Games, Role-Playing, Tools and models as a learning process to simulate groundwater management negotiation.

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ABSTRACT

How to make relevant decisions to preserve the quality of the hydrosystem and human wellbeing? This work assists in answering this question at a local level. A negotiation support simulator for a regional project is proposed which includes the numerous actors involved in water resource management projects. This simulator combines negotiation support tools and role-playing game for gravel extraction in an alluvial aquifer. During the simulation, each participant acts out the role of specific entity with their own objectives and stakes. Together, the players have to decide around the negotiating table, where is the best location for a new gravel pit location in the territory? During the negotiation process, they have to defend their interests and to accept the territory as a multidimensional entity (biophysical and human), to achieve a balanced solution. For this endeavor, each player may use different tools to design a spatial argumentation from GIS territorial representation. For example, to show the impact of the gravel pit on the aquifer, a player can create a resource for persuasion with a physical model (MODFLOW) or a biological model (subterranean ecology). The simulation familiarizes players with the complexity of territorial arbitration and negotiation support tools (GIS, physical and biological models). Furthermore, players are aware of the difficulty to produce *more ecological negotiations and consider human aspects in conservation of water resources*.

INTRODUCTION

Aquifers are very important water resources for human uses (e.i. supply, industry, irrigation, watering, or leisure activities) and for hydrosystem biodiversity. In addition, aquifers are in danger because they are treated as invisible resource. For Roux (2006), this vulnerability is composed of two criterions:

1) Vertical propagation speed of pollution to the aquifer;
2) Regeneration speed of water quality.

The aim of this work consists in simulating groundwater management negotiation, accompanied by a mediator, to reduce this vulnerability using an example of gravel extraction in an alluvial aquifer. This simulation makes use of an on line/web simulator composed simply of html pages, role-playing and negotiation support tools (e.i. physical model). Its design is based on the negotiation learning process developed by De Carlo (2003), notion of spatial representations proposed by Lardon & al. (2001) and the concept of spatial argumentation (Paran, 2005 available on line : http://www.agora21.org/entreprise/sommaire7.html ; Paran & Graillot, 2006).

Objectives of this negotiation simulation consist in design a commonly arrived decision to know:

- Where is the best new gravel pit location in the territory?
- What is the best method of rehabilitation after gravel extraction?
- Who is the more qualified to manage the site after rehabilitation?

This paper presents the method used to simulate groundwater management negotiation. It focuses on the use of physical model to design spatial argumentation for decision making. First results are discussed at the end of this paper.

METHOD TO SIMULATE GROUNDWATER MANAGEMENT NEGOTIATION

This section locates and presents the contested region defining its hydrogeologic characteristics. Then simulator architecture is described focusing on tools, and especially the physical model, for spatial argumentation.

Hydrogeologic View of the Area for Simulation

The study area was an alluvial aquifer located in the sedimentary plain of the Forez which is part of the Loire River catchment, France. This sedimentary plain has an area of 750 km². Average altitude is 340 m and the plain is crossed from south to north by the Loire River (Duclos 1967). The Forez aquifer is essentially fed by rainwater and is drained by the Loire River. The general groundwater flow direction is from southwest to northeast. The aquifer consists of quaternary alluvial deposits (gravels, sands, clays) and the surface area and volume of the aquifer are 10 km² and 18 km^3, respectively. The lower confining bed which consists of Oligo-Miocene impermeable claystone is located at a depth of 6 m below the soil surface. Although the Loire River is generally considered as one of the last semi-natural large rivers in France, the Forez plain has been highly modified by human activities including river embankment, intensive agriculture, and in particular gravel extraction (Ulmer 1997). Gravel pits either formed artificial ponds fed by groundwater or they were filled in with demolition materials.

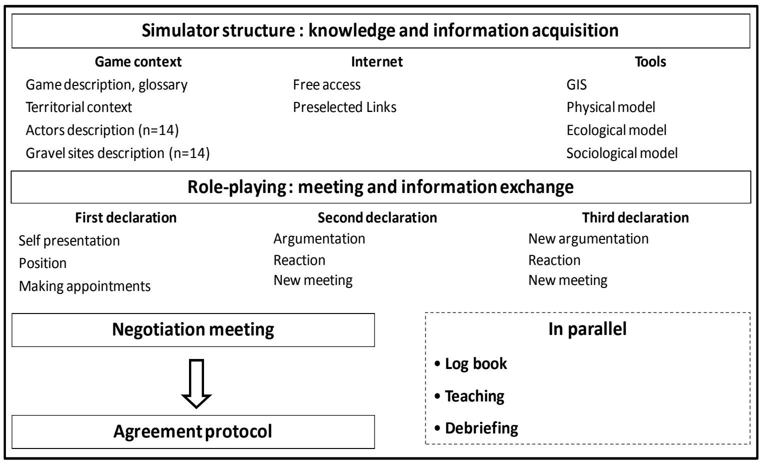

Figure 1. Simulator structure and role-playing game to simulate negotiation

Figure 2. Negotiation simulator home page (only in French at present)
On line: http://www.emse.fr/site/negociation/index.html

Simulator Structure and Role-Playing Game to Simulate Negotiation (figure 1.)

