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Dossier « E. Ostrom »

A multimethod approach to study the governance of social-ecological systems

Marco A. Janssen[1], François Bousquet[2], Elinor Ostrom[3]

[1] Systèmes socio-écologiques, Center for the Study of Institutional Diversity, Arizona State University, Tempe, USA / Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, USA
[2] Systèmes socio-écologiques, UPR GREEN, CIRAD, Montpellier, Cedex 5, France
[3] Économie politique, Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, USA / Center for the Study of Institutional Diversity, Arizona State University, Tempe, USA

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Abstract – In this paper, we discuss the lessons learned from a project that combined different types of methods to study the interaction of ecological dynamics, experience of resource users, and institutional arrangements. We combined theoretical computational models, laboratory experiments with undergraduate students in the USA, field experiments, and role games with villagers in rural Thailand and Colombia. The expectation at the start of the project was that specific experience with resource management would affect the way participants play the game and the rules they would develop. We found that contextual variables, such as trust in other community members and the feeling of being an accepted member of the community, and also the ecological context had significant explanatory power, more than experience. Another conclusion from using these different methods is the fact that the quality of resource management lies more on the possibility of communication rather than on the types of rules crafted or selected.

Mots-clés :
Colombie ;
Thaïlande ;
jeux de rôles ;
pêcheries ;
foresterie ;
irrigation

Résumé – Une démarche multiméthode pour l'étude de la gouvernance de systèmes socio-écologiques. Cet article présente les résultats généraux d'un projet de recherche international visant à tester une combinaison de différentes méthodes pour étudier les interactions entre dynamiques écologiques, expérience des usagers des ressources et organisation des institutions. Nous avons combiné des modèles de simulation informatique, des expérimentations en laboratoire avec des étudiants aux USA, des expérimentations de terrain et des jeux de rôles au sein de communautés rurales en Colombie et en Thaïlande. L'hypothèse à l'origine du projet était que l'expérience de ceux qui ont participé à ces expérimentations affecterait leurs résultats. Nous avons trouvé que des variables contextuelles, telles la confiance dans les autres membres de la communauté ou le sentiment d'appartenance à la communauté ainsi que le contexte écologique, ont un pouvoir explicatif plus important que l'expérience des participants. La seconde conclusion que l'on tire du croisement de ces méthodes est le fait que la qualité de la gestion des ressources dépend plus de la possibilité de communication entre les usagers que du type de règles qu'ils choisissent ou qu'il créent.

Introduction

Increasing efforts are devoted to studying social-ecological systems (SESs) in an effort to understand principles of effective governance. This endeavor is challenging due to the complex temporal and spatial dynamics at multiple levels and scales. The complexity of SESs requires the use of multiple methods to derive different types of knowledge, varying from field studies and experiments to agent-based models and role games. In Poteete *et al.* (2010), the use of multiple methods in practice has been discussed in detail, resulting in a revised theory of collective action and the *Commons* that includes three elements: individual decision making, microsituational conditions, and features of the broader social-ecological context.

In this paper, we discuss the lessons learned from one of our projects that combined different types of methods to study the interaction of ecological dynamics, experience of resource users, and institutional arrangements. We combined theoretical computational models, laboratory experiments with undergraduate students in the

Corresponding author: F. Bousquet, bousquet@cirad.fr

USA, field experiments, and role games with villagers in rural Thailand and Colombia. We discuss the methodological challenges experienced in combining the different methods, as well as resulting methodological innovations. For example, the practice of field experiments and role games was adjusted after the investigators, who had experience with different methods, worked together to undertake both field experiments and role games in the same villages. Another example is the development of new laboratory experiments based on observations during field experiments. Moreover, we elaborate on how these methods have led to improved insights into the theoretical framework proposed by Poteete *et al.* (2010).

By going back and forth between case studies, experimentation, and formal modeling, we can address specific theoretical puzzles inspired by empirical observations and replicated and disentangled with formal models. The paper ends with lessons learned and methodological challenges ahead to study the fit between institutional arrangements and ecological dynamics.

Case study: dynamics of rules in *Commons*

An important question with regard to collective action of natural resources is the fit between ecological dynamics and institutional arrangements. How can appropriators craft effective rule structures? A long-term project to address this problem is used here as an example of the use of multiple methods. The project, which started in 2004 for a period of six years, was funded by the National Science Foundation of the USA. The project included scholars from Arizona State University (USA), Indiana University (USA), Universidad de los Andes (Colombia), and Cirad (France).

The original aim of the project was to understand how resource users craft effective institutional rules, how these are related to the ecological dynamics and the expertise of the participants. Such information would be of use to develop formal models of institutional change and adaptation, for example in the face of climate change. Since existing experimental work was mainly focused on comparing the effects of one institutional arrangement *versus* another, not how participants crafted rules, new experiments needed to have designs in which the rule-crafting could be observed more closely and that would generate new data that could be used to develop formal models.

From the start, the project aimed to include laboratory experiments with undergraduate students, field experiments, and role games with villagers in Colombia and Thailand. These countries were chosen because of existing contacts with an experimental economist, Juan-Camilo Cardenas, who had performed many field experiments in Colombia, and a modeler of social-ecological systems, François Bousquet, who had combined role games and agent-based modeling in Southeast Asia. Other investigators in the project were faculty from diverse disciplines at Indiana University, namely cognitive scientist Robert Goldstone, computer scientist Filippo Menczer, and political scientist Elinor Ostrom. The principal investigator, Marco Janssen, is an applied mathematician, who moved to Arizona State University during the project. All investigators were familiar with the details of some of the methods, but not with all.

During the beginning of the project, the investigators needed to get familiar enough with each other's method to start designing experiments. Building upon an existing experimental environment developed by Goldstone (Goldstone and Ashpole, 2004), new laboratory experiments were developed in which participants experienced spatial and temporal dynamics. Inclusion of those dimensions was important since meta-analysis of field studies has shown that these are critical to distinguish different types of institutional arrangements (Schlager *et al.*, 1994). With these laboratory experiments, microsituational variables could be manipulated and rule-crafting could be observed, especially when communications could be recorded because participants were using text-based chat rooms (Janssen *et al.*, 2008; Janssen and Ostrom, 2008). Using high-resolution experimental data, agent-based models could be tested in a rigorous way (Janssen *et al.*, 2009).

