Glacier Melting and Retreat: Understanding the Perception of Agricultural Households That Face the Challenges of Climate Change

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Abstract

In recent years a rise in glaciers equilibrium line, both in Colombia and Latin America has been observed. Glacier melting and retreat lead to a change in the availability of water, which largely affects agriculture, being it responsible for 10-14 percent of Colombian GDP. Using framed economic experimental games we studied the decisions made by farmers that depend on high-mountain water about water use and their response to institutions that facilitate adaptation to climate change. Results show that farmers react to reduction in water availability increasing the use of surface water from districts, ignoring that this source also depends on climatic conditions. When players face the possibility to adapt to climate change, they tend to invest in such strategies but consumption of water is not reduced. From the results, policy recommendations emerge about strategies for facing water scarcity in a climate-change scenario.

Key Words: Water use, glaciers and paramos, framed economic experimental games, behavioral responses to scarcity.

1 Introduction

Glaciers from Los Andes play an important role in water management, keeping river flows and being a key factor for the functioning of irrigation systems, as well as of hydroelectric plants of various cities. Quito, La Paz and Lima are good examples of large cities that depend on these water sources. Glaciers are also a water source that recharges aquifers, which are important for different populations and ecosystems that rely on them (CAN-SG et al, 2007).

Nevertheless, this provision of services is only sustainable in the long term, under adequate climate conditions that keep the equilibrium between snow melting and accumulation, known as the glacier equilibrium line (Braithwaite, 2008). In basins with high glacier coverage, (ablation) ice melting is compensated with snow precipitation, maintaining the water equilibrium in the basin (Braithwaite, 2008; Rupper and Roe, 2008; Poveda and Pineda, 2009). High amounts of ablation have been reported in Latin American countries, such as

Peru, Bolivia, Ecuador and Colombia. In the case of Colombia, eight glaciers disappeared during the second half of the twentieth century, being the consequence of the loss of 43.56 km^2 of ice in the mountains. (Morris et al, 2006). Today, it remains only four snow-covered mountains: Nevado del Ruiz, Nevado de Santa Isabel, and Nevado del Tolima, and two high mountain ranges: the Sierra Nevada del Cocuy and the Sierra Nevada de Santa Marta. (IDEAM, 2001b).

The fourth report from Intergovernmental Panel on Climate Change (IPCC) for Latin America, identifies an average glacier retreat from 10 to 15 meters per year in Colombia, forecasting the disappearance of Colombian glaciers in less than 100 years. (Magrin et al, 2007). However, Poveda and Pineda (2009) conclude that glacier loss will occur before this date, estimating a glacier retreat rate of 3 km^2 per year. According to these estimations, Colombian glaciers will disappear in 2024.

Vuille et al. (2003) analyze the causes of glacier retreat, concluding that an increase in temperature plays an important role in snow melting. When glaciers are located in places with higher temperature, such as places near the equator, the glacier's equilibrium line is higher, reducing the area covered permanently with snow. In some cases, this line is located at a higher height than the glacier, and as a consequence, these glaciers will disappear in the mid and long term (Favier et al, 2004a).

Various studies have found a strong correlation between the rate of glacier retreat, local and global climate change, and El Niño-Southern Oscillation. During the last 30 years, a 1°C increase in the average temperature has been reported in weather stations located at high altitudes (Seidel and Free, 2003; Ceballos et al, 2006). Besides, the "El Niño" events are related to a temperature increase between 1°C and 2°C. (Díaz and Graham, 2006; Bradley et al, 2009). Both events cause an increase in glacier melting (Francou and Pizarro, 1995) and if climate change continues and accelerates, this melting will reduce water availability. Another event that is related to global warming in high mountains is the change in precipitation, from snow to water precipitation, which accelerates glacier melting. (Favier et al, 2004b).

Since the end of the 20th century, there has been a great interest in studying, debating, and developing new policies to deal with the effects of climate change in human activities. In the United Nations Climate Change Conference, two main strategies were identified to respond to the threat of climate change: mitigation and adaptation. Mitigation involves finding mechanisms to reduce, store, or absorb emissions of greenhouse gases. Adaptation, on the other hand, refers to dealing with climate change with policies that reduce its negative effects or exploit its positive effects (UNFCCC, 2006b).

Today, it is clear that both strategies, mitigation and adaptation, must be carried jointly. Mitigation is not enough by itself, because even if efforts of reducing greenhouse gases are successful, adaptive strategies must be implemented. This is necessary because climate change events occur after a long lag period, meaning that the current global warming is caused by emissions from decades ago.

The first communication of the Colombian Institute of Meteorology and Environmental studies (IDEAM) in the United Nations Framework Convention on Climate Change revealed that changes in water availability caused by the disappearance of Colombian glaciers, and the transformation of mountain ecosystems, should be considered along with changes in land fertility, and concludes that the agricultural sector will be one of the most affected by climate change in mountains. This sector has represented between 10 and 14% of Colombian GDP during the last 20 years, and generates jobs for about 4 million people (DANE, 2011).

Different studies have analyzed the strong effects that climate change will have on the agricultural sector (Smit et al., 1996). In Colombia, it is expected that there will be changes in crop growing cycles, making them vulnerable to hot and dry seasons (Ibañez et al., 2010; Ramírez-Villegas et al. 2012). Besides, a rise in temperature will increase the rate of diseases in crops, reducing them and increasing production costs (Ramírez-Villegas et al., 2012). Temperature rise will also displace crops to higher altitudes, generating variations in expected returns (Pabón, 2003).

As well as mitigation of climate change, which requires the effort of nations to invest in the efficient use of energy and its conservation, large investments will be needed in the agricultural sector to promote the efficient use and conservation of natural resources, mainly water resources, as a strategy for adapting to climate change (Hall et al, 2008).

Adaptation can be done in different ways, depending on its specific purpose, time scale and mechanism. Particularly, there are four main adaptation strategies: reactive adaptation, anticipated adaptation, planned adaptation, and autonomous adaptation. (Schneider et al, 2000; Smit and Skiner, 2002; Bradshaw et al, 2004; Tol, 2005). Reactive adaptation refers to actions that react to the event of climate change, either diminishing or controlling its effects. Anticipated adaptation corresponds to actions taken before climate change occurs, to minimize its effects. Planned adaptation consists in policies or strategies that alter the adaptive capacity of an economic system (like the agricultural system), or facilitate the adoption of strategies for the whole system. Autonomous adaptation refers to all adaptation strategies that are implemented individual, and therefore, benefits derived from this adaptation are private.

The adaptability of a given sector depends on vulnerability to climate change. Colombian agriculture is characterized by the existence of inequality, related, among other factors, to large diversity of crops, cropping systems, different occupation and deforestation rates, and different cropping strategies. This makes the whole system more vulnerable, with different impact throughout the country, and makes it more difficult to implement a national adaptation plan (Pabón, 2003; Motha, 2007; Poveda, et al. 2010). Different adaptation strategies have been implemented throughout the world, like changes in crops that are planted, (Bedõ et al. 2005; Challinor et al. 2007; Krishnan et al. 2007), in sowing dates and improvements in irrigation systems (Byjesh et al. 2010; Srivastava et al. 2010). These are related to the physical, economic, political and environmental limitations of each community. (Smit et al., 1996; Adger et al. 2009). Bradshaw et al. (2004) affirm that even though adaptation has been identified as a response to variability caused by climate change in the agricultural sector, the way each farmer decides to adopt it remains unknown. Natural sciences define a range of adaptation possibilities, but social behavior determines which options are adopted and which are not. As a matter of fact, many worldwide investigations are focused in predicting how people will react to climate change impacts, and which political and social instruments are more efficient for promoting the implementation of adaptation strategies.

Some examples of effective adaptation are described in recent literature. Thomas et al. (2007) analyze collective action as an adaptation strategy to climate change in various communities of farmers in Africa, finding out that farmers distribute risk among members of the community, by harvesting in community plots. On the other hand, Millner (2012) shows, using a theoretical model, that individuals that have access to short term weather predictions have less adjustment costs and this allows them to improve their adaptation strategies. Finally, Milinski et al. (2006) and Milinski et al. (2008) use economic experimental games with students, and show that students that are better informed about climate change and its possible impacts make larger contributions for weather conservation. In these lab experiments, reputation and risk levels also play an important role in cooperation. Larger contributions are made in treatments where the identity of players is revealed or scenarios with greater risk.

