"Dynamics of Rules and Resources: Three New Field Experiments on Water, Forests and Fisheries"[1]

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Abstract.

Most common-pool resource experiments, inspired by the ground-breaking work of Ostrom, Gardner and Walker (1994), involve a typical structure of a static non-linear social dilemma with a rival but non-excludable good that is extracted by a number of players. However there are specific ecological features of relevant common-pool resources that can be incorporated into an experimental design and tested in the field or the lab. Stock effects, spatial effects or vertical downstream externalities are issues that natural scientists and economists have studied in forests, fisheries or watershed management although experimental works on these ecological aspects are rather scarce.

We designed three resource specific games to capture particular characteristics of common-pool resources and apply them in six villages in Thailand and Colombia. In each village we recruited 60 people and conducted three games. A water irrigation game capturing the downstream externalities and collective action problem of provision and appropriation stages where all players need to contribute to a public project that produces water which is then extracted sequentially by each of the players starting with the one located upstream, leaving the remaining water to the next player downstream, and so on. In our forestry game players start with a number of standing trees that can be cut by any of the players; in any round each player can extract between zero and a fixed number of trees. The remaining trees re-grow at a certain rate and the resulting trees are then left for the next round for individual extraction. The game ends at a maximum number of rounds or when no trees are left. Finally, the fisheries game involves two possible fishing sites that can have high or low levels of stock. Each player needs to decide where to fish between the two sites and her individual effort of fishing. Depending on the aggregate level of fishing effort in each site, the stock level will change for the following round and will determine the fishing returns. All games involve a social dilemma where individual interests clash with the socially optimal outcome. Lessons can be derived regarding the design of better resource management rules and a better understanding of how resource specific dynamics affect the social dilemmas in common-pool resources.

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http://www.public.asu.edu/~majansse/dor/nsfhsd.htm

1. Introduction and motivations for a new wave of experimental designs

The last few decades have witnessed an increase in the use of experiments for the study of various environmental and natural resource phenomena (Sturm and Weimann, 2006; Cherry et.al, 2007). Much of this work involves a better understanding of the behavioral foundations of decision-making when facing environmental externalities and uncertainties, and a more careful understanding of how incentives and institutions affect such decisions and their environmental outcomes.

On one area of work, several economists and psychologists have made significant contributions to the study of how behavioral particularities of humans may affect society's value of resources and the environment. A vast literature has studied the problems of biases involved in economic valuation studies, and thanks to behavioral approaches and experimental techniques, better explanations and calibration methods now exist to improve these valuations thanks to seminal works by Kahneman, Tversky and co-authors (See Kahnemann et.al. 1990 and Horowitz and Macconnel, 2002). We now know better about discounting future benefits and costs within alternative behavioral approaches, or the valuation of environmental losses as opposed to environmental gains (See Shogren, 2004 for a survey) and the risk attitudes towards uncertain outcomes, including environmental risks.

Another branch of experimental work applied to environmental and resource issues involves the study of how incentives and institutions affect decisions and outcomes. Experimentalists have used experimental designs to study how markets fail or achieve social efficiency and how different instruments or incentives aimed at correcting the market failure can improve outcomes. These designs include the design and analysis of water management systems and markets (Cummings et.al. 2003, Ward et.al 2006), network markets for resource allocation (e.g. energy network markets, Denton et.al. 2001), or marketable permits for pollution (Murphy and Stranlund, 2006 and 2007) and external regulations including taxes and subsidies.

A third group of experiments have focused on the typical problems of group externalities or social dilemmas associated with common-pool resources and public good issues with direct applications to resource and environmental issues. Ledyard's survey (1995) of experiments on the voluntary contributions mechanism to study public goods problems originating in the 1980s work by economists and psychologists such as James Walker, Mark Isaac, R.Ames, and G.Marwel and Ostrom, Gardner and Walker (1994) for the case of common-pool resources, are probably the most significant seminal works that generated a stream of experimental variations to understand the behavioral and institutional foundations of why would people, despite the clear incentives to free-ride, engage in cooperative behavior and refrain from over-exploiting a common-pool or contribute voluntarily to the provision of a public good. Field experiments in this area include Velez et.al 2008 and 2008; Cardenas et.al 2000; 2002; 2004; Rodriguez et.al 2008.

Further, most of these studies have involved university students as their experimental subjects, and only a few have been applied in the field with non-student samples. Field experimentalists from various disciplines in social and natural sciences have expanded the wealth of research by heading to the field and run experiments with subjects that are familiar with the problem in question. The richness from expanding the demographic variation of the subject samples was also enriched by including more explicit framings to the protocols in order to better connect the experiment with the context of the participants.

However, when evaluating the experimental literature that has studied environmental and resource issues, we can see that most of the motivations and inputs in the designs have come from behavioral and institutional concerns, and less from the characteristics of the ecosystem, its functions and its resource dynamics. The externalities have remained for most of the cases as symmetric, linear and with only one dimension of interdependence. Most public goods production functions and externalities have been linear, and most common-pool designs have maintained the simplicity of a quadratic function of benefits on group effort.

This has been a wise decision at a time when the behavioral predictions from the economic literature needed to tackle the problem of the very weak empirical and laboratory support for the selfish free-riding prediction. By keeping the production function externalities and dynamics simple, experimentalists have been able to tackle the main issues with respect to social dilemmas and behavior that have been contributing to the literature about cooperation, trust, reciprocity and pro-social behavior in general. We now know that reciprocity plays a major role in explaining behavior of individuals in social dilemmas, that free-riding is a strategy chosen by only a small fraction of players, that players do respond although partially to pecuniary incentives and that individuals are altruistically willing to contribute to a public good or refrain themselves from over extracting a common-pool either because they care about the others, inequality or the environment per se.

Meanwhile, the natural resource, environmental and ecosystem management literature has provided for a long time enough evidence that understanding the ecosystem functioning needs to be incorporated into the study of human-ecosystem interactions (Clark, 1976). Maybe it is time for a next step and introduce also the ecological complexities of the social dilemmas in environmental and natural resource problems into the behavioral analysis. With this paper we propose a next wave of experimental designs to augment the knowledge that the experimental literature has brought to environmental and resource economics.

In particular, we believe that the following aspects of ecosystems can be introduced into these new experimental designs. The first particularity of resources is its dynamics over time. Most resources availability to humans depends to the stock situation in previous rounds and experiments can incorporate such feature in various ways. Also there are asymmetries with respect to watershed management where the externalities flow unidirectionally across players from upstream to downstream agents, but not vice versa. Additionally, watershed management suffers from two inseparable issues involving a collective action dilemma: provision and appropriation. Individuals face a conflictive dilemma at the provision level for the production, maintenance and distribution of water, and another dilemma in the appropriation of the resource itself. Also, some resources (e.g. fisheries) are used by humans making simultaneously decisions about effort and location and such decisions interact in a more complex way (the tragedy of the commons can be triggered either by a spatial decision, an effort decision or by the interaction of the two).

And finally, we want to highlight the fact that for a great deal of ecosystems and regions were natural resources are economically and ecologically valuable, the stakeholders or decision making agents are villagers with certain degrees of education levels, cognitive abilities and socio-economic characteristics that vary much more than in the case of a group of college students. Also, these villagers have a longer experience of trial and error making resource extraction decisions than the usual student. Therefore, we have chosen the strategy to head to the field lab and conduct our experiments with stakeholders that face this reality of ecological and economic complexities on a daily basis.

2. Ecosystem dynamics, individuals and institutions

When it comes to the governance of social-ecological systems, one size does not fit all (Young, 2002). Experience from the governance of system X cannot directly be implemented in system Y. As proposed by Ostrom (2007), we need to develop a diagnostic framework to identify the relevant components of social-ecological systems in terms of resource dynamics and resource governance. Such a diagnostic framework likely will consist of nested layers of more detailed attributes of social-ecological systems that are not relevant for all social-ecological systems.

From a systematic comparison of case studies, Schlager et al. (1994) and Janssen et al. (2007) both identified the main distinction in types of resources with regard to self-governance of common pool resources: whether the resource units are mobile (fishery, pastoralism), or whether infrastructure is developed to guide the resource flow (irrigation systems, internet). In performing experiments of decision making in commons dilemmas, we should distinguish explicitly the resource dynamics.

There is substantial literature on the fit between institutions and ecological dynamics (e.g. Young, 2002). An institutional arrangement that works perfectly for one resource problem might be a dismal failure if applied to another resource problem (Acheson, 2006). This would not be as problematic if there were clear classes of case studies instead of the heterogeneity in ecological and social processes we observe in the world around us.

An innovation we made in previous years is to include ecological dynamics more explicitly in resource experiments in the lab (see Janssen et al. in press; Janssen and Ostrom) and the field (this chapter). So, what are the main ecological dynamics to include? It is nowadays widely recognized that ecosystems dynamics is complex. Concretely, watershed are governed by interactions between upstream and downstream inhabitants for water flows, the spatial interactions between fishermen and fish population as well as the ecological interactions among the multiple species lead to unpredictable dynamics, multiple forest resources such as log trees or non timber forest products have very different ecological dynamics and are exploited by different stakeholders. In his paper on ecosystem complexity, Holling (1987) defines three concepts that have dominated causality in ecological systems and that define the principles for the management of ecosystems. The first one is based on the notion of equilibrium (balance of nature), the second one defines several states of stability (nature engineered or nature resilient). This second perception is interested in dynamics caused by variability, by events that occur at small scales. The third point of view is the one of organizational change (nature evolving). The system changes: external events lead to perturbation of the system, but also, especially when human beings are part of the system, the actors of the system may, by themselves, change the organization of the system. This third point of view corresponds to the approach adopted by the sciences of complexity: the general state of a set of interacting entities may converge toward attractors, may be disordered, or may exhibit patterns of organization that change from one to another in an unpredictable way (Wolfram, 1984; Langton, 1992). There is a need to take into account both the resource dynamics and the heterogeneity of stakeholders. Very often these two questions were addressed separately, either exclusively from the point of view of "an ecological system subject to human disturbance" or, alternatively, from the point of view of "a social system subject to natural constraints". In the first case, scientists make a careful description of the dynamics of the resource, with management constituting a definition of the various forms of exploitation which can be sustained over the long term by this resource. Social dynamics are summarized in terms of the type of resource exploitation they entail. In the second case, researchers generally concentrate on the problem of resource use, considering homogenous economic agents who share the same rationality. The perception of the collective is not taken into account.

Models are considered as very useful tools to integrate social and ecological dynamics. Several authors have been using agent-based models in the field of ecosystem management for many years. This kind of application was begun by Lansing and Kremer who studied water management in Bali, Bousquet et al. for fisheries management (1993), Deadman and Gimblett (1994) for park management, and Kohler and Carr (1996) for archeological issues, Janssen (1999) for lake management and Dean et al. (2000) and Balmann (1997) for agricultural land management. If we view ecosystems in terms of people and management problems, Epstein and Axtell (1996) study the structuring of networks and their effect on the management and distribution of resources. In a more applied context, we note the studies of Antona et al.(1998) on the organization of economic exchanges between harvesters of renewable resources and consumers. Barreteau and Bousquet (2000), Feuillette et al (2003) and Mathevet et al. (2003), among others, propose models and simulations that involve relations among one or more natural resources, agents who can individually exploit the common land and act on the common resource, and sets of interactions between agents who coordinate their actions or exchange information. A good overview is given in Janssen and Ostrom (2006).

A good starting point is to look at existing experimental designs that have addressed the problems of ecological externalities and resource problems. In traditional common pool resource experiments the payoff structure is based on a static game where each round plays as a fresh new game with exact same conditions. It would be more relevant and externally valid to led the state of the resource be dependent on the actions of the participants in the previous rounds, as well as on local conditions surrounding the specific resource. Regarding the payoffs function, common-pool resource games have traditionally used a payoffs function that is concave on the group effort, while public goods have often used a linear one, but in both cases the strategic game remains within a static context with no interdependence between the payoffs structure of one round to the next.

The major innovation in the experimental design here proposed is adding more ecologically relevant dynamics of the resource. The experiments discussed in this paper will include some basic dynamics like multiple equilibria, renewal rates, asymmetry of access, but will not include variability. We decided to develop three kinds of experiments which mimic in an abstract way key ecological dynamics relevant for forestry, fishery and irrigation. As described in the next section, our experiments will include:

- non-linear behavior of the resource, e.g. in the relationships between effort, resource stock and returns from effort

- asymmetry of access to the resource, e.g. because of the upstream-downstream location of resource users
- space, e.g. in the relation between location and resource stocks
- path-dependency due to the dynamic interactions, e.g. a resource availability at a given time t highly dependent on decisions previously achieved

3. Our design for 3 games

In the previous section we discussed the importance to include more relevant ecological dynamics in studying the ability to overcome common pool resource dilemmas. We have developed three kinds of experiments representing dilemmas in forestry, fishery and irrigation. In this section we discuss the general design of the experiments and the three typological, and how we have organized the experiments.

Since we aimed at designing an experiment that could be implemented in the field with stakeholders that in their daily lives face the kind of dilemmas and dynamics we want to study, we needed to develop a simple pencil and paper design to be used in a field setting where participants have a wide range of formal education levels and cognitive abilities. After a two year period of pretesting designs we were able to head to the field for the final experiments here reported. The complexity of ecosystems included are very stylized, but well understood by the participants with the design developed.

The experiments were held in six 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, which is located in the West of Thailand, in three separate locations. One of the locations in the coastal area, and the other two in the inland. The Colombian experiments were conducted in three different rural sites. The fishery community is represented by a village on Barú Island, (rural area of Cartagena city, in the Caribbean coast). The irrigation community is located in the Fuquene lake basin area, located in the Andean region of Cundinamarca and Boyacá. And the forestry community is located in the Pacific coast tropical forest area.

For all these locations permission were given when needed by the head of villages to perform experiments. The experiments were held during the first 6 months of 2007. Typically four days of experiments were followed by in depth interviews with a sample of relevant stakeholders of the village.

In each village each of the three resource games was conducted with 4 groups of 5 people. As a result 360 individuals have participated in the experiments according to Table 1.

