Testing cooperative game theory through a contextualized role-playing game about irrigation water management: construction and test of the experimental protocol

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Testing Cooperative Game Theory through a Contextualized Role-Playing Game about Irrigation Water Management

Construction and test of the experimental protocol

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List of abbreviations

ARISE	Action Research on Institution, Social aspects and Economics of water management
CE	Contextualized Experiment
CEEPA	Centre for Environmental Economics and Policy in Africa
CGT	Cooperative Game Theory
CIRAD	Centre de coopération Internationale en Recherche Agronomique pour le Développement *French Agricultural Research Centre for International Development*
ComMod	Companion Modelling
CPR	Common-Pool Resource
DE	Decontextualized Experiment
DWAF	Department of Water Affairs and Forestry
EE	Experimental Economics
GIS	Geographic Information Systems
INRA	Institut National de la Recherche Agronomique French National Institute for Agricultural Research
IP	Performance Index
Kat AWARE	Role Playing Game and Model developed in the Kat River Basin (Eastern Cape, South Africa)
MAS	Multi-Agent Systems
PD	Prisoners' Dilemma
RPG	Role-Playing Game
SAFeWater	South African – French Network for Research in Water Science and Technology
TK	Tversky and Kahneman (1981)
UP	University of Pretoria
VCM	Voluntary Contribution Mechanism
WUA	Water Users Association
ZAR	South-African Rand

Note for the reader

The objective of this Master was to realize, during 4 months of stage at the University of Pretoria, a literature review on Cooperative Game Theory and Experimental Economics, to build-up an experimental protocol and to test it by conducting two game sessions. No additional time was allowed to produce the present document, which was therefore written at the same time of the research activities. For this reason, some parts of this document are not developed and refined as much as the author and his supervisors would have wished. These parts will be deepened in future works already scheduled within this research program. Moreover, due to the fact that the author of this Master is not English mother tongue, despite the efforts and helps a number of language errors and imprecise expressions are certainly still present in the document. The author apologizes for this.

Mathieu Désolé

Introduction

This thesis is based on the work of construction and test of an experimental protocol adopting a simplified Role-Playing Game (RPG) to test hypotheses issued from Cooperative Game Theory (CGT). The RPG context refers to the case of common property water allocation among farmers and derives from observations made during a participatory project on water governance in the Kat River Basin (Eastern Cape, South Africa).

During this experience based on an approach called Companion Modelling (ComMod), a Role Playing Game called KatAWARE was developed to reproduce the functioning of a real catchment – the Kat River - and allows local stakeholders (members of a WUA) to play around water management in order to :

- understand the complexity of the system;
- understand the relations between agents;
- understand the impact of different water allocation strategies on the water flows, the profits, employment and domestic users' satisfaction;
- build up a catchment strategy within a Water Users Association (WUA).

Local stakeholders played two sessions of the KatAWARE RPG (Farolfi and Rowntree, 2007). Once the ComMod process was ended, the RPG outcomes (first session) were compared with theoretical results from a Cooperative Game Theory (CGT) model calibrated on the same data (Dinar et al, 2006). Several similarities resulted from this comparison, even if the complexity and the dynamic nature of the RPG determined differences in absolute terms. In particular, the distribution of the payoffs among the three sub-basins that resulted from the CGT model was similar to the one observed as an outcome of the RPG session.

The encouraging, though still vague, results of this first comparison between RPG and CGT outcomes suggested to deepen the analysis in the direction of an experimental use of the RPG in order to test a certain number of hypotheses made by the CGT. Particularly, a) individual rationality of agents in a cooperative situation is tested: through the RPG, we observe if players behave rationally according to the CGT predictions (profit maximization through the optimal use of water). b) We can also test players' attitude about the allocation of common resources in a coalition in order to get the highest possible payoff (concept of side payments). c) We finally verify whether the distribution of RPG payoffs obtained playing cooperatively (through grand coalition) correspond to the CGT outcomes calculated through the Shapley value.

