DESIGNING SERIOUS GAMES TO UNDERSTAND THE CHALLENGES OF THE ANTHROPOCENE

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ABSTRACT

The challenges of the Anthropocene require a deep transformation of the world's economic organization. In order to manage such a change, it is necessary to have a systemic vision of the resources, processes at stake and their interdependencies. One possible approach to modeling part of this complexity is biophysical flow accounting. One of the challenges is to involve populations in participatory processes. It is therefore important to understand the systemic effects. However, biophysical accounting tools remain too complicated.

This is why we have designed serious games to present the issues in a simple way, to articulate them with concrete experiences already lived by citizens and to take a step back, by mobilizing their participation, their emotions and the discussions.

The first game was designed to show the geographical transfer of pressure through the description of the steps leading to the purchase of a chicken, starting with the vegetable culture allowing to feed it.

The second game was designed to show the competition of use between resources. Designed as a board game, it also involves reflection on the cooperative and competitive aspects of many societal situations.

Keywords: Sustainability, Multi- / Cross- / Trans-disciplinary processes, Education

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Cite this article: Boissier, M., Jost, V., Mangeot, M., Viénot, L. (2023) 'Designing Serious Games to Understand the Challenges of the Anthropocene', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.140

1 INTRODUCTION

The Anthropocene, formalized in 2000 by Crutzen and Stoermer (2021), is a geological era defined by the fact that the human footprint on Earth is comparable to large geological events. It poses physical (planetary limits) and social challenges to humanity (Raworth, 2013). These challenges require us to imagine and implement alternatives to the current global economic organization. Placing ourselves in the frameworks of strong sustainability and ecological economics, we choose here the accounting in biophysical flows (stocks and funds) (*i.e.* material, energy, human labor, type and land uses) as a grid for the analysis and design of these alternatives (Courtonne, 2016). These tools are indeed relevant to highlight systemic effects (interdisciplinary understandings, spatial and temporal scales) on resources and important pressures to consider for the transformation of territories. However, these tools remain for the moment expert tools, difficult to apprehend by all the inhabitants of the territories. However, one of the challenges of the future ecological transition is to involve the populations in participatory processes in order to put their knowledge, wishes and specific capacities for action in synergy (Biggs et al., 2021).

It is therefore important that the systemic effects highlighted by the biophysical flow analysis can be understood by citizens. This is why we have designed serious games : to present the issues in a simple way, to articulate them with concrete experiences already lived by the citizens and to take a step back, by mobilizing their participation, their emotions and the discussions.

Section 2 returns to biophysical accounting and specifies the popularization goals of our playful devices. Section 3 introduces the notion of games and possible design tracks. In section 4, we detail each of the two designed games two designed games (Vienot and Boissier, 2022a,b). Finally, we propose in section 5 an analysis of these games through the test sessions conducted.

2 UNDERSTANDING SYSTEMS THINKING THROUGH BIOPHYSICAL ACCOUNTING: OBJECTIVES OF THE GAMES

2.1 Biophysical accounting for the design of socio-technical alternatives

Biophysical accounting analyzes the organization of a territory via the energy and material flows (and stocks) and thus via the resources and pressures of this territory.
Equipped with various methods (life cycle analysis, input-output analysis, footprints, material and energy flow analysis...) (Courtonne, 2016), this approach facilitates a systemic vision.
From the analysis of material flows on a territory (e.g.: cereal sector in Rhône-Alpes), we can conceive alternatives by choosing to modify the value, or even the arrangement, of certain flows: the conservation of mass will then impose us to modify others until we return to a coherent situation. For example, if we want to increase exports, we will have to change production or other types of consumption. Thus, desirable modifications called “solutions” are identified, which ultimately involve compromises that are sometimes difficult to anticipate.
We can take this analysis further by coupling it with other regions and resources. For example, we can look at the water required by cereal production in each region of France. A region-by-region analysis of grain flows can then highlight the virtual import of water between French regions, inducing pressures on these territories Courtonne et al. (2016) (see Figure 1).