[Insert Table 1 here]

The general outline of the experiments is as follows[2]. In each experiment 5 individuals participate. They may know each other, but they do not know the decisions of the other individuals during the experiment. Only the aggregate outcomes of the decisions are presented to the group. They are not allowed to communicate with others during the experiment. Assistants are available during the experiments for those participants who have difficulty with reading and/or arithmetic. After instructions and practice rounds, the participants will play 10 rounds. They are not told the number of rounds in advance. After the 10th round, three different rules are presented for which one can vote to be implemented in a subsequent series of rounds. The three rules represent a property type of rule, a lottery type of rule, and a rotation type of rule, and are all aimed at solving the resource dilemma. The participants turn in their vote, and are asked to fill out a brief survey on their opinions about characteristics of the rules, before the result are announced. If two rules get two votes, an additional round of votes between those two candidates is used to define the final chosen rule.

Ten rounds are played with the new rule implemented. The first round after the election has the same starting situation as round 1 of the experiment. Before the participants receive their payments, they fill out a general survey on their demographics and resource use within the village. The duration of an experimental session was about 3 hours and the typical earnings of the participants was one day of labor.

The participants were recruited via word of mouth and flyers hanged throughout the village, and participants of 18 years and older could participate. Special emphasis was done to recruit adults from households engaged in the resource extraction of that village. Only one member of a family was allowed during the same session. At the end of the series of experiments a handful of people were identified for in depth interviews. Those individuals were selected among the participants to receive a representative sample of the community. At the end of the week, a session was organized to discuss the experiments and their situation in relation to natural resources.

a. 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 5 magnets from the board. The stock will regenerate. For every 10 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 given by the following table:

[Insert Table 2 here]

When participants collect as much as possible as fast as possible, the stock will be depleted in 5 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 (figure 1), for a sequence of 10 periods or rounds.

[2] See the field protocols in the Appendix.

[Insert Figure 1 here]

After ten rounds the participants can vote for one of the three following rules:

- **Rule 1 (Lottery).** Each round two participants are drawn who can harvest. If somebody harvest when (s)he is not allowed to do so, a penalty may be received. Each round a dice is thrown, and when a six is through, an inspector comes and rule breakers get a penalty. The penalty consists of paying back the harvested amount plus an extra 3 tokens.

- **Rule 2 (Rotation).** A fixed schedule is defined which two participants are allowed to harvest each round are able to harvest. In round 1 A and B can harvest, then C and D, then E and A, etc. The same mechanism of monitoring and sanctioning is used as rule 1.

- **Rule 3 (Property).** Everybody has the right to harvest 0, 1 or 2 units per round. If a higher amount is harvested, a dice determine whether the participant is caught, pays back the harvest plus 3 tokens.

b. **Water Irrigation Game**

In the irrigation game participants get each round 10 tokens and have to make first a decision 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 decide 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 public good. This game includes the dilemma of upstream participants who need the help of downstream participants to generate a favorable size of the public good. However, the downstream participants can only get benefits from the public good 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 public goods game in the contributions stage, and then face a resource appropriation dilemma when they extract from the generated resource, creating once again a common pool resource problem. In Table 3, the water provision generated is defined as a function of the total investments of the five participants. Clearly under these incentives and rules, the Nash equilibrium is that nobody invest in the water provision, and all receive 10 tokens for a group earnings of 50 tokens. In the cooperative (social optimum) solution, everybody invests her 10 tokens in the public good, producing 100 units of income in each round. Therefore, for a sequence of 10 rounds, the group earnings would sum 500 tokens and a social optimum could go up to 1000 tokens.

[Insert Table 3 here]

After 10 rounds the participants can vote on one of the following three rules:

- **Rule 1 (Lottery)**. Each round the order in which participants can collect from the common resource is randomly drawn after everybody has made their decision how much to invest in the water provision.

- **Rule 2 (Rotation)**. There is a fixed rotation system of the order in which people can collect from the common resource, starting with ABCDE in round 1, then BCDEA, etc.

- **Rule 3 (Property rights)**: Each participant receives the right to use 20 percent of the common resource. The order to extract water remains the same for all the rounds: ABCDE. A dice is thrown in each round. When 6 is thrown, participants who collect a higher amount than the share of 20 percent have to pay back the excess water harvested, and also pay a penalty of 6 additional tokens.

c. 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 they can choose to go to, and they can choose to exert low or high levels of effort. There is a slightly higher return from a high effort compare to a low effort (see Table 4 below). The payoff table is the same for both locations, and the initial state of the resource is the high fish availability. 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 in two consecutive rounds not more than one unit of effort is invested in that location. 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 10 rounds, this opportunistic behavior will result in 200 tokens for the 5 people group. However, if they would be able to coordinate 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.

[Insert Table 4 here]

After ten rounds the participants can vote for one of the following three rules:

- **Rule 1 (Lottery).** Each round the location where each of the participants is allowed to fish is randomly determined by throwing a dice for each participant. When a participant harvest in a location illegally, a throw of a six of the dice leads to paying back the harvest points.

- **Rule 2 (Rotation).** Each round one of the location is banned from fishing: A in rounds 1 and 2, B in rounds 3 and 4, etc. If a participant is caught fishing illegally the harvested amount need to be returned.

- **Rule 3 (Property right):** Each participant can exert an effort of 0 or 1 per round. In case a participant is caught putting two units of effort, the participant need to pay back the harvested amount.

4. Field results: patterns of behavior and outcomes.

a. Our participants.

The field experiments for this study were conducted during the first semester of 2007 in Thailand and Colombia, with 360 villagers invited to voluntarily participate in 72 sessions, and we avoided having in the same session two people from the same household. In each country we conducted 12 sessions for each game. Each villager participated in only one session of 5 players and 20 rounds which took about 2-3 hours including instructions, game decisions, payment and ex-post individual interviews to collect basic household data and a set of questions regarding the experiment.

The average age of our participants was 39 years (Std.Dev 14.6), and 34 percent of them were females. About two thirds of them reported living in that village for their entire life. Their households were in average of 5 members (also the modal household size), with less than 10 of households having 2 or less members and 10 percent of households with 8 or more members. The education level of the participants varied as well. 7 percent of them had no formal education, and about 30 percent of them with some or complete primary education. 47 percent of the players had secondary education and only some 12 percent received technical or university training. About 82 percent of them reported owning some land.

At the end each participant was paid in private according to the tokens earned in its respective game, plus an additional show up fee. In average each player earned the equivalent to 1-2 days wage for her participation in a 2-3 hours session.

b. Choices and outcomes in the games.

The results here reported illustrate how our three game designs can offer new insights to the understanding of the complex relationship between experimental behavior and particular ecological features we incorporated into the three games described before. Some of these patterns seem robust although were unexpected

We will conduct the analysis in the following manner. For each of the games we will describe the patterns of individual and group behavior and study how it affected the individual and group earnings over time. Recall that every session included 10 periods or rounds under a baseline treatment where players could not communicate with each other, and a second sequence or stage of 10 more rounds where they had the chance to vote for one of three possible rules (lottery, rotation or property rights) and face the voted rule with a imperfectly enforced regulation that would punish non compliance. In all cases the groups were told by the experimenter that the rule was aimed at regulating the way the resource was harvested and/or who would have the right in each round to harvest it (See protocols in the appendix).

Before we present the results for each of the games, let us briefly summarize the main overall patterns observed.

First of all the data suggests that once again the Nash prediction of selfish maximizers of individual tokens is not a good predictor for the average player in these experiments. Although there is a minority of players that do followed a strategy of extracting the maximum possible of units of the resource, such fraction of players did not seem to reflect the majority nor it invaded as an evolutionary strategy the rest of players. On the other hand we do not observe either a trend towards the maximization of the group outcomes during the first or the second stage under the voted rules.

Overcoming the temporal and spatial ecological features of the resource dynamics proved to be a difficult task both with and without rules to govern extraction levels and assignment of rights to the resource users. As it will be shown later, the dynamic effects of the forestry and fishery games imposed a difficulty for the players who found it quite difficult to recover back higher levels of the stock which could substantially increase earnings.

With respect to the rules implemented during each of the sessions we observed that they had a weak but positive impact over behavior and outcomes. The first rounds after the rule was implemented in each of the games did show a change towards more cooperative behavior across all games and sessions, the dynamics of the behavior and the resource seemed to shift the group behavior towards a similar equilibrium achieved before the rule was applied, with some exceptions and qualifications to be discussed below. For instance, the rules helped to improve substantially the distribution of earnings across the players in the watershed location.

c. Field results for the Forestry Game.

Our forestry game starts with a resource stock of 100 trees and where 5 players can extract from 0 to 5 trees in each round, unless limited by the available stock according to Table 2. In each round, after extraction, every 10 standing trees will yield one more tree that is available to the group for extraction. The two graphs below (Figures 2 and 3) summarize the observed behavior and the resulting outcomes for the forestry game. Figure 2 shows the mean and 95 percent confidence interval for the levels of harvest or trees extraction by individuals over time, and for the two stages of the game.

[Insert Figure 2 here]

The first stage (rounds 1-10) clearly show that most groups start from a high level of individual extraction of about 4 units which is slowly reduced by only one unit halfway in round 5. However, with a group extraction (forest depletion) oscillating between 15 and 20 units, the growth rate of the resource of 10 percent of standing stock would not allow for much recovery of the forest creating a much difficult setting for balancing renewal and extraction, as it can be seen in Figure 3 where we graph the available stock of the resource in each round. Notice that at round 5 about half of the forest stock has been depleted. In general the rate of decrease in extraction overrides the capacity of re-growth of the resource.

[Insert Figure 3 here]

The second stage does show a different pattern. The two graphs suggest that with a lower initial levels of extraction somewhere between 2 and 3 units per player the resource stock is sustained for a longer period (by round 15 about 75 percent of the trees are standing) and by the end of the second stage most of the sessions showed that our participants left somewhere between 20-40 percent of the trees. In fact notice that by the end of the first stage the confidence interval suggests that a significant number of groups did not deplete entirely the forest by round 10, although they did know that the stage would be stopped by this round.

Comparisons across the two countries during the first stage show no major difference which would suggest that the game induced a robust behavior regardless of the context or culture, for the baseline case. However it is interesting to notice that a very small but valuable difference in the very first rounds after the rule (t=11-13) help to provide much better conditions for a more sustainable extraction of the forest in the Thailand case (Fig.3) and substantially higher stock levels by the end of the final round (t=20). This illustrates one of the points we have highlighted about the importance of studying these non-linearities and dynamics of the ecological conditions of the resource within our experimental designs[3].

d. Field results for the Water Irrigation Game.

The irrigation game involves two individual decisions, namely, provision and appropriation of the resource (i.e. contributions from 0 to 10 tokens to the public fund that produces water, and extraction from the available water units in each upstream-downstream location). Water produced and available for the group to extract is based on Table 3. Figure 4 shows the average and 95 percent confidence interval for the levels of contributions by all players in each round, and for the two stages before and after the rules were introduced. From the start of the

[3] The plausible explanations for the observed difference across the two countries are not explored here and will be the subject of analysis elsewhere.

first stage the Thailand sessions show lower higher levels of contributions for the production of water for the group. The decrease over time of such contributions, consistent with baseline voluntary contributions or public goods experiments seems to be present, especially for the Colombian sessions. In figure 5 we show the final average earnings for the players for this game. Recall that final earnings are the sum of the tokens not invested in the public fund and water units extracted by the individual, and that the exchange value of each of the units (kept or extracted) is the same.

[Insert Figure 4 here]

[Insert Figure 5 here]

In both cases we observe a similar pattern of decrease in the level of social efficiency due to the lower contributions to the public fund which in turn produce less water for the group as a whole, according to Table 3 in the design. In fact the rules did not have a positive impact. On the contrary, the individual earnings for the second stage decreased from an average of 17.43 units per round per player to 15.34 units (p-value=0.0256, Mann-whitney p-value=0.0062) for the entire sample.

However, the more striking result for the change from the first to the second stage is the dramatic improvement in the distribution of water from upstream players to downstream players. In the figure 6 we report the average water units extraction in each of the locations in the watershed and compare the first stage (rounds 1-10) to the second stage (rounds 11-20). While in the first stage players A and B were concentrating most of the water leaving those downstream with much less of the resource available, the second stage witnessed a redistribution that improved the earnings of players D and E at the end of the sequence.

[Insert Figure 6 here]

The losses in efficiency seem to be compensated by the gains in distribution. It is necessary, however, to explore the reasons why the rules were so ineffective in this case to increase contributions to the public good, and if other rules could bring the efficiency and distribution hand in hand to the groups.

e. Field results for the Fishery Game.

In our fishery game each payer could exert an individual effort of 0,1 or 2 units in one of the two possible sites A or B. Therefore the group effort in the two sites ranges between 0 and 10 units for the 5 players involved in any particular round. Such group effort would be distributed between the two sites. The returns or fishing harvest per effort unit from each site would depend on the stock level of that particular site, according to Table 4. Further, the stock level (Low or High) of one site depended on the aggregate effort exerted in that site in the previous round.

Figure 7 shows the mean group effort in each country of our sample with its respective 95 percent confidence interval. Two main results are easily observed. The ineffectiveness of the rules in the second stage as no major change is observed across stages (a Mann-Whitney test comparing rounds 8-10 with rounds 11-13 or 11-20 shows no significant difference, p-value=0.3181). Also, Colombian groups apply a higher effort to the fishery if compared to the Thailand cases. The difference in the group means is of about one unit of effort, with a p-value=0.000.

[Insert Figure 7 here]

As a result, group earnings (See Figure 8) could not be sustained at high levels after the third round both before and after the rules were applied. For the second stage higher earnings were sustained for an extra round or two but such improvement did not last. The reason is that the group efforts on both sites A and B were sufficiently high to bring both sites to the low level of stocks as required by Table 4. Recovering back from low to high stocks of fisheries was very difficult. Figure 9 shows precisely this problem by graphing over rounds the percentage of groups from our sample that had a high fish stock for each of the sites A and B with a clear pattern of decrease in available stocks over time and very few cases of groups that were able to recover back to high stock levels. Notice that both before and after the rules by the third round only around 30 to 40 percent of the groups still showed high stock levels.