The field experiments and role games went through two years of preparation before the first experiments could be performed. Due to differences in methodologies used by the various investigators, new problems needed to be solved if both experiments and role games could be performed in all six villages in two different countries. Experiments went through a series of tests at the lab and then in the field. Once the protocol was written in English, it was translated in Thai and Spanish. It was then reviewed and approved by the institutional review board to ensure that human subjects are treated ethically and that their rights and welfare are adequately protected. This preparation of experiments and role games led to innovations for field experiments (Cardenas *et al.*, to appear. For the first time, this project combined role games and field experiments. Having the villagers first participate in field experiments, and then, later, adjust the field experiments into role games in line with their local context, represented innovations in the methodology of role games.

Some laboratory experiments performed later in the project were based on experiences derived from the field experiments. For example, an irrigation game characterized by asymmetry of access to the resource led participants in field experiments to balance efficiency (investment in infrastructure) and equity (allocation of water). This was translated into a downloading game in

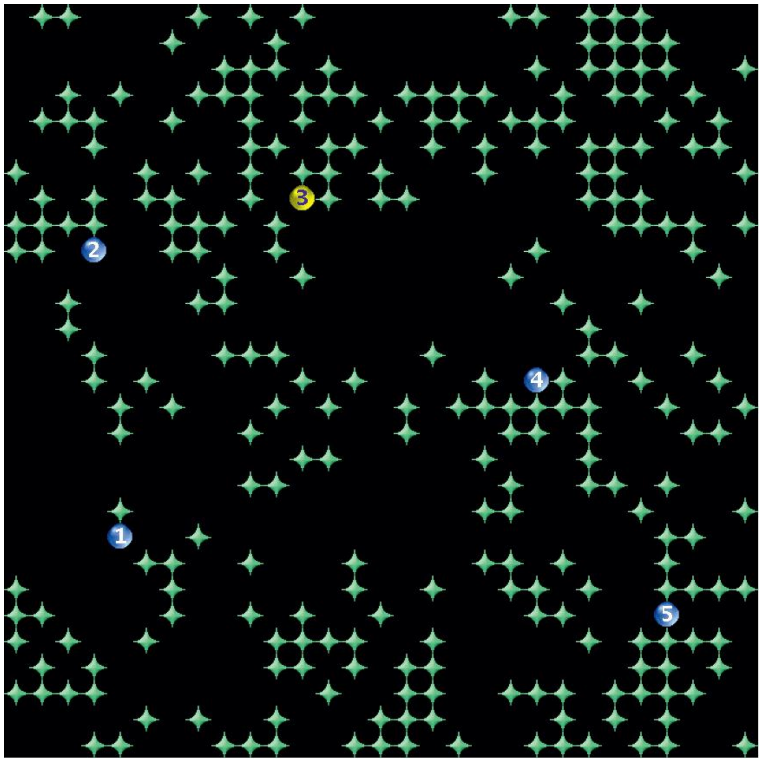

Fig. 1. A screen shot of the experimental environment. The star-shaped figures are resource tokens, the circles are avatars of the participants (lighter color is participant's own avatar (here it is Number 3), darker color represents other participants).

a laboratory experiment with a similar payoff structure, and similar findings (Janssen *et al.*, to appear). In the laboratory experiments, communication was allowed, which resulted in higher levels of cooperation and coordination over the rounds. There was more variability in the outcomes for the field experiments. The experimental designs that came out of this project would not have been possible if it had focused on one methodology. Scholars familiar with different methods who were challenging each other led to innovative designs that other scholars are now beginning to adopt.

We now discuss in more detail some of the results from the project before we discuss the implications for methodology and theory.

Laboratory experiments

The main research question related to performing laboratory experiments was what kind of rules would participants choose in different types of resource ecologies. In doing so, we have developed a new experimental environment that includes more relevant ecological dynamics than traditional experiments. Unlike previous experiments that utilize static, one-shot, or repeated interactions to investigate these issues, we investigate a real-time dynamic resource-harvesting setting. The software used for this experiment is open-source and available at http://commons.asu.edu. Participants appropriate renewable tokens from a shared renewable resource environment (Fig. 1).

In our experiments, groups of four or five share a few hundred cells. In order to collect a token, a participant must position their avatar on the location of that token and explicitly press the space bar. Each token harvested is worth \$0.02 USD. Participants have complete information on the spatial position of tokens and can watch the harvesting actions of other group members in real time.

Empty cells have the potential to generate new tokens each *second*. The probability that a given empty cell will generate a token is density-dependent on the number of adjacent cells with tokens. The probability p_t is linearly related to the number of neighbors: $p_t = p * n_t/N$ where n_t is the number of neighboring cells containing a green token, N (= 8) is the number of neighboring cells, and $p = 0.01$ or 0.02. If an empty cell is completely surrounded by eight tokens, it will generate a token at a higher probability than an empty cell that abuts only three tokens. At least one adjacent cell must contain a token for a new token generation to occur. Therefore, if participants appropriate all of the tokens on the screen, they have exhausted the resource and no additional token generation will occur. By designing the environment in this manner, we capture a key characteristic of many spatially dependent renewable resources. The optimum level of appropriation depends on the initial starting conditions and probabilistic renewal of the empty cells. If we ignore the spatial variability, the optimal strategy is derived by keeping the resource at a 50% density and all tokens are harvested during the last second of the experiment.

Before we discuss a series of experiments in more detail, we first discuss the initial sets of experiments. In Janssen *et al.* (2008), the effect of an endogenous rule change from open access to private property is examined as a potential solution to overharvesting in *Commons* dilemmas. Five participants share a common resource and could not communicate. When they got the option to invest in private property in the second round of the experiment, half of the participants did. If a majority in a group invested in the option of private property, this option was implemented. Otherwise, the common-pool resource situation remained. Groups who had experienced private property in the second round of the experiment, made different decisions in the third round when open access was reinstituted in contrast to groups who experienced two rounds of open access. At the group level, earnings increased in Round 3, but this was at a cost of more inequality. No significant differences in outcomes occurred between experiments where rules were imposed by the experimental design or chosen by participants.