2.2 A simplification of the model: identification of important systemic effects

These tools still remain “expert”, without an interface allowing citizens to test alternatives (work is currently underway to remove the conceptual, mathematical and computational barriers to this (Mauviel, 2020)). We choose here to simplify them, identifying certain systemic effects that they particularly highlight.. We then draw on biophysical analysis to create games popularizing and putting these effects into discussion:

- **Competition in resource uses:** Many uses require the same resource (soil, material, energy, ...).
- **Geographic transfer of pressures:** a territory externalizes pressures when local consumption involves external production that induces pressures in the producing territory.

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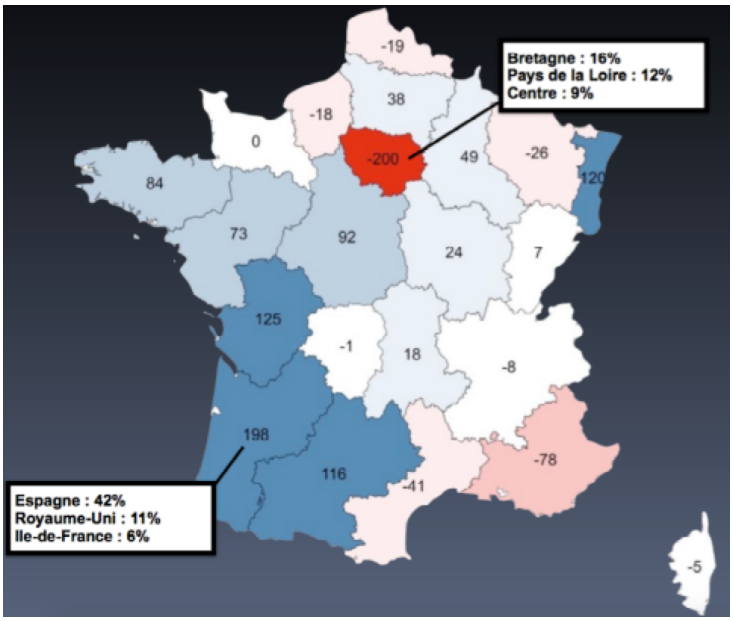

Figure 1. Virtual net export of irrigation water via the cereal sector (million m^3)

- **Transfer between pressures:** a production alternative shifts the pressure on the environment from one type to another.

2.3 Objectives of this work

In this work, we wish to create devices that allow us to discuss the systemic effects mentioned, and in particular the geographical transfer of pressures and the competition for the use of resources. In order to evaluate the relevance of these devices, we have chosen the ENCORE (Hassenforder and Ferrand, 2021) (External, Normative, Cognitive, Operational, Relational, Equity) analysis grid, with particular attention to the

- **Cognitive effects:** to the learning and to the modifications of individual representations,
- **Normative effects:** in what way the awareness of these devices can shed light on and modify choices,
- **Relational effects:** in what way the workshops impact the relations between the participants.

Observation during the workshops follows the grid proposed in Daré et al. (2020) and is detailed in Vienot and Boissier (2022a,b).

3 GAMES TO APPREHEND COMPLEXITY

In line with the *Simulation and Gaming* trend and famous complexity apprehension games (Meadows and Meadows, 1993; Meadows et al., 2016; Becu, 2020), we have chosen gaming as a tool for discussing the use of biophysical coherence constraints and models. These games are split into two phases : a playing and a debriefing one.

3.1 Playing phase: the power to act exacerbated by the playful situation

In order to analyse a game without locking it into a too rigid definition (Becu, 2020), Gilles Brougère has developed the "playfulness pentagon", see Figure 2, a multi-criteria characterisation of a playful situated activities with five features (de la Ville et al., 2010). The first two (underlined in the list) are necessary. The other three are reinforcing and are not necessarily present in a game:

- **non-literality**: one "fakes" and "another reality" takes place, the objets and situation meaning something else than usual,
- **decision-making**: one makes performative decisions with immediate consequences,
- **rules**: one agrees on the rules for making a decision. The limit of cheating is clear to all,
- **uncertainty**: one does not play if one knows how the game will end,

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- **frivolity**: actions made in a game have no real-world consequences, "losing" has no materiality, it is only a psychological disappointment of a few moments.

