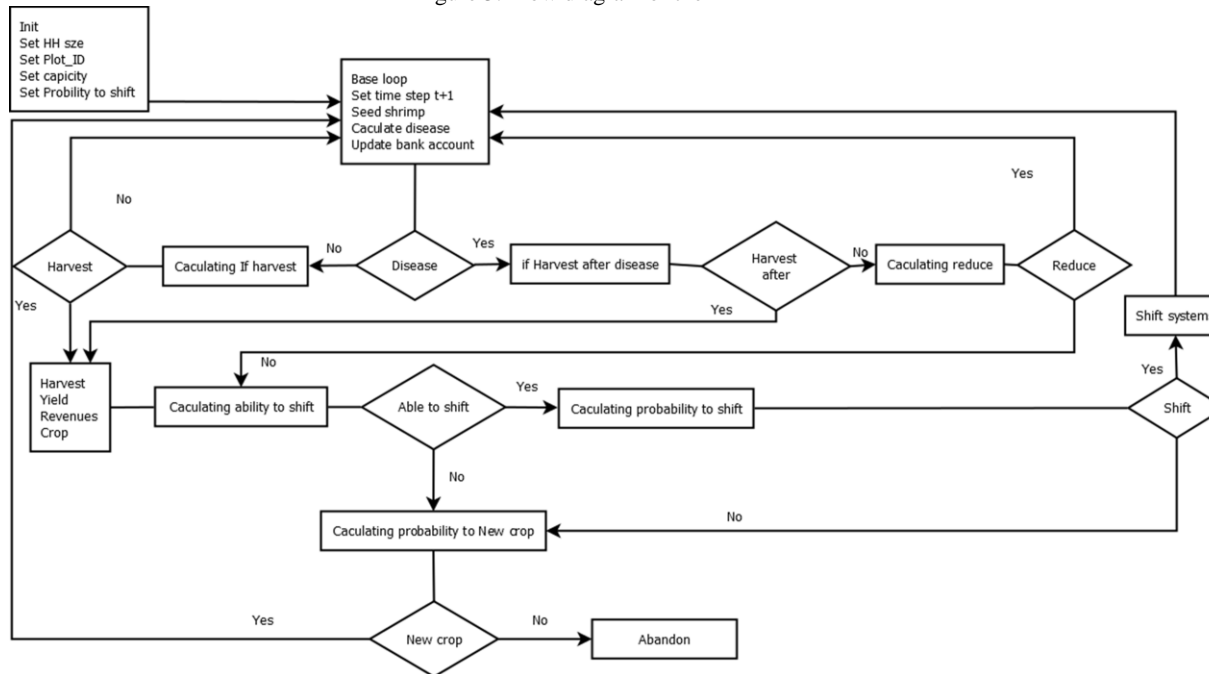# 4 Preliminary Results

4.1 Role Play Game

As mentioned two role playing sessions have been played (see Figure 4) in the Tra Vinh province in the four communes. 55 Players played the first version of the game in October 2016 and 42 played in November 2017 of which 31 also participated in the first gaming session. Directly after the

game an exit survey was administrated. Various questions were asked mostly related to the learning and social interaction and rated on a five point Likert scale (1 = difficult/nothing; 5 = very easy/a lot). Below a preliminary overview is given by highlighting the outcomes of some selected questions.

As a result from the first RPG session the average score on the question "*do you understand more about the risks of shrimp*

of the gaming on the knowledge development of the farmers is limited. Also, when it comes to social interaction, the influence of the game is perceived limited: on the question "*did you hear suggestions of others that influence your decisions in the game*" the average score was 1.8 (std. dev. 1.1). On the question "*did you give suggestions to help other people to make decisions*" the average score was also 1.8 (std. dev. 0.9).

Figure 3: Flow diagram of the ABM

farming" was 2.6 (std. dev 0.8). The question "*how easy was it to play the game*" resulted in an average score of 2.86 (std. dev. 0.81). These results indicate that the perceived influence

Figure 4: The role playing game

In the second round of RPG sessions 31 players were present who also played at the first session while 11 players only played during the second session and were exposed only to the redesigned game. The average score on the question: "*do you understand more about the risks of shrimp farming*" was 3.1 (std. dev. 0.7). There was no significant difference between the players who only were exposed once to the game with those who played both the first and second version of the game. On the question: "*how easy was it to play the game*" resulted in an average score of 2.83 (stdev 0.77); with a slight difference between players who played the first time and those who played it a second time: 2.5 and 2.9 respectively. On the question: "*did you hear suggestions of others that influence your decisions in the game*" the average score was 1.5 (std dev 0.7) where players who played once score an average of 1.8 (0.9) and the players who played twice scored 1.4 (0.7). On the question "*did you give suggestions to help other people to make decisions*" the average score was 1.8 (std. dev. 0.85) where players who played once scored on average 2 and the players who played twice 1.8.