When we included face-to-face communication, we observed informal arrangements to divide up space and slow down the harvesting rate in various ways (Janssen and Ostrom, 2008). We observed that experienced participants, who had participated in an earlier experiment, in the study above, where private property was used as one way of controlling harvesting in this renewable resource environment, are more effective in creating rules, although they mimic the private-property regime of their prior experience. Inexperienced participants need an extra round to reach the same level of resource use, but they craft a diverse set of novel rule sets.

The third set of experiments is reported in Janssen (2010). In this study, we used an updated version of the experimental software using a square-shaped environment, like Figure 1, with four participants. We included a first round where a resource could be harvested by just one participant to confirm that participants avoid overharvesting if they do not share the resource. We also designed each round to last for four minutes. We communicated the length of the round to the participants to avoid that rapid overharvesting is caused by the uncertainty of the duration of a round.

After the individual round, four participants are randomly matched, leading each and every time to a rapid collapse of the resource. We continued the experiment for three rounds in which we allowed communication *via* text messages, chat, for five minutes. We were interested in the effect of communication and the type of rules they crafted. The earnings improved significantly with the allowance of communication. Text analysis shows that participants create informal institutions that define when, where, and how to appropriate the resource and this varies with the ecological dynamics in the different treatments. These treatments differ by the regeneration rate, and spatial heterogeneity *vs.* homogeneity of the resource regeneration rate. The informal arrangements focus on several possibilities: (1) dividing up the space into four areas, (2) waiting or not to harvest at the start of the round, and (3) how many seconds before the end of the round can the rules be ignored so as to collect all the remaining tokens.

By analyzing the content of all messages and coding them into twenty different categories, we find that the amount and distribution of communication messages – not the content of the communication – explain the differences between group performances.

The first three studies showed that participants are able to craft rules to avoid the tragedy of the *Commons*. We also gained sufficient experience with this new experimental environment to be ready to use it to test the recent findings in experimental economics that costly punishment increases gross earnings. We include costly punishment by allowing participants to click on the number of the avatar, which reduces their own earning by one token and the other participant's earning by two tokens. We performed a number of experiments in which we varied whether we start with communication and/or costly sanctioning for three rounds, or end with it (Tab. 1).

Our experiments show, however, that costly punishment is used but lacks a gross positive effect on resource harvesting unless combined with communication (Janssen *et al.*, 2010). Figure 2 shows that costly punishment does not lead to a significant change. Communication after three rounds without communication (and costly punishment) increases the earnings, and thus performance. However, if communication and costly punishment are allowed (and used), the earnings drop significantly when communication and punishment are no longer allowed.

Field experiments

We performed a series of experiments in six rural villages in Thailand and Colombia: three in Thailand and three in Colombia. The villages were selected to represent a dominant resource use of one of the three resource appropriation activities: fishery, forestry, and irrigation. In Thailand, experiments were performed in the Petchaburi watershed, situated in western Thailand, in three separate locations: one in the coastal area, and the other two in inland areas. The Colombian experiments were conducted in three different rural sites. The fishery community is represented by a village on Barú Island, a rural

Table 1. Experimental design.

Name	Number of groups (individuals)	Practice	Periods 1–3	Periods 4–6
NCP-CP	6 (30)	Individual resource	Neither communication nor punishment (NCP)	Communication plus costly punishment (CP)
CP-NCP	6 (30)	Individual resource	Communication plus costly punishment	Neither communication nor punishment (NCP)
NCP-P	5 (25)	Individual resource	Neither communication nor punishment (NCP)	Costly punishment (P)
P-NCP	6 (30)	Individual resource	Costly punishment	Neither communication nor punishment (NCP)
NCP-C	5 (25)	Individual resource	Neither communication nor punishment (NCP)	Communication (C)
C-NCP	5 (25)	Individual resource	Communication	Neither communication nor punishment (NCP)

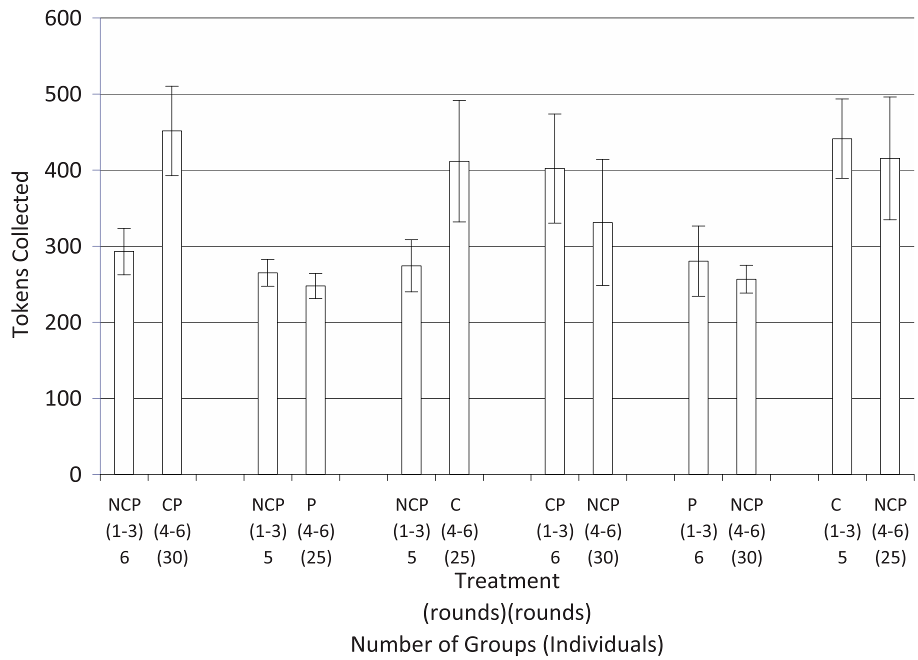

Fig. 2. Average net number of tokens collected by groups per period. The tokens lost due to punishment are subtracted from the total tokens harvested. Six different treatments are distinguished with combinations of No Communication or Costly Punishment (NCP), Communication (C), Costly Punishment (P) or Communication and Costly Punishment (CP) [based on Janssen *et al.* (2010, p. 616)].

area of Cartagena city on the Caribbean Coast. The irrigation community is located in the Fúquene Lake basin area, located in the Andean region of Cundinamarca and Boyacá; the forestry community is located on the Pacific Coast tropical forest area. The experiments have been replicated with college students in Bogota and Bangkok.