[Insert Figure 8 here]

5. Lessons: What did we learn from applying these games in 6 villages in Colombia and Thailand?

Forests, watersheds and fisheries are key resources that provide benefits to societies around the world. Most of these resources are exploited by human groups of different levels of socio-economic and demographic levels who need these resources for their daily lives. The interactions within these human groups and between the groups and their ecosystems require the understanding of the ecological and economic systems involved. We contribute to this challenge by designing new experiments and apply them in the field in villages where resource users face these interactions between ecological functioning and economic incentives.

Our new experimental designs were aimed at incorporating a set of ecological complexities to standard economic experiments regarding a social dilemma in the use of a common-pool resource or the provision of a public good. These ecological complexities are well documented in the literature and by adding them into new experiments we can now augment our knowledge about behavior in the laboratory regarding environmental and natural resource issues. We adapted existing games from the common-pool resource and public goods games literature and designed a set of three games for these particular problems to address complexities such as resource dynamics (forestry and fishery games), spatial effects (water irrigation and fishery game) and non-linearities (all three games).

By bringing these three designs to the field in 6 villages in Colombia and Thailand were a substantial fraction of villagers would depend on the use of common pool resources such as these, we added to the issue of external validity and tested some predictions regarding the behavior of economic agents who derive direct benefits from the extraction of these resources while facing the "tragedy of the commons".

The results provide some lessons about the potential of these designs for providing further insights into the understanding of the human-ecosystem interactions. From our sample of 72 sessions we could find no evidence of groups confirming the hypothesis of selfish maximizers of monetary payoffs which would drive the individuals to the tragedy in all three games. No group was able either to achieve the group optimal outcome.

In the forestry game exhaustion of the resource as predicted in the Nash strategy of Figure 1 did not happen. In the water irrigation game contributions to the public fund were above the zero prediction and in average all five players had the opportunity to get some water from upstream players, although the selfish Nash prediction is for players not to contribute and therefore to produce no water for the group to extract. In the fishery game not all players chose their maximum possible effort, although their decisions still had a large impact on the stocks in each of the sites.

These are not striking news to the experimental literature, and we expected so since our design wanted to resemble the basic social dilemma condition of this literature. Meanwhile, our designs can help us analyze the impact of individual and group on the resource stock and on the earnings of the players because of the features introduced in the designs[4]. For instance, a small difference in the forestry group extraction in the first rounds seems to have a lasting effect in the possibilities to sustain the possibility of extracting trees over time because of the path dependency of the resource dynamics; the same case was observed for the fisheries' stocks because of the group efforts and the difficulty to recover back the high levels of the stock.

Both in the case of the forestry and the water irrigation games we observed that groups did not exhaust the resource entirely, leaving some units in the ground, that is, money was left in the table. In the forestry game the average number of standing trees in the last period of each stage was significantly above zero (See Figure 3), and significantly higher in the last round of the second stage. In the case of water, the average last player (E) in the downstream sequence did not extract all remaining units (a simple test shows that the water extracted as percentage of available water for player E is statistically different from 100 percent).

Overcoming the fisheries trap is a major puzzle in our fishery game. Once a group fell in the low stock, there were individual attempts to decrease effort but these were not sufficient to sustain for two rounds a low group effort in that site and allow for its recovery back to high stock levels. Again, we did not observe that all players were following a selfish strategy, and several players were choosing only 1 unit of effort instead of the 2 allowed. Further, why not even under rules for allocating more evenly the efforts among the two sites were the groups able to recover back from low stocks of fish in each of the sites? We believe such trap is related to the non linear relation between group effort and group payoffs in a particular site. The marginal opportunity cost from decreasing group extraction in one unit was not constant across the levels of group effort. Bringing group extraction to the required levels for the recovery of the stock was much more expensive in terms of foregone income if we compare to higher group effort levels. Next variations of the game could explore the sensitivity of the result to changing the relative payoffs between 1 and 2 units of efforts, or the number of rounds required to induce the change from low to high stocks or viceversa.

Hopefully with these new games we can contribute to a new wave of experimental designs that augment the wealth of research on the interactions between behavior and institutions by adding the ecological features of ecosystems into tractable models and controlled settings both for the lab or the field.

[4] The application of the rules in average had rather minor impacts, although such effect varied within countries across sessions. The effectiveness of each of the rules is not evaluated here and left for another study, as well as explanations of the higher levels of pressure over the resources for the Colombian cases of most of the games.

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Figures and Tables

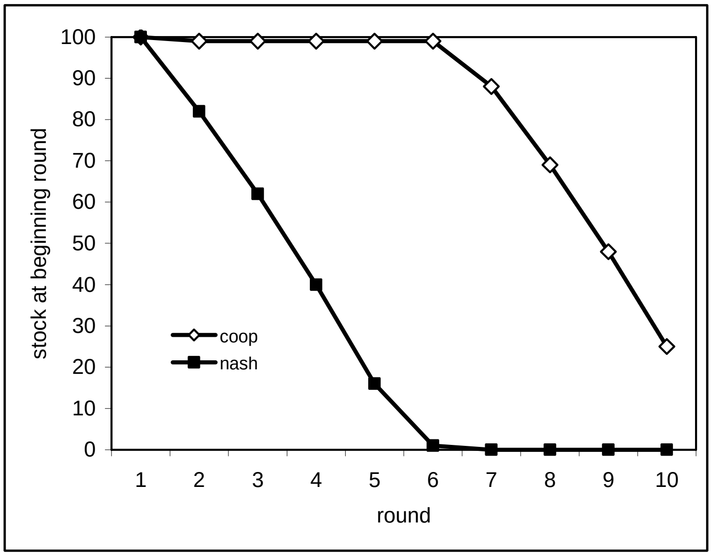

Figure 1: Cooperative optimum and Nash equilibrium (Forestry game).

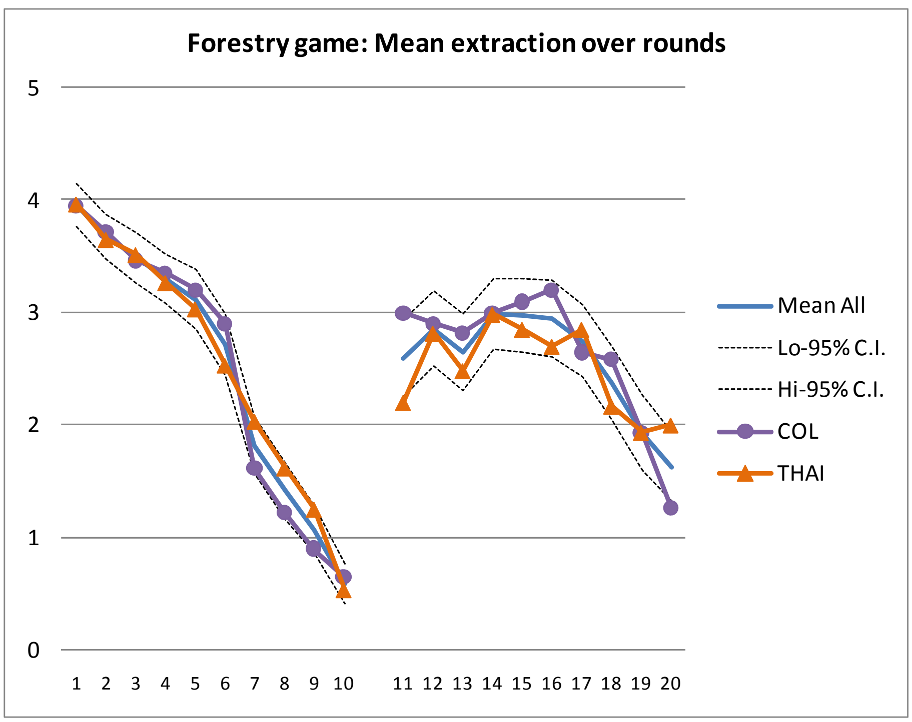

Figure 2. Forest harvest over rounds (Forestry game)

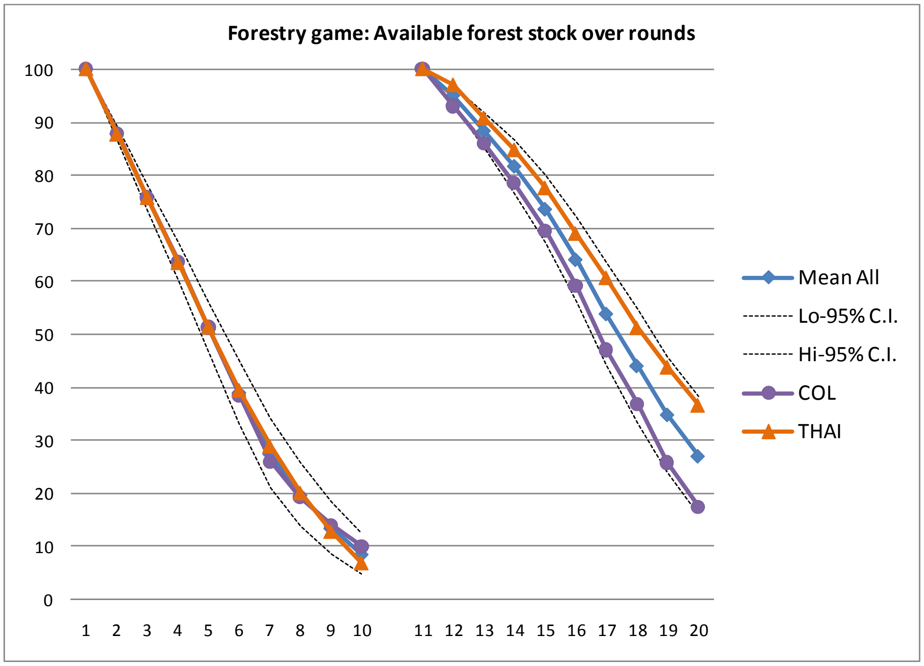

Figure 3. Available forest stock over rounds (Forestry game).

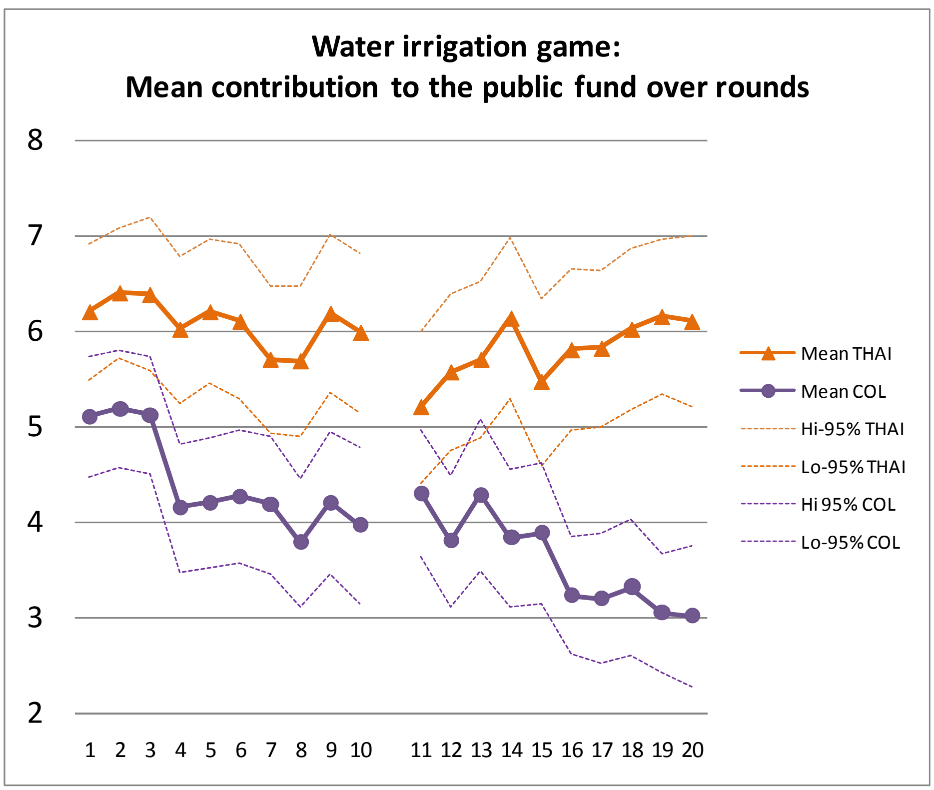

Figure 4. Contributions to the public fund (Water Irrigation game)

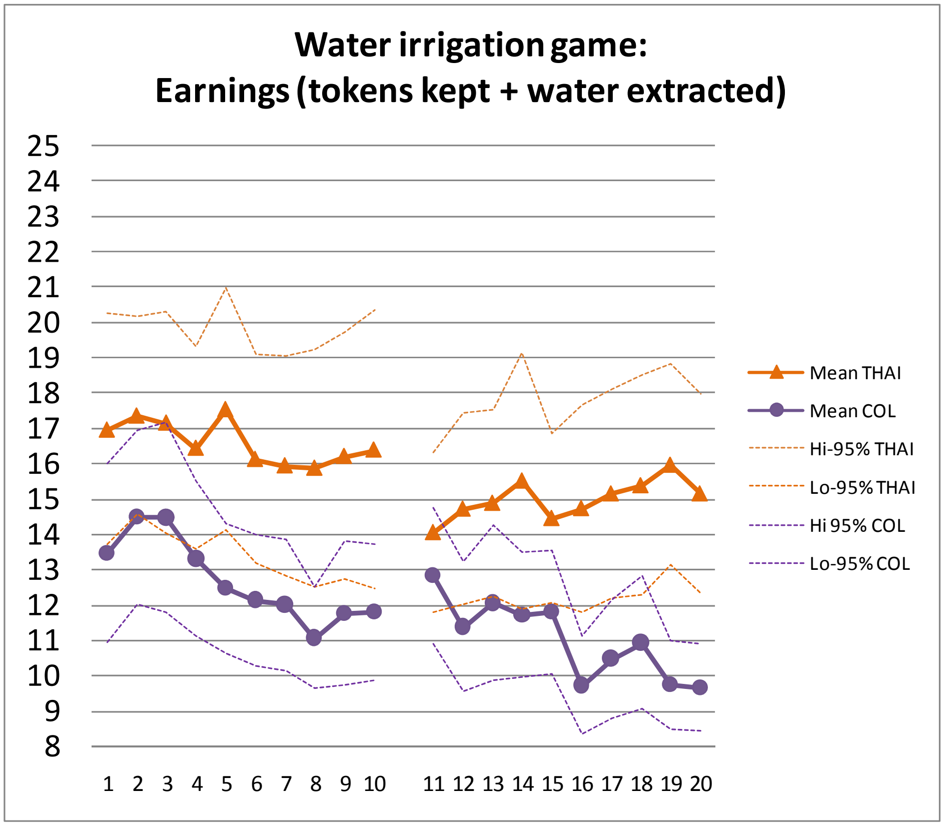

Figure 5. Earnings (tokens kept and water extracted). (Water Irrigation Game).

