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Participatory computer simulation to support collective decision-making: Potential and limits of stakeholder involvement

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Abstract

System models in agriculture and natural resource management are usually developed by researchers to advise policy makers on the likely outcomes of alternative scenarios. Except for data collection, stakeholders—like farm households—are rarely involved in the research process. Companion modeling (ComMod) has been developed as a modeling approach to include various stakeholders in a continuous feedback loop between researchers and stakeholders. Whereas other ComMod approaches have used role playing games as an interface between researchers and stakeholders—assuming that stakeholders have difficulties understanding a computer model—this paper explores the potential of a participatory modeling approach in which stakeholders are directly confronted with the model by assessing its assumptions, interpreting simulation results, and suggesting scenarios.

The approach is applied to two villages in a watershed in northern Thailand. One lowland village, populated by farmers of mostly Thai ethnic origin, depends partially on an upland village inhabited by farmers of Hmong ethnic origin for its water supply. Water scarcity has led to conflicts between these two villages in the past.

In three rounds of participatory simulation sessions the potential of the ComMod model was tested. Our findings confirm that researchers face particular challenges in making local stakeholders understand the model as a reproduction of reality and not as reality itself. The idea of a scenario as a hypothetical situation was also difficult to convey. An ex-post analysis among participants showed that farmers who attended several sessions had a clear understanding of the model and one-third of the participants thought it useful to exchange points of view with the other community and to define new collective rules for water sharing. Applying ComMod in a context that is characterized by social tensions and power differentials, however, needs careful consideration of the potential implications on less powerful actors.

Keywords: Multi-agent systems; Companion modeling; Participatory research; Water scarcity; Thailand

Introduction

Agent-based modeling is a means to explore, explain, and assess the complex interactions between ecosystems and human actions. These models are most frequently used to enhance our scientific understanding or to recommend corrective policy action (Parker et al., 2003). Stakeholders, such as farmers, extension workers or local administrators, are usually only contacted at the time of primary data collection and are otherwise bypassed in the transfer of knowledge between the researcher and the policy maker. Still, those stakeholders are often directly affected by the new policies partly or fully, based on the results of those models. This is a severe drawback since the quality of the model, the relevance of its assumptions, and the efficacy of its use could be improved by involving stakeholders more actively in the development, testing, and use of the model. Companion modeling (ComMod) has been developed as one such approach that seeks to enhance stakeholder

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involvement in computer modeling, particularly in the field of natural resource management (Bousquet et al., 1999).[1] Yet many scholars have assumed that computer models are too much of a black-box that restrain rather than enhance the involvement of local stakeholders (Barreteau et al., 2001).

A common response to this perceived shortcoming has been the employment of role playing games (RPGs) as interface between stakeholders and modelers (Barreteau, 2003). With RPGs we refer to a model or a partial representation of reality, where players interact by following some rules and playing a specific set of roles. The use of RPGSs as an interface with stakeholders assumes that the latter would be unable to understand a computer model. This paper, however, explores the potential of a participatory modeling approach in which stakeholders are directly confronted with the model by assessing its assumptions, interpreting simulation results, and suggesting scenarios.

Stakeholder involvement in computer simulation is particularly challenging in cases where various sectors and stakeholder groups compete for the use of a scarce resource. In many watersheds of northern Thailand agricultural transformation, expansion of irrigated areas in the lowland, increase in dry season-irrigated agriculture, and recent institutional planning policy on land cover have increased the pressure on the management of natural resources (Laungaramsri, 2000; Walker, 2003; Neef, 2004). In recent years, conflicts over collective management of natural resources and, more particularly, over water have become more severe (Prabudhanitisarn et al., 2002; Neef et al., 2006). In many cases the underlying issue involves, on the one hand, water scarcity—its extent varying from severe and regular lack of water during the whole dry season to occasional water insufficiency depending on climate years—and, on the other hand, sets of communities and other stakeholder groups with dissenting perspectives regarding water management, different degrees of sociopolitical integration and varying levels of tenure security with respect to natural resources. Ethnic minority groups in the upper watershed areas, in particular, have been disadvantaged by lack of secure land, water, and forest rights due to the expansion of national parks, watershed conservation areas, and forest reserves in Thailand (Vandergeest, 2003; Walker, 2003).

The objectives of this paper are twofold. First, it tests the assumption whether stakeholders can be confronted directly with an abstract computer model of human–ecosystem interaction, understand the internal working of the model and differentiate between reality, scenarios and prediction. Second, it explores whether such an approach can be used as a decision-support tool to facilitate the negotiation over natural resources between stakeholders with conflicting interests. A case study of two village communities in northern Thailand is used to meet these objectives. Both villages (one northern Thai and one a Hmong ethnic minority community) are linked through an upstream–downstream interdependence and farmers in both communities depend on irrigation for their livelihoods. Additional stakeholders include a drinking water company in the downstream area and households consuming water. Discussions among stakeholders and researchers about the model and its results were organized through a series of three participatory simulation sessions.