In each village, each of the three resource games were conducted with four groups of five people. As a result, 480 individuals participated in the experiments (see Tab. 2). We performed three types of games in each village: fishery, forestry, and irrigation. The basic structure was that participants first experienced ten rounds of the game, and then could vote for a rule change. The three types of rules participants could choose from were lottery (random access to the resource), rotation (predefined schedule for when to access the resource), and quota (limited allowable harvest). After the voting, the group continued with the rule they elected. All decisions were made in private.

The goal of the experiments was to test how relevant experience with resource management affected the decisions participants made and the rules participants elected. We expected that, for example, a fishery game would be played differently, more cooperatively, by fishers than by foresters and farmers. After each experiment the players were asked to answer a set of questions on the set of rules (How efficient do you think this rule is for managing the resource? How fair do you think this

Table 2. Experimental design and sample.

Sample	Fishery village	Irrigation village	Forestry village	City	Total
Fishery game	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	160
Irrigation game	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	160
Forestry game	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	160
Total	120 people 24 sessions	120 people 24 sessions	120 people 24 sessions	120 people 24 sessions	480 people 96 sessions

Table 3. Maximum harvest allowed (forestry game).

Current resource level	Individual maximum harvest level
25–100	5
20–24	4
15–19	3
10–14	2
5–9	1
0–4	0

rule is for managing the resource? How much personal freedom do you think this rule allows you in managing the resource? How much do you think this rule would advance your own self-interest as measured by your total earning? All things considered how attractive do you find this rule?). An individual survey was done with a section on collective action and trust. At the end of the series of experiments a handful of people were identified for in depth interviews.

Forestry game

The key feature of the forestry game is the renewable component of the stock of timber. The stock is represented as 100 magnets, trees, on a board. In each round, participants can take a maximum of five magnets from the board. The stock will regenerate. For every ten magnets on the board, one magnet is added, with a maximum of 100 magnets. When the stock is below 25 trees, the maximum number of magnets each individual is allowed to extract is indicated in Table 3. When participants collect as much as possible as fast as possible, the stock will be depleted in five rounds, and the tokens collected by the group is 119. When they cooperate and maximize, the group earning the group total can increase to 165 for a sequence of ten periods or rounds.

The resources are rapidly overharvested in the first ten rounds (Fig. 3). After participants have voted for one of the rules (55% voted for rotation, the other two rules split the rest of the votes), the decline of the resource slows down and participants harvest on average a 20% more trees. However, due to the frequent rule violations the net earnings did not increase. If we look at the individual level behavior of the participants we see that when harvesting is not allowed 70% break the rule. When a rule is broken, a lower amount of trees is harvested than normal. This leads to a reduction of the harvesting pressure, but due to penalties being paid when caught illegally appropriating trees, the net earnings do not increase. More in-depth statistical analysis reveals that participants who feel less accepted as a member of the community are more likely to break the rules (Janssen *et al.*, in preparation). Furthermore, those who have a higher level of trust in others in the community are more likely to break the rule, probably because they trust others will accept the rule breaking as is usual in these circumstances. We do not find that games played in villages dominated by forestry make different decisions than other villages.

Water irrigation game

In the irrigation game, participants receive ten tokens each round and must first decide how much to invest in a public fund that generates water for the whole group to share; then each player, in sequential turns from upstream to downstream players, decides how much to extract from the generated water. Each token kept (not invested) has a monetary value for the player and is equal to the value of each unit of water extracted.

Participants have positions A, B, C, D, or E, where A has the first choice to harvest water from the common infrastructure. This game includes the dilemma of upstream participants who need the help of downstream participants to generate a favorable size of the common infrastructure. However, the downstream participants can only get benefits from the common infrastructure when upstream participants avoid the temptation to deplete the common resource and leave water for players downstream.

Under this asymmetric game, participants first experience a contribution dilemma and then face a resource appropriation dilemma when they extract from the generated resource. In Table 4, the water provision generated is defined as a function of the total investments of the five participants. Clearly under these incentives and rules, the

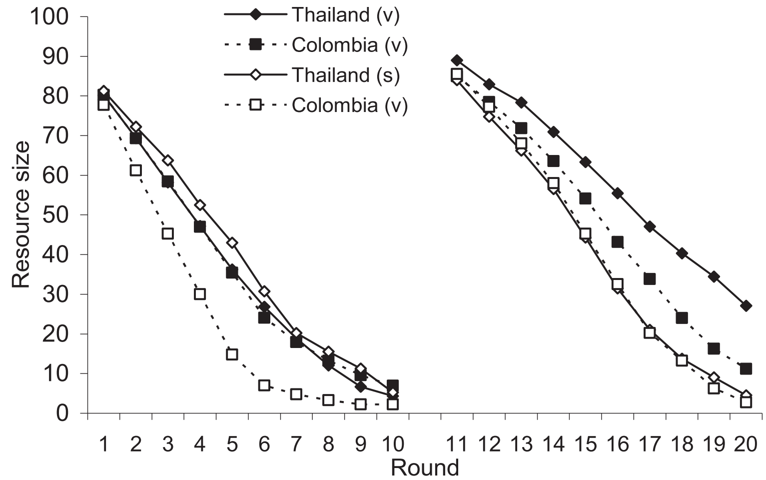

Fig. 3. Average resource size, number of trees, for the villages (v) and student groups (s) in Colombia and Thailand.

Table 4. Water production as a function of units invested in public funds (water game).

Total units invested by all five players	Water available
0–10	0
11–15	5
16–20	20
21–25	40
26–30	60
31–35	75
36–40	85
41–45	95
46–50	100

Nash equilibrium is that no one invests in the water provision, and all receive ten tokens for a group earnings of fifty tokens. In the cooperative (social optimum) solution, everyone invests his/her ten tokens in the public good, producing 100 units of income in each round. Therefore, for a sequence of ten rounds, the group earnings would sum 500 tokens and a social optimum could go up to 1000 tokens.