Although more RPG sessions are planned, some preliminary patterns can be already observed. First of all it appears that the redesign of the game did not really improve on the perceived ease of use. Secondly the effect on perceived gain in knowledge as well as sharing knowledge also seems rather low.

Table 1: Values for the main input variable for Improved Extensive (IE), Intensive Systems with Peneaus Monodon (INT-mono) and Penaeus Vanamei (INT-vana) and Integrated Mangrove Systems (IMS).

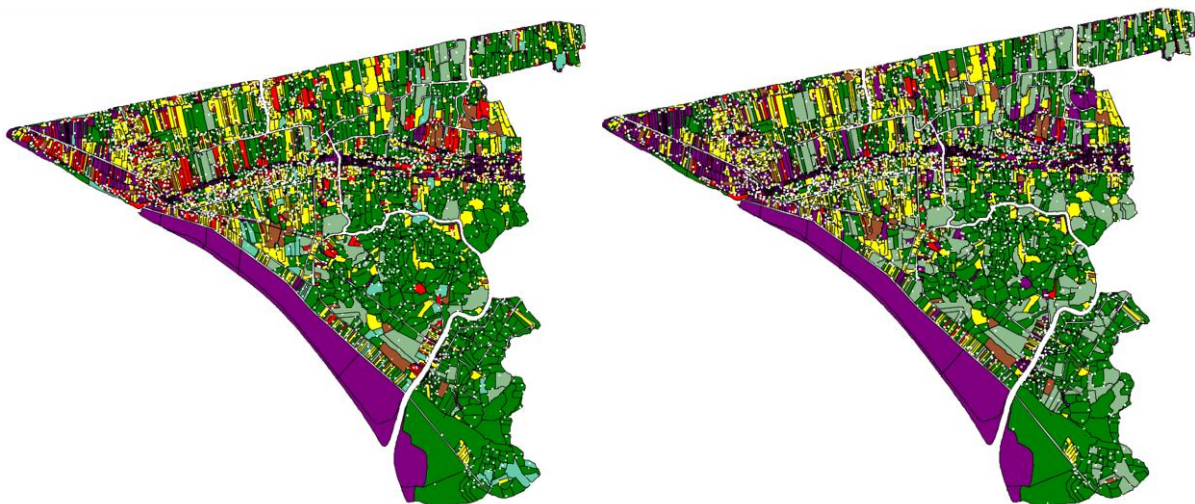|	IE	INT_mono	INT-vana	IMS
Household expenses Mvnd/person/month)	1.6	1.9	3.0	2.0
Aveage HH size (persons)	4	4	4	4
Average HH loan (Mvnd/ha/year)	90	115	113	49
% of households having a loan	59	71	71	61
Second income (Mvnd/ha/year)	11.5	12.7	44.2	5.6
Successful harvest time (month)	3	4	3	2
Crop Cost (Mvnd/ha/month)	17	122	218	3
Seed costs (PL) /m^2	8	25	72	4
Risk of severe disease outbreak (%)	12	30	30	10
Yield (kg/ha/cycle) – successful crop	163	5814	8897	105
Yield (kg/ha/cycle) – failed crop	38	1431	2853	30
Investment cost (Vnd/ha)	85	234	291	79
Shrimp price (Vnd/kg)	158,000	152,000	98,000	163,000

4.2 Agent Based Model

The current version of the ABM implements a 'business as usual' scenario for the famers in the region. Currently two types of shrimps are grown in the study region: the Giant Tiger prawn (Peneaus Monodon), and the Whiteleg shrimp (Penaeus Vanamei). They differ in yield, price, and chance of diseases as well in their investment and operational costs. Besides the three shrimp farming systems shown in Figure 2 also hybrid systems are found. These are combinations of intensive with improved extensive systems and integrated mangrove systems with both intensive ponds as well as improved extensive ones are found. Based on the socio economic farmer survey Table 1 summarizes the most important input variables used in the current version of the model. Using observation and results from the RPG initial assumptions about the risk-taking behaviour and the probability to shift to another shrimp-farming system are

adjusted in the ABM.