The approach raises questions about technical, methodological, and sociopolitical issues. Technical issues—referring to the physical model development and the integration of its various modules—were previously discussed in Becu et al. (2003) and Ramanath and Gilbert (2004). In this paper we focus on the latter two issues, whereby 'methodological issues' refer to the process of involving stakeholders in model validation and scenario development and 'sociopolitical issues' are concerned with the social, institutional, and political context that bears on this process and affects the outcome in terms of negotiation and collaborative decision-making.

The paper starts with a brief introduction to the ComMod approach. After describing the context of the case study in northern Thailand, it gives details on the biophysical and socioeconomic components of the model. This is followed by a report of the three rounds of participatory simulation sessions. We then present results of an ex-post analysis among the participants of these sessions. The paper concludes with an assessment of the potential and constraints of participatory modeling.

Companion modeling

ComMod is an approach that combines multi-agent systems (MAS) with participatory research (Bousquet et al., 1999; Barreteau, 2003; Bousquet et al., 2005). MAS is a suitable tool for capturing the complex human-environment interactions in a spatial way, which can be recognized by the stakeholders. MAS applications conducted in the ComMod approach are, therefore, stakeholder-driven and can incorporate the multiple—and sometimes dissenting—views of various stakeholders (Etienne et al., 2003; Becu et al., 2005). ComMod approaches typically pursue two objectives. First, they seek to understand the complex biophysical and social environment; and second, they aim at supporting the negotiation and collective decision-making process in the management of common resources (ComMod Group, 2003; Bousquet et al., 2005).

The ComMod approach involves an iterative feedback loop between researchers and stakeholders in which the MAS is used as a tool that facilitates this communication. Fig. 1 illustrates this concept. The cycle includes three main stages: field work, modeling, and simulation. Fieldwork includes the primary data collection to calibrate a

[1] Other approaches where stakeholders are more or less actively involved in the modeling process include mediated modeling techniques (e.g. Antunes et al., 2006; Messner et al., 2006), integrated assessment (e.g. Pahl-Wostl, 2003; Hare et al., 2003; Jakeman and Letcher, 2003), and multi-criteria analysis (e.g. Hayashi, 2000; Jiang and Eastman, 2000).

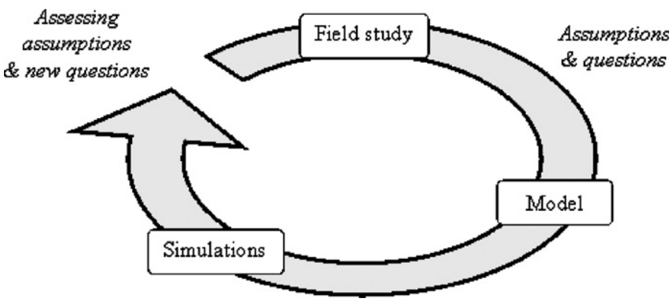

Fig. 1. Companion modeling approach involving stakeholders in model development.

preliminary version of the model and subsequent interaction with stakeholders that are used to refine the model. For this application, participatory simulation sessions are the medium for this interaction. During these sessions, the model and its hypothesis are presented to the stakeholders, simulations are run, and results are discussed. The discussions help the researchers to review the model's assumptions and to identify scenarios of interest to the stakeholders. A new version of the model is then developed and again discussed with the stakeholders for further refinement. Through this process the model develops into a shared representation of reality (Bousquet et al., 1999).

Scenarios are used to explore alternative options for sharing a common resource. Such scenarios can inform stakeholders about possible gains or losses (e.g., water supply and crop yields, as in this study) and thereby create mutual understanding among stakeholders with conflicting interests. Such mutual understanding might then assist stakeholders in finding a compromise.

Water allocation in the Mae La Ngun catchment

The case study is located in the Mae Sa watershed (Chiang Mai province, northern Thailand) and involves two villages in the Mae La Ngun catchment ($\sim$6.88 km^2). Pha Nok Kok is an upstream Hmong village cultivating litchi (partly irrigated during the dry season), gerbera cut-flowers (a biannual crop, harvested and irrigated all year round), and vegetables (grown during the rainy season). Pha Nok Kok is located within the boundaries of the Suthep-Pui National Park and farmers have not been issued secure land titles. Pha Nok Kok farmers take their irrigation water from the Mae La Ngun creek and its tributaries. The village of Muang Kham is located further down the creek and is a lowland Thai village growing irrigated cash crops, such as sweet pepper, chrysanthemum, and vegetables. Unlike their counterparts in Pha Nok Kok, farmers in Muang Kham hold secure land titles.

Farmers in Muang Kham, hence, depend on the upstream parts of the catchment for their water supply in the dry season. Water has become scarce since the early 1990s due to an increase in water use. During the dry season, farmers from Muang Kham complained that Pha Nok Kok farmers were using too much water (Neef et al., 2006). After negotiation, farmers agreed that vegetables in Pha Nok Kok would not be irrigated during the late dry season, which effectively meant that farmers could not grow vegetables during that time. In addition, lowland farmers in Muang Kham adopted drip irrigation and private groundwater wells to secure water supply and reduce their dependence on farmers in Pha Nok Kok. Although these actions relieved the problem to a certain extent, occasional water shortages still occur towards the end of the dry season, and village leaders are still looking for a more satisfying solution. After discussion with the village leaders, the ComMod approach was applied with the following objectives:

- to understand the interactions between the upstream and downstream villages;
- to build a shared view of water allocation and management options among the various stakeholders involved; and
- to support negotiation and collective decision-making among stakeholders.