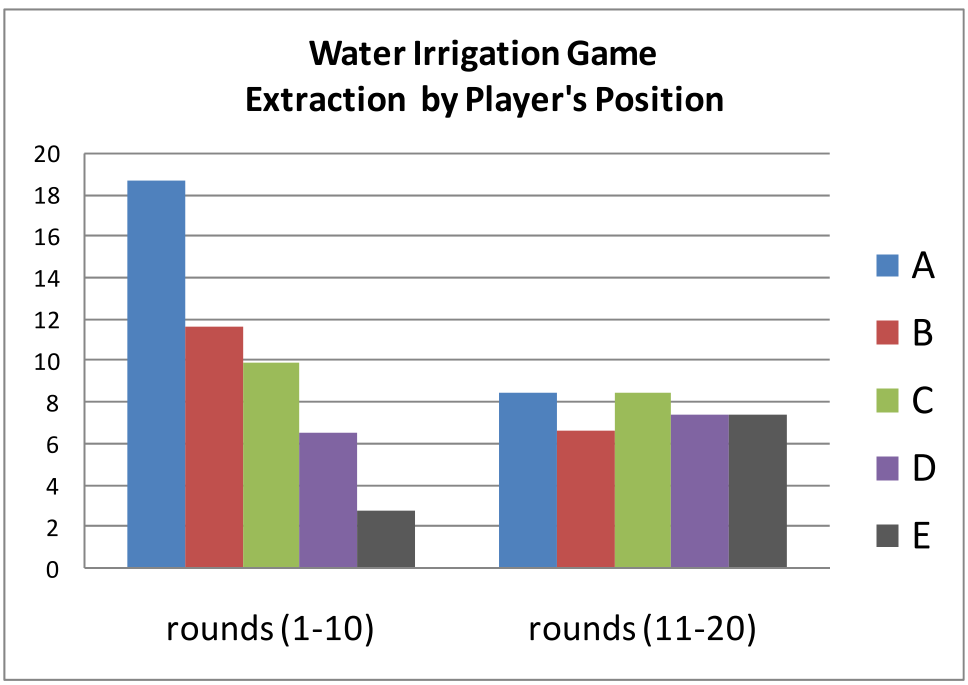

Figure 6. Water extraction by location in the watershed (Water Irrigation Game).

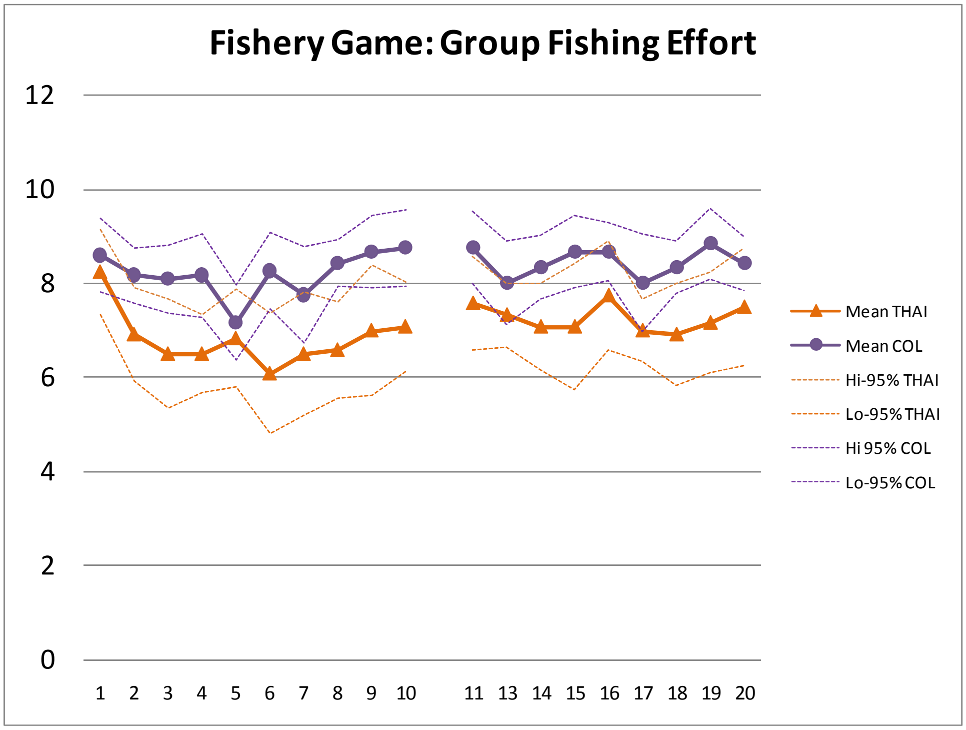

Figure 7. Group fishing effort (Fishery game)

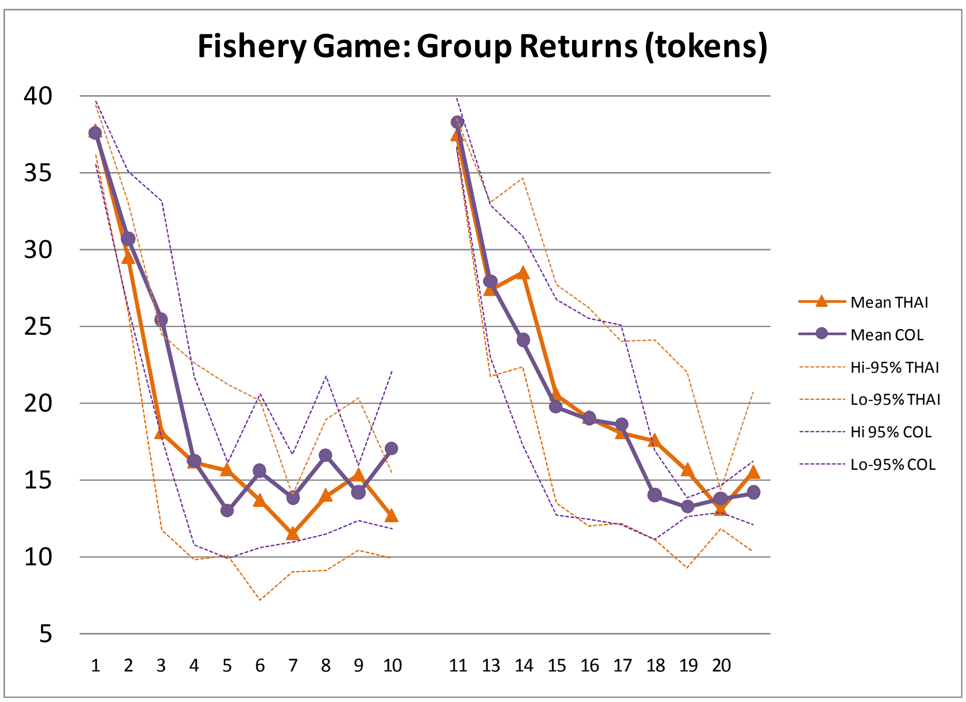

Figure 8. Group earnings (Fishery game)

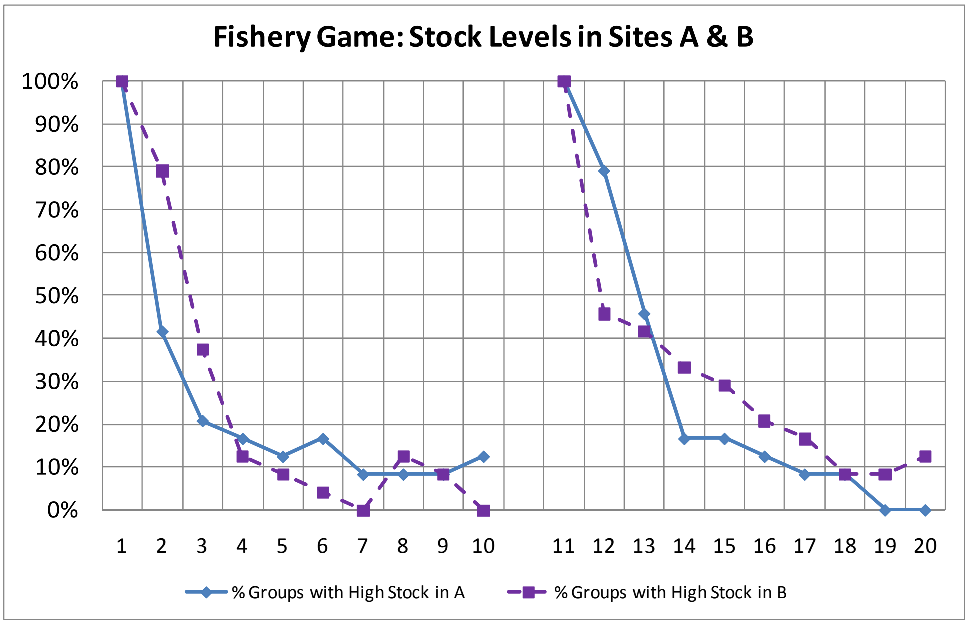

Figure 9. Stock levels in sites A and B (Fishery game)

Tables.

Sample	**Fishery Village**	**Irrigation Village**	**Forestry Village**	**TOTAL**
Fishery game	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	**120**
Irrigation game	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	**120**
Forestry game	20 Colombia 20 Thailand	20 Colombia 20 Thailand	20 Colombia 20 Thailand	**120**
TOTAL	**120 people 24 sessions**	**120 people 24 sessions**	**120 people 24 sessions**	**360 people 72 sessions**

Table 1. Experimental design and sample.

Maximum harvest table	
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

Table 2. Maximum harvest allowed (Forestry game)

Table of available water quantity	
Total units invested by all 5 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

Table 3. Water production as a function of units invested in public fund (Water game)

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

Table 4. Returns (tokens) from effort and fish availability in one location (Fishery game)

Instructions to participants in English, Thai and Spanish.

Forest game

We would like to thank you for accepting this invitation. We will spend about three hours explaining the activity, playing and answering a short survey at the end. Let's start.

The following exercise is a different and entertaining way to actively participate in a project about individual decisions and natural resources. Besides participating in this exercise and earning money, you will participate in a workshop in the coming days in order to jointly discuss the exercise as well other topics about natural resources. The funds to cover these expenses have been donated by a scientific body.

In this exercise it is intended to recreate a situation in which a group or family must make decisions about the use of a forest. You have been selected to participate in a five person group recruited from a group of people who have been subscribed to be willing to participate.

This exercise is different than experiments in which other persons in this community have played already. Therefore, comments you have heard from other persons do not apply necessarily to this exercise.

You will play several rounds equivalent, for example, to years or wood harvest seasons.
Let's pretend this group has an area of forest with 100 initial resource units. Each round you have to make a decision about how many resource units you want to harvest. You can harvest a maximum of 5 units and minimum of 0 units of the resource.

[Visual explanation; we have a number of magnets on the board which represent the forest units. The instructor shows what happens if a number of units are harvested]

Between the rounds the resource is regrowing. For each ten units of the existing resource, one new unit is added for the next round.

[visual explanation; the monitor shows with the magnets that for each row of 10 magnets one new magnet is added to the forest, use rows of 10 magnets on the board]. The forest cannot grow to more than 100 units.

Each participant makes a harvest decision. Each harvest unit is equivalent to $1. For example, if you harvest 100 units during 20 rounds you will receive $100.

When the size of the resource is less than 25 units, the maximum harvest is less than 5 units.

In the MAXIMUM HARVEST LEVEL TABLE, that is green, which will be distributed now [MONITOR distributes the MAXIMUM HARVEST LEVEL TABLE at the same time he shows a poster on the wall of the same table]. I will announce the maximum quantity of units you can harvest according to the size of the resource at the beginning of the round and post it on the wall.

In order to make decisions in each round you must write down your decision on your YELLOW DECISION SHEET, a number between 0 and the MAXIMUM HARVEST LEVEL depending on the current resource level. [MONITOR shows the yellow decision sheet at the same time that shows a poster on the wall with the same card]. Please check your player number on the yellow decision sheet. This will be your player number from now on.

Observe that the sheet has a row with the round number. Next there is a row marked with "my harvest decision", in this space you will write down the harvest level you decided in this round.

It is very important to know that you must make your decisions privately. Therefore, you need to write down the numbers on the decision sheet in private and you can not show them to the rest of the group members. The MONITOR will collect the YELLOW DECISION SHEETS from all of you and she or he will sum the total of units the group decided to harvest. When the monitor announces the group harvest total I will write on the board the new resource level. You will then get the decision sheets back for the next round.

Let us explain this with an example (Use visual explanation).

Suppose the current size of the resource is 68. Each of you decided to harvest 3 units, and thus a total of 15 units. The resource size reduces to 53 (68-15) and then 10% of 53, which is 5 units, is added, which leads to 58 units. Thus 15 units are harvested, and the size of the resource, after regrowth, is reduced with 10 units. And each participant earned 3 points during this round.