On the other hand, it is also possible to observe adaptation strategies that have failed. Bradshaw et al. (2004) study crop diversification as an adaptation strategy in Canadian farms. Even though crops have diversified at an aggregate level, it is observed that each farm specializes more in a given crop, and this is explained by costs associated by costs related to scale economies. This shows that even though diversification can be considered a good adaptation strategy, it may not be adopted by farmers, due to economic costs.

Ward and Pulido-Velasquez (2008) show that investments in better irrigation systems do not reduce water consumption in all cases, because farmers perceive that they are using less water per unit of area with the new system, and feel that their right to use water is being violated, so the farmers increase the cultivated area to use the same amount of water they used before the system was implemented.

This shows that mechanisms of social organization, values, perceptions, knowledge, and human relationships, are important to understand and predict the reaction of a community to changes in climate.

Projects led by the IDEAM and Conservation Internacional Colombia, such as the National Pilot Project of adaptation to climate change, have been a first approximation to analyze the adaptive capacity in high mountain regions, designing and implementing an adaptation program in the Macizo de Chingaza, which includes collection of information about climate change, reduction of adverse impacts in water regulation, land use planning models, and estimation of vulnerability of the productive ecosystems of the region. One of the main conclusions of this project is that, in order to reduce the vulnerability of communities in high mountain regions with adaptive strategies, it is necessary to work directly with the communities with methodologies that require active participation, engaging academia and science during the whole process.

Considering these efforts, this study aims to study the effect of climate change in the behavior of farming communities that use water coming from high mountains. To do this, economic experimental games are applied in the field, that simulate events caused by climate change in a controlled environment, in order to analyze decisions made by people about water use and decisions about engaging in adaptation strategies under different collective cooperation arrangements.

This study wants to answer two questions. How changes in water availability as a result of climate change affect its use for agricultural purposes, in communities that depend on high-mountain ecosystems and glaciers for the provision of water? How different institutions or arrangements for engaging in adaptation strategies affect the adoption of such strategies and the use of water in a climate change scenario?

The rest of this document is organized as it follows: Section 2 presents the theoretical model and the experimental design included in the methodology, along with the details of the game. Section 3 describes the main results, including data analysis and econometric results. The last section presents a discussion on the most relevant results of the research.

2 Methodology

2.1 Theoretical Framework

Human being depends on the supply of water to satisfy vital needs. However, the development of urban populations, agriculture that depends in extensive irrigation, and fast industrial development have generated a strong pressure over this vital resource. One way of analyzing this situation from an economic perspective is to consider water as a common pool resource. This means that it is a rival good but, at the same time is not excludable. The aggregate extraction of this kind of goods may cause what is known as the tragedy of the commons, where each individual, considering only his/her private benefits, consumes a greater quantity than the social optimum, causing overexploitation of the good or resource (Hardin, 1968).

Different economic experiments examine human behavior under social dilemmas related to the extraction of common pool resources (Ostrom et al., 1992; Ostrom et al., 1994; Casari and Plott, 2003; Cárdenas and Ostrom, 2004; Cárdenas et al., 2004; Velez et al., 2005; Alpízar et al., 2007; Moreno-Sanchez and Maldonado, 2010). These experiments are based on a payoff function that establishes that individual extraction of the resource raises private benefits, although it does at a decreasing rate, while aggregated extraction reduces individual earnings, representing the typical dilemma of the extraction of a common pool resource. Our model follows this approach related to the extraction of common pool resources, represented by the following payoff function.

$$\pi_i = f(x_i) + g\left(S, \sum_i x_i\right) = \alpha x_i - \frac{\beta {x_i}^2}{2} + \gamma\left(S - \sum_{i=1}^{n} x_i\right)$$

The first term of the equation represents the benefits obtained from the extraction of the resource, where α reflects the price per unit of the resource that is extracted, x_i. The second term of the equation represents the costs of extraction, which are positive and consider an increasing marginal cost. The sum of these two terms represent the individual payoff function $f(x_i)$. The third term $g(.)$ corresponds to the externality that is caused by the group extraction on the individual benefits, where γ is a parameter that determines the importance of this externality in the payoff function. In this model the amount of resource that is available for the whole group is limited by the stock or amount of resource S.

Based on this payoff function, the strategic decisions made by a group of *n* users are simulated. These users can extract from a given quantity S of a common pool resource. In this experiment, the common pool resource is a wáter reservoir used for agricultural purposes, and managed by a water district.

The optimum private quantities that are extracted from a common pool resource are different from the social optimum. The private optimum –the Nash equilibrium- can be obtained by maximizing the payoff function:

$$\max_{x_i} \pi_i = f(x_i, S) + g\left(\sum_i x_i\right) = \alpha x_i - \beta\frac{{x_i}^2}{2} + \gamma\left(S - \sum_{j=1}^{n} x_j - x_i\right), j \neq i$$

Its solution is given when we solve:

$$\frac{\partial \pi_i}{\partial x_i} = \alpha - \beta x_i - \gamma = 0$$

If symmetry is assumed and there are no differences between players, it is possible to obtain the Nash Equilibrium:

$$x_i^{nash} = \left(\frac{\alpha - \gamma}{\beta}\right)$$

The social optimum is obtained when the sum of the benefits of all players is maximized,

$$\max_{x_i} \sum_{i=1}^{n} \pi_i = \sum_{i=1}^{n} \left[\alpha x_i - \beta \frac{x_i^{\,2}}{2} + \gamma \left(S - \sum_{i=1}^{n} x_i \right) \right]$$

First order conditions of this equation imply:

$$\frac{\partial \pi_i}{\partial x_i} = \alpha - \beta x_i - n\gamma = 0$$

$$x_i^{soc} = \left(\frac{\alpha - n\gamma}{\beta} \right)$$

This means that the extraction that is socially optimal is less than the private individual optimal, which is the Nash equilibrium. It is important to notice that the amount of resource available *S* does not have an effect on the incentives of individuals, because private and social optimums do not depend on the abundance of the resource.

However, our experimental design includes a stochastic component that represents weather fluctuations and affects the availability of the resource. These fluctuations are exogenous, representing the uncertainty related to weather and climate change. Following a stochastic process, the amount of water available can be either normal (S_n) or low (S_b). When climate change is introduced, extreme events reduce water availability even more, to a value of (S_s), generating drought periods. In any case the amount of water available in the reservoir will be defined by S_t with, $S_n > S_b > S_s$. If private and social equilibriums are not modified after including weather fluctuations, the benefits of each player do depend on the amount of resource that is available, as shown:

$$\pi_{i,t}^{nash} = \alpha x_{i,t}^{nash} - \beta \frac{{x_{i,t}^{nash}}^2}{2} + \gamma \left(S_t - n x_{i,t}^{nash} \right)$$

$$\pi_{i,t}^{soc} = \alpha x_{i,t}^{soc} - \beta \frac{{x_{i,t}^{soc}}^2}{2} + \gamma \left(S_t - n x_{i,t}^{soc} \right)$$

With this information, the game is designed and divided in three stages. During the first stage of the game, players can face two possible states of nature: normal (*n)* or low (*b*) availability. The resource available is either S_n or S_b. As a consequence of natural weather variation, the state *b* occurs with a probability of *p* and the state *n* occurs with a probability of *1-p*. Individuals that play their Nash equilibrium will have the following expected benefits.

$$E\left(\pi_{i,t}^{nash}\right) = p\left[\pi_{i,b}^{nash}\right] + (1-p)\left[\pi_{i,n}^{nash}\right]$$

In the second stage of the game, climate change is introduced, and climate events are stronger and more frequent. In this case, the possible states of nature are either S_n or S_s and drought (S_s) will occur with probability of *q*, with *q* > *p*. Individuals that play their Nash strategy will have the following expected benefits:

$$E\left(\pi_{i,t}^{nash}\right) = q\left[\pi_{i,s}^{nash}\right] + (1-q)\left[\pi_{i,n}^{nash}\right]$$

During the third and last stage of the game, there is the possibility to anticipate and adapt to climate change, and even though an extreme event occurs, the preventive actions that were taken will allow the availability of the resource to keep in stock levels related to natural climate variation, not extreme. This adaptation has an investment cost of c and its effect will last during Kcropping cycles or rounds. This means that adapting reduces the effect that climate change has in the resource availability, during the next K rounds after the investment is made. Adaptation allows access to a resource stock of S_b, when it could have been S_s if adaptation did not take place.