To achieve these objectives a MAS model was developed and used as a medium of communication between stakeholders (Vinck, 1999), which would reflect the differences in opinions between stakeholders and could facilitate collective decision-making. The model is described in detail in the following section.

Description of the MAS model

In computer science, MAS are composed of autonomous agents capable of interaction. Agents can interact either directly or through changes in their common environment. Human organizations or society can be considered as a multi-agent system (Ferber, 1999). In addition to agents, MAS models in land-use science have a second component, which is a cellular model representing a physical landscape (Parker et al., 2003).

For this application, the MAS model was built on the Cormas platform developed by Bousquet et al. (1998) (see http://cormas.cirad.fr/). Cormas serves as a framework for integrating cellular automata representing the biophysical environment with an agent-based decision component representing the stakeholders.

Biophysical component

The biophysical component consists of three smaller models: a water balance calculating water transfer at the plot level, a hydrological model aggregating plots' water balance and calculating water flow at the catchment subunit level, and a crop yield model. These models are based on the CatchScape3 model developed for a similar area in northern Thailand by Becu et al. (2003). CatchScape3 has a time step of 10 days.

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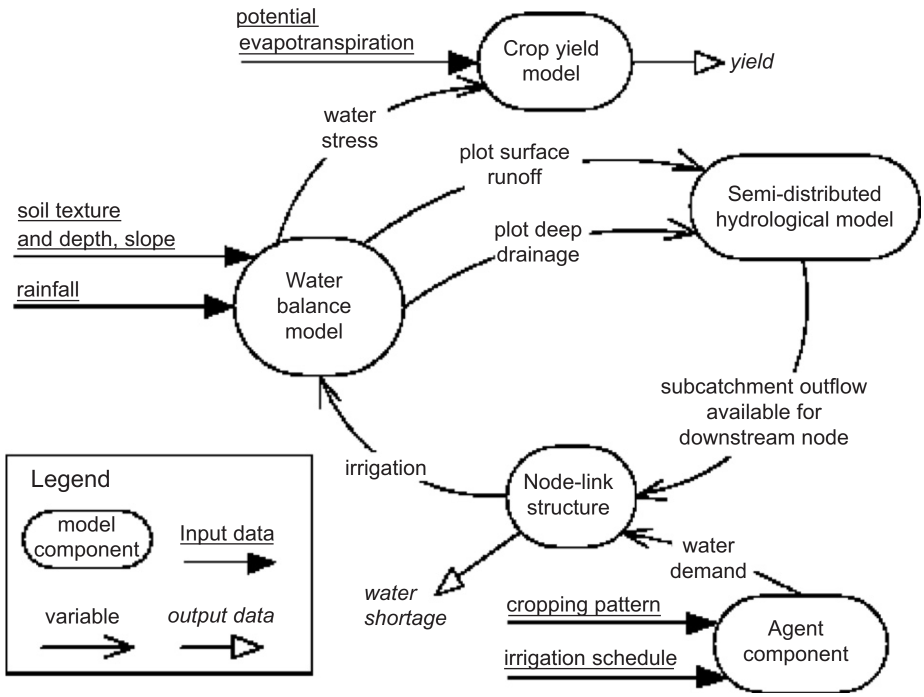

Fig. 2. Model components and data flows.

The study area is modeled as a set of single plots and the water balance model is run for each plot separately and is a function of soil texture, soil depth, slope, and the evapotranspiration of crops grown. The water balance model calculates deep drainage and runoff values at each time step and for each plot. These two variables are then used in the hydrological model to calculate the outflow of an area composed of several plots (Fig. 2). It uses a delay function for the runoff and a transfer function for the deep drainage. The water balance model also calculates a level of water stress for each plot; this water stress that together with crop-specific parameters capturing a crop's tolerance to water stress enters the crop yield model, based on the FAO CropWat model (Smith, 1992), to calculate a crop yield. Both, the water balance and the crop yield models ,are based on the Catchcrop model (Perez et al., 2002) and calibrated for a selection of crops and soil types in the study area.

A digital elevation model of the catchment was used to delineate subunits that are used to estimate water discharge at each outlet of a subunit, called a node. At each time step, the model first calculates the runoff and deep drainage of the plots in the most upstream subunit of the catchment. Part of the total runoff of the plots is directly transferred to the subunit's node, while the other part is delayed over the next steps in order to simulate the system's kinetics. The total deep drainage in the subunit is added to a reservoir representing the aquifer whose outlet flows to the subunit's node at each time step. The water discharge of this second node will then be the sum of what was received from the above node (after uptake withdrawal) and the runoff and deep drainage transfer from its own subunit. This sequence, called a node-link structure (Hromadka and Whitley, 1999), is repeated up to the last node in the area, which is the outlet of the whole catchment. Fig. 2 shows the model components and data flow graphically.