For each 10 units of resource 1 unit is added. If there are no 10 units of resource we do not increase the resource, it means if there are less than 10 units we do not add 1 unit more. If the resource is less than 5 units, no units can be harvested any more. Now let's continue with the next round. Now the current size of the resource is 58 units. It means that the maximum harvest allowed remains 10 units according to the MAXIMUM HARVEST LEVEL TABLE.

Again, each player decides how many units to harvest and again we calculate the resource decreasing and its increase in a 10% for new level of the resource.

Now we are going to explain the PLAYER CALCULATION SHEET, the white sheet the MONITOR has handed in to you.

[Before we start the monitor will announce one additional rule for this group.]

To start the first round of the game we will organize the seats and desks in a circle where each of you face outwards. The monitor will collect in each round your YELLOW DECISION SHEET. Finally, to get ready to play the game, please let us know if you have difficulties reading or writing numbers and one of the monitors will seat next to you to assist you with these. Also keep in mind that from now on no conversation or statements should be made by you during the game unless you are allowed to.

We will have first a few rounds of practice that will NOT count for the real earnings, just for practicing of the game.

[up to three practice rounds are performed and questions are addressed during the practice]

The initial size of the resource is 100 units

[After the practice rounds announce that the initial size of the resource is again 100 units and that the decisions are now real and affect the earnings]

INSTRUCTIONS FOR THE FOREST GAME
SECOND STAGE

[After 10 real rounds we let the participants vote for one of three rules.]
We give you the opportunity to start over the game with a different rule. I will describe three rules and you write down on your VOTING CARD your favorite rule. The monitor will collect the votes and count them. [If two rules get 2 votes, we do a new voting round with only these to rules]
The rule which derives the most votes will be implemented.

Rule 1. With this rule only two participants can harvest each round. Who is allowed to harvest is determined by drawing two cards with players numbers. The instructor writes down the player numbers who are allowed on the board.
When someone harvest, but is not allowed to, this participant may get a penalty. Every round we throw a dice after the decisions are made and the yellow sheets are turned in. If we throw a six an inspector is in the forest and will catch the rule breakers, the participants who harvested in a turn it was not allowed to. In that case the participant has to payback the harvest plus an extra 3 units. If the dice shows any other number everybody keeps its earnings and we pass to the next round.

Rule 2. With this rule each participant will have its turn to extract forest unit. Only two participants can harvest each round. In this way it will be a rotation scheme to extract forest units. Each participant will be assigned randomly a turn card to extract forest units: The extraction order is:
Round 1: extracts wood the player **A, B**
Round 2 extracts wood the player **C, D**
Round 3: extracts wood the player **E, A**
Round 4: extracts wood the player **B, C**
Round 5: extracts wood the player **D, E**
Round 6: extracts wood the player **A, B**
Round 7: extracts wood the player **C, D**
Round 8 extracts wood the player **E, A**
Round 9: extracts wood the player **B, C**
Round 10: extracts wood the player **D, E**

(explain explicitly that after this rule is chosen, players get randomly a character A, B, C, D or E. player 1 may for example get turn D)

When someone harvest, but is not allowed to, this participant may get a penalty. Every round we throw a dice after the decisions are made and the yellow sheets are turned in. If we throw a six an inspector is in the forest and will catch the rule breakers, the participants who harvested in a turn it was not allowed to. In that case the participant has to payback the harvest plus an extra 3 units. So, if participant whose turn is A is writing down on the decision sheet to harvest 3 units when only the player with turn C is allowed to harvest, we throw a dice, and when we throw a six, participant with turn A do not get the points on its decision sheet, and we subtract an extra 3 from the total collected points of player with turn A. If the dice shows any other number everybody keeps its earnings and we pass to the next round.

Rule 3. Each of you can harvest legally 0, 1 or 2 units per round. If a participant writes a higher amount than 2 on its game card, he or she can be caught by the inspector and has to pay a penalty. In every round we throw a dice. And when we throw a six, and the participants who harvest more than 2 units in that round, do not get the points it wrote down on its game card, and we subtract an extra 3 points from it's total so far.

Summary:
Rule 1: only 2 persons, randomly determined, allowed to harvest in each round.
Rule 2: only 2 persons, predetermined sequence, allowed to harvest in each round

Rule 3; a maximum of 2 units can be harvested in each round by any person

Do you have any questions about the rules?

Write down your favorite rule on the VOTING CARD, by writing a 1, a 2 or a 3. And turn it in to the monitor

[When we determine the results of the voting the participants fill in the survey on the rules;
When we are determining the voting results, we ask you to fill in this survey about the rules we just described].

INSTRUCTIONS FOR THE IRRIGATION GAME
FIRST STAGE
We would like to thank you for accept this invitation. We will spend about three hours explaining the activity, playing and answering a short survey at the end. Let's start.

The following exercise is a different and entertaining way to actively participate in a project about individual decisions and natural resources. Besides participating in this exercise and having the chance of earn money, you will participate in a workshop in the coming days in order to jointly discuss the exercise as well other topics about natural resources. The funds to cover these expenses have been donated by a scientific body.

In this exercise it is intended to recreate a situation in which a group or family must make decisions about the use of water to irrigate its plots. You have been selected to participate in five persons group among persons who have been subscribed to participate. This exercise is different to others in which others persons have played already in this community. Therefore, comments you have heard from other persons do not apply necessarily to this exercise. You will play several rounds equivalent, for example, to years or irrigation seasons.

Each round consists of two decisions. First, each of you decide how much to contribute to a public fund in order to maintain irrigation canals. The sum of the contributions will affect the amount of water units available for the five players. The next decision is for each player to take some part of the water units available. Each unit you collect during the game is equivalent to $1. For example if you get 100 units during 20 rounds of the game you will receive $100.

We now discuss the first decision in detail. Each round you have 10 units to spend. You can spend some of it in the public fund, or you can keep the rest. You can think of this as the amount of labor you invest in the maintenance of the irrigation system. The level of this effort is between 0 and 10. On the green TABLE OF AVAILABLE WATER QUANTITY and the poster we show how much water will be available for the group of five players depending on the total contributions.
[the MONITOR shows TABLE OF AVAILABLE WATER QUANTITY in the poster and distribute the table to participants].

This table contains the information that you need to calculate the resulting size of the public fund available depending on your contribution and those of the other 4 players. The decision of the contribution is written down on the yellow DECISION SHEET like I will show you right now and provided to the monitor [the Monitor shows the yellow decision sheet on the board].

The monitor calculates the level of the public good and posts this amount on the board. The Monitor will collect the yellow DECISION SHEETS of 5 participants and he will sum the total units that the group decided to contribute to the public fund. We will write on the board the new current size of the public fund.
[explanation: we may use coins or magnets to explain the allocation of the 10 tokens. We may use as an illustration a pink pig where subjects put in their coins and the instructor can define the total investment]

For example, everybody invest 2 units in the maintenance of the irrigation system, and keep the 8 other units for themselves. In that case no water is available to be distributed among the players. As a result everybody ends up with 8 units at the end of that round.

Another example is that everybody invests 10 units in the maintenance of the irrigation system, which leads to 100 units of water to be allocated among the 5 players.

Remember decisions are made private and everybody can decide on how much they want to invest in maintenance.

After the first decision is made, the monitor collects the yellow sheets, and decides the total amount of water available. This amount will be written on the board. Next, all the players get back their yellow decision sheets.

The next decision is to take **a quantity of water for irrigation**. Everybody has the same size of land for irrigation. The money you earn is directly dependent on the water you take from the public pool. Each one of you will receive, FOR ALL THE ROUNDS, randomly a card marked with the following characters: A, B, C, D and E. The player who obtains character A will be the first to decide how much water she/he takes to irrigate her/his plot. It means that characters on the cards define the order in which the properties of each player are situated through an irrigation canal [the monitor shows a draw in the board that represents the situation].

The player who has the card with the letter A decides how much water to take and writes down his/her decision on the YELLOW DECISION SHEET. [Monitor shows the allocation decision spot on the yellow decision card on the poster on the wall]. The Monitor will subtract the collected water from the available water and write the remaining amount of water on a WHITE piece of paper to show this to player B, who has the second option to make a decision. This process continues until player E has made a decision.

[example: given is an amount of water, represented as an amount of coins/magnets. The instructor shows what happens if first player A takes from the pool, then B, etc.]

Then the next round starts with first turning in the contribution to the public good.

It is very important to remember always that the decisions are absolutely individual, it means, the numbers you write down on the game sheets are private and you must not show them to the others members of the group.
Are there any questions about this? [MONITOR: pause to resolve questions.]
Remember that the points you earn depend on your own decisions and will become money at the end of the exercise.

[Before we start, the monitor will announce one additional rule for this group.] To start the first round of the game we will organize the seats and desks in a circle where each of you face outwards. The monitor will collect in each round your YELLOW DECISION SHEETS. Finally, to get ready to play the game, please let us know if you have difficulties reading or writing numbers and one of the monitors will seat next to you to assist you with these. Also keep in mind that from now on no conversation or statements should be made by you during the game unless you are allowed to.

We will have first a few rounds of practice that will NOT count for the real earnings, just for practicing of the game.

Now we will distribute the cards with the letters from A to E which we draw randomly from a bag.

INSTRUCTIONS FOR THE IRRIGATION GAME
SECOND STAGE
After 10 real rounds we let the participants vote for one of three rules to take water for irrigation. We give you the opportunity to start over the game with a different rule. I will describe three rules and you write down on your VOTING CARD your favorite rule. The monitor will collect the votes and count them. [If two rules get 2 votes, we do a new voting round with only these to rules]
The rule which derives the most votes will be implemented.

Rule 1. In this rule we draw for each round, after you have contributed to the maintenance of the irrigation system, and the monitor has announced the size of the water available, the order in which you can take water for irrigation will be assigned randomly.
[5 color cards with player numbers 1-5 will be drawn from a non-transparent plastic bag]

Rule 2. There will be a fixed rotation in which you can collect water. This order is a 5 round rotation system:
Round 1: ABCDE
Round 2: BCDEA
Round 3: CDEAB
Round 4: DEABC
Round 5: EABCD
Round 6: ABCDE
Round 7: BCDEA
Round 8: CDEAB
Round 9: DEABC
Round 10: EABCD

Rule 3: Each of you has a right of 20% of the water of the irrigation system. This amount is calculated after the available water is announced. The order to extract water remains the same for all the rounds: ABCDE. A dice is thrown in each round. When 6 is thrown, an inspector arrives and will check the water extraction. The subject pays back the extra amount taken, and an extra amount of 6 units if more than 20% is taken.

Summary:
Rule 1: randomly determined turn when to take water
Rule 2: rotating turns to take water
Rule 3: equal water rights

Are there any questions about the rules? [The Monitor pauses to answer questions]
Write down your favorite rule on the voting card, by writing a 1, a 2 or a 3. And turn it in to the monitor.

INSTRUCTIONS FOR THE FISHERY GAME
FIRST STAGE
We would like to thank you for accepting this invitation. We will spend about three hours explaining the activity, playing and answering a short survey at the end. Let's start.

The following exercise is a different and entertaining way to actively participate in a project about individual decisions and natural resources. Besides participating in this exercise and having the chance of earn money, you will participate in a workshop in the coming days in order to jointly discuss the exercise as well other topics about natural resources. The funds to cover these expenses have been donated by a scientific body.

This exercise is intended to recreate a situation in which a group or family must make decisions about the use of a fishery resource. You have been selected to participate in a group of five persons among those who have been registered to participate. This exercise is different to others in which others persons have played already in this community. Therefore, comments you have heard from other persons do not apply necessarily to this exercise. You will play several rounds equivalent, for example, to years or fishing seasons.

The resource is spread in two locations A and B. Each round you have to make a choice which location to harvest, and whether to put in 0, 1 or 2 levels of effort. The resulting harvest from the effort put in harvesting depends on the condition of the resource. The state of the resource depends on the condition in the previous round and the amount of effort invested in the previous round.

Depending on the condition of the resource the amount of fish is defined by the PAYOFF TABLES for conditions LOW and HIGH. To be able to play you will receive the blue
PAYOFF TABLE equal to the one shown in the poster. [MONITOR: show PAYOFF TABLE in poster and distribute PAYOFF TABLE to participants]. This table contains all the information that you need to calculate the amount of resource units available depending on the current resource level and the quantity of units harvested by the 5 participants of the group. Each participant makes a harvest decision. Each harvest unit is equivalent to $2. For example, if you harvest 50 units during 20 rounds you will receive $100.

When you chose to put your effort in a location with a high payoff situation, you can harvest 0, 7 or 8 depended whether you put in 0, 1 or 2 units of effort. The resource condition can change in each fishing place. The condition depends on the decisions of others. The HIGH condition can move to a LOW condition when FIVE or more units of effort are invested in a location. A LOW condition can move to a HIGH condition when not more than ONE unit of effort are allocated in the same fishing place for two successive rounds.

For example a HIGH PAYOFF TABLE will be a LOW PAYOFF TABLE in the next round when 6 units of effort are applied in one location. A LOW PAYOFF TABLE will move into a HIGH PAYOFF TABLE when no effort is invested in the location for two rounds.

At the beginning of each round, the monitor will announce the condition of the resource at each of the two fishing locations. To play in each round you must write your decisions, a character A or B , and a number 0, 1 or 2 on the YELLOW DECISION SHEET like the one I am about to show you. [… MONITOR: show **yellow decision sheets** and show in the poster…]

It is very important that we keep in mind that the decisions are absolutely individual, that is, that the numbers we write in the game card are private and that we do not show them to the rest of members of the group. The monitor will collect the 5 sheets from all participants, and will define the harvest for each individual and the condition of the resource in the next round.

When the monitor announces the harvest in each location and the conditions of the resource at each location, we will write these conditions on the boards so that you know which payoff table to use.

Remember that the points you earn depend on your own decisions and will become money at the end of the exercise.

Let us explain this with an example.
[here we run a round with an example]

Are there any questions about this? [MONITOR: pause to resolve questions.]