Technically, the simulator is designed and functions like a web-site and is written in html language with interactive links (figure 2.). By visiting the simulator each participant can find all necessary information to know what to do and create context for negotiation:

1) A short description of the game development stage by stage;

2) The territorial context, location, the gravel industry and gravel rehabilitation techniques are presented;

3) A glossary which defines all the key words used in the simulator.

To begin virtual negotiation participant have to choose their role to play. A game helps to gives all information and particulars about:

1) The 14 actors implied, like gravel industrialist, nature protector, fisher, hunter, famer, mayor or administration (e.i. name, activities, documentation, goals, stakes, territorial perceptions, or social relationships);

2) The 4 gravel sites in bargaining (e.i. location, profitability, impacts on groundwater, ecosystem, sociosystem or landscape).

This information is deliberately fragmentary to force each participant to meet each other and interact as well as use different tools. If the simulator gives knowledge and information on a computer, role-playing is the way to simulate negotiation in a room around a table. During the game, each participant has to write in a log book. It is very important to keep a trace of what happened during the simulation and analyze its development. Furthermore, there are debriefings to take stock of the situation stage by stage and teaching sessions to help participant and answer any theoretical questions.

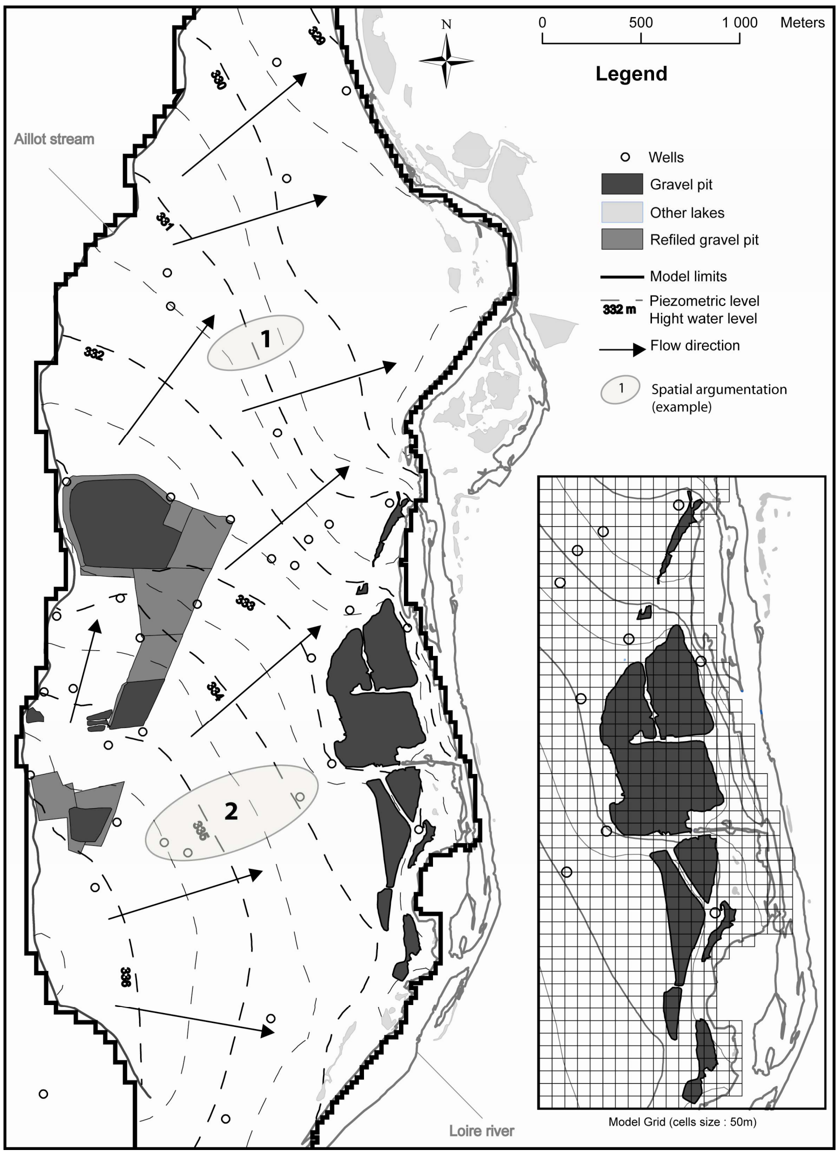

Figure 3. Spatial argumentation: examples in ellipses with number 1 and 2 (Paran, 2007)

The role-playing session is organized in several stages supervised by a mediator. First, each one has to make a preliminary public declaration to present the actor he (or she) plays and their position. Secondly, they begin to design an argumentation, based on meeting with the other actors or experts (e.i. hydrogeologist, ecologist or sociologist) and using tools, to defend his best gravel site and his best rehabilitation (e.i. wildlife reserve, refilled for agriculture, water storage or leisure activities). This resource persuasion is improved with the news of two declarations which take account of other actor's reactions. Thirdly, a final negotiation meeting is organized to decide, if possible, the final choice and write an agreement protocol with the help of a mediator.