The node-link structure also simulates the allocation of water to the plots according to the water demand at each time step. For this, each plot is linked to the nearest upstream node. If the demand for one node can be met, the corresponding volume of water is transferred to the plots. If the demand cannot be met, some percentage of the demand will be allocated, which creates a water deficit for the plots. Agents' water demand is specified in the next section.

Spatial data on land use, soil types, elevation, and the stream network were included as attributes of the plots. All spatial data had been collected within the Uplands Program.[2] A raster format was used to represent all spatial data with each grid cell representing an area of 0.32 ha. Fig. 3 shows the land use and soil types in the catchment.

Rainfall data were obtained from a weather station maintained by the Uplands Program a few kilometers east of the research area. Three hydrological periods between 2001 and 2005 were used. The parameters of the transfer function, which is the most sensitive component of the hydrological model, were calibrated by comparing the simulated water discharge at the catchment outlet with

[2]Thai-Vietnamese–German Collaborative Research Program for Sustainable Land Use and Rural Development in Mountainous Regions of Southeast Asia. http://www.TheUplandsProgram.net.ms

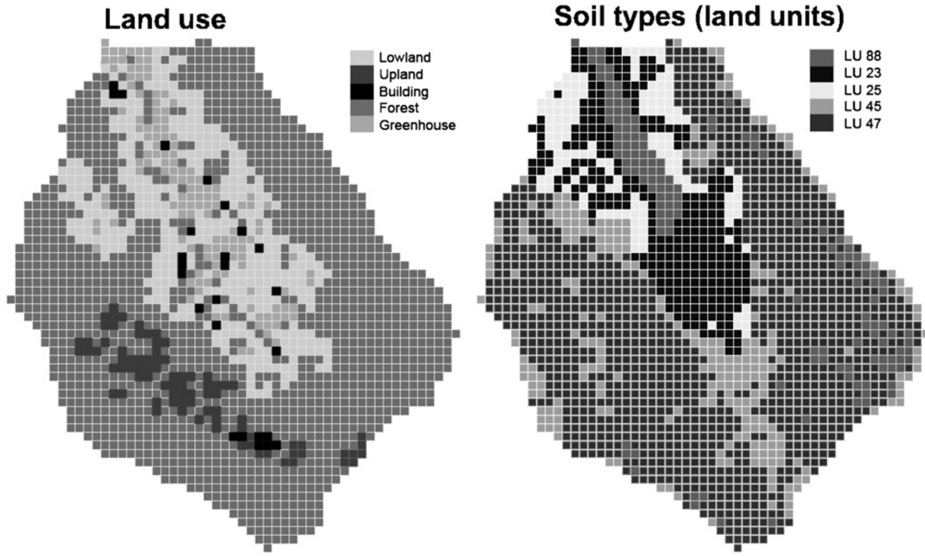

Fig. 3. Spatial interface of the model—view of land use and soil type of each plot.

the observed outlet discharge from comparable nearby catchments, as no discharge measurements were available for the Mae La Ngun catchment.

Agent component

Agents are model representations of the stakeholders. Three types of agents were identified: upstream and downstream farmers using water to irrigate crops, a drinking water company located in Muang Kham, and households in Pha Nok Kok consuming water from the stream.

Agent-farmers go through a sequence of planting, irrigating, and harvesting crops. Crop choice was not endogenous in the model, but taken from a survey to reproduce the observed cropping pattern. Scenarios were used to explore the impact of changes in cropping patterns. Three different cropping patterns for Muang Kham and one for Pha Nok Kok were identified. Each cropping pattern has a given irrigation schedule that farm agents follow. Each node's water demand is the sum of crop water demands of farm agents in a catchment subunit and follows the agents' irrigation schedule and crop choice. A distinction was made between water demand and actual water supply as simulated by the biophysical component.

Apart from seasonal changes in cropping patterns, the agricultural water demand is constant in the model. There is, hence, no feedback between the water balance and agent-decisions regarding crop choice as, for instance, implemented in Berger (2001) and Becu et al. (2003). In reality, farmers might adjust their land use or adopt different irrigation methods as a response to changes in the water supply. However, this simplification made the model much easier to understand by the stakeholders. The agent representing the drinking water company pumps underground water. The amount pumped is a function of water availability in the underground reservoir as calculated by the deep drainage in the hydrological model and varied between 1 and 6 m^3 at each time step.[3] Finally, the agents representing household water-users in Pha Nok Kok consumed 240 m^3 of water per time step, as estimated from a survey average of 60 l/person/day (March 2005). The actual water supply depends on the simulated water discharge at the nearest node. In the following section we discuss the results from the simulation sessions, their respective settings, and the process of stakeholder involvement.