Before we start, and once all players have understood the game completely, the monitor will announce one additional rule for this group. To start the first round of the game we will organize the seats and desks in a circle where each of you face outwards. The monitor will collect in each round your yellow GAME CARDS. Finally, to get ready to play the game, please let us know if you have difficulties reading or writing numbers and one of the monitors will seat next to you to assist you with these. Also keep in mind that from now on no conversation or statements should be made by you during the game unless you are allowed to.

We will have first a few rounds of practice that will NOT count for the real earnings, just for practicing of the game.

In the first round you use the HIGH PAYOFF TABLE in each location.

Suppose total fishing effort in a location is more than 4 in a high payoff table, then the payoff table drops to a low payoff table. In case of a low payoff table, if two subsequent rounds of less then 2 units of investment, the system flips back to the high payoff table.

INSTRUCTIONS FOR THE FISHERY GAME
SECOND STAGE
[After 10 real rounds we let the participants vote for one of three rules.]
We give you the opportunity to start over the game with a different rule. I will describe three rules and you write down on your VOTING CARD your favorite rule. The monitor will collect the votes and count them. [If two rules get 2 votes, we do a new voting round with only these to rules]

The rule which derives the most votes will be implemented.
Rule 1. With this rule we draw randomly for each player a location the player is allowed to fish. When we throw a 1, 2 or a 3 you can harvest in A. Otherwise you can harvest in B. Then you can fill in your location and your effort on the yellow DECISION SHEET. We throw a dice each round. When you harvest in a location which you are not allowed to, the result of the dice throwing affect your payoff. When we throw a six an inspector comes to the region and check on your locations. If you are located in a place you are not allowed to, you have to pay back the harvest points. For example if the player harvests in the place A with 2 effort units when the allowed place to fish is B and the dice yield 6, the player pays back the harvest.

Rule 2. Only one location is allowed to be fished in each round. There is a rotation AABBAABBAABBAA of a ban where you are not allowed to harvest. It means that:
Round 1 ban in A
Round 2 ban in A
Round 3 ban in B
Round 4 ban in B
Round 5 ban in A
Round 6 ban in A
Round 7 ban in B
Round 8 ban in B
Round 9 ban in A
Round 10 ban in A

Thus in the forth round you are not allowed to harvest in location A. When you harvest, but are not allowed to, the throwing of a dice determines whether you need to pay a penalty. If we throw a six, the penalty is to return back the harvest plus.

Rule 3: Each of you can put an effort of 0 or 1 per round. We throw a dice every round. If we throw a six, an inspector comes to the region to check on your effort levels. If a participant writes 2 units of effort on its game card, and the inspector is present, the participant does not get the points it wrote down on its decision sheet.

Summary:
Rule 1: randomly determined location where to fish
Rule 2: rotating turns where to fish
Rule 3: maximum of 1 unit of effort per round.

Do you have any questions about the rules?
Write down your favorite rule on the VOTING CARD, by writing a 1, a 2 or a 3. And turn it in to the monitor.

Forms that will be used to document informed consent and assent (e.g., written consent form, written assent, cover letter).

CONSENT FORM

Participant No.: ___

Place and Date: ___________________ Time of the exercise: ___:___ AM/PM

You have been invited to participate in an exercise that is part of a research about management of natural resources. Due to your experience with managing natural resources, your participation is very important for this research. The exercise and the following workshop will give important information for all of us including your community. The funding for this project came from International Organizations and the Andes University.

This research does not imply experiments with human beings, animals or vegetable material. For that reason your participation will not have any risk for your health.

At the end of the exercise, you will receive an amount of cash depending on your earnings during the exercise. After the exercise is over, you need to answer some questions about the exercise in which you participated today. Also, there will be some questions about your experience as a user of natural resources. What you earned in the exercise and your answers in the survey will be **confidential. This information will be used just for academic purposes.**

In addition to this exercise you may be selected to participate in a workshop to discuss the results of the exercise. The workshop will be held in________ at _________am/pm.

Your participation in the exercise is completely voluntary. You may leave the exercise at any time. However, if you decide to leave before the exercise is over you will not receive what you earned. The amount of money that you earn during the exercise will be given to you, after you finish answering the questions of the survey.

If you want a copy of this consent form, please ask us for it.

AGREEMENT:

I, ____ state that I understand the information given above and my rights and commitments during the exercise. I also understand that I can leave the exercise at any time declining to receive the money earned in the exercise.

Signed, _____________________________, c.c. _____________ of ________________

I, Juan Camilo Cardenas/Francois Bousquet, Professor of the Andes University / CIRAD, certify that this information will be use in a confidential manner and only for academic and community educational purposes. I also certify that we will pay to each participant the amount of money earned during the exercise.

Signed, ________________, c.c. 79.361.300 of Bogotá / ID number?.

CONSENT FORM

Participant No.: ___

Place and Date : ___________________ Time of the exercise: ___:___ AM/PM

You have been invited to participate in an exercise that is part of a research about management of natural resources. Due to your experience with managing natural resources, your participation is very important for this research. The exercise and the following workshop will give important information for all of us including your community. The funding for this project came from International Organizations and the French Agricultural Research Centre for International Development.

This research does not imply experiments with human beings, animals or vegetable material. For that reason your participation will not have any risk for your health.

At the end of the exercise, you will receive an amount of cash depending on your earnings during the exercise. After the exercise is over, you need to answer some questions about the exercise in which you participated today. Also, there will be some questions about your experience as a user of natural resources. What you earned in the exercise and your answers in the survey will be **confidential. This information will be used just for academic purposes.**

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If you want a copy of this consent form, please ask us for it.

AGREEMENT:

I, ____ state that I understand the information given above and my rights and commitments during the exercise. I also understand that I can leave the exercise at any time declining to receive the money earned in the exercise.

Signed, ______________________________, c.c. _____________ of ________________

I, François Bousquet, Researcher of the French Agricultural Research Centre for International Development, certify that this information will be use in a confidential manner and only for academic and community educational purposes. I also certify that we will pay to each participant the amount of money earned during the exercise.

Signed, ________________, c.c. ????? of Bangkok.

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

Voting card	
Player number	**1**
I vote for the rule number	

Voting card	
Player number	**1**
I vote for the rule number	

Voting card	
Player number	**2**
I vote for the rule number	

Voting card	
Player number	**2**
I vote for the rule number	

Voting card	
Player number	**3**
I vote for the rule number	

Voting card	
Player number	**3**
I vote for the rule number	

Voting card	
Player number	**4**
I vote for the rule number	

Voting card	
Player number	**4**
I vote for the rule number	

Voting card	
Player number	**5**
I vote for the rule number	

Voting card	
Player number	**5**
I vote for the rule number	

<table>
<tr><td colspan="4">Player calculation sheet
Player no: Time:
Place:
Date:</td></tr>
<tr><td rowspan="3">Round</td><td>A</td><td>B</td><td>C</td></tr>
<tr><td colspan="2">My Decisions</td><td rowspan="2">My points</td></tr>
<tr><td>Place (A/B)</td><td>Effort (0,1,2)</td></tr>
<tr><td>Practice 1</td><td></td><td></td><td></td></tr>
<tr><td>Practice 2</td><td></td><td></td><td></td></tr>
<tr><td>Practice 3</td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td></tr>
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<tr><td>9</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td></td><td></td><td></td></tr>
</table>

Player calculation sheet

Player no: Time:

Place:

Date:

Round	A	B	C	D
	My Decisions		Fine (Y/N)	My points
	Place (A/B)	Effort (0,1,2)		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Maximum harvest table	
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

A	B	C	D	E

1	2	3	4	5

Player calculation sheet Player no: Time: Place: Date:	
Round	My Harvest Decision
Practice 1	
Practice 2	
Practice 3	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Player calculation sheet Player no: Time: Place: Date:			
Round	A	B	
	My Harvest decision	Fine (0 or A+3)	My points (A-B)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Table of available water quantity	
Total units invested in the public fund by all 5 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

Player calculation sheet Player no: Time: Capital letter: Place: Date:				
Round	My Decisions			
	A	B	C	D
	Contribution	Amount of water extracted	Amount kept = 10-A	Earnings: B+C
Practice 1				
Practice 2				
Practice 3				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Player calculation sheet Player no: Time: Capital letter: Place: Date:				
Round	My Decisions			
	A	B	C	D
	Contribution	Amount of water extracted	Amount kept = 10-A	Earnings: B+C
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Player calculation sheet Player no: Time: Capital letter: Place: Date:					
Round	My Decisions				
	A	B	C	D	E
	Contribution	Amount of water extracted	Amount kept = 10-A	Fine (0 or B+6)	Earnings: B+C-D
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Monitor calculation sheet (lottery)
monitor:

Time:
Place:
Date:

Round	Points table A	Points table B	Dice	Randomly drawn locations					Decisions (Place / Effort)					group effort	
				1	2	3	4	5	1	2	3	4	5	A	B
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															

Monitor calculation sheet (rotation of banning) monitor:					Time: Place: Date:						
Round	Points table A	Points table B	Dice	Banned location	Decisions (Place / Effort)					Group effort	
					1	2	3	4	5	A	B
1				A							
2				A							
3				B							
4				B							
5				A							
6				A							
7				B							
8				B							
9				A							
10				A							

Monitor calculation sheet (maximum 1 unit of effort) monitor:	Time:	

				Place:						
				Date:						
Round	Points table A	Points table B	Dice (6? Yes or no)	Decisions (Place / Effort)					Group effort	
				1	2	3	4	5	A	B
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Monitor calculation sheet		Votes	No. Rule		
monitor:	Time:		1	2	3
	Place:	Round 1			
	Date:	Round 2			

Round	Points table A	Points table B	Decisions (Place / Effort)					C group effort	
			1	2	3	4	5	A	B
Pract 1									
Pract 2									
Pract 3									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

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<tr><td colspan="3" rowspan="4">Monitor calculation sheet
monitor:</td><td colspan="2">Time:</td><td rowspan="2"></td><td colspan="2" rowspan="2">Votes</td><td colspan="3">Rule numbers</td></tr>
<tr><td colspan="2">Time:</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td colspan="2">Place:</td><td></td><td colspan="2">Round 1</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Date:</td><td></td><td colspan="2">Round 2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Round</td><td rowspan="2">Resource size (A)</td><td rowspan="2">Maximum individual harvest level</td><td colspan="5">Harvest decisions</td><td>B</td><td>C</td><td></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>Group total forest</td><td>Remaining forest (A-B)</td><td>Regrowth of forest (0.1*C)</td></tr>
<tr><td>Pract 1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pract 2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Pract 3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>10</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Monitor calculation sheet (lottery) monitor: Time:	

Place:

Date:

Round	Resource size (A)	Maximum individual harvest level	Harvest decisions					B	C			
			1	2	3	4	5	Group total forest	Remaining forest (A-B)	Regrowth of forest (0.1 * C)	Allowed players	Dice
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Monitor calculation sheet (rotation)														
monitor:			Time:					Capital characters for players						
			Place:					1	2	3		4	5	
			Date:											
Round	Resource size (A)	Maximum individual harvest level	Harvest decisions					B	C	D				
			1	2	3	4	5	Group total forest	Remaining forest (A-B)	Regrowth of forest (0.1 * C)	Allowed players	Dice		
1											A,B			
2											C,D			
3											E,A			
4											B,C			
5											D,E			
6											A,B			
7											C,D			
8											E,A			
9											B,C			
10											D,E			

Monitor calculation sheet (maximum harvest 2) monitor:			Time: Place: Date:								
Round	Resource size (A)	Maximum individual harvest level	Harvest decisions					B	C		
			1	2	3	4	5	Group total forest	Remainin g forest (A-B)	Regrowth of forest (0.1 * C)	Dice
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Monitor sheet	calculation						Votes	Rule numbers		
monitor:	Time:	Extraction player no.						1	2	3
	Place:	1	2	3	4	5	Round 1			
	Date:						Round 2			

Round	Contribution decisions					Total Fund	Water available	Extraction decisions				
	1	2	3	4	5			1	2	3	4	5
Pract 1												
Pract 2												
Pract 3												
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Monitor calculation sheet (lottery)

monitor:	Time:
	Place:
	Date:

Round	Contribution decisions					Total Fund	Water available	Extraction order	Extraction decisions				
	1	2	3	4	5				1	2	3	4	5
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

Monitor calculation sheet (rotation)																	
monitor:	Time:												Extraction player no.				
	Place:												1	2	3	4	5
	Date:																
Round	Contribution decisions					Total Fund	Water available	Extraction order					Extraction decisions				
	1	2	3	4	5			1	2	3	4	5	1	2	3	4	5
1								A	B	C	D	E					
2								B	C	D	E	A					
3								C	D	E	A	B					
4								D	E	A	B	C					
5								E	A	B	C	D					
6								A	B	C	D	E					
7								B	C	D	E	A					
8								C	D	E	A	B					
9								D	E	A	B	C					
10								E	A	B	C	D					

<table>
<tr><td colspan="6">Monitor calculation sheet (property)
monitor: Time:
Place:
Date:</td><td colspan="4" rowspan="1"></td><td colspan="5">Extraction player no.
1 | 2 | 3 | 4 | 5</td></tr>
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"Vertical Asymmetries and Collective Action in Watershed Management"

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Abstract

Watersheds have the characteristic of connecting people vertically by water flows, making relationships among users of water more complex. The location of the people along the watershed defines their roles in the provision and appropriation of water. Verticality in watersheds thus imposes a challenge to collective action. This paper presents the results of field experiments conducted in four watersheds of two different countries: Colombia (South America) and Kenya (Africa). We recruited around 639 watershed inhabitants from upstream, midstream and downstream locations in these basins and conducted field experiments to study the role that location and verticality plays in affecting cooperation at the provision and appropriation decisions. Two field experiments were conducted: the "*Irrigation Game*" a new experimental design that includes the provision and appropriation nature of the resource, and the *"Water Trust Game"* an adaptation of the Trust Game where we explicitly announce the actual location upstream or downstream of the two players. The results show that reciprocity and trust are very important motivations for upstream-downstream cooperation and that the role of upstream players has important implications in water provision decisions. Results from both experiments suggest that the lack of trust from downstream players towards upstream players restricts the possibilities of cooperation among the watershed users.