To do so, the Kat RPG was simplified and "polished" of all elements needed when used in the context of stakeholders' negotiation support, but not directly related to the CGT hypotheses being tested. Nevertheless, a certain degree of contextualization was maintained (farmers producing cabbage that compete for irrigation water, stock of water available in a dam, etc.). The adoption of this RPG for experiments to test CGT hypotheses triggers an important research question: **can we use a Role Playing Game derived from a negotiation process as a contextualized laboratory experiment to test hypotheses?** This question is particularly relevant in the field of Experimental Economics, where experiments are usually conducted in a very de-contextualized way (Eber et Willinger, 2005) in order to avoid different understanding of the context by the players, due to their culture, education, experience, personality, which influence their own perception of the context.

To provide insights on the issue of game contextualization, some CGT hypotheses previously mentioned can be tested also through a de-contextualized version of the game. The results obtained through the contextualized game, the de-contextualized one and the theoretical model based on Economics assumptions of agents' rationality can be compared in order to answer the main research question.

After having played the games with "candid players" represented by university students, a further step of the research consists in playing with "real" stakeholders involved in water management (farmers, water managers, decision makers). This step aims at isolating the "experience" complexity component (the personal representation of a context, built up through the own history and education and the experience acquired in the field) that influences players' behaviour.

During the 4 months of stage at University of Pretoria, this Master has focused on the preparatory work of this research, consisting in 1) produce a literature review on CGT and Experimental Economics (EE) in the field of water management; 2) the degradation of the original RPG into a simplified game to be used in a laboratory; 3) the design and test of an experimental protocol to be followed during the implementation of the experimental phase. These three steps were realised in close collaboration and under the supervision of the CEEPA/CIRAD team involved in the axis 3 of the SafeWater ARISE project. At the same time, the theoretical CGT model that backs the experiment was developed by Dr. Stefano Farolfi (CEEPA/CIRAD) and Prof. Fioravante Patrone (Un. of Genova – Italy). This Master did not contribute directly to the development of the model, which is included in the thesis for reasons of clarity and to provide complete information about the research.

This document describes the above-mentioned research steps covered so far: The literature review (*Chapter 1*) provides some references in the field of Experimental Economics (EE) and Cooperative Game Theory (CGT), with particular attention to the applications to water management. *Chapter 2* presents the CGT model used to compare the experimental results with theoretical Economic assumptions; *Chapter 3* describes the simplified RPG and the proposed protocol for experiments. Particularly, the two test sessions conducted at University of Pretoria are thoroughly detailed and the consequent evolution of the game and of the protocol is provided; *Chapter 4* concludes and provides the way forward of this research activity.

Chapter 1: Literature review

This chapter presents a literature review on the use of Experimental Economics (EE) to test Economic hypotheses with particular emphasis on Cooperative Game Theory to study Economic agents' behaviour in water management. This review is divided in three axes. Each axis leads to the elaboration of the research question developed in the present work: can we use a Role Playing Game derived from a negotiation process as a contextualized laboratory experiment to test Economic Theory hypotheses?

The first axis recalls the Companion Modelling experience developed around the water management issues in the Kat River Basin, South Africa. The second axis is a survey on earlier publications on Experimental Economics and Cooperative Game Theory, focusing more precisely in experiments around the management of a Common-Pool Resource such as water. The third axis is a review of the main methodological issues of Experimental Economics, focusing more specifically on the technical aspects faced during the development of our protocol.

1.1. Experimental Economics and Companion Modelling

As it will be presented below, one of the principles of an experiment is to give a study the possibility to be reproduced afterwards. Rouchier (2006) discusses two different approaches that gather empirical data and link them to models and simulations: Experimental Economics, and Companion Modelling, which *"accompanies observed social groups when they negotiate over renewable resource issues"*.