Results from three rounds of participatory simulation sessions

A total of three rounds of participatory simulation sessions were organized in three-month intervals. The first and the third rounds were held for participants from both villages together at the office of the local Tambon (subdistrict) Administrative Organization (TAO). The second round—consisting of three separate sessions—was organized in the community meeting halls of the upstream (two sessions) and the downstream village (one session), respectively. All households in the two villages received a formal invitation letter in Thai language signed by the responsible scientist and distributed in person by a Thai research assistant, several days prior to the events.

The participatory sessions served two roles: stakeholder validation of the model and stakeholder negotiation about water allocation. At each round an adjusted version of the model—based on the results of the previous meeting—was presented and discussed with the stakeholders. Participants included farmers from the two villages, the village headmen, the elected representatives of the TAO, and the manager of the drinking water company. The number of participants varied from 6 to 15 persons.

[3] *Source*: Own survey conducted in March 2005

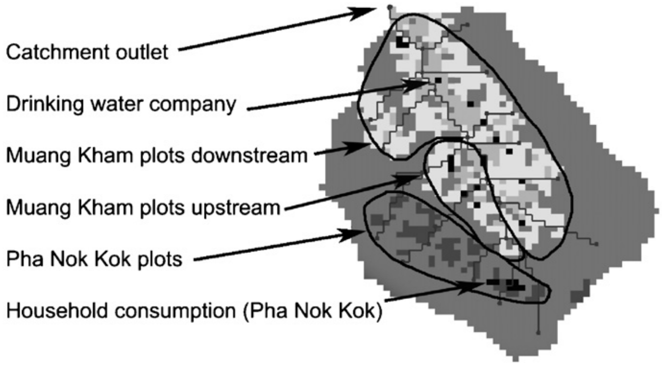

Fig. 4. Location of the simulated water scarcity results on the spatial interface.

Simulation of water shortages

Fig. 4 shows the location of the five types of water uses considered in the model. The cropping area of Muang Kham was split into an upstream and a downstream part as the upstream part was assumed to be differently affected by the Pha Nok Kok's water use.

The simulation runs from 1 April at a 10-day time step for a period of three years. The input data used for the simulation are the rainfall and potential evapotranspiration records of three hydrological periods (2001–2005). The climatic becomes gradually drier in each subsequent year, lowering the volume of outflows.

Table 1 presents the results for the dry season (~November–March/April) for the first two years of the simulation. The first column shows the frequency of severe water shortages for the five groups of agents. The second column shows the average percentage of water demand that was not satisfied by the biophysical component. How this affected crop yields is shown in the third column, in which simulated actual yields are expressed as a percentage of the yield potential.

Simulation results indicate that the lack of water for Pha Nok Kok and the upstream part of Muang Kham is in the same range, while the downstream part of Muang Kham is rarely short of water. These results are at odds with the commonly held view that upstream people have better access to water than downstream people, but they confirm a study by Sangkapitux and Neef (2006) in the same watershed, which also found water supply to be less secure in upstream than in downstream communities. There are two explanations, both of which have been integrated in the model. First, the downstream area benefits from the input of lateral subcatchments flow. Second, private groundwater wells secure the water supply but are mostly found in the downstream part of the lowland village.

The findings are similar for each of the three years in the simulation, though the drier the year, the greater the lack of water. Household water consumption in Pha Nok Kok shows the same trend, yet in this case water shortages occur later in the dry season. The water company never lacks water, not even during the third and driest year. The loss in crop yields is most severe in dry years and the upstream part of Muang Kham is again similar to Pha Nok Kok.

During the first participatory simulation session only the first water shortage indicator was presented, while the other two were introduced in subsequent sessions. During those sessions, participants suggested three scenarios that are shown in Table 2 and are hereby discussed.

Simulation results suggest that an expansion of sweet pepper cultivation in Muang Kham would solve the problem of water shortages in this village. A shift to gerbera in Pha Nok Kok would, however, increase water shortage for both villages. The construction of a water reservoir in Pha Nok Kok (storage capacity of $8000\,m^3$) would substantially reduce water scarcity in this village and slightly decrease water shortages in the lowland village as well. In this scenario, the reservoir would be used by Pha Nok Kok farmers to store water during the rainy season and for irrigation during the dry season. Still, the downstream village would benefit through a reduced water withdrawal from the stream by the upland farmers during the dry season.

Setting of the sessions

Each session had one moderator and two observers who were recording the participants' reactions and discussions in order to assess the perceptions about the model and the discussions about water use. After an introduction, the model's interfaces—displayed on a large screen using an LCD projector—were explained and one or two scenarios were simulated step by step and year by year to show the gradual changes of cropping patterns and water availability throughout the three years of simulation.

Model results were presented using two types of interface. A spatial interface showed a view of the current cropping pattern using a color code for each crop (far right in Fig. 5). A second interface visualized the results for each water user for each year. Stylized facial expressions ('smileys') were used instead of graphs and corresponded to a severe, medium, or low water shortage[4] (right in Fig. 5). At the end of each simulation year the results were summarized on a whiteboard and participants were invited to interpret the results for each stakeholder in the model (left in Fig. 5).