The non-literality, the decision-making and the frivolity create an environment in which the power to act is exacerbated (Becu, 2020). Indeed, these features push players to perform actions that immediately impact the course of the game (decision) but without effects on reality (non-literality and frivolity). This reduces the gap between what the person wants and what she does. The game then becomes a relevant tool for uses that go beyond simple entertainment: it can be used as a tool for studying postures and behaviors or as a mean of dialogue on the transformation of a real situation that has been made playful for the workshop.

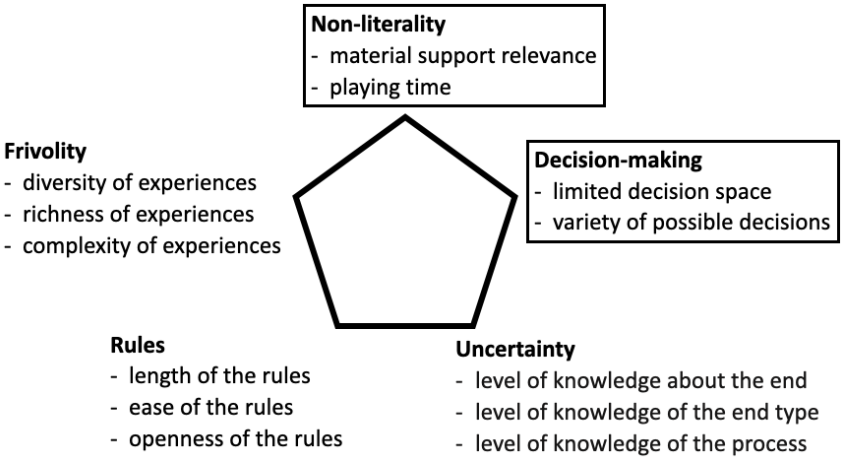

Figure 2. Playfulness pentagon and index, adapted from (de la Ville et al., 2010; Lardinois, 2000). Non-literality and Decision-making are necessary

3.2 Debriefing phase: exit from the game situation to return to reality

The game situation, by its reliance on the non-literality, is an environment detached from the real situation in which the participants will make decisions. If this increases the power to act, the return to reality is not obvious. On the contrary, the debriefing time allows the group to disengage from the playful situation to step back from what has been lived (Becu, 2020; Crookall, 2010). This reflective time allows the participants to analyze their experiences and conceptualize them in order to transform them into learning. This is also a time during which the participants can question the game device. Finally, especially in the context of a workshop set up by researchers to understand players' attitudes, the debriefing is a time during which the research experience is explained to the players.

The debriefing time is done in cycles of back and forth between real and game situations. The structure we choose is the following (Becu, 2020; Daré et al., 2020):

1. [Game] **Sharing emotions:** this time allows to unload emotions present in the game phase, which could interfere with learning and reflexivity.
2. [Game] **Reviewing the events of the game:** each in turn, players quickly review their game phase by explaining to others their reasoning and resulting actions.
3. [Game] **Identification of blocking points in the game:** the players identify together the problems encountered in the game, the obstacles that hindered or frustrated them.
4. [Reality] **Back to reality:** the players reflect on the parallels between the situation played and reality, and in particular about the obstacles and problems identified in step 3. The returns to reality are also times to discuss with the facilitators the limits of the game and therefore the assumptions chosen to build the model of reality it is based on.
5. [Game] **Identification the levers of action in the game:** the players think together about how the obstacles in the game situation could be lifted.
6. [Reality] **Analysis of these levers of action in real-life situations:** players question the relevance of the courses of action identified in step 5 to real-life situations.
7. [Reality] **Projection into the future:** reflection on the use of the identified levers of action.

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4 DESIGNING TWO GAMES ABOUT BIOPHYSICAL ACCOUNTING AND RELATED SYSTEMIC EFFECTS

In this section, we present successively the two games we have developed. All materials (rules, game materials, debriefing and observation guides) are available at (Vienot and Boissier, 2022a,b).