Companion Modelling (ComMod) (ComMod Group, 2003) is a participatory and a negotiation support approach that takes place in the field. The 'field', unlike the 'laboratory' used in EE, is an environment, which has not been constructed or manipulated by an experimenter who therefore cannot control it. The field is also a complex system. The two objectives of ComMod are firstly to understand complex environments, and secondly to support collective decision in complex situations. These objectives correspond to a global objective of increasing the knowledge either for the scientist or the field stakeholders through a permanent and iterative confrontation between field circumstances and modelling processes.

The common approach developed in ComMod is based on cycles or *"loops"* of communications between the stakeholders and the scientists. Many tools as Multi-Agent Systems (MAS), Role-Playing Games, or Geographic Information Systems (GIS) are used as a way to share viewpoints and to support the dialogue between both parts. In some ComMod experiences, like the one in the Kat River, the researcher starts building a first preliminary model to explicit the theoretical *"pre-conceptions"* (Farolfi and Rowntree, 2007). The confrontation of this first model with the stakeholders allows revising and re-building it, taking into account the field situation and the stakeholders' questions and remarks. This dynamic process leads to the construction either of a new model derived from the previous one or a totally new one. Stakeholders learn collectively by creating, modifying and observing simulations (ComMod Group, 2003).

The local stakeholders are part of the framing process in the ComMod approach. As a consequence, experiments developed with ComMod are unique. Therefore, it is impossible to reproduce the same experiment with others players in order to gather data and compare it. Rouchier (2006) stresses that the first and most obvious limit of ComMod is "*the lack of accumulation of a knowledge that could be generalized to more than one situation*". Reproducibility of the experience is the strength of Experimental Economics, which establish a methodology with standards to describe the settings and the results of an experiment. The author suggests that an intermediate approach could be chosen between Com Mod and EE.

In a ComMod approach, which involves many disciplines in the analysis (e.g. Sociology, Psychology, or Economics) many phenomena could be observed and some could be seen as 'exhibits', consisting in empirical regularities that are discovered and for which, at the time, there are no well-developed theoretical explanations (Sugden, 2005b). This particular use of a game or an experiment to 'exhibit' phenomena will be presented later in the text. ComMod experiments could give rise to new research questions derived from the results, but different from the original research framework. One could see the exhibit function of ComMod and the consequent move to laboratory to run experiments and test hypothesis as a further "loop" or cycle within the ComMod process. This loop moves away from the stakeholders originality involved in the process and becomes a research-oriented phase of ComMod, where the negotiation component (stakeholders' participation) is completely absent. The new loop becomes also mono-disciplinary (Economics in our case) and refers to a specific problem of the Economic Science. This replication of a same contextualized experiment in many different fields will provide a capitalization of data.

An example of emergence of a new research question during a ComMod approach took place in the Kat River project (Farolfi and Rowntree, 2007). This ComMod experience included a Role-Playing Game (RPG) played by local stakeholders (members of a Water Users Association, WUA) in order to understand the complexity of the system, the relation between agents around water management, and also the impact of the strategies of water allocation in the field in order to build up a common strategy for the WUA. The two RPG sessions played during the ComMod experience allowed observing cooperation among the different players in the use of the water available from the Kat dam, situated upstream the catchment. This observation suggested an attempt of comparison between the results obtained through one of the two RPG sessions and a Cooperative Game Theory (CGT) model calibrated on the same data (Dinar et al., 2006).

The comparison showed some similarities about players' behaviours and the distribution of profits (payoffs). It was an encouraging result with regard to the attempt to compare outcomes obtained through both empirical and theoretical approaches. However, these two approaches show many differences, that cannot allow concluding definitely about the robustness of such similarities in the outcomes. Therefore, replications are needed to verify the strength of the results. Consequently the idea emerged to construct a "polished", though still contextualized game derived from the RPG used in the Kat to replicate experiments in order to test cooperative behaviour of agents around water allocation.