Our experiments show that there is a dynamic interaction between equality in the use of the common resource and the level of the contributions to the creation of a common resource (Janssen *et al.*, submitted). The initial levels of investments are explained by the level of trust participants have in other people in the community. Higher levels of trust correlate with higher investments. The investment levels are reasonably stable over the rounds, and systematically lower for students compared to villagers (Fig. 4). We also observe a distribution of investments into the public infrastructure that is independent of the position of the participants. However, the level of collected water is unequally distributed (Fig. 5). Participants upstream derive a higher share compared to participants downstream. Statistical analysis shows that inequality in the distribution of benefits in one round triggers lower levels of group contributions, reducing efficiency and triggering even more inequality in contributions and distribution of the resource among players (Janssen *et al.*, submitted).

A fishery game

In the fishery game, participants decide each round where to fish and how much effort to exert. There are two locations, A and B, to which they can choose to go. In each location, they can choose to exert low or high levels of effort. There is a slightly higher return from a high effort compared to a low effort (see Tab. 5). The payoff table is the same for both locations, and the initial state of the resource is the high fish availability (Tab. 5). However, when the total effort in a location is five or more units, the state of the fish stock will move to the low availability. This situation can only be reversed when not more than one unit of effort is invested in that location in two consecutive rounds. When participants behave opportunistically, they move to the low state of both resources in two rounds, and get stuck in that situation for the remainder of the rounds. For a sequence of ten rounds, this opportunistic behavior will result in 200 tokens for the five-person group. However, if they coordinated their efforts, the cooperative solution leads to 382 tokens by spreading the effort equally over the two resources where at least two people do not exert the maximum effort.

Figure 6 shows the average earnings over the rounds (Castillo *et al.*, submitted). The earnings drop quickly due to the state of the resource switch from high to low payoffs. However, the states of the fishing grounds remain low for most of the groups due to persistent high levels of effort. After rules are elected, the flip to the low payoff state was delayed, leading to higher earnings. The pattern is the same for both countries. If we look at all the villages, we find that fishing villages do overharvest more

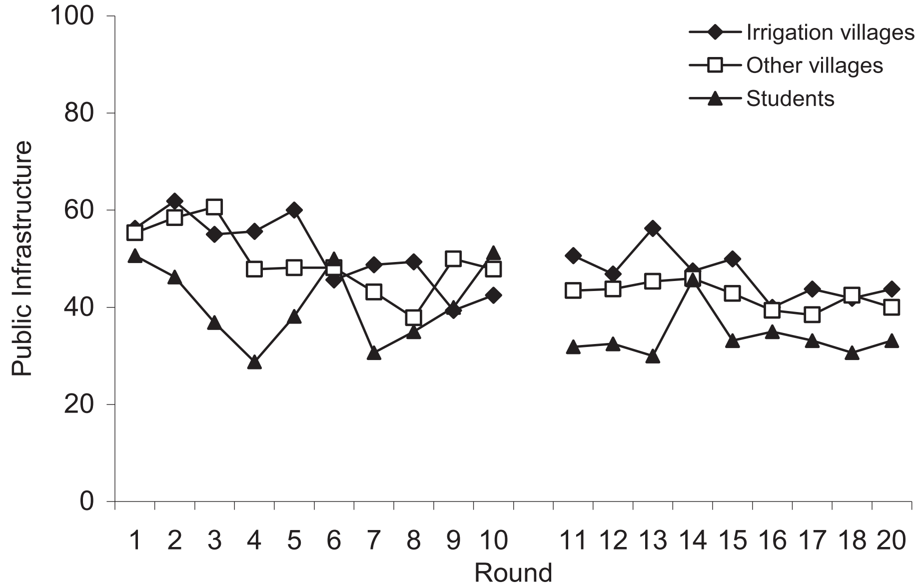

Fig. 4. The average level of the generated public infrastructure for irrigation village groups, groups from other villages, and student groups.

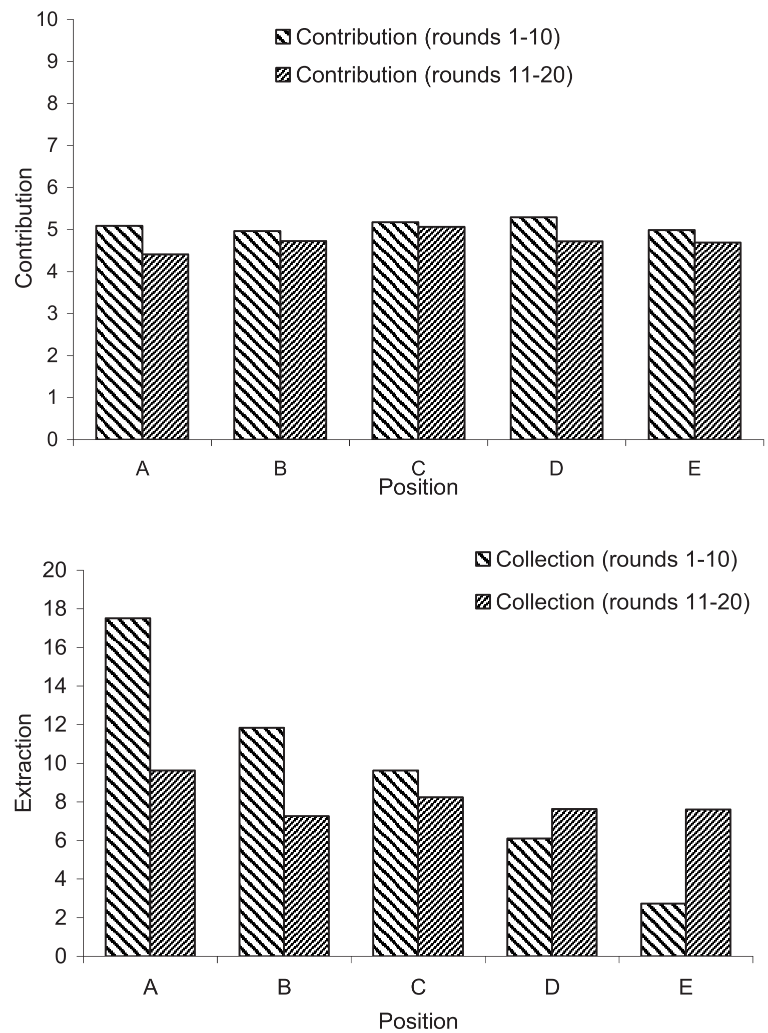

Fig. 5. Average investment in public infrastructure (top) and extraction from the water resource by location in the watershed (bottom) averaged over ten rounds.