4.1 Four tracks to design the playing phase in relation with biophysical accounting

We present here four tracks followed for the design of our games:

- **Minimality:** As explained in section 2, we wish to enable citizens to apprehend visible systemic effects through a biophysical analysis of a situation. In order to allow an easier understanding of these effects, we have decided to focus each of the constructed devices on only one of them each time, trying to avoid any complexity that is not involved in the chosen effect.
- **Material support:** We choose to work only with material objects, without recourse to digital in the game, in order to take advantage of the spontaneity and tangibility that this allows (Duke, 2014).
- **Game mechanics to discuss biophysical accounting in territories:** A structured list of game mechanics is proposed by Rotenberg (2015). Since biophysical accounting implies notions of territory, resource and metabolism, we have relied in this list on two categories that echo them:
  - territory
  - resource management / transformation / combination.
- **Abstraction:** Although we wish in this work to highlight systemic effects on biophysical resources or pressures, different levels of abstraction can be tested: we can choose during the game phase to give a reality to the resources (water, cereals, CO_2, ...) or to keep abstract resources (red, blue counter, ...).

4.2 The chicken game: geographical transfer of pressures

Number of players: up to 8; Workshop time: 45 minutes playing and 1 hour debriefing.

4.2.1 Game objectives

The "Chicken Game" aims at highlighting the geographic transfer of pressures (see 2). For example, a country that imports grain also imports, virtually, the water that was used to grow that grain. This country then imposes pressure on the water resources of the country that produced these grains (see Figure 1).

We aim here to provoke on participants different types of effects:

- cognitive: questioning the participants' representations of a territory (what is interior and exterior, near and far) and the spatial scale they feel the most comfortable with. The objective is also to teach participants the concept of metabolism (*i.e.* that any product comes from a by-product that has been transformed), make them gain autonomy and curiosity to be interested in all stages of production chains.
- normative: pushing participants to question their choices, preferences, and views of responsibility (especially producer versus consumer). We also question the way in which these choices are made, by explaining the need for multi-criteria approaches (we cannot focus on only one type of environmental pressure or compare them easily).
- relational: allowing participants to make their priorities explicit thus facilitating dialogue on the transformation of territories.

4.2.2 Principle of the game

In this game, we follow the steps of making a roasted chicken, from the cultivation of soybeans in Brazil to the French supermarket. Each player represents a stage with its location and the pressures induced (land use, energy needs, water needs and greenhouse gas (GHG) emissions). Each of the players has information only about her/his step. One player plays the consumer. In the first phase of the game, the consumer (with the help of a magic card that allows him to discover the stages of production) walks up the production chain while the other players draw their way of representing the situation (see Figure 3). In a second phase, the consumer goes back down the chain, collecting pieces materializing the different pressures and ends up in the supermarket with all the pressures induced on the chain. Following this, a debriefing time is conducted.

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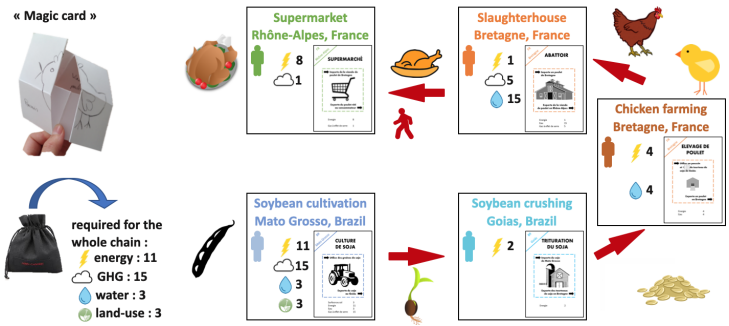

Figure 3. Chicken game

Figure 4. Cooperate or Compete game

4.2.3 Game design

To design this game, we prioritize first the representation of the systemic effect (minimality), then the design of the material support, and finally the playfulness. For this game we leave abstraction aside. For this game we choose not to work on abstraction.

Table 1. Chicken game: playfulness and biophysical accounting

	Playfulness
Non-literality	role-playing game, short playing time
Decision-making	non-performative: drawing
Rules	open
Frivolity	magic card
Uncertainty	revelation of information during the game
	Biophysical accounting representation
Minimality	– several geographical areas (territory), – production units (factories) defined by resource conversion formulas, – differentiation of consumer and producer points of view, – limited number of resources (and pressures) chosen to weigh on the whole chain while remaining meaningful and few in number, – NO notion of distance and transport.
Support	– production cards and tokens representing resources – "magic card" allowing to go up the production chain by manipulating an object.
Game mechanics	– territory is represented by the production cards – resource transformation is represented by the magic card
Abstraction	No abstraction in this game. The resources are directly soil, water, energy and GHG. A work of quantification and simplification of the pressures was made from life cycle analysis databases.