In order to determine if adapting is actually a good strategy, the game must be solved using backward induction. The player assumes that, no matter the state of the resource, the result would be that all players, including himself, will play the Nash equilibrium. If all players decide to adapt, this will make the resource stock to reduce only to S_b, instead of S_s , given the probability of *q* of a climate event to occur. If individuals do not adapt, the resource stock will reduce to S_s, being $S_b > S_s$.

The expected payoff for a player during the following *K* rounds if he decides to adapt would be:

$$A = \sum_{k=1}^{K} E\left(\pi_{i,t}^{nash}\right) - \mathrm{c} \ = K\left\{q\left[\pi_{i,b}^{nash}\right] + (1-q)\left[\pi_{i,n}^{nash}\right]\right\} - c$$

If the group decides not to adapt, the expected payoff would be:

$$B = \sum_{k=1}^{K} E\left(\pi_{i,t}^{nash}\right) = K\left\{q\left[\pi_{i,s}^{nash}\right] + (1-q)\left[\pi_{i,n}^{nash}\right]\right\}$$

If we suppose that individuals are symmetric and risk neutral, they would prefer to adapt and pay a cost of *c* for doing so, as long as $A > B$.

When we consider the particular case in which an individual is indifferent between adapting and not adapting, we will have:

$$K\{q[\pi_{i,b}^{nash}] + (1-q)[\pi_{i,n}^{nash}]\} - c = K\{q[\pi_{i,s}^{nash}] + (1-q)[\pi_{i,n}^{nash}]\}$$
$$c = qK\{[\pi_{i,b}^{nash}] - [\pi_{i,s}^{nash}]\}$$

Therefore, if the individual cost of adaptation is equal to c*, the player will be indifferent between adapting and not adapting. If the cost of adaptation is higher, the player would rather take the risk of facing the drought. On the other hand, with a lower cost, we conclude that the individual will always want to adapt.

2.2 Model Parameters

The different states of the water resource are defined, according to climate variation, as $S_n = 80,\ S_b = 60$ y $S_s = 40$ and the value of parameters as $\alpha = 100$, $\beta = 10$ and $\gamma = 20$. With these values, private and social equilibriums can be calculated. Under these conditions, social optimum requires that there is no extraction of water. However, Cardenas (2004) considers that is convenient to eliminate the possibility of extracting zero units in an experiment, to avoid conflict between participants, which can be related with policies that prohibit the use of resources and that can generate high degree of aversion. Therefore, the minimum value that a player can extract will be 1 unit. In Table 1 is observed that if all the five players of the group extract only one unit, the benefits for each player will be 1,595 points with a normal state of the resource, 1,195 points in a low state, and 795 with a drought state. On the other hand, it is observed that the private optimum extraction level is eight (8) units. If all individuals extract their private optimum (Nash equilibrium), the individual benefits per round will be 1,280 points in a normal state, 880 in a low state, and 480 in a drought state.

Table 1 Benefits and extractions with Nash equilibrium and with social optimum

State	S_t	$x_{i,n}^{nash}$	$x_{i,n}^{soc}$	$\pi_{i,n}^{nash}$	$\pi_{i,n}^{soc}$ ($x_{i=1}$)
Normal	80	8	0	1,280	1,595
Low	60	8	0	880	1,195
Drought	40	8	0	480	795

There has been a discussion in some experimental games, arguing about the fact that the Nash equilibrium in a corner solution may bias the decisions of participants. To avoid this bias, this game allows a player to extract a larger quantity than the one defined by the Nash equilibrium (8 units), and it is possible to extract up to 9 units of water. If individuals would extract this amount of water, the decision will not be efficient neither from a private nor a social point of view, because they would have greater benefits extracting fewer units. This is denominated as the exacerbation of the tragedy of the commons (Maldonado and Moreno Sánchez, 2009).

To summarize, players participate in groups of five people and in each round they should decide their level of extraction or usage of water for their crops, which could be a value between 1 and 9 units.

2.3 Game Structure

Working with groups of five people that are led by an instructor, during a session of 21 rounds, each of the members of the group must decide, along three stages, between 1 and 9 units, which will be his/her level of extraction, given a state of the water resource. The first and second stages are composed of 6 rounds, while the third stage includes a total of 9 rounds.

Each round represents a cropping cycle equivalent to one year. For each round, the instructor announces the state of weather for the cropping cycle. To do this, the instructor takes a ball from a black bag that contains balls: green (normal state), yellow (low state) or red (drought state). The proportion of each color varies depending on the stage of the game. Once announced the state of the weather and therefore the availability of water, each player decides –privately- how much water to use. Afterwards, the instructor collects the extraction decisions of the participants and records them in a computer, where the total extraction is calculated by adding the individual extractions. The instructor announces the total extracted by the group for the given round, so each player can calculate their benefits, using a payoff table that is specific for each state of the resource. At the end of the 21 rounds, the individual benefits are added and paid in cash to each player. Each point during the game corresponds to 1 Colombian peso (COP). Each player receives an average payment of 1.5 minimum diary wages determined by law, that correspond to approximately COP$26,000, equivalent to about 14 USD.

The game details are explained in a protocol of the experiment. Given the characteristics of the game, the game is classified as a framed field experiment (Harrison and List, 2004).

2.4 Stages of the Experiment

The game consists of three stages, as mentioned before, and this is their description and their characteristics..

2.4.1 Stage I. Natural Weather Variation

During the first stage of the game, all of the groups play the same game. In this stage, players face either conditions of normal or low amount of precipitation. The probability that a negative natural variation occurs (low precipitation) is $p = \frac{1}{4}$. Therefore during the first stage of the game, the probability of playing with the normal state of the resource is $\frac{3}{4}$, and the probability of playing with a low state is $\frac{1}{4}$. This is represented by using a black bag with three green balls (normal state) and one yellow ball (low state).One of the four balls is extracted at random to choose the state of the resource during each round. Six rounds are played this way during the first stage.

This stage simulates a scenario before climate change occurs, in which there could be either normal events or events related to a decrease in rainfall.

2.4.2 Stage II. Climate Change

During the second stage of the experiment, all groups continue playing under the same rules. In this stage, players face either normal weather conditions or drought conditions. The probability of an extreme negative variation, that leads to drought, as a consequence of climate change, is $q = {}^{2}/_{5}$. Therefore, during the second stage of the game, the probability of playing with a normal state of the resource is ${}^{3}/_{5}$, and the probability of playing under a drought state is ${}^{2}/_{5}$. This is represented in the game by putting three green balls (normal state) and two red balls (drought state) in the black bag, and taking one out during each round to determine the state of the resource. This stage also consists of six rounds.

This stage simulates a scenario in which climate change is present, and dry seasons are more severe and frequent. These extreme events reduce benefits significantly at any level of extraction.

2.4.3 Stage III. Possibility of anticipated adaptation to climate change

During the third and last stage of the game, each group can be exposed to different treatments and some of them have the chance of adapting to climate change with anticipation..

In this game, anticipated adaptation is represented by the construction of a collective reservoir that allows the community to store additional water additional to the water that is provided by the irrigation district, so if adopted, in periods where there are drought conditions, the amount of water available will be equivalent to a low state of the resource. If the adaptation strategy is adopted, this is represented by replacing the two red balls from stage II, with two yellow balls. The probability of playing under a normal state of the resource is still $^3/_5$, and the probability of playing under a low state is $^2/_5$, if there is adaptation. The decision of adapting or not is in place for a period of 3 rounds ($K = 3$), so each group that takes the decisión of adapting will perceive the benefits of adapting during three consecutive periods during the third phase. This means that the reservoir has a life time of 3 rounds or cropping cycles. This last stage consists of nine rounds, so the groups that can adapt have three chances of making the decision of adapting.