Four topics were proposed for discussion during each session: (1) the relevance of the model's assumptions (e.g. cropping patterns, irrigation schedules); (2) the main findings concerning water allocation between the different water users; (3) model improvements for the next model version and (4) possible further scenarios to be tested for a subsequent session. [R2.2] Session after session, the topics leading to most discussions shifted from model validation (topics 1 and 3) to stakeholder negotiation (topics 2 and 4).

[4]Severe water shortage is when actual water supply is less than 50% of the water demand; medium is in between 50% and 75%; low is above 75%

Table 1
Simulated water shortage during first and second year of the baseline scenario

	Year 1 (rainy year)			Year 2 (moderately dry year)			Year 3 (dry year)		
	Shortage period (days)[a]	Water deficit (%)[b]	Yield reduction (%)[c]	Shortage period (days)[a]	Water deficit (%)[b]	Yield reduction (%)[c]	Shortage period (days)[a]	Water deficit (%)[b]	Yield reduction (%)[c]
Muang Kham downstream	0	–	11	10	46	15	10	69	18
Muang Kham upstream	40	20	15	70	26	31	130	58	56
Pha Nok Kok	60	26	19	80	24	32	130	60	59
HH water (Pha Nok Kok)	50	–	–	70	–	–	150	–	–
Water company	0	–	–	0	–	–	10	–	–

[a]Number of days severely short of water.
[b]% of water demand not satisfied during the shortage period.
[c]Simulated yield depletion as % of yield potential (water unconstrained).

Table 2
Simulation results of three scenarios in terms of frequency of severe water shortages

	Baseline	More sweet pepper in Muang Kham	More gerbera in Pha Nok Kok	Water reservoir in Pha Nok Kok
Muang Kham (upstream)	70	0	90	60
Pha Nok Kok	80	80	90	30

Fig. 5. Model interfaces. Results board (right) and participant assessing results (left).

This was an expected process during which stakeholders first assimilate the tool and then use it for negotiation.

In the following section we present the results for each of the three rounds. The focus will be on the use of the model with local stakeholders and the outcomes regarding the negotiation process.

First round

During this first round, stakeholders from both villages were brought together to discuss the baseline scenario. Our intent was to moderate an interactive process from the very beginning in which both upstream and downstream stakeholders exchange their points of view in an open atmosphere. Participants had a varied understanding of the model's interfaces. Remarks by some indicated that they understood the simulation results. Other participants had difficulties orienting themselves on the map and understanding the changes between the time steps in the model. For some participants it was evidently difficult to understand the model as an abstract representation of reality as they were confusing facts observed in reality and results or elements from the model. Participants from both villages realized that water scarcity affects both villages in similar

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ways, after which they explained to each other how they currently deal with water shortages. Yet, the discussion stagnated when participants were asked to suggest possible solutions or scenarios that could be explored with the model. Existing tensions between the Hmong and the Thai communities, more widely observed in northern Thailand (Vandergeest, 2003), may have accounted for this. It was therefore decided to organize separate meetings in each village, thereby compromising on our aim of having different stakeholders interact directly during the sessions.

Second round

As the first round had not yielded any testable scenarios, individual interviews were used to define these and results were discussed in sessions of the second round. Participants in the two sessions held in Pha Nok Kok included farmers and representatives of the TAO, while the manager of the drinking water company also joined in the session in Muang Kham .

Participants had a better grasp of the model interfaces as they became more familiar with it. This became evident in Pha Nok Kok when, at the beginning of the first meeting, one participant explained to the others how the model was functioning and what the interfaces were showing.

As all participants came from the same village they were more inclined to discuss the scenario results, the implications for the different stakeholders, and the practical feasibility of proposed solutions. Interestingly, downstream stakeholders were mostly interested in the implications for their own village, while upstream stakeholders were concerned about the impact on both villages. The ex-post analysis, presented in Ex-post analysis section below, confirmed that their peculiar concern for their downstream peers was to make sure that their Hmong community would not be blamed in a conflict over natural resources and land use.

Third round

To stimulate the search for compromised solutions, all stakeholders were invited to a final session. We believed that this final round could initiate a public negotiation process between representatives of both villages, but we were proven wrong: although invited, stakeholders from Pha Nok Kok decided not to attend the session. The unequal balance of power between stakeholders might explain their decision, since Pha Nok Kok farmers have much more to lose in the negotiation process than their Muang Kham counterparts. The only representative from Pha Nok Kok present at the meeting was the receptionist of the TAO office, whom we invited on the spot and who reluctantly joined the session.

As some participants had not attended any of the previous sessions, time was needed to explain the basics of the model again. The scenario of a water reservoir in Pha Nok Kok was discussed and downstream farmers showed dissatisfaction with its location—suggesting that it should be located nearer downstream so that farmers from Muang Kham could also use it. It was unfortunate that upstream farmers were not present to discuss the relocation of the reservoir. During this last session, participants also discussed the type of outcome indicators used for the simulation results and suggested more suitable alternatives. For example, the model counted days when there was severe shortage of water. But when it came to assess the impact of a reservoir, participants asked for a more detailed categorization including days when there was moderate shortage of water and thresholds between moderate and severe lack of water were discussed.