4.3 Cooperate or Compete: competition between resources

Number of teams: 3, (3 to 6 players); Workshop time: 60mn playing and 60mn debriefing.

4.3.1 Game objectives

The "Cooperate or Compete" game aims to highlight the competition for the use of resources, in other words the trade-offs to be found in the multiple possible uses of the same resource (see 2). For example, in the real world, agricultural production can be used for food or to produce bio-fuels.
We aim here to provoke on participants different types of effects:

- cognitive: enabling the understanding of the systemic effect and modifying each person's analysis of an alternative (in particular by assessing whether the alternative involves competition in resource use). We also test here the impact of the abstraction of design on the representations people make from reality.

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- normative: having the game and its rules criticized, its framework questioned and, during the debriefing, the "real society's framework" questioned.
- relational: sharing different representations evoked by the same abstract object, sharing the experience of a board game in a post-growth context, establishing relationships of trust and cooperation despite a competitive goal.

4.3.2 Principle of the game

In this game, players must go through each round together by creating required (3 different types, represented by the triangle, diamond and parallelogram in Figure 4 must be met). To satisfy each unit of need, there are 2 possible recipes, consuming different raw materials (bottom of Figure 4). These raw materials are obtained by exploiting a hexagonal territory (7 territories on the plateau). Some raw materials are renewable and others are non-renewable: the latter allow more efficient recipes, but they are depleting (obtained by a roll of the die, with increasing difficulty as the territory is exploited). Gradually deprived of these efficient recipes, players must fall back on renewable resources, leading to competition in their uses.

This game, inspired by the (blockbuster) board game "The Settlers of Catan", (Teuber, 1995) is calibrated so that collaboration is required to meet vital needs. However, the final victory is individual.

4.3.3 Game design

During the design of this game, we prioritize first the playfulness, then the abstraction and design of the material support (abstract material design, based on simple monochrome geometric shapes), and finally the representation of the systemic effect (minimality).

Table 2. Cooperate or compete game: playfulness and biophysical accounting

	Playfulness
Non-literality	rather long board game (2h with debrief)
Decision-making	– identical for all rounds of the game and for all players. – wide choice space: moving workers, territory to exploit, taking risks on non-renewables, choosing recipes, impact of an action on other players, negotiations, trading materials with other teams.
Rules	– reasonable, closed and rather difficult – minimal numerical quantities facilitating manipulations and calculations
Frivolity	low, but likely collective defeat inducing revolt, acceptance and learning
Uncertainty	– type of ending known: constraint of a number of survival rounds (6) – unknown ending and course: dependencies on dice rolls, individual choices, and degree of cooperation
	Biophysical accounting representation
Minimality	– small number (3) of vital needs to be satisfied in each of the 6 playing rounds – each unit of need can be satisfied with 2 "recipe" of raw materials – raw materials extracted by exploitation of territories – extraction of non-renewable materials requiring a die roll of increasing difficulty.
Support	simple, monochromatic geometric objects for all game components
Game mechanics	– turn-based board game with workers to be placed individually on hexagonal terrain intersections, allowing extraction of raw materials – individual transformations of resource combinations into products
Abstraction	maximum abstraction allowing players to represent contexts of their choice and to free themselves from the affects associated with certain types of products

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5 DEVICE TESTING AND RESULTS

We conducted 10 tests of game and debriefing workshops:

- the chicken game and associated debriefing was tested twice, once with researchers in the field and the second with 7 young adults in a board game bar.
- the "Cooperate or Compete" game and associated debriefing was tested six times, with researchers in the field, young adults in a board game bar, and children of INRIA staff from 14 to 16 years old.

These first device tests were aimed at measuring the effective popularization of systemic effects present in the biophysical analyses of a socio-technical alternative. We have thus evaluated in these tests how the playfulness and the biophysical accounting representations chosen could facilitate create cognitive, normative and relational impacts on the participants. To this end, observations grids have been created. We recall that the tests described here were preliminary tests, to improve our games before setting more rigorous protocols (e.g. laboratory experiments). Nevertheless, the discussions that took place during the debriefing times as well as the observation of the game times allow us to confirm the interest and originality of this work.