As it will be discussed in the next section, most experimental economists have a common agreement about the use of "decontextualized" experiments, consisting in experiments developed in an environment as neutral as possible. This environment is created in a laboratory, where the experimenter controls all the parameters of the experiment. According to the experimental economists, only such experiment, composed by neutral instructions which allow the control by the experimenter of the likely players' interpretations of the environment, allow the comparison of its outcomes with ones obtained through the model based on the assumption which is tested.

Instead, in the ComMod approach, stakeholders are involved in the design of the Role-Playing Game; consequently the game is as much "contextualized" as possible. By using a game derived from a ComMod experience to run experiments in a laboratory, the question is to verify if such contextualized game can be useful to test theoretical assumptions.

In conclusion of this part, the present research could be seen as a bridge between ComMod and Experimental Economics, because a contextualized RPG derived from a ComMod RPG is used to test theoretical assumptions through laboratory experiments. The choice of an EE approach is motivated by the possibility to reproduce many times the experiment, with the clear willingness to gather data and capitalize knowledge.

1.2. Cooperative Game Theory and Experimental Economics

The second axis of the literature review, developed in this section, looks at the epistemological basis and the main characteristics of Experimental Economics (EE), whereas methodological problems of EE will be discussed in the next axis. As Cooperative Game Theories (CGT) hypotheses will be tested in this research project, a short overview of CGT literature, particularly applied to the field of water management is also provided.

1.2.1. What is Experimental Economics (EE) ?

1.2.1.1. Epistemological basis

For a long time, Economics was perceived as a descriptive Science more than an experimental one. Sugden (2005) reminded what Milton Friedman (1953) said: "*Unfortunately, we can seldom test particular predictions in the Social Sciences by experiments explicitly designed to eliminate what are judged to be the most important disturbing influences*."
Although experimental methods have a long history in Economics, it is only in the last twenty-five years that they have gained real acceptance in the discipline, as demonstrated by the Nobel Prize in Economics awarded in 2002 to Daniel Kahneman and Vernon Smith (Eber et Willinger, 2005).

EE involves players in a game and specifically studies their behaviour when facing a particular situation. Consequently, EE is not exclusively concerned by Economic issues and also takes into account results derived from Psychology in order to study agents' behaviour. In situations where the Economic Theory does not work at all, economists need to accept their limitations and look to disciplines like Psychology for the answers (Binmore, 1999). EE crosses the boundaries of both disciplines and takes part of what Simon (1959) named more generally the *"Behavioural Science"*, which gather Economics and Psychology. Simon (1959) proposed that the psychological model of an adaptive man could complete the model of the neoclassical *"homo oeconomicus"*. However, Rubinstein (2006) criticized the use of Psychology on Economics by highlighting the limits of psychological experiments and argued that these limits are lowering Economics standards instead of opening the range of Economic researches.

Every Economic theoretical field potentially has an EE application. Cardenas and Carpenter (2005) listed the different theoretical themes in Economics which have been studied through the use of experiments (cf. table 1).

Theme	Application
Preferences and norms	▪ Social preferences (altruism, trust, reciprocity, fairness, cooperation) ▪ Risk and time preferences ▪ Intra-household allocation and bargaining ▪ Gender, ethnic, racial discrimination
Social dilemmas	▪ Public Goods provision and Voluntary Contributions Mechanisms ▪ **Common-Pool Resources** ▪ Prisoner's dilemma, Trust, Third party punishment Games ▪ Self-governing institutions ▪ Non-subgame perfect solutions (e.g. communication, punishment)
Well-being	▪ Behavioural effect of poverty and inequality ▪ Norms and poverty ▪ Behavioural effects on Environment or Health outcomes
Asymmetric information in incomplete contracts	▪ Land, labour and credit markets ▪ Gift-exchange in labour and land contracts ▪ Share-cropping and other land arrangements
Biases, heuristics & decision making	▪ Loss aversion and endowment effects ▪ Hyperbolic and other non-linear discounting ▪ Risk & Stakes ▪ Expectations
Institutions behaviour and feedback	▪ Institutional determinants of behaviour (e.g. crowding in and out, intrinsic and extrinsic motivations) ▪ Behavioural determinants of institutions (e.g. property rights-formal vs. informal, individual vs. collective) ▪ External regulations, self-governance and imperfect monitoring

