MODELLING COMPLEX HUMAN-AQUIFER INTERACTIONS USING SIMULATION GAMES: An Agent-Based Approach

Never Stand Still | Faculty of Engineering | School of Civil and Environmental Engineering

Juan Carlos Castilla-Rho

PhD candidate in Hydrogeology and Water Resources (UNSW), funded by the Chilean government and UNSW

Supervisors: Gregoire Mariethoz (UNSW), Rodrigo Rojas (CSIRO) & Martin Andersen (UNSW)

EFFECTIVE MANAGEMENT OF GROUNDWATER REQUIRES A HOLISTIC VIEW OF COMPLEX HYDROLOGIC, CLIMATIC AND SOCIO-ECONOMIC PROCESSES

GROUNDWATER PROBLEMS ARE DRIVEN BY

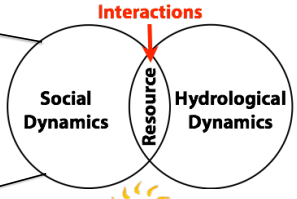
- Many actors
- Multiple points of view
- Rapidly changing realities
- Evolving, continuous, iterative processes
- Uncertainty
- Environment <-> Society interactions
- Actor <-> Actor interactions

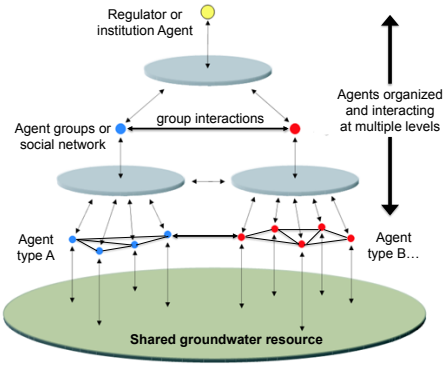
- **Socio-economic dynamics are often the most difficult to formalize.** Today, the oversimplification of social dynamics is common practice: humans are considered impartial observers or external drivers influencing groundwater but not being influenced by it.
- **However, the interactions between society and groundwater are two-way:** human decisions affect aquifer conditions, which at the same time affect future human decisions.
- **If we intend to better understand and manage human and natural impacted aquifers, there is a need to find methodologies that integrate hydrogeological and socio-economic dynamics**

AGENT-BASED MODELLING: A TOOL TO "GROW" ARTIFICIAL SOCIETIES FROM THE BOTTOM UP

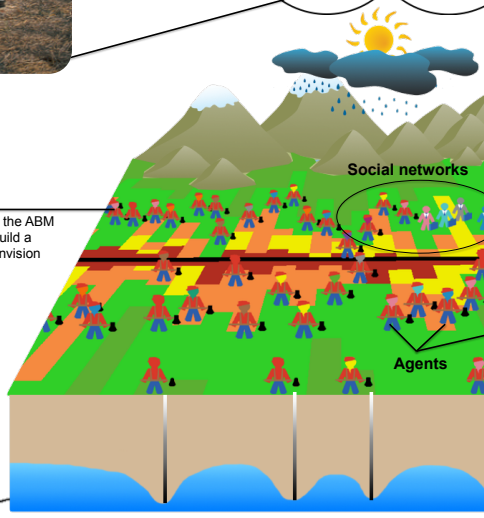
- **Agent-Based modelling (ABM) explicitly accounts for interactions between actors as well as feedbacks between human and groundwater systems**, by focusing on the elementary entities of society rather than on their collective behaviour. These elementary entities are called **agents**.
- Agents are implemented into individual pieces of computer code and are then situated in an environment, which they interact with. **Agents are unique, self-directed, and interact with each other through behavioural rules and a set of social abilities**.
- **The distinguishing feature of ABMs is the concept of emergence**: system patterns and complex order arising from the micro-level interaction of heterogeneous agents, who influence each other and adapt in order to be better suited to their environment

AGENT-BASED MODELS ALLOW US TO BUILD INTERACTIVE GROUNDWATER MANAGEMENT "LABORATORIES"





Agents
- Farmers
- Households
- Mining companies
- Government institutions
- Environmentalists



Interactions

Agents are organized and interact at multiple levels, e.g. water user associations, management districts, basin-scale regulation, etc.

Participatory simulation

Scientists, managers and stakeholders use the ABM as a scoping and exploration tool. Actors, build a shared representation of the system, and envision scenarios arising from their decisions.

Agent behaviour

Agents can be reactive or cognitive, their behaviour derived from surveys, heuristic rules, microeconomic theory, evolutionary programming or heuristic models

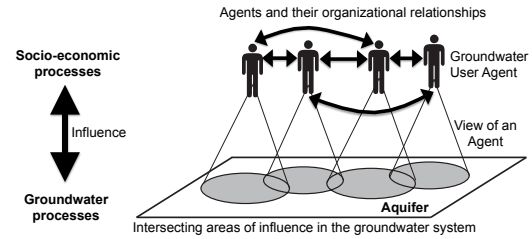
Agent-based model

The ABM couples a spatially explicit model of socio-economic processes with the groundwater model

Groundwater model

A fully-featured MODFLOW model defines the resource shared by agents

AN INTEGRATED, SPATIALLY EXPLICIT REPRESENTATION OF GROUNDWATER AND SOCIO-ECONOMIC PROCESSES



- Encourages collective decision-making and improved assessments in the water sector.
- A "participatory" ABM design is a unique and novel way to lead multi-party negotiation tables dominated by distrust and uncertainty, contributing to relieve tensions and building trust between actors.
- Provides a basis for sustainable expansion of the resources sector and water resources in developing countries.
- Allows more resilient, far-reaching solutions to groundwater management.

RESEARCH PORTFOLIO

Synthetic ABMs of generic groundwater management topics
- Resilience metrics for GW systems
- Conjunctive management of surface water and groundwater
- Water trading
- Water banking

Case study, Coupled hydrogeological and social model
- Copiapó Basin, northern Chile (Atacama Desert, ca. 18.000km^2)
- Complex GW-SW interactions
- Agriculture vs. Mining vs. Public Supply
- Inefficient water trading
- Multiple stakeholders with different viewpoints