However, adaptation has a given cost that participants must pay if they want to follow this strategy. To estimate this cost, the difference between expected earnings with low and drought states is calculated, assuming risk neutrality. The value of the adaptation costs that makes the player indifferent between adapting and not adapting is 480 units. This is the value that reflects the cost of adaptation, and should be the amount paid by each player to construct the reservoir needed to reduce the effects of the extreme event. To make calculations easier during the experiment, the value is rounded to 500 units. As the group is made up of five persons, the total cost of the reservoir is 2,500 units. Considering this value, the three treatments of the experiments are now proposed and explained.

2.5 Experimental Treatments

As mentioned, this experiment included four treatments; each one was implemented during the last nine rounds of the experiment, during the third stage. Some groups keep playing in a similar way they played stage II, there were no possibilities of adapting. This group is the baseline group, which is used as a comparison to estimate the effect of the other three treatments.

The other groups that were exposed to the other three treatments had the possibility of investing in the construction of a reservoir that would allow them to adapt to climate change during the next three rounds of the game. Each treatment proposes a different collective strategy to make the decision of investing or not in the construction of the reservoir. The treatments are voluntary contributions, simple voting and communication.

2.5.1 Voluntary Contributions

In this treatment, each individual decides, in a private and confidential way, how much he/she wants to contribute for the construction of the reservoir, having the option of not contributing. Afterwards, the instructor picks up the statements about their voluntary contributions, records the result in a computer, and obtains the total value of the group contributions, adding the five individual bids. If the contributions reach or exceed the investment cost needed (2,500 points), the instructor announces to the group that the reservoir is constructed, and each player must pay the points they committed to invest, even if the sum is larger than 2,500. On the contrary, if contributions do not exceed the 2,500 points needed for the construction of the reservoir, the reservoir is not build and nobody contributes any value.

If the reservoir is constructed, the red balls are replaced with yellow balls, and in case of extreme events, the state of the resource is low, instead of drought. This is valid only during three rounds. After three rounds, players should decide again if they want to make voluntary contributions to construct the reservoir.

2.5.2 Simple voting

In this treatment, each individual voted in favor or against the construction of the reservoir. If they vote in favor of the reservoir, they commit to make an individual contribution of 500 points. This decision is private and confidential. The instructor collects the votes, records them, counting the votes and obtaining a final result. If at least three players vote in favor of the construction of the reservoir, the monitor announces to the group that the reservoir will be constructed, and each player must pay 500 points, which correspond to one fifth of the total cost of the reservoir (2500 points), no matter if they voted in favor or against. On the other hand, if at least three players vote against the construction of the reservoir, nobody has to pay any contribution and the reservoir is not constructed. Again, this decision is only valid during three rounds, and after the third round, the voting process takes place again to decide if the reservoir is constructed.

2.5.3. Communication

Under this treatment the group was able to vote in favor or against the construction of the reservoir, following the same rules of the simple voting treatment, but now the players were allowed to communicate among them during five minutes before voting. After that, decisions are made in a private and confidential way. It is worth to remember that no other group is able to communicate during the game and decisions taken are always individual and confidential.

In Table 2, the main elements of the game are summarized: stages, number of rounds, and treatments.

Table 2: Summary of treatments, rounds, and stages

	CONTROL	TREATMENT I	TREATMENT II	TREATMENT III
Rounds 1-6	Natural variation			
Rounds 7-12	Climate change			
Rounds 13-21	Climate change	Adaptation by simple voting	Adaptation by simple voting with communication	Adaptation by voluntary contributions

2.6 Study Area

The experiments were done in the department of Boyacá, in the communities of Chiquiza, San Pedro de Iguaque and Samacá, and in the city of Duitama (with participation of people from the communities of Duitama, Sogamoso, Nobsa and Tibasosa). All of them are communities that depend on high mountains for obtaining water for consumption and agriculture. However, they show differences in terms of social, economic and natural conditions.

3 Results

During 2012, in the month of September, we conducted several workshops to conduct experimental economic games in four agricultural communities in the department of Boyacá, Colombia, mentioned above. A total of 120 individuals participated in the experimental games, with the distribution of places and treatments shown in Table 3.

Table 2 Participants in the experimental economic games by location and treatment

Location	Treatment				Total
	Base line	Voluntary Contributions	Simple Voting	Communication	
Chíquiza	10	5	5	10	**30**
San Pedro de Iguaque	5	10	10	5	**30**
Samacá	5	10	5	5	**25**
Duitama	5	10	10	10	**35**
Total	**25**	**35**	**30**	**30**	**120**

The results of the experiment are focused on two main variables: the water extraction decisions under different states of the resource, and the decisions of adaptation to climate change.

3.1 Water use decisions

3.1.1 Effect of different states of availability

As explained in the methodology, the game is divided in three phases; during the first phase (six rounds), players have the possibility of face states of moderate reduction in rainfall, with a probability of 25%. In practice, this reduction occurs in 24.3% of the rounds in all places. From this first phase is observed that when the state of rainfall is normal, the average extraction is 5.6 units, whereas when there are periods of reduced rainfall (low state), the extraction of water is increased to 6.4 (Table 3). This increase by 0.8 units is statistically significant ($p<0.001$) and implies that players perceive that they must compensate the reduction in the rainfall pattern with greater extraction of water from the irrigation district, unaware that the maintenance of the water supply for the district also depend on rainfall.

In the second phase of the game it was included the effect of climate change, which not only increases the severity of weather events but that also makes them more frequent. The game was designed so that now weather events were observed with a probability of 40%. In practice, these events occurred in 47% of the rounds, a higher value than expected. In this second phase, water extraction under normal conditions was 5.7 units, which is not statistically different from the average extracted during the first phase under normal conditions ($p>.1$).

When players faced drought condition water extraction was increased to 6.5 units on average. This increase of 0.8 units is statistically significant ($p<0.01$).

Table 3 Average levels of extraction in each phase according to the state of the resource

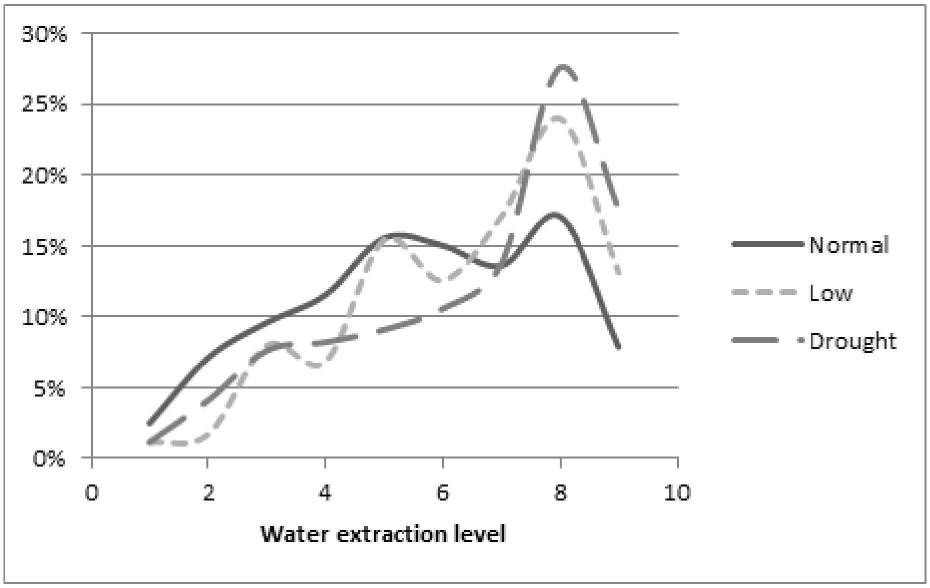
	State of weather			
Phases of the game	Normal	Low	Drought	**Total**
Phase I – normal cycles	5.57	6.39	.	**5.77**
Phase II – climate change	5.72	.	6.51	**6.09**
Phase III – possibility of adaptation	5.69	6.31	6.35	**5.92**
Total	**5.65**	**6.34**	**6.46**	**5.93**

However, if we compare the extraction under moderate reductions of rainfall in the first phase (low state) with extraction under extreme reductions in the second phase (drought state), these averages are not statistically different; i.e. the change in consumption pattern looks similar when facing moderate reductions than when facing extreme reductions.