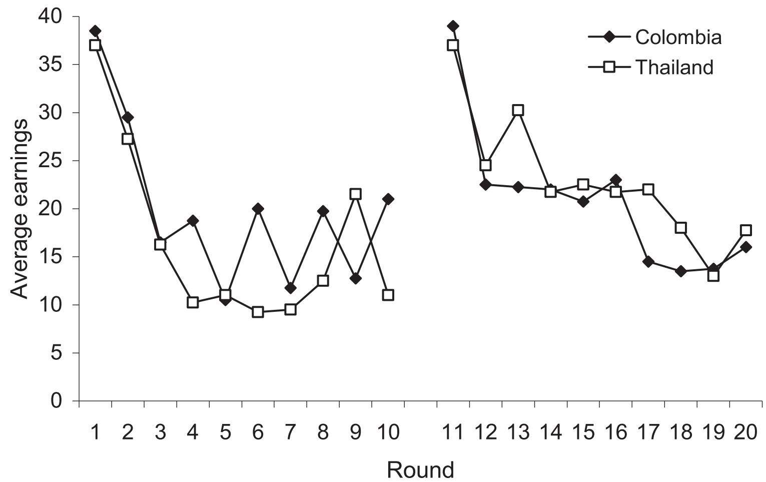

Fig. 6. Average group earnings in the fishing villages of the sample.

Table 5. Returns (tokens) from fishing effort and fish availability in one location (fishery game).

Fish available in location	Fishing effort		
	0	1	2
High	0	7	8
Low	0	2	3

than other rural villages and significantly more than the student groups.

Return visits

A year after the field experiments, we returned to the villages to discuss the settings and the results of the experiments. We then started to develop a role game of the experiment that was most relevant for the village (Castillo, in preparation). Through a self-construction process, the objective was to assess the type of context that needed to be added for relevant decision making. Given a set of guiding questions, a group of villagers adjusted the experiment to make it more relevant to their situation. Depending on the experiment, they included more ecological complexity (species, spatial heterogeneity), different types of actors (middlemen, industrial fishers), and technology (gear). After a role game was developed, it was played with new participants from the village.

Some general lessons can be drawn. For the forestry role-games in both the Colombian and Thai cases, the key driver is the system of economic transaction between the wood cutters and the buyers. The demand for wood drives the harvest effort. For the irrigation role-games, the villagers put the focus on water sharing but did not pay attention to the water-provisioning issue. The problem of provisioning is in fact a stake at a higher organizational level where water is shared among big canals. Locally, the farmers are less concerned. In Thailand, for example, a small group of farmers (about ten) on a common canal share the water according to the different needs. The sharing is collectively decided with the leadership of one farmer who takes the responsibility to visit the higher organizational level when the total amount allocated to the small canal is insufficient. With regards to the fishing villages, return visits have shown that the two ecological contexts are very different. The abundance of fish is poor in Colombia and rich in Thailand. However, in both cases, the fishermen played very competitive roles leading to the "tragedy of the *Commons*" pattern. The rationale is: "what is not caught by me will be caught by others." From the role games, we can understand that the fishermen brought their own "reality" in the field experiment, leading to difficulties for coordination. It also appears that (1) broader context affects cooperation levels at the local scale and (2) high levels of trust among local fishermen are not sufficient for resource sustainability when trust in external rule designers and enforcers is low (Castillo *et al.*, submitted).

Lessons learned

The expectation at the start of the project was that specific experience with resource management would affect the way participants play the game and the rules they would develop. We expected that participants with more relevant experience would achieve higher levels of performance and choose rules that increased the performance more than those groups who had less relevant experience. These expectations have been partly confirmed. Participants in laboratory experiments who were invited to participate a second time crafted effective rules more rapidly in line with previous experiences. In the field experiments, we derived mixed results. In general, the choice of rules did not improve the average earnings of the groups. It is interesting to note that students were more eager to vote for property rights while villagers preferred rotation and lottery types of rules. Although participants could vote for the rules, the three options were chosen by the experimenters and participants might experience those options to be imposed on them. We decided to have the same kind of rule choices for each game and each village in order to compare the outcomes. These rule choices might not have fit the local context in various cases, as shown for instance during return visits to irrigation villages.

We found that resource-specific experience led to lower cooperation in the fishery game among fishers. Since fishers in the communities where we performed the experiments expected the other fishers to be highly competitive (as shown earlier), they overharvested the resource more quickly than groups in other villages. When the experimental settings match the reality of the players, like for the fishery, we see that they actually imported their specific experience in the experiments. But this does not mean that they performed better, as in reality they do not perform well at preserving the resource and collectively maximizing their income.

We found that contextual variables, such as trust in other community members and the feeling of being an accepted member of the community, had significant explanatory power, more than experience. We included a sophisticated survey, but in hindsight, we should have included more options to measure the contextual variables of the social fabric of the community. Information about power relationships and status of the participants of the games might have been especially useful information.

Originally, we expected to have a tighter connection between the field and the laboratory experiments. However, the development cycles of the field and laboratory experiments are quite different. We invested more in software development for the laboratory experiments and started to focus more on communication since the use of text chat provides insightful opportunities. Although software development is slow, one can perform new experiments every year. The development, pretesting, and implementation of field experiments took years. Practical limitations led us to not do many experiments in one community nor to include novel treatments. The results of the field experiments led to many new questions, and we plan to perform a series of laboratory experiments with the design of the field experiments in order to narrow down research questions for future experiments in the field. We found a consistency between lab experiments and role-playing games: when villagers set a role playing game, they very often create an arena for communication but do not give any orientation on what will be the content of communication (rules, roles). This is consistent with the lab experiments, which revealed that the amount of communication is more important than the content of communications.