Table 1. Economic themes and experimental application

1.2.1.2. The objectives of experiments in EE:

1.2.1.2.1. Experiment as a test of the Theory

Rubinstein (2001), one of the contemporary theorists, stated that Economic Theory is an abstract investigation of the concepts involved in real life decision making, rather than a tool for predicting or describing real behaviour. Consequently, Economic theorists' goal is to clarify the connections between different types of concepts and patterns of reasoning. They attempt to draw links and *understand* rather than *predict*.

To illustrate Economic experimentalists' practice, Rubinstein (2001) used the example of the Nash's Theory. Many experimentalists naively interpreted Nash's Theory to be predictive. Researchers tried to test whether the outcome of the Nash bargaining solutions is indeed obtained. Rubinstein said that *"it would be a miracle if the Nash formula could provide a prediction of the complex activity we call bargaining"*. The fact that Nash axioms analytically deduce the solutions does not mean that human beings behave accordingly to them. It is more the interpretation, rather than the predictions of the solution which should be the subject of the experimentation.

A way for the interpretation of the Theory is the use of a model (Hausman, 2005). A good model is realistic if it describes a situation as it is perceived by decision makers rather than a presentation of the physical world. Models are not meant to be isomorphic with respect to reality but rather it must be similar to the way in which the world is perceived by the human beings. In Economic Theory, the interpretation of a model is essential because assumptions which are plausible with a certain interpretation may be absurd with another (Rubinstein, 2006). Once Economic Theory is interpreted in a model, assumptions derived from this Theory can be tested in an EE experiment. Experimentalists run experiments not to see whether Economic Theory work or not, but to classify Economic environments into those where the Theory works and those where it does not (Binmore, 1999).

1.2.1.2.2. Experiment as an exhibit of new phenomena

Some EE researches have discovered empirical regularities for which there were no well-developed theoretical explanations. Such experimentally-observed regularities ("exhibits" or "phenomena") have served as benchmarks for subsequent theoretical work. Increasingly, theories are being constructed with the intention of explaining, or at least accommodating experimental observation (Sugden, 2005a and 2005b).

An example of a new Theory arisen from observation of empirical regularities is provided by Kahneman and Tversky (1979). They run some experiments in which the same problem of decision-making under risk was described in different ways. The major Theory of decision-making under risk is the expected utility model. According to this Theory, the utility of a risky project is equal to the expected utility of its outcomes. The expected utility is obtained by weighting the utility of each possible outcome by its probability. When faced with a choice, a normatively rational decision-maker will prefer the alternative that offers the highest expected utility, whatever the way the problem is presented.

However, the results obtained illustrated that people 'exhibit' patterns of preference which appear incompatible with Expected Utility Theory. Consequently, Kahneman and Tversky (1979) proposed a new model, called *"Prospect Theory"* which modifies Expected Utility Theory in order to accommodate their experimental observations[1].

1.2.1.2.3. Experiment as a decision support.

EE allows public decision-makers to test the effectiveness of political systems before implementing them or to assess the impact on social welfare of new regulations (Tisdell and Harrison, 1992; Cummings et al., 2004). For instance, Willett and Sharda (1997) used an experiment for evaluating the effectiveness of two different policies to

[1] Let with x and y be prospect outcomes with probability p and q respectively. Values v(.) are associated with these outcomes. According to prospect theory, there are decision weights π(.) associated with the probabilities, such that the overall value of the prospect equals $\pi(p)*v(x)+\pi(q)*v(y)$ instead of $p*v(x)+q*v(y)$ from expected utility theory (Tversky and Kahneman, 1981).

manage water quality. EE can help also private decision-makers (i.e. entrepreneurs) to simulate market strategies and their consequences on firm profit (Eber and Willinger, 2005).