The reluctance of representatives from the upstream village to join in this final event raises important questions about the impact of the approach in a context of stakeholders with conflicting interests yet unequal negotiating power. As Hmong farmers do not own land titles, their plots being located in a national park area, they might risk their land use rights if the model showed that their activities aggravate water scarcity in the catchment. On the other hand, Thai farmers in Muang Kham have secure land ownership and better relationships with government agencies and the local administration. It is noted that previous negotiation in the late 1990s had already resulted in self-imposed restrictions by Pha Nok Kok farmers not to grow vegetables in the dry season. As stated in the introductory section, the fact that ‘hill tribes’ are blamed for environmental problems is quite common in northern Thailand (Neef, 2004; Tomforde, 2006). An ex-post analysis was carried out to grasp some of these issues.

Ex-post analysis

The purpose of the ex-post assessment was to better understand why stakeholder participation dropped during the third session and to assess how participants had perceived the model and the impact of these sessions. The assessment entailed 18 individual interviews using a semi-standardized questionnaire among all people who attended one or more sessions and group discussions in both villages. Interviews were conducted by a Thai researcher unfamiliar with the previous sessions to minimize researcher bias in conducting the assessment.

Understanding the model

In the individual interviews we asked the participants whether they understood (1) the interface of the model, (2) why the interface changed after each time step, (3) what the model was doing during each step and (4) how it calculated the water shortages for each water user.

75% of the participants stated they had understood the model’s interfaces and the simulation process. Five months after the last session those villagers could give details about the meaning of the interfaces (e.g., the cropping patterns shown on the spatial interface and the meaning of figures

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and charts displayed). Those participants also understood the dynamics of the model, such as changes in cropping patterns and water availability. However, only a third of the participants understood that the outcome indicators, such as water scarcity and crop yields, were calculated by the model and only half of those had an idea of how the calculations were done.

The understanding of the model correlated strongly with the number of sessions a participant had attended ($r = 0.64$, $p < 0.01$). Nearly all participants who had attended two sessions understood the model's interfaces and simulation results and participants who understood how calculations were done had attended at least three sessions. These results indicate that stakeholders, such as farmers and administrative staff, can learn to understand the model but that it takes substantial time.

Perceptions about the purpose of the model

Each of the 18 participants was asked what they believed was the purpose of the model and the meetings. One-third of the participants believed that the model was a tool for researchers to teach the villagers. This group did not understand the possibility of using the model to test scenarios. Half of this group thought that the model was to describe and analyze the current situation and eventually find solutions, whereas the other half thought it was to predict what would happen in the future.

A second third of participants perceived the model as a research tool that could help in finding solutions by discussing its results together. Finally, for the last third of participants, the purpose of the model was mainly to support dialogue among stakeholders. These latter two groups were well aware of the possibility of using the model to test scenarios. Yet only 25% of the respondents understood how we could explore the system and search for solutions by testing various scenarios. These participants were also most active in proposing new scenarios for testing. Unfortunately, the format of the individual interviews did not allow us to provide evidence that the understanding of the purpose had changed over time.

Impact of the model

Participants were also asked in the individual interviews whether (1) they learned anything new about water allocation; (2) the sessions were useful to think and discuss about water allocation; and (3) they thought these sessions had affected or would affect water allocation. Responses to questions 1 and 2 differed markedly between the two villages, while the impact of the sessions was seen controversially in both villages. Whereas all participants in the upstream village stated that they had learned something new about water allocation and scarcity, only half of the respondents in the downstream village stated that they did. This difference probably reflects the fact that the downstream area of this village does not face regular water shortages since they have access to diverse water sources (surface water, springs, groundwater wells), while water scarcity is a recurring problem in the upstream area of the Thai village, Muang Kham, and the entire Hmong village, Pha Nok Kok.

Participants were also asked whether these sessions would have an impact on future practices. A first third of the participants was rather skeptical and said that these sessions will have no effect, either because it is only a research project (without a budget for improving water infrastructure) or they found that a satisfactory solution had already been found in the late 1990s (see above). Another third of participants were not sure what could be done after these sessions. The last third thought that these sessions enhanced exchange and dialogue between the two communities and would help defining new collective rules in the future. Participants from Pha Nok Kok belonging to this last third commented that besides helping them to face future water scarcity, the process was useful in promoting joint learning between the two villages, in obtaining coordination among stakeholders, and in preparing for collective decision-making. This view seems to contradict the fact that farmers from Pha Nok Kok did not attend the final session, but it appears to be related to their particular attitude towards water sharing and their position in the sociopolitical context, as discussed below

Attitudes towards water sharing and sociopolitical disparities

Participants considered the sharing of water as 'natural' and this sharing has become a common feature in the relations between the communities. Respondents in both villages also agreed that Pha Nok Kok villagers are affected more by water scarcity than villagers in Muang Kham. This is an important result since the common view in Northern Thailand is that downstream water users suffer from upstream villagers' overintake of water (Walker, 2003). Yet, participants from the two communities expressed markedly different views on the potential consequences of not sharing water in the future. Eight out of nine respondents in Pha Nok Kok stated that not sharing water would negatively affect their downstream peers and induce a conflict between the two villages, while respondents in Muang Kham unanimously agreed that whether or not they share water has no effect on farmers in Pha Nok Kok, which reflects their downstream position in the catchment and also the fact that these farmers increasingly resort to groundwater for irrigation.