Media grab: Group communication can be better than regulation for increasing collective action around water management; upstream residents have a key role to play in initiating catchment-level processes.

Introduction

Watersheds connect people vertically by water flows, making relationships among users of the resource complex. The interdependency among users along the social and biophysical scales of the watershed generates challenges to water and watersheds management. The location of the people along the watershed defines their role in the provision and appropriation of water, so verticality in watersheds imposes a challenge to collective action.
Watersheds are characterized by an important biophysical and socio-economic heterogeneity that generates a variety of actors. These actors face different economic and environmental possibilities, like the different access to the resources, especially water in terms of its quantity and quality. *"Watersheds may include grazing land, agricultural land, residential areas, forests, wetlands, common waterways, and water-storage structures, each of which may be used by a variety of resource users. Lateral flows of water, soil, and nutrients between source and destination areas may link those resource users to other stakeholders, some of whom live outside the watershed. Effective watershed management requires coordination in the way that various stakeholders use and invest in the resources"* (Knox et al, 2001).

The connection among actors in a watershed involves the requirements for coordination and cooperation in the management of natural resources that means a necessity to improve their collective action possibilities. The cooperation in the provision and appropriation of water can be affected by the rival nature of the resource and the asymmetries on their access. Trust and reciprocity are important mechanisms in a relationship that involves externalities and coordination failures and these factors are enhanced by the aware about dependence among participants (Ostrom, 1998; Ostrom and Gardner, 1993).

In this study we conducted new experimental designs in the field with the participation of rural communities' inhabitants of four watersheds of two countries: Colombia and Kenya. Through these experiments we expected to observe the factors that can enhance trust and collective action in a context of dependence among people in different locations along a watershed that means asymmetric access to better quantity or quality of water.

We recruited 639 watersheds inhabitants from upstream, midstream and downstream locations of Coello River and Fuquene lake watersheds in Colombia and Awach and Kapchorean rivers in Kenya. The *Irrigation Game* was conducted with a sample of 355 participants and the *Water Trust Game* with a sample of 284 participants from both countries. The gender composition of the sample was of 48% for the irrigation game and of 51% for the water trust game. Table 1 below shows the sample distribution across basins, games and treatments. Not all cells were sampled due to budget and time restrictions. However we guaranteed that both games were conducted in both countries, and within each country we obtained data for all treatments of the irrigation game.

	Participants in Irrigation Game (1 session = 5 players, 20 rounds)					Participants in Water Trust Game (1 Session = 2 players, 1 round)	
Basins	Base Line	Communication	High Fine	Low Fine	Total Irrigation Game		Total Basin
Awach (Kenya)	20	20	20	---	60	124	184
Kapchorean (Kenya)	20	20	---	20	60	---	60
Coello (Colombia)	20	30	20	30	100	---	100
Fuquene (Colombia)	35	35	35	30	135	160	295
Total	95	105	75	80	355	284	639

Table 1. Distribution of the participants across watersheds, games and treatments.

The field experiment approach was used in order to achieve a better understanding of the effect of participants' location on water systems and the factors that influence provision decisions on this context. Two field experiments were conducted: the *"Irrigation Game"* a new experimental design (Cardenas et.al 2008a) that includes the provision and appropriation nature of the resource and the *"Water Trust Game"* an adapted version of the Trust Game framed around water that presents the dependence among players related to water and compensation (reverse) flows. In all games the participants received monetary incentives based on the tokens earned during the games. The average payment received by players ranged between 1 and 1.5 days of work paid at the minimum wage rate.

Experimental design

Irrigation game

This game introduces the asymmetries in the water provision and access to the resource among players. In this game five players make two decisions in each round, one of contributing to a public project to produce water for the group and another of extracting water for individual gains from irrigation. In the first part of the game, players make decisions of how many tokens to invest in a public fund to maintain water canals, from an initial endowment of ten tokens in each round. The amount of available water for the group is increasing in the group contributions according. Non contributed tokens are kept in a private account. These tokens kept are paid at the same monetary rate than the water units to be extracted in the second stage of each round. The second decision of the players is the individual water extraction from the total water produced. This decision is taken according to the location of the players along the water canal, which is defined randomly for the entire sequence of rounds, and is represented by a letter: A for the player in the first position and E for the player in the last position. The water is allocated therefore according to the location in the following manner. Player A first receives all the water produced by the group project, and decides how mucho water to extract. The remaining water is then shown to player located in B who then decides how much to extract and how mucho to leave to the remaining players downstream, and so on for players C,D and E. This sequence is conducted for 10 rounds

After the first ten rounds of baseline treatment, rules changed for some groups and this change is announced aloud to the players. Some groups were permitted to communicate; other face external regulation treatments and other groups continued playing with the baseline conditions.
In the **face-to-face communication** treatment, players were allowed to communicate with the other players in the group before returning to their places to make their own private decisions. Likewise in the baseline, they know the aggregate decision but not the individual decisions after each decision round. In the **external regulation** or **penalty treatments** players were told that there would be a chance of being monitored each round. The experimenter rolled a dice in front of the participants each round and if the number obtained was 6, all the participants would be inspected. Thus, with a probability of 1/6 of being inspected, the monitor would verify if the player had extracted more than the allowed water amount, namely, 20% of the produced water by the group in the provision stage, and if so, they would pay a fine. In the high penalty treatment, the fine was the extra water in excess extracted plus six units from the earnings; in the low penalty treatment the fine was just the extra amount taken.

Water trust game

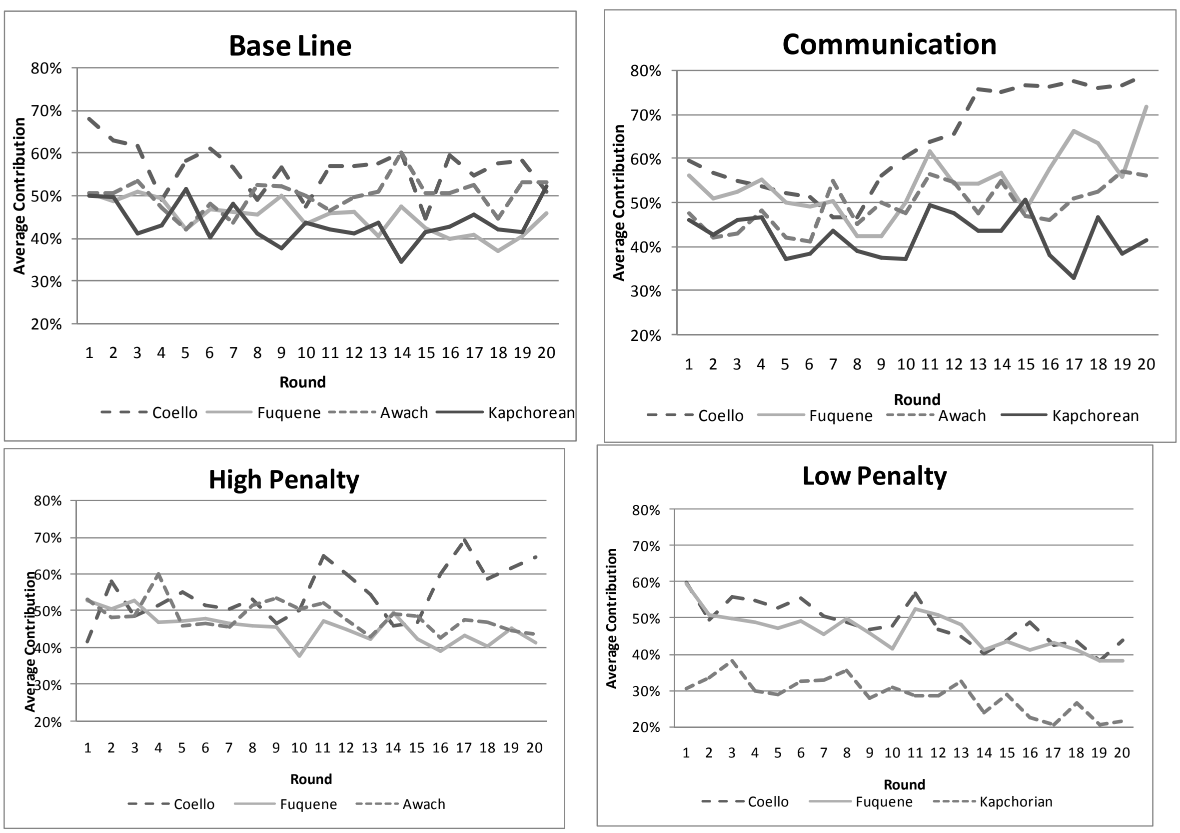
Based on the standard trust game (Berg et al 1995), we adapted the basic incentives structure as a *water trust game (WTG)* framed around water production and distribution between two people located in different positions of a watershed. At the beginning of the game both players are endowed with 8 tokens. Player 1 (the proposer) can send any fraction from 0 to 8 tokens of her initial endowment to player 2 (the responder). As in the canonical version of the trust or investment game, the amount sent by player 1 is tripled before it reaches player 2 who then decides how to split the tripled amount plus her initial endowment between herself and player 1. This increase in the amount being sent reflects how a decision in favor of watershed conservation would increase the possibilities of a greater social outcome to be distributed along the watershed members. In our framing we explicitly framed the decision of player 1, if upstream, as the quantity of clean water sent to player 2 downstream, and player 2's decision as an economic compensation for the water provided by player 1. If the game started with a downstream player, also such decision was framed as an economic compensation for the water provided by player 1.

We implemented the trust game using the strategy method, that is, players 2 were asked the complete strategy of responses to each possible offer by player 1. Therefore player 2 had to respond, without knowing yet the amount offered by player 1, how many tokens she would return to player 1 for each possible offer by player 1 (0, 2, 4, 6, 8 units). During each session we also asked each of the players the amount the expected from the other player. A typical experimental session lasted between 2 and 3 hours including the time of explaining the rules and practice rounds to make sure every participant had understood the incentives and rules of the game.

Results and discussion

Irrigation game

The Social Optimum or Maximum Social Efficiency is a contribution of 100 units of water that means an individual contribution of 45-50 tokens. Nash Equilibrium is zero-contribution obtaining a suboptimal result of 50% of the maximum social efficiency possible. The overall results replicated the patterns of previous public goods or CPR games where predictions of non-cooperative game theory were not a common result and communication improved cooperation.

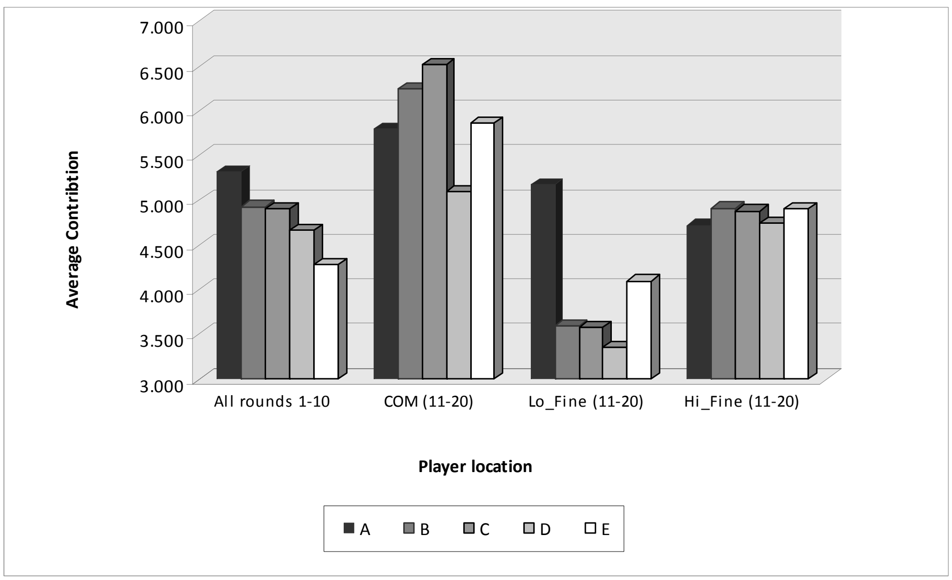


Graph 1. *Irrigation Game* contribution by treatment (Baseline, Communication, High Penalty and Low Penalty)

The four panels in Graph 1 show the average contributions in the first stage of the game as a percentage of the endowment in each round. The contribution was on average 4.82 tokens, i.e. 48.2% of players' endowment, for the ten initial rounds. For the second stage of the game (rounds 11-20), the groups that continued playing under the baseline condition continued a similar pattern (47.1% of their endowment), whereas the groups that could communicate reached a contribution of 5.9 tokens on average. The penalty treatments groups obtained an average contribution of 4.83 for high penalty and 3.96 for the low penalty groups.

The variance of the contributions behavior was rather constant and similar across the four treatments or across the watersheds. The standard deviation of the contributions ranged between 2.5 and 3 units and remained constant over rounds. We did observe a slightly higher variance for the communication data (sd=2.05 units for rounds 11 to 20 compared to 2.83, 2.64 and 2.88 for the baseline, high and low penalty treatments respectively). This higher variance in the communication treatments is expected as the dynamic of a group conversation induces a significant number of players to contribute their entire endowment while other players remain in the low contributions, namely the free-riding strategy, creating a more dispersed distribution if compared to the normal distribution observed in the base line data.

However, a look at average and variance of the contributions may hide an important piece of information for our analysis of cooperation in watersheds. These are averages of five players who are located asymmetrically along the watershed, with contributions being greater for the head-ender (player A) intermediate for players B and C in the mid-stream location, and low for the last two players downstream, as shown in graph 2, in the left section where we report data for the first ten rounds of all sessions, before they learned under which institution they would play in the subsequent rounds. The remaining sections of graph 2 show the average contributions by players under the different treatments and for each location.