This result seems counterintuitive; in order to elucidate the scope of these results, we analyzed the frequency with which each level of extraction is determined throughout the game. Figure 1 shows that the Nash equilibrium (8 units) was the most frequent level of extraction. However, under normal climatic conditions a greater proportion of extractions lower than 8 units is observed, being the values of 5 units as frequent as the 8-unit extraction. Under low state, the proportion of cases in which are extracted 8 and 9 units increased; but also increases the frequency of extraction of five units, becoming a distribution that appears to be bimodal. Meanwhile, when the drought is reached it is observed the greatest proportion of cases of extraction of 8 units (also of 9 units), and others lower levels of extraction are reduced.

That is, although on average similar values of extraction are observed in both conditions of low availability and drought, this first observation really does not capture the players themselves are changing their decisions by increasing the level of resource extraction when weather conditions are more severe.

Figure 1 Relative frequency of average water use for each possible level of extraction during phases I and II



In Phase III, the probability of facing changes in normal weather patterns remains at 40%; in practice, the normal events occurred in 63% of the rounds. About 21% of the rounds, players adopted adaptation strategies and could face low resource conditions instead of drought, and in 16% of the rounds there was no adaptation and players faced drought conditions. Later it is analyzed in detail this phase, where there exists the possibility of adaptation.

Although the results reported so far are given in aggregate averages per phase, the analysis can also be seen along the rounds. Figure 2 shows the evolution of the average individual extraction of water during the 21 rounds for each of the communities where the experiments were held. Regarding to differences between populations, it is observed that the highest average extraction levels occur predominantly in the town of Chíquiza, while the lower extraction levels correspond to the municipalities of Samacá and Duitama (Table 4).

Overall, the average extraction levels are lower during the first six rounds, and tend to increase from the seventh round onwards; the city of Duitama is the only population in which the average extractions decrease after the first six rounds of the game.

Figure 2 Path of average water extraction decisions, along the 21 rounds of play for each locality analyzed

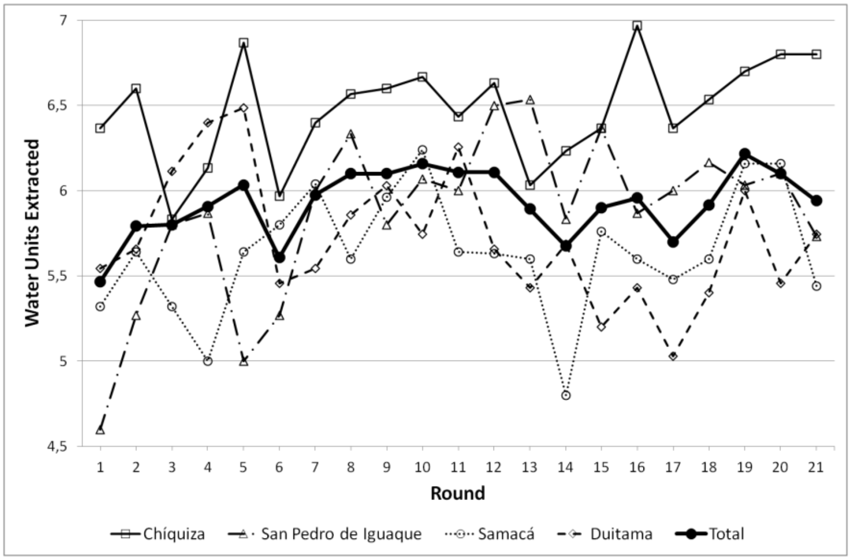


Table 4 Comparison of average extraction levels among localities

Locality	Average extraction	Chíquiza	San Pedro de Iguaque	Samacá
Chíquiza	6.47			
San Pedro de Iguaque	5.86	-0.61 ***		
Samacá	5.64	-.0.83 ***	-0.22 *	
Duitama	5.72	-0.75 ***	-0.14 ns	-0.08 ns

*** significant at 99%   ** significant at 95%   * significant at 90% ns non significant

As mentioned above, the growing trend on average extraction levels appears to be related to the occurrence of adverse events in the weather (low water availability and drought tables). To test this, an analysis was performed by community average extraction, for each of the states of the resource, normal, low and drought (see Table 5), finding that in most cases there are significant differences between the average of extraction with a high availability of water resources comparing to the average extraction with low availability of water resources, and comparing to average extraction with drought events.

These results show that the average water extraction at the community level is also higher when there is less water available. Similarly, in some cases, no significant differences among average extractions with low resource state and drought state are observed, again indicating that the effect on water consumption of a smaller quantity of water available may be equal under natural conditions of low rainfall and in conditions of extreme drought events related to climate change.

Table 5 Statistical analysis of differences in average water extraction decisions under each state of the resource, for the surveyed communities

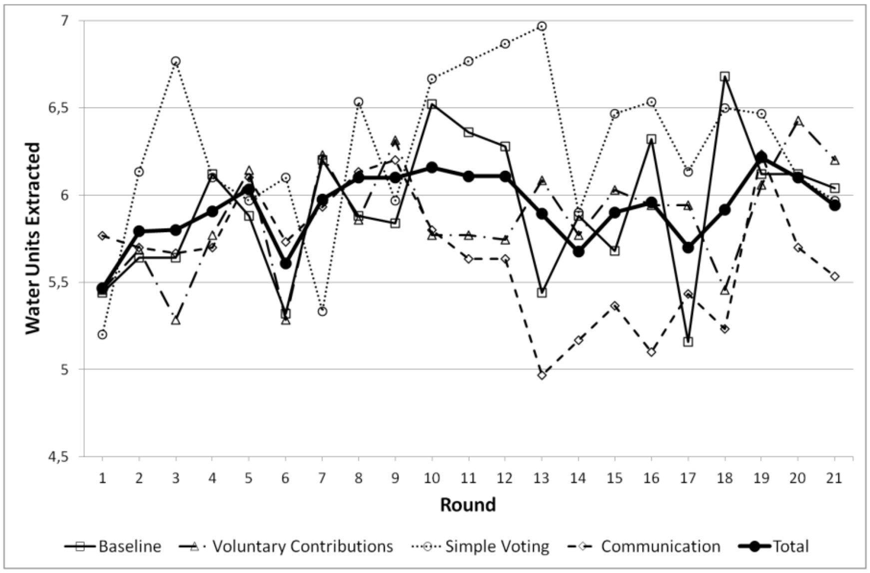
	Chíquiza		
State of the Resource	**Average Extraction**	**Normal**	**Low**
Normal	6.44		
Low	6.23	0.22 ns	
Drought	6.83	-0.39*	-0.60**
	San Pedro de Iguaque		
State of the Resource	**Average Extraction**	**Normal**	**Low**
Normal	5.63		
Low	6.53	-0.90 ***	
Drought	6.18	-0.55 **	0.35 ns
	Samacá		
State of the Resource	**Average Extraction**	**Normal**	**Low**
Normal	5.11		
Low	6.31	-1.20 ***	
Drought	6.73	-1.62 ***	-0.42 **
	Duitama		
State of the Resource	**Average Extraction**	**Normal**	**Low**
Normal	5.37		
Low	6.37	-1.00 ***	
Drought	6.30	-0.94 ***	0.07 ns

*** significant at 99% ** significant at 95% * significant at 90% ns not significant

3.1.2 Effect of treatments

With respect to differences between treatments, Figure 3 shows that, in general, during the first six rounds (Phase I), the extraction was similar between groups, there is only one round in which groups tend to separate, but the differences are not significant. In the second phase, when participants face climate change, the behavior becomes more erratic, and some groups tended to extract more than others; the differences, however are not significant with the rest of the groups (except when comparing the two extreme groups).

Figure 3 Path of the extraction decision average along the 21 rounds of play for different treatments



When players reached phase III where the possibility of adaptation becomes effective, is observed on average that participants in groups facing simple-voting rule tended to extract more (6.34 units per round) than the other treatments, and the differences are statistically significant (Table 6).