To conclude, our experiments, both the lab and the field, have led to new insights and methodological innovations. Social context seems to be more important than resource-specific knowledge in explaining the behavior in experiments. This confirms the recent focus on conditional cooperation. Participants use information of the social context to determine the types of participants in the game, and behave accordingly. This information might be derived from communication or from knowledge about other community members (in case the group members in the experiment are known, as was the case in field experiments).

Capturing context: a framework of collective action

In recent years, there has been an increased interest in field experiments and conducting experiments with nontraditional subject pools, such as hunter-gatherers. Henrich *et al.* (2010) focus on cultural differences and market integration that explain different levels of cooperation. Within the same culture, we also see differences in the decisions that participants make in social dilemma games (Gurven *et al.*, 2008). We need to move beyond the broad notions of "culture" and "context" and be more precise in identifying specific attributes.

Poteete *et al.* (2010) present an alternative framework of collective action and the *Commons* based on field studies and experiments, and stress the importance of microsituational variables, the broader context, and the relationship between them (Fig. 1). The conventional theory was pristine in the simplicity of its model of human behavior. All individuals were thought to be selfish and rational. Individuals were assumed to have complete information about the structure of the situation they are in, including the preferences of other actors, the full range of possible actions, and the probability associated with each outcome resulting from a combination of actions.

Decades of fieldwork and experiments emphasized that not all humans behave like selfish rational beings, and that participants do not complete information about all situations of interest to theorists. Furthermore, alternative formal modeling approaches, such as agent-based modeling, have shown that conditional cooperation can be explained for a wide spectrum of conditions (Axelrod, 1984). The project that we described is an illustration of the importance of using multiple methods that start to unravel the complexity of collective action.

The alternative framework provided by Poteete *et al.* (2010) is not complete, but it provides a starting point to identify the important attributes of action situations that need to be measured in empirical studies.

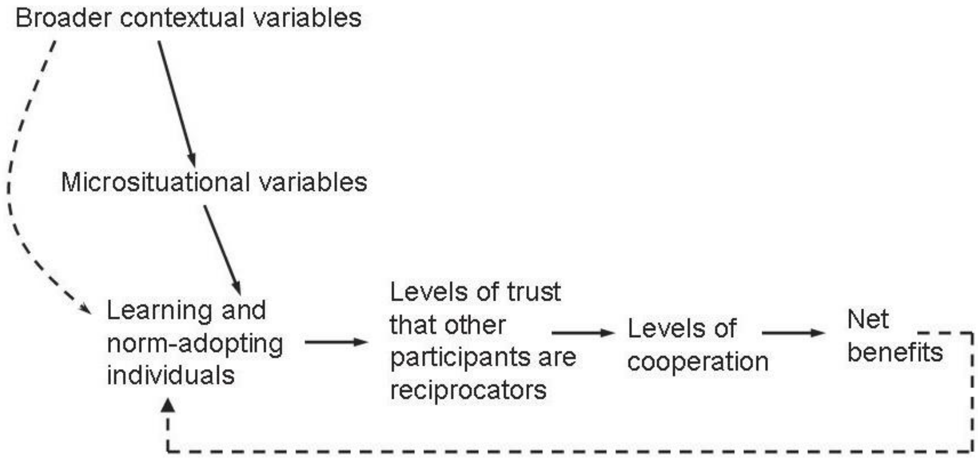

Fig. 7. Conceptual framework of collective action where broader context and microsituational variables affect the levels of trust and cooperation [based on Poteete *et al.* (2010, p. 221)].

Instead of assuming selfish rational individuals maximizing a particular type of payoff function with complete information, we need to base analyses on assumptions about individuals who have imperfect knowledge, who learn and adopt norms, and who are influenced by microsituational and broader contextual variables. Poteete *et al.* (2010) believe that behavior is more directly influenced by microsituational variables, which in turn are influenced by the broader contextual variables (Fig. 7). Examples of microsituational variables include group size, heterogeneity among participants, reputation, and time horizons. Examples of broader context are policies at higher levels of organization, resource dynamics, history of social relationships, and geography. For a more in-depth discussion of this alternative framework, we refer to chapter 9 of Poteete *et al.* (2010). We will now emphasize the application of the framework to our case study.

The microsituational variables in our experiments confirmed the high levels of cooperation we observed. The *group size* is relatively small – four or five people. The *reputation* of the other participants could be well estimated since the participants were fellow undergraduate students, or known community members. They had *repeated interactions* and could not change the group composition. When *communication* was possible, the level of cooperation often increased.

In field experiments, communication was not possible, but was introduced during the role games in the return visits. In some situations, communication did not improve cooperation, as the level of trust between people was too low. *Information* about the actions of others is extensive and accurate but limited to the group level in the field experiments. During the role-playing games, the players often set the information system to be aware of others' actions or others' demands. *Costly punishment* was an option in lab experiments, while sanctions were executed by the experimenter in the field experiment. In the role-playing games, the villagers did not keep the punishment options. A microsituational variable that may limit the level of cooperation is when the *time horizon* is known to be limited.

During the return visits, the broader context was more important. The lack of trust between the fishermen and the agencies in charge of resource management in the two fishery villages was very clear, explaining partly how reluctant the fishermen are to adopt rules. The other explanation lies in the lack of leadership or conflict among subgroups of fishermen. In the case of forestry villages, we have seen that both Thai and Colombian harvests are driven by the demand for forest products. For the irrigation village, the very conflictual situation between farmers and governmental bodies in Colombia is the key issue. In Thailand, the quality of the social relationships among farmers leads to a collective sharing of the water.

Ostrom (2007) introduced a diagnostic approach to study social-ecological systems. She acknowledged the many variables that can influence the level of collective action. Instead of measuring all possible variables, we need to define a multilayered system of indicators that match the social-ecological system of interest. In any case, this means that we need to measure contextual variables more systematically than is often done. Especially with regard to experiments, we need to derive more relevant information to interpret the actions in the experiments (Bouma *et al.*, 2008; Anderies *et al.*, submitted). In this project, we introduced the role-playing games, which allow the introduction of more context in the experiments. As the role-playing games are crafted by the stakeholders, after being in the experiments, researchers obtained better information about the relevant variable in a situation from the stakeholders' perspective.