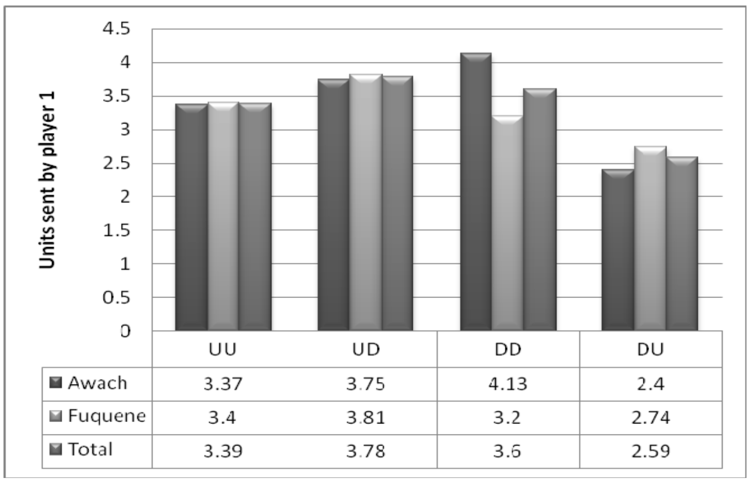
Graph 2. *Irrigation Game* contribution by player location (rounds 1-10 all groups and treatments)

Recall that these locations are assigned randomly at the start of each session and remain constant throughout the game. The results of the first ten rounds (see left portion of Graph 1) suggest that in a baseline situation, as one individual is assigned a unit further down in the irrigation system, her willingness to contribute to the public fund that provides water for all players is lower, showing an erosion of the possibilities of building collective action along the watershed. The limitations of space allowed for this paper constrains us to report details about the particular behavior over time and across treatments for each of the types of players along the irrigation system. However, we can see from Graph 2 that communication increases substantially the contributions of all players, and particularly of downstream players. Notice also the poor performance of the fines, low and high if compared to the baseline or the self-governance solution, and how the higher fine if anything helped produce a more fair contribution across locations. We will discuss implications of such findings later on.

Water trust game

Recall that regardless of the location, the Nash prediction in the trust game is for player 1 to send zero and player 2 to return zero tokens. Under non-binding contracts there are no obligations nor warranties of positive returns on any amount offered by player 1. On the other extreme, the maximum social efficiency is achieved when the first mover sends all her endowment producing 32 units to be distributed among both players depending on the decision by player 2. What we observe, and as several other studies using the Trust Game, players 1 offer positive amounts and players 2 returned positive amounts, proportional to player 1 offers. The interesting variation of our design is whether location of the player, Upstream (U) or Downstream (D) had an effect in offers and amounts returned.

Graph 3 compares the results of average amount offered, in units, by player 1 to player 2 by treatment[1]. Across the two watersheds in Colombia (Fuquene) and Kenya (Awach) players 1 sent on average 3.34 units out of their 8 units endowments (41.8%) to player 2. However, the four treatments do show differences worth discussing. We observe that the DU treatment (downstream participants being player 1 and upstream participants as players 2) shows lower (and statistically significant) offers. In average, the offers sent by players 1 located in upstream positions were higher than when players 1 were located downstream. Recall that in all treatments both players were informed of the actual location of the other player in the watershed.



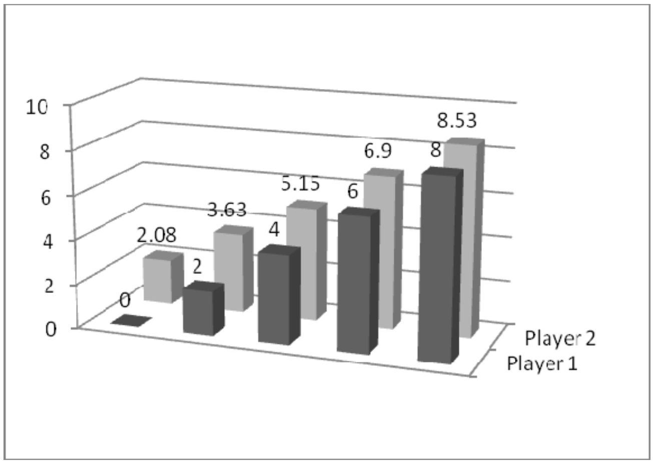
Graph 3. Average amount of units sent by player 1 to player 2

The more striking difference appears when players 1 are located downstream and must send their offers to players 2 located upstream. This phenomenon is observed in both the Kenya and Colombia samples.

Let us turn our attention to players 2 behavior. Graph 4 shows the average amounts, in tokens, retuned by player 2 as a response to each of possible options that player 1 could offer to player 2 in our design. We are able to capture this information because we use the strategy method in the trust game, that is, we ask players 2 to elicit their responses to all possible offers by player 1, before they realized the actual offer. The results show that more trust is responded reciprocally, consistent with much of the literature using the trust game (See Cardenas and Carpenter, 2008) for a survey of field and lab experiments using the canonical version of trust game)[2]. However it is worth noting that players 1 received in average positive returns on their investment, that is, the average unit sent to player 2 generated a >1 return, although the returns where much higher for lower contributions, including getting in average 2.08 units for a zero offer!.

[1] UU=player 1 and player 2 are both located upstream; UD=Player 1 is upstream and player 2 downstream; DD= player 1 and player 2 are both located downstream; DU=Player 1 is downstream and player 2 upstream.

[2] The variation of the two observed decision variables, offers by players 1 and responses by players 2 showed a standard deviation of 2.04 units for players 1's offers. With respect to responses by players 2 we need to calculate the standard deviation for each possible response with standard deviation values of 2.17, 2.81, 3.52, 4.50 and 6.05 units for 0, 2, 4, 6 and 8 offers by player 1 respectively.



Graph 4. Amount sent by player 1 and returned by player 2

These two phenomena, that downstream players seem to be less trusting, and that individuals in general include reciprocity in their strategic behavior, could explain in part why we observed in the irrigation game such lower contributions by players downstream; players D and E suffer more explicitly the negative effects of water over extraction by players upstream and therefore are more sensible to such unidirectional externalities. Experience with such externalities can drive a reduction of trust among downstream inhabitants towards the rest of watershed users, and it is well reflected with both the experimental and actual location of the players in both games.

Contextual analysis

There are several types of variables at the individual, experimental session, and regional level that can also help explain the variation of the behavioral variables by our participants in the two games, beyond the experimental design and treatments. Due to lack of space we cannot report here a regression analysis to explain the contributions by players in the provision stage of the irrigation game, and the offers levels by players 1 in the water trust game, to confirm our hypothesis of a downstream erosion of cooperation in the vertical collective action problem because of decreased trust by the downstream players in the game. The econometric analysis is discussed in detail in Cardenas et.al (2008b) where we explored the individual contributions in the irrigation game as a function of the experimental conditions, including the round, the location in the irrigation system and the institutional treatment (baseline, communication, high fines and low fines); we then continue with the individual characteristics given the richness of the demographics we were able to sample in the field. We included several context controls such as dummy variables for the watersheds and also for the particular five players context. We chose therefore to run a robust standard errors fixed effects model where the fixed effects were captured by each of the particular 71 sessions conducted in the four watersheds. We test several formulations of the estimator including a pooled data model, a semi-pooled model with dummies for the watersheds, and an unpooled model where we estimate one separate regression for each of the watersheds. We also tested different institutional changes in round 11 for these sessions and compared them to the baseline treatment where players continued after round 11 under the same rules and incentives. Confirming our basic results reported here, we find that that the location in the irrigation system (A,B,C,D,E) does play a significant role in the level of contributions; in the unpooled model for each of the watersheds we find that only for the case of Awach such effect is not significant under the baseline treatment, although it is statistically significant for the communication treatment[3]. Also, we observe the powerful effect of the communication treatment in increasing contributions for all estimated models. However, the introduction of high and low fines seem to have a poorer effect in the contributions; if anything, some of the estimated models show a positive effect of the high fine, and for the case of low fines all coefficients are negative and not significant (See Cardenas, 2004; 2005) for similar results comparing these type of regulations with a face-to-face communication treatments in common-pool resource experiments conducted in the field.

We also find that the contributions by the other people in the group in the previous round help explain contributions with a negative effect. That is, the higher the contribution by the other four players the smaller the contribution by the average player in the next round. This contradicts the reciprocity effect but the size

[3] We do not think it is a country effect or an experimenter effect because the Kapchorean watershed did show statistically significant effects for the location of the players in the game, and the experimenters were the same in both Kenyan locations.

of the coefficient is rather small. It could be, as a reviewer wisely suggested, that players would perceive that the group was making a sufficiently high effort and therefore they could save some of the tokens fdor their own income, but also that when contributions were substantially low, they felt that an extra effort should be made to increase the group contributions. However, this effect changes substantially if we study separately the institutional context of the regulation in the second stage, that is, this coefficient varies with the treatment. We found that lower levels of contributions for the two Kenyan watersheds and the effect of the "others contributions lagged" turns out to be positive and significant for the Colombian basins whereas negative for the Kenyan ones. We had already shown the much stronger effect of communication for the Colombian cases.

With respect to demographic characteristics of the participants, we find that more educated, older people, living in larger households seem to contribute more to the provision stage of the game. Other factors do not seem to present a robust effect across the different subsample models estimated.

The analysis of the role of the different regulatory treatments shows that the asymmetry in the coefficients for the player location is decreased for the case of the communication treatment. One of the major effects we observed of the self-governed solutions generated in the face-to-face communication within the groups is that players began to contribute in a more homogenous manner as well as distributing better the water along the sequence. The watershed effects remain robust with the Colombian watersheds showing higher levels of contributions for all treatments and with the Coello watershed showing a substantially higher level of contributions in all treatments.

As for the case of the water trust game, we conducted an equivalent regression analysis. In this case we have 142 observations (pairs) for 284 participants in this game, and sampled from different locations in two of the watersheds (Fuquene for the case of Colombia and Kapchorean for the case of Kenya). We conducted all possible permutations of pairs for upstream and downstream locations of the players with the purpose of studying if there is in fact an effect of the actual location of the people in the watershed on the level of trust, a key element of collective action.

We estimate the amount offered by player 1 to player 2 as a function of the same kind of explanatory variables used in the previous analysis. Model (1) considers the pooled data set, whereas model (2) includes a dummy for the Fuquene watershed which turned out to be significant (also consistent with the higher levels of contributions in the irrigation game for the Colombian samples). Models (3) and (4) consider the separate samples for each of the watersheds.

Some robust results are worth mentioning. Reciprocal behavior drives trust by players 1. Those expecting more are sending more amounts to players 2. This is consistent across the estimated models. Older and more educated people and females have a slight but not significant tendency to offer less. However, the more time the player has lived in the community the higher the offers with a significant effect.

Let us now turn to the verticality effect. We had already in our descriptive analysis of offers (See Graph 3) that the actual location of the player in the watershed might be playing a role. We do find that Player 2's location is significant and negative for all estimated models meaning that when the offers come from downstream players and player 2 is upstream, such offers decrease. That is, downstream players trust less upstream players and that has a significant effect on trust and social efficiency since each token not sent represents three less tokens not generated for the social efficiency of the pair of players.

Conclusions

The challenge of vertical collective action emerges from the asymmetry in the location of players along the irrigation system. Head enders or upstream players have better opportunities to capture the benefits of a public project that maintains or produces water because they have an earlier access to the resource. On the other hand their actions cause direct externalities to those downstream. Therefore, tail enders or downstream players notice two effects on their well-being: those upstream have better chances to benefit from the resource, and their appropriation actions affect them directly. Further, the appropriation by those downstream has no direct effect on players upstream and therefore the possibility of signaling through reciprocal responses is less available for downstream players. In our irrigation game this mechanism seems to operate through the contribution stage. Players downstream are willing to contribute less than upstream players to the public project; it seems that the effect is if anything of negative reciprocity which triggers even more the vicious cycle of reciprocity, trust and reputation well described by Ostrom (1998).

These effects can create a similar negative effect to that of heterogeneity in collective action in this case because of location. The distance created by these asymmetries i.e. better resource availability and unidirectional externalities from those upstream seems to reduce the level of trust and cooperativeness of downstream players.

It seems that one major challenge to solve the vertical challenge is to address the asymmetries in a manner that players perceive a more fair allocation of the resource and of the effort contributed to provide the resource. Remember, irrigation and water systems require solving both the provision and the appropriation problems, and proportionality between contributions and appropriation is part of the challenge. *"When rules are based on a clear principle of proportionality and all participants recognized that the rules enable them to reach better outcomes than feasible in the "state of nature" game, and all are prepared to punish rule breakers, more productive equilibria are reached and sustained over time"* (Ostrom and Gardner, 1993).

The challenge is to bring downstream players to the group-oriented outcome of the game by creating better allocations of effort and resource extraction along the watershed. This is what the face-to-face communication treatment achieved in our results. It balanced the effort between upstream and downstream contributions and therefore increased substantially the water produced by the irrigation system, providing better chances for the downstream players (D and E) to obtain water in each round. *"Asymmetries among participants facing common-pool resource provision and appropriation problems can present substantial barriers to overcoming the disincentives of the "state of nature" game between head-end and tail-end farmers. However, these asymmetries are frequently overcome in settings where farmers are made aware of their mutual dependencies; after all, head-enders and tail-enders may need the resources provides by tailenders when it comes to maintaining the system over time"* (Ostrom and Gardner, 1993).

The lack of trust among the two ends of the watershed, and in particular of players downstream, who suffer the most effects of the decisions and better location by those upstream, imposes a major challenge here. Further research is needed to explore the impacts of simply informing better about the expectations and intentions of both players upstream and downstream and how different government and non-government actors can play in decreasing this lack of trust that we observe both because of the experimental location or the actual locations of our hundreds of participants in Colombia and Kenya. Acknowledging these asymmetries, and addressing them to increase trust among head and tail enders could provide better foundations for the implementation of self-governed solutions for watershed management.

On the methodological side, combining these experimental methods with other tools in the field can offer reflection spaces for communities as well as deeper understanding of the dynamics of behavior and rules. In fact the design of the irrigation game reported in this paper emerged from a NSF funded project where collaborators from these different approaches have been applying lab and field experiments as well as role games[4].

Acknowledgements.

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