Table 6 Comparisons of average levels of extraction between treatments

Treatment	Average Extraction	Baseline	Voluntary Contributions	Simple Voting
Baseline	5.94			
Voluntary Contributions	5.99	0.05 ns		
Simple Voting	6.34	0.40 **	0.35 *	
Communication	5.41	-0.52 **	-0.58 ***	-0.92 ***

*** significant at 99%   ** significant at 95%   * significant at 90%   ns non significant

They are followed by the groups under the voluntary-contributions rule (6 units per round) and the baseline (5.9 units), that extract –statistically– the same amount on average. Groups exposed to the communication rule are the only ones who extract below the baseline, reducing extraction of water up to 5.4 units on average. This reduction in extraction is statistically lower than the average for the other three treatments. This behavior also generates that groups under communication obtained the largest payments. The effect of communication is a result consistent with other experimental games which allows interaction between players for decision making (Alpizar et al., 2011; Cardenas et al., 2004; Hackett et al., 1994; Ledyard, 1995; Sally, 1995).

3.1.3 Parametric Estimation

One way to evaluate the effect of different resource conditions and treatments, controlling for other characteristics, is through an econometric model that explains extraction decisions in each round. Since each individual makes decisions along the 21 rounds of the game, the data is treated as a panel where effects intra-player and inter-player are considered separately. To do this we use two econometric models: one of them is a random-effects model generalized-least-squares for panel data; the other is a Poisson model fitted for panel data. This second model is used under the condition that the dependent variable, extraction, takes discrete values between 1 and 9, and therefore has a Poisson distribution with mean equal to the variance; considering that the extraction show a mean of 5.93 and a variance of 4.81, there are no intuition of biases because of the effect of over dispersion.

Both models are reported in Table 7, where explanatory variables include:

- State of the weather: categorical dummy variables for the state of the weather, which may be low, or drought, being normal the omitted value.
- Treatments: categorical dummy variables for each one of the four treatments included: baseline, voluntary contributions, simple voting and communication.
- Adoption of adaptation strategies: categorical dummy variables to indicate when the individual was in a round and in a group where decision of adaptation was made, discriminated by treatments.
- Places: categorical dummy variables for each one of the four communities (Samacá is omitted).
- Perception of climate change: in the post-games survey the participants were asked if they perceived that actual drought periods were shorter, longer or that had not changed during the last 10 years. They were also asked about their perception of environmental

temperature: if they thought that had increased, decreased or remained unchanged. Categorical variables are used for each of these answers.

- Agricultural activity: to control for specific characteristics of the agricultural activity of each player two variables were included: the number of parcels planted during the first semester of 2012, and the aggregate area dedicated to crops in that semester.
- Individual characteristics: assessed the relevance of variables that consider gender, age, education and income of participants. One variable that captures much of the individual effect is the level of education, variable included in this model.

Econometric analysis confirms that indeed the presence of low or drought states encourage players to extract a larger amount of water; on average, participants extract 12-13% more, equivalent to 0.7 to 0.8 units; however, the increase in the amount of water consumed under the two scenarios of rainfall reduction is not statistically different. As for treatments, the simple voting treatment is the only one that induces a significant increase in water consumption. Additionally, the groups under communication succeed to significantly reduce extraction during the periods of adaptation, unlike other treatments where no significant effects are observed.

Regarding the places where the exercise is performed, in the community of Chiquiza is where the resource is more extracted, and the difference is significant compared to the results elsewhere. Perceptions have significant effects on how people make their extraction decisions, although sometimes associated with positive effects and sometimes associated with negative effects. Own agricultural activity also affects decisions of the players; in general, having greater amount of parcels and greater planted area induces players to reduce the level of extraction. Finally, education has an effect on the extraction: more educated people tend to extract a bit more.

This econometric analysis confirms the nonparametric results: the state of the resource affects the extraction levels, although there are no statistical differences between the low state and the state of drought, in terms of the increase in water use; and communication allowed the groups reach to deal with climate change reducing the extraction, while other strategies do not succeed to this.

Table 7 Econometric analysis of extraction decisions

Variable	Units	Poisson Coefficient		GLS Coefficient		Mean Value
State of wather						
Low state	1 yes, 0 no	0.121	***	0.723	***	0.160
Drought state	1 yes, 0 no	0.137	***	0.826	***	0.203
Treatments						
Voluntary Contributions	1 yes, 0 no	0.030	ns	0.212	Ns	0.280
Simple voting	1 yes, 0 no	0.107	**	0.699	**	0.254
Communication	1 yes, 0 no	0.005	ns	0.069	Ns	0.254
Adoption of adaptation strategies						
Adaptation in VC	1 yes, 0 no	0.040	ns	0.225	Ns	0.065
Adaptation in SV	1 yes, 0 no	0.031	ns	0.182	Ns	0.091
Adaptation in CO	1 yes, 0 no	-0.094	***	-0.507	Ns	0.097
Places						
Chíquiza	1 yes, 0 no	0.174	***	1.053	***	0.254
San Pedro	1 yes, 0 no	0.054	ns	0.331	Ns	0.254
Duitama	1 yes, 0 no	-0.012	ns	-0.065	Ns	0.280
Climate change perception						
Shorter droughts	1 yes, 0 no	-0.256	***	-1.374	***	0.093
Longer droughts	1 yes, 0 no	-0.012	ns	-0.055	Ns	0.703
Lower temperature	1 yes, 0 no	0.113	*	0.739	**	0.119
Higher temperature	1 yes, 0 no	0.102	**	0.589	**	0.729
Agricultural activity						
Parcels	Number	-0.005	ns	-0.027	***	1.847
Crops area	Hectare	-0.010	ns	-0.058	**	1.582
Individual characteristics						
Education	Years	0.007	**	0.043	*	7.449
Constant		1.546	***	4.526	***	
Number of observations		2478				
Number of grups		118				
Wald chi2(18)		122.56				
Prob > chi2		0.000				

*** significant at 99% ** significant at 95% * significant at 90% ns non significant

3.2 Adaptation to climate change

During the last 9 rounds of the game, which correspond to the third phase, players have the possibility to adapt. This adaptation can be explained, among others, by the frequency of weather events during the game. Figure 4 shows the percentage of occurrence of events for each one of the phases in each one of the communities analyzed, and the rate of adoption of the adaptation strategy in each one. Adaptation rates for the treatments with the possibility of adapting fluctuate between 67 and 83%, averaging 74%. This level of adaptation occurs under an average of 36% of negative events in resource availability, both in low availability and droughts, along the 21 rounds that comprise the game.

Figure 4 Average percentage of occurrence of events reducing water availability for each stage, followed by the average percentage of successful investments in adaptation during the third phase (9 rounds), for each of the communities

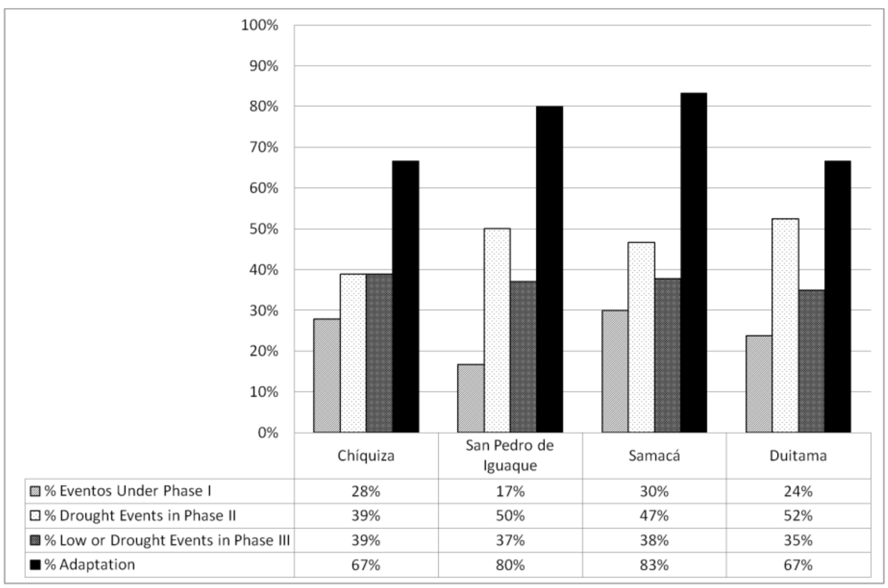


Table 8 summarizes the average percentages of investment in adaptation and negative events on water resources, by population and treatment. The municipality with the highest percentage of negative events was Samacá, with 38%, being at the same time the place where the adaptation rate was higher, with 83%. Meanwhile, the village of San Pedro de Iguaque had the lowest percentage of negative events (35%), but in turn obtained the second highest percentage of adaptation (80%). The localities of Chiquiza and Duitama had the same average rate of adaptation (67%), with an average percentage of negative events also very similar (36-37%).