The ABM was initiated with 3150 agents following a distribution extracted from official statistics (16% intensive, 35% improved extensive, 45% Integrated Mangrove and 4% farmers with hybrid (mixed) systems). The locations of the farms were determined using the cadastral and land use data-sets of the Tra Vinh province as well as manual classification using Google Earth imagery. The simulated time step is one month. At each step the 'bank account' of the agent is updated based on income (positive or negative) from shrimp and second jobs (see Table 1) a agent can decide to shift to another system if its resources are sufficient and if its willingness to do so is high enough. Figure 5 shows the spatial distribution of shrimp farming system at the initial stage (*t=1*) and after 10 years (*t = 120*). It is noticed is that the area of intensive shrimp farming decreased while the area with hybrid farms combining an integrated mangrove system with an intensive pond increases. This is mainly due to the fact that

Figure 5: Spatial distribution of the shrimp farming systems at year 1 (left) and year 10 (right). Red: Intensive Systems; Yellow: improved extensive; Brown: hybrid Improved Extensive and Intensive; Light green: hybrid Intensive and IMS; Dark Green: integrated mangrove systems; Purple: protected areas.

the relative high risk of intensive farming (high change on diseases) leads to many farms stopping or shifting. This is confirmed by the average household income which initially

statistic and spatial data, in order to represent current practices in the study area. The model results show a system where non-hybrid farming systems are slowly being replaced by
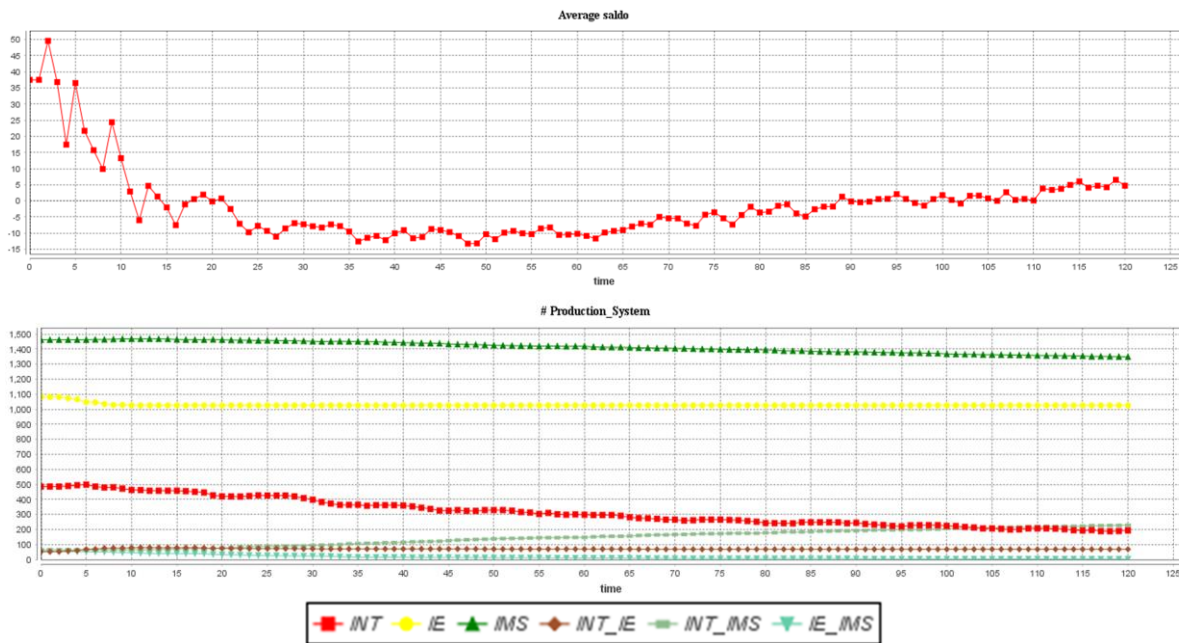

Figure 6: development of average household income and number of production systems, including hybrid systems.

decreases while later the income slowly increases (Figure 6). It also can be seen that the number of pure intensive (INT) farms decreased from around 500 to 200 farms in year 10 same counts for the pure integrated mangrove system which decreased with about 100 farms in 10 year. Systems that combine an integrated mangrove system with an intensive pond increase from about 60 in year 1 to about 230 in year 10.

5 Conclusions

In this paper, first results of a study where we combined RPG and ABM are presented. In this study the RPG was meant as a learning intervention targeting local farmers with the objective to help them learn about the effects shrimp farming practices have on environmental quality of in the Vietnamese Mekong Delta. Also, the RPG was used as tool to gain additional insights about farmers' decisions which was then used for the ABM development.

The ABM simulates individual decision-making of shrimp-farmers and serves as a kind of artificial laboratory to policy-makers to assess the effect of various economic and policy scenarios. From the results obtained from two RPG sessions no clear effects of RPG on the development of knowledge was shown, yet. Specifically no clear development of knowledge on issues of risk perception and sharing of information was observed.

For the current ABM we used the data collected during an socio-economic survey (N=132), then combined with formal

hybrid systems where an integrated mangrove system is combined with a more intensive one. The underlying processes apparently driving this toward this result can be linked to the high risk of white spot disease associated with intensive systems. The current scenario will offer useful input for a policy workshop planned for summer 2018 and also for other activities done by our team, and that of our project partners.

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