5.1 Results from the chicken game

Cognitive effects: participants seemed to understandthat there is a geographical transfer of environmental pressures. Yet, they focused more on the discrete values chosen to quantify the pressures in the game than on the effect itself, missing out a discussion on how this effect could be present in reality.
Relational effects: participants clearly shared their representations of the world, by debating the reality of the discrete numbers chosen for the discrete pressures.

5.2 Results from cooperate or compete

Cognitive effects: participants clearly engaged in the game making choices with collective consequences. Because of unexpected power relations allowed by the rules as well as the abstraction chosen for this game, players did not understand the systemic effect while playing. The debriefing phase was then crucial to make sure of the cognitive effects of this game.
Relational effects: the players are involved in choices with collective consequences. Thus, they really share their representations of resource management in the game. Once again, the debriefing is important to bring back these learnings to reality.

6 ANALYSING THE DESIGNING CHOICES

Two different strategies were chosen to design these games. In the chicken game (section 4), we have favoured the biophysical accounting representation over the playfulness of the game. In the "Cooperate or Compete" game, on the contrary, we sought playfulness before "minimizing" the mechanism of competition for resources use.

Table 3. Comparison of the two games

	The Chicken Game	Cooperate or Compete
Playfulness	Decision-making space not performative enough. Drawing comparison very interesting in terms of relational effects. Improving the playfulness by adding uncertainty, allowing the players to "bet"?	Decision-making space performative, non-literality allowed by the abstraction and the power relations. Favours players commitment and risk-taking.
Minimality	Adapted: mechanisms sufficient to discuss the geographical transfer of pressure and the questions underlying it.	Unanticipated power relations between players, blurring the highlighting of competition for resources use. Specific discussion about power relations added to the debriefing to then be able to focus on the systemic effect at stake.
Support	Adapted.	Adapted.

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Game mechanics	Adapted to understand the systemic effect but not enough for the playfulness.	Adapted with a hard work on choosing the recipes' values to balance between playfulness and systemic effect understanding.
Abstraction	No abstraction, tokens represent directly soil, water, energy and GHG. Return to reality in the debriefing phase easy. However, discretization from real quantified data to a limited number of tokens crucial for understanding the systemic effect at stake : questioned by the players and thus hindered the understanding of the simple pressure transfer mechanism.	Great abstraction, players played spontaneously, without connotation. Return to reality during the debriefing difficult, with a challenge for the facilitator to allow the players to understand the effect of competition between resources and to put it in parallel with real life contexts.

7 CONCLUSION AND FUTURE WORK

In this work, we choose to use games to popularize and discuss with a large audience the systemic effects highlighted by a biophysical analysis of socio-technical alternatives. Although this work is too preliminary to provide quantitative results on the effects of these workshops on the participants, the first results obtained confirm the interest and originality of developing playful workshops to discuss systemic effects. The playful situations created allow the participants to get involved in the workshop and the discussion time allow us to observe awareness and learning.

The first tests we made give us elements to continue improving the design of the two games presented. These first results also allow us to get feedback on the design choices made and therefore on those to be made. Indeed, in addition to improving existing devices, a short-term perspective is to continue creating these games to study other systemic effects. The next step will be to set up an experimentation to quantify the cognitive, normative and relational effects on the participants and to evaluate their learning. The workshops discussed take time: a game phase lasts between 45mn and 1h30 followed by a debriefing phase at least as long. This allows only one systemic effect to be discussed in a test session. In order to discuss these effects more broadly in a shorter time, these games should be redesigned to be shorter. Otherwise, one could imagine a single game bringing together different issues. However, this would mean giving up the minimality hypothesis which greatly facilitates learning (we have indeed seen in the analysis of the "Cooperate or Compete" game that the introduction of power relations is detrimental to the discussion of competition in the use of resources).
Finally, these tools of sensitization could be transformed into tools of reflection to be solicited during participatory processes, when the citizens reflect together on the transformations to be carried out on their territory. We could then move from a game to a modeling tool that the territory's actors could use, mixing the systemic effects presented and a biophysical analysis with other issues and other tools.

ACKNOWLEDGMENTS

This project has received financial support from the CNRS through the MITI interdisciplinary programs through its exploratory research program.

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