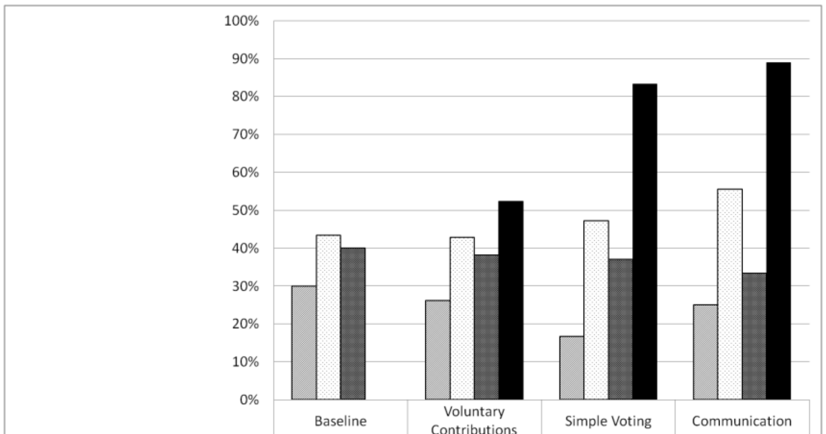
Table 8 Average percentage of occurrence of events in total 21 rounds played, and average percentage of investments in adaptation during the third phase, by population and treatment

Location	Treatments							Total	
	Baseline	Voluntary Contributions		Simple voting		Communication			
	Event	Event	Adaptation	Event	Adaptation	Event	Adaptation	Event	Adaptation
Chíquiza	29%	43%	*100%*	38%	33%	38%	67%	36%	67%
San Pedro	38%	33%	50%	38%	*100%*	29%	*100%*	35%	80%
Samacá	38%	33%	67%	43%	*100%*	43%	*100%*	38%	83%
Duitama	57%	38%	17%	24%	83%	38%	*100%*	37%	67%
Total	**38%**	**36%**	**52%**	**34%**	**83%**	**37%**	**89%**	**36%**	**74%**

Regarding to treatments, the voluntary contributions mechanism generates the lowest rate of adaptation with only 52% overall and only 17% in Duitama. The second most effective treatment to achieve adaptation is the simple voting mechanism, with a rate of adaptation of 83%, although in Chiquiza was successful in 33% of cases. Finally, the communication mechanism prior to the vote generates the highest rates of adaptation with 89% of success. The comparison between simple voting and communication shows that the effect of communication, known as "cheap talk", (Ostrom et al., 1994), increases the rate of adaptation in all localities, even when the percentage of adverse events is lower. Figure 5 shows the occurrence of events throughout the game, differing by phases. There is a certain correlation between the occurrence of extreme events in Phase II and the adoption of adaptation strategies in Phase III.

These results show the importance of adaptation strategies and how they can vary from place to place, probably due to specific characteristics such as market integration, existing institutional arrangements, heterogeneity and social capital of groups, among other characteristics. For example, Chiquiza, where the most effective mechanism was the voluntary contributions, is characterized for being an community isolated from the market, small, difficult to access, where there is no irrigation district and where public utilities (such as the aqueduct) depend on the participation of the whole community. There it can be inferred a high social capital –and presumably more social control– which leads the participants to be less likely to be free riders from the contributions of others. At the other extreme is Duitama, a community located in an intermediate city, fully integrated with markets with highly heterogeneous actors, higher levels of income and education, with an irrigation district organized and functional. There, the individual interests are much stronger and social capital – together with social control– is lower, which presumably encouraged more the participants to provide low contributions and expect others to do the sufficiently high contribution for achieving adaptation.

Figure 5 Average percentage of occurrence of events with low resource status or drought for the three phases, followed by the average percentage of investments in adaptation during the third phase (9 rounds) for each treatment



	Baseline	Voluntary Contributions	Simple Voting	Communication
% Eventos Under Phase I	30%	26%	17%	25%
% Drought Events in Phase II	43%	43%	47%	56%
% Low or Drought Events in Phase III	40%	38%	37%	33%
% Adaptation		52%	83%	89%

A way to confirm these effects is through a parametric exercise which allows relating the adaptation decision with characteristics of the game, the location and the individuals.

3.2.1 Parametric Estimation

The decision to adapt to climate change is a variable of interest in this study. This decision might depend on several features that can act simultaneously. To understand better this process, the adaptation is analyzed in an econometric model. This model seeks to explain what motivates players to want to adopt an adaptation strategy for their community (group). However, this decision is manifested in different ways depending on the treatment to which the player is exposed. In simple voting groups and communication, willingness to adopt the strategy is expressed through a vote of approval or disapproval. In groups of voluntary contributions, this willingness is expressed through a value in terms of points for the construction of the reservoir.

For our analysis, we construct a variable called Intention, which expresses the decision in terms of equivalent monetary values that players would be willing to contribute to the construction of the reservoir, as an adaptation mechanism. In the case of treatment of voluntary contributions, this value has been expressed in points or pesos. For cases of simple voting treatment and communication treatment, the conversion is as follows: when the individual votes in favor, it is assumed that willingness to pay is 500 points, which is the mandatory contribution in the event that there is consensus on the construction of the reservoir. Another transformation that is done is that since adaptation investment is useful for three rounds, these values are divided into three and each third is assigned to each of the respective round. This corresponds to the dependent variable of the model.

Among the independent variables are those related with the treatments employed and communities included. Regarding the game itself, it is controlled by the round of play in the third phase, as well as by the number of rounds during phases I and II in which the individual had faced both low state and state of drought. Additionally, three variables associated with individuals were also included: i) a categorical variable that captures whether the individual has perceived changes in climate over the past 10 years; ii) a categorical variable that captures whether the individual has undertaken actions related to changes in land use in response to changes in climatic conditions; iii) a variable that allows approximate the income level of the household.

The econometric model is based on the panel format of the database, using information from the last phase of the game and estimated by generalized least squares with random effects; the impact of these variables on the decision to contribute to the construction of the reservoir as adaptation measure. Results are presented in Table 9.

Econometric model shows that the treatments actually induce players to contribute to the adaptation and that the scheme of voluntary contributions is the one which generates the greatest incentives, although the difference between treatments is not significant. The rounds generate a negative effect, which means that players are reducing their willingness to pay as the game advanced during phase III. However, the results for phases I and II do not appear to generate a determinant effect on the willingness to contribute to adapt.

The three individual variables show effect on the willingness to contribute: individuals who think that the climate has changed in recent years, that have made efforts to address climate change and that have higher incomes, are more likely to contribute in investments that allow facing climate change.

Table 9 Econometric estimation of adopting the decision of adaptation

Variables	Units	Coefficient	
Treatments			
Simple voting	1 yes, 0 no	154.92	***
Communication	1 yes, 0 no	166.96	***
Voluntary Contributions	1 yes, 0 no	189.95	***
Places			
Chíquiza	1 yes, 0 no	-8.880	Ns
San Pedro	1 yes, 0 no	-0.395	Ns
Duitama	1 yes, 0 no	-36.880	Ns
Game			
Round	1-9 in phase III	-5.459	***
Previous low-state rounds	Number of rounds	8.762	Ns
Previous drought-state rounds	Number of rounds	-7.218	Ns
Individuals			
Change in land use	1 yes, 0 no	77.891	**
Income	MLMW[a]	10.292	*
Perception of temperature change	1 yes, 0 no	68.361	**
Constant		-3.453	Ns
Observations		1,053	
Individuals		117	
Wald chi2(12)		135.58	
Prob > chi2		0.000	

*** significant at 99%   ** significant at 95%   * significant at 90% ns no significant

[a] minimum legal monthly wages

4 Discussion

The objective of this study is to analyze the effect of climate change on the behavior of agricultural communities in the use of water resources coming from high mountains. This objective is achieved through answering two research questions: how changes in water availability –as a result of climate change– affect the decisions about its use as a productive input in agricultural communities that depend on glaciers and high mountain water sources to its provision?, and, how different institutions or allocation mechanisms for adaptation decisions affect the use and management of water in a climate change scenario?