The concern of upstream farmers for their downstream neighbors' access to water probably relates to their inferior sociopolitical position. Their location within the boundaries of a national park makes them 'illegal residents' in a strict interpretation of the law (Tongpan et al., 1990). In addition, being a 'hill tribe' puts them in an inferior position in dealing with local authorities (Tomforde, 2006). Avoiding conflict seems to be a rational response given these conditions.

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Discussion and conclusions

This application points to several methodological challenges in using participatory computer simulations with local stakeholders.

Computer simulations vs. role-playing games

The use of a visual computer interface to show simulated changes in the system is not trivial. It took more than one session for participants to gain a full understanding of what was shown on the screen and for them to give meaningful comments about the model's results and assumptions. The model was relatively advanced in terms of model complexity when it was first presented to the stakeholders; this complexity made it difficult for stakeholders to familiarize themselves with the model and to create a sense of co-ownership. This appropriation,[5] which comes after the model's assumptions are well understood, thus only occurred after several sessions and only among few participants.

A common response to the perceived shortcoming of participatory computer simulations has been the use of RPGs as interface between stakeholders and modelers (Barreteau, 2003). Boissau et al. (2004), for instance, have alternated the use of MAS and RPGs to assess in a joint process the driving forces of land-use changes in the northern Vietnamese uplands. In Senegal, a similar approach has been used to mediate resource conflicts between farmers and pastoralists (D'Aquino et al., 2003). When using RPGs, stakeholders are directly involved in the design of the model. Therefore, the model's appropriation is much easier and faster than with computer simulations alone. On the other hand, more time is needed to develop the model, as all modeling choices are open to discussion.

Tools exist, but there is a trade-off between time and money spent and the degree of stakeholders' appropriation one wants to reach. If appropriation by local communities has a cost, it also has a return on investment: a strong appropriation stimulates the adoption by stakeholders of the project recommendations (Hare et al., 2003). Depending on the objectives, a balance has to be found between the use of one tool or the other. That is why RPGs and computer simulations are often used in complementary fashion by ComMod practitioners. They alternate the use of each tool according to the stage and needs of the decision process (Bousquet et al., 2005; Castella et al., 2005).

Perception of the model and the role of the researcher

In this application, as for many early stage ComMod processes, it was difficult for local stakeholders to clearly understand the purpose of the model and the role of the researchers. Stakeholders had their own expectations about the sessions, for instance, some expected more recognition of their problems while others expected infrastructure to be built, and this influenced their perception of the model. The role of the researchers was furthermore ambiguous as a researcher was neither a person with full knowledge, as participants were asked to reconsider the model's assumptions, nor was he a fully neutral mediator, as he had his own objectives, nor could the researchers contribute to the physical implementation of the suggested scenarios. The perceived role of the researcher somehow evolves along the process as the model's purpose becomes clearer to participants. The results of the ex-post analysis indicate that at the end of three rounds of participatory simulation sessions, the researchers were perceived as neutral facilitators by some Pha Nok Kok participants and as an ambiguous mix of knowledge holders and development agency by Muang Kham farmers.

Implications and commitment to a ComMod process

This study shows that ComMod can have important sociopolitical implications when implemented in a situation of conflicting interests and an unequal balance of power. In such a situation, stakeholders might be risk-averse and avoid the negotiation process in a public sphere. This calls for a long-term commitment to joint learning and action in which understanding between the various stakeholders is gradually built up. On the other hand this also requires researchers to take responsibility and fully commit to the mediation process. In a ComMod process, researchers are no longer silent observers but become stakeholders themselves, as they are interfering with the system. The consequences of researchers' involvement cannot be anticipated and could disrupt the balance of power between stakeholders. This points to an ethical aspect of the research, which is also laid down in the ComMod charter (ComMod Group, 2003; see also http://commod.org) for which the researcher should bear responsibility. This ComMod charter is an evolving institution, the content of which is continuously discussed and modified by the members according to their experiences in the field. It underlines our limited control of the outcomes of a ComMod process. Yet, acknowledging our limits and reconsidering our knowledge is a first step towards our legitimacy as researchers acting on the ground and taking an active part in the decision-making process under study.

Dealing with evolving experimentation conditions

Combining tools and means such as those suggested in the above also enables the research to use triangulation methods to cross-check results. This is a key point in such a dynamic and adaptive research process: issues and peoples' perspectives are likely to change from one session to the other as different people participate in each session.

[5]Appropriation in its sociological meaning is the assimilation, acknowledgement and personal interpretation of concepts, ideas or objects (Thomas, 2000).

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Combining information obtained from participatory meetings with data gathered in surveys, RPGs, informal talks, and focus group interviews should be used to get more robust results.

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