Discussion

This project combines different methods to test a framework for collective action applied to renewable resource management. Both methods are based on "learning from action situations." Experiments in the lab, experiments in the field, and role-playing games put people in action situations. These methods differ by the level of control on the actors and the level of context they embed. While some propose very simple settings allowing generic conclusions, others include more context, allowing a better understanding of the decision-making process of the players (individual and collective). We propose here an articulation of the methods.

With lab experiments, we provided a renewable resource to the players, looked at the type of rules that players craft, and tested the role of sanctioning and communication. The field experiments were more contextualized. We measured the effect of rules in both settings. We associated the field experiments with self-constructed role-playing games to assess what type of context the players would add to make the experiments closer to reality. While doing so, we could assess how close to reality the earlier experiments were, and thus have a better understanding of the actions of the players during the experiments. For instance, during the field experiments, contrary to our hypothesis, we observed that the fishermen were worse than other types of stakeholders at playing the fishery experiments. We had thought that experienced people would be better at optimizing the results on a game similar to their reality. The role-playing game revealed that in the field, the fishermen are actually very individualistic, lacking trust in others' ability to respect any rule. Fishermen bring their experience to the experiments, but this does not mean that they will perform better. With the combination of methods, we find that microsituational variables and broader context are both important in explaining observed behavior in experiments.

Given the importance of context, we need to perform experiments with communities in different contexts, including undergraduate students in Western societies and small-scale societies that have limited interaction with modern economies. This will require collective action among scholars who study collective action. We need to build up (cyber) infrastructure to collect and compare case studies and experiments to advance our understanding of governing the *Commons*.

Another conclusion from using these different methods is the fact that the quality of resource management lies more on the possibility of communication rather than on the types of rules crafted. Lab experiments have shown that the amount and distribution of communication is more important than the content of the interactions. The field experiments did not allow communication and crafting of rules. In general, we did not find an influence of the type of rule selected. In the role-playing games, we observed that in most cases stakeholders included negotiation arenas as part of the game environment, but did not specify the management rules. Again, like in the lab experiments, the organization of communication is more important than the content of communication. In closing, the various research activities stress the importance of social capital and trusting relationships in communities. Experience and knowledge of resource governance might be important, but not as important as the trust relationships in small communities. Whether this finding scales up to governance of social-ecological systems are larger scales is an open question.

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References

Anderies, J.M., Janssen, M.A., Bousquet, F., Cardenas, J.-C., Castillo, D., Lopez, M.-C., Tobias, R., Vollan, B., Wutich, A., submitted. The challenge of understanding the role of context in experimental studies of common pool resource governance.

Axelrod, R., 1984. *The Evolution of Cooperation*, New York, Basic Books.

Bouma, J., Bulte, E., van Soest, D., 2008. Trust and cooperation: social capital and community resource management, *Journal of Environmental Economics and Management*, 56, 155-166.

Cardenas, J.-C., Janssen, M.A., Bousquet, F., to appear. Dynamics of rules and resources: three new field experiments on water, forests and fisheries, in List, J. and Price, M. (Eds), *Handbook on Experimental Economics and the Environment*, Edward Elgar Publishers.

Castillo, D., in preparation. *Institutional Arrangements and Mental Models in Common Pool Resources*. Ph.D. Thesis, University Paris X Nanterre, Paris.

Castillo, D., Bousquet, F., Cardenas, J.-C., Janssen, M.A., and Worrapimphong, K., submitted. Context matters to explain field experiments: results from Thai and Colombian fishing villages.

Goldstone, R.L., Ashpole, B.C., 2004. Human foraging behavior in a virtual environment, *Psychonomic Bulletin and Review*, 11, 508-514.

Gurven, M., Zanolini, A., Schniter, E., 2008. Culture sometimes matters: intra-cultural variation in division norms among Tsimane Amerindians: real or spurious?, *Journal of Economic Behavior and Organization*, 67, 587-607.

Henrich, J., Ensminger, J., McElreath, R., Barr, A., Barrett, C., Bolyanatz, A., Cardenas, J.-C., Gurven, M., Gwako, E., Henrich, N., Lesorogol, C., Marlowe, F., Tracer, D., Ziker, J., 2010. Markets, religion, community size, and the evolution of fairness and punishment, *Science*, 327, 1480-1484.

Janssen, M.A., 2010. Introducing ecological dynamics into common-pool resource experiments, *Ecology and Society*, 15, 2, 7.

Janssen, M.A., Anderies, J.M., Joshi, S., to appear. Coordination and Cooperation in asymmetric *Commons* dilemmas, *Experimental Economics*.

Janssen, M.A., Bousquet, F., Cardenas, J.-C., Castillo, D. and Worrapimphong, K., submitted. Field experiments of irrigation dilemmas.

Janssen, M.A., Goldstone, R.L., Menczer, F., Ostrom, E., 2008. Effect of rule choice in dynamic interactive spatial *Commons*, *International Journal of the Commons*, 2, 2, 288-312.

Janssen, M.A., Holahan, R., Lee, A., Ostrom, E., 2010. Lab experiments for the study of social-ecological systems, *Science*, 328, 5978, 613-617.

Janssen, M.A., Ostrom, E., 2008. TURFs in the lab: institutional innovation in dynamic interactive spatial *Commons*, *Rationality and Society*, 20, 371-397.

Janssen, M.A., Radtke, N.P., Lee, A., 2009. Pattern-oriented modeling of *Commons* dilemma experiments, *Adaptive Behaviour*, 17, 508-523.

Ostrom, E., 2007. A diagnostic approach for going beyond panaceas, *Proceedings of the National Academy of Sciences*, 104, 39, 15181-15187.

Poteete, A.M., Janssen, M.A., Ostrom, E., 2010. *Working together: Collective action, the Commons, and multiple methods in practice*, Princeton, NJ, Princeton University Press.

Schlager, E., Blomquist, W., Tang, S.Y., 1994. Mobile flows, storage and self-organized institutions for governing common-pool resources, *Land Economics*, 70, 3, 294-317.

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