The first result that draws attention from this experimental game designed to answer these two questions is that when climatic events reduce the availability of rainwater, individuals react by increasing the use of water –surface water in this case– available through the irrigation districts or reservoirs, although this increases the pressure on the water available. That is, players utilize the surface water as a substitute for rainwater, although with this they seem to ignore the fact that the availability of surface water also depends on weather conditions. Because of being considered a common-pool resource, this decision marginally compensates the decline in profits, but the group overuse reduces those and finally it is not possible to recover the level of profit with the additional effort. In general, individuals do not recognize that reducing water extraction could generate a higher profit.

It is also noted that this additional pressure on water sources appears to be similar in the two scenarios of scarcity: when the resource is moderately reduced (low state) and when it is reduced drastically (drought state). This result seems counter-intuitive; but, once the data is explored in greater detail the explanation is found. Although the average values of water use are similar in the two scenarios of scarcity, their distribution vary in each case: when conditions of moderate reduction of water are faced (low state) we observed a bimodal distribution, with some players concentrating the extraction in 5 units, while another group increases the extraction level to 8 units, causing an increase in the average in comparison with the normal state. When conditions become severe (drought), the distribution is concentrated around the level of eight units, but the frequency of extraction at other levels does the average stay at a similar level. Overall, the results are consistent with the observations of Blanco et al. (In Press) in the basin of Coello (Tolima, Colombia), where they find that the available stock of water resources affects the decisions of extraction, depending on the magnitude of change in the availability of the resource; when the resource becomes scarce but still is sustainable, there is a bimodal distribution in the extractions, but when the resource comes at risk of extinction, there is an escalation in non-cooperative strategies, depleting the resource. However, the authors cannot distinguish whether such behavior is the effect of the risk of resource depletion or difference of payment between high and low state. In our experiment, considering that extraction earnings above Nash equilibrium are lower compared to Nash, we could say that it is the availability of the resource what generates its overexploitation.

The second result of interest is that adaptation strategies do not generate a significant reduction in the levels of water extraction and, on the contrary, once adopted tend to stimulate an increase in the use of the liquid. The reaction is predictable if assumed that players use the adaptation mechanism as an insurance that allows them to be protected against extreme events, and once the adaptation is made, they seek to recover the investment in the proposed project (Moral Hazard). Only in the case of the communication strategy it is possible to observe a slight reduction in the average of water use, by about half a unit. When players are able to communicate with each other, they can not only strengthen the possibility of investing in the adaptation strategy but may also discuss the possibility of approaching the social optimum decision, reducing the individual level of extraction. Quite much literature has analyzed the effect of communication on the decisions of use of common pool resources or public goods, and the reasons range from improving the understanding of the game until persuasive effects by leaders or creating group identity (Buchan et al., 2006; Bochet et al., 2006; Ostrom et al., 1994; Bochet y Putterman, 2008, Ostrom et al., 1994).

A third result of interest is observed in the analysis of the effect of treatments on the willingness to pay for the adaptation strategy (intention). Several studies in the literature have studied the provision of public goods with threshold under binary contribution schemes "all or nothing" (van de Kragt et al., 1983, Rapoport and Eshed-Levy, 1989; McBride, 2006), similar to the proposed through the treatments of voting; under discrete contribution schemes (Suleiman and Rapoport, 1992; Menezes et al., 2001), and under continuous contribution schemes, similar to that proposed by the treatment of voluntary contributions (Bagnoli y Lipman, 1989; Palfrey y Rosenthal, 1990; Bagnoli y McKee, 1991; Cadsby y Maynes, 1999; Fischbacher y Gaechter, 2008; Dannenberg et al., 2011).

Cadsby and Maynes (1999) find that continuous contributions, comparing to binary, significantly increase the contribution and make it easier to achieve the provision. The coefficients that reflect the effect over intention for each one of the treatments in this experiment seem to agree with these results, being voluntary contributions the treatment that generates the greatest intention, followed by communication and lastly simple voting, although those differences were not statistically significant. A possible explanation for such insignificance is observed in the scheme under which the treatment of voting was constructed, where the contribution of each individual depends on a democratic decision, while on most common experiments with binary inputs, the decision of contributing is individual and voluntary. Similarly, the threshold provision of a public good is usually defined by a number of players lesser than the total members of the group; in our experiment the threshold is the unanimity of contributions.

Another variable of great influence on cooperation is conditional cooperation, which refers to the individual's perception over the cooperation of others (Fischbacher et al., 2001). However, Fischbacher and Gaechter (2008) conclude that in experiments on public goods with threshold, individuals actually behave like imperfect conditional cooperators, leading to the dissolution of cooperation over time, even in the absence of free riders. This result holds when making comparisons between countries (Kocher et al., 2008), within countries (Herrmann and Thoni, 2009) and between social groups (Martinsson et al., 2009)

On the other hand, Dannenberg et al. (2011) conducted a laboratory economic experiment to evaluate the effect of uncertainty and ambiguity concerning to the threshold of provision on cooperation in the production of a public good with continuous contributions. In this experiment, in a similar way to ours, the public good does not represent a gain or benefit to society but avoidance of a loss, which in our case is a mechanism of adaptation to climate change. These authors conclude that under uncertainty, equal initial contributions are essential to maintain cooperation during the next rounds of the game. This is consistent with our results, where in most cases the adaptation was successful in the first round of decision; but, in some cases, contributions were well above the threshold and with a high variance (data not shown), so that for the next round of decision cooperation decreased and adaptation was not successful.

In this sense, it is important to generate institutional mechanisms that allow sustaining cooperation over time. There are therefore required not only public policy measures that discourage the behavior of free riders, but also additional measures to maintain confidence of conditional cooperators. Some of these measures include mechanisms such as communication within the group, and the inclusion of endogenous rewards and punishments, usually imposed through voting (Tyran and Feld, 2006; Rauchdobler et al., 2009; Sutter et al., 2010).

Fischer and Nicklisch (2007) provide a good example of conditional cooperation, by the study the effect of the ex interim vote on cooperation in the provision of a public good with threshold, where individuals propose their contributions first and then decide by vote, subject to the contributions reached, if they want to provide the public good or not (with repayment in case to desist from the provision). They find that only unanimous voting is a good mechanism to promote cooperation, while the contributions obtained under simple majority voting schemes are equal to those obtained under public voting schemes without effects on the provision of the good. In this sense, the simple majority voting may not be sufficient to generate and maintain cooperation; in our experiment communication was a good support mechanism to maintain conditional cooperation, by including communication in our experiment not only the coefficient of intention to adapt increased, but also adaptation results were obtained mostly unanimously.

Other variables to have into account in the provision of public good with threshold include the repayment or not of the contributions (Menezes et al., 2001), the existence of imperfect information over the preferences of individuals (Palfrey and Rosental, 1984; Palfery and Rosenthal 1990), and the level of heterogeneity or homogeneity of the group (Bagnoli and McKee, 1991). In this sense, it is also worth noting that the results vary between communities analyzed, so that is why it is important to consider aspects of income and poverty of the communities, their integration into the market, the existence of irrigation districts and effectiveness in its use, and how different institutions affect the decisions made within communities. It is generally seen that in the first two phases, Chiquiza community, characterized by being a low-income population, isolated from the market and with climatic characteristics of greater water scarcity and without an irrigation district for agricultural activity, exhibited the highest levels of water use, being significantly higher than the other three communities. At the same time, this community, where the most precarious conditions may also mean a higher level of social capital, tended to be more responsible with community decisions and therefore strategies such as voluntary contributions proved to be effective. At the other end, communities with higher income levels, greater market integration and, –therefore– less dependence on social capital tend to have more individualistic attitudes and the propensity to behave as free riders is greater. In such cases, the strategies of voluntary contributions were less effective, while voting could be a more effective mechanism for the adoption of adaptation strategies. In most cases, however, the communication strategy encourages the adoption of the adaptation strategies.

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