Tools to Design Spatial Argumentation

Here, the argumentation is not only verbal but needs to be spatial. For this, each participant can use different tools, with the help of an expert, to design this argumentation and especially GIS (Geographic Information System) to represent reasons cartographically. Different tools are available to the player. Physical model (ModFlow) for a better understanding of the functioning of aquifer and simulate the future gravel pit's impact on it, biological model (subterranean invertebrate) and chemical model to refine this understanding with a different perspectives, multi-criteria analysis (MCA) for a valuation of the ecologic potential of the future gravel pit and sociological model for a better comprehension of actors.

RESULTS: NEGOTIATION AND SPATIAL ARGUMENTATION…

…Design with Physical Groundwater Flow Model

A finite-difference groundwater flow model (ModFlow type) was used with data from the following parameters; water level measurements in multiple wells, permeability values obtained from resistivity measurements and pumping tests, and estimates of rainfall, evaporation, and infiltration. The model provided piezometric levels for cells in a grid every 50m. The model was calibrated by modifying permeability until the calculated piezometric levels and the measured piezometric levels were similar (average error: 24cm). Details of the groundwater flow model were provided by Mimoun (2004).

With results of ModFlow, it is possible to design spatial argumentation on GIS maps making easier the choice of the new gravel site. The figure 3 gives two examples of spatial argumentation:

1) Argument 1 shows that site with strong hydraulic gradient must be avoided because it adversely impacts on aquifer flow;

2) Argument 2 shows that sites with wells upstream must be avoided too because wells could be pump out. Physical model can refine these arguments by simulating the impacts of futures gravel sites on hydraulic gradients and piezometric levels.

…Design by Another Physical Way

It is possible to design many physical representations and argumentations based on hydraulic objects (e.i. wells, piezometers, limnimeters, gravel pit, refilled gravel pit, stream), topography, geology (e.i. substratum level, alluvium nature), hydrogeologic attributes (e.i. permeability, gradients, flow speed, aquifer thickness, vadoze thickness). For example, we can spatialize aquifer pollution vulnerability in function of its vadoze thickness, quarry gravel richness in function of alluvium permeability.

DISCUSSION

Finite-difference groundwater flow models with regular grid are not the only existing models. For example, we can use finite-difference groundwater flow models with irregular grid which conforms better to hydrologic object shape (Mimoun, 2004) or analytic elements models which represent better hydrologic shape and field reality (Dauvergne & al., 2003). It could be very interesting for a better understanding of model results by actors.

But sometime, physical models are not sufficient for understanding aquifer functioning when they don't reflected a reality adapted to actors. Indeed, physical models present limits regarding their calibration (what is data precision?), their interpretation and significance (can the all actors understand these models?). Then it must be necessary to design another kind of argumentation for better representation of hydrosystem complexity and vulnerability:

- Firstly, a biological model based on subterranean invertebrates could be mobilized. These organisms are indicators of aquifer thickness and permeability (Paran & al., 2005). Then, a spatial argumentation for horizontal and vertical aquifer vulnerability and potential quarry gravel richness could be represented and designed. As we can use different physical models we can use different biological models based on different organisms (e.i. benthic invertebrates, macrophytes).
- Secondly, groundwater physico-chemical models could provide compelling reasons too (Paran & al., 2005). For example, we could show on map farming pollution with nitrates and its influence on gravel pit lakes water quality (e.i. eutrophication) in case of leisure activities rehabilitation; or impacts of refilled gravel pits on groundwater quality in wells.

- Thirdly, sociological models (Paran, 2005) could be use for a better understanding of actor territorial representations of hydrologic objects (e.i. aquifer, gravel pits lakes, river) and relationships (e.i. actors in conflict, in cooperation).

CONCLUSION

Finally, this work shows one way to mobilize physical model in a learning process to simulate groundwater management and design spatial argumentation with territorial representation like maps from GIS. This work takes all its direction by associating different kinds of complementary representations to build argumentation, because a territory, in our case groundwater, is multidimensional and made of physical, ecological and human dimensions. Moreover, maps are not the only way for argumentation, comprehension, and conciliation of typically complex environmental decisions. We can imagine other representations like 3D views, movies, or landscape diagram in accordance with sensitivity of the different territorial actors (Lardon & al., 2001).

In this manner, our work is a contribution helping to make relevant decisions to preserve the quality of the hydrosystem and human wellbeing. This work assists in answering this question at a local level, in a context of alluvial gravel extraction, and proposes a negotiation support system for a regional project including numerous actors involved in water resource management projects. The simulation familiarizes players with the complexity of territorial arbitration and negotiation supports tools (GIS, physical and biological models). Furthermore, players are aware of the difficulty to reach a *more ecologic negotiation and human conservation of water resources*.

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