1.2.1.2.4. Experiment as an educational tool.

Involving students with experiments in a classroom could be a tool in order to teach Economics concepts and mechanisms (Brañas-Garza, 2006). Boone and Van Witteloostuijn (1999) incorporated an experiment in a two-week "skills training course" in applied Game Theory for undergraduate students specialized in Business Administration or Economics. The purpose of the course was to teach students to apply and understand the consequences of formal Game Theory. The experiment was a tool to deepen the students' understanding of behaviour in a game-theoretical setting.

1.2.1.3. The characteristics of EE experiments

In any Sciences, an experiment has two principles. 1) It consists of setting-up a controlled environment in order to reproduce artificially theoretical conditions and parameters and 2) it insures that the study can be reproduced afterwards.

1.2.1.3.1. Parameters control

Experiments are designed to test theoretical predictions, or more precisely to test the assumptions of a model derived from the Theory. Therefore, an experimental environment is deliberately configured to be like the Theory (Sugden, 2005a). Theories are developed in "abstract" conditions and the simulation of such conditions is possible in a laboratory. Just as it is needed to use clean test tubes in chemistry experiments, economists know that they cannot test Economic assumptions in circumstances in which these assumptions should not reasonably be expected to work (Binmore, 1999).

Experiments in a laboratory have advantages because observation of real facts in their natural environment (i.e. in the field) does not allow isolating precisely the factors influencing them. The experimenter can reproduce artificially theoretical environments by trying to control all these factors.

Moreover, some situations are difficult to observe in the field because they seldom appear spontaneously in real-life and need particular circumstances to become visible. The laboratory provides the conditions to provoke such situations and to observe their consequences (Eber and Willinger, 2005).

1.2.1.3.2. Reproducibility

Economists can generate their own data from experiments and do not have to rely on one another's data. Series of experiments allow the scientific community to build upon and critique one another's work in ways that are not as readily available to economists using non-experimental methods (Roth, 1991). The replication of an experiment by the scientific community would prevent erroneous conclusions.

However, replication of experiments is not really rewarded because professional rewards are given to original or new experiments (Rubinstein, 2001). In fact, the system deters the researchers from running either the replication or the refutation of experimental results.

1.2.1.4. The limits of experiments in Economics

1.2.1.4.1. External and Internal Validity

The first limit presented to criticize the use of experiments in Economics is the lack of '**external validity**'[2] or 'parallelism'. This issue is not only the characteristic of Economics topics, but concerns the whole Social Sciences that adopt empirical methods. The question is to know whether players' behaviour observed in one experiment is not just an 'artefact' created by the laboratory atmosphere of the experiment, and therefore not extendable to any case (Eber and Willinger, 2005).

Experiments, in general, have the reputation of being high in '**internal validity**', i.e. the ability to draw confident causal conclusions from the results of a research (Loewenstein, 1999). However, EE experiments also face criticisms about internal validity. Specifically, experimental economists are "alleged" to run experiments in different places and times with different players without taking into account these differences in the interpretation of their results. During the time which separates two experiments, an event could occur and probably influence players' behaviour, removing internal validity from the experimental research (Loewenstein, 1999).

1.2.1.4.2. Contextualization[3]

The most controversial issue in the EE is about the experimental context. A common agreement among experimenters in the EE research field is to make neutral or 'abstract' as much as possible the context of the experiments. It is argued that the experimenter loses control on the experimental parameters since players have different interpretations of a given context (Eber and Willinger, 2005). However, the argument stating that the players have the same perception of a neutral context is controversial, as a too neutral experimental context could induce players to misinterpretation of the treated issues due to a lack of a cognitive representation (Loewenstein, 1999; Pillutla and Chen, 1999; Harrison and List, 2004).

1.2.1.4.3. Stationary replication

Some experiments are composed by several rounds per session, with strictly the same game features in each round (Willinger and Ziegelmeyer, 1999). The main interest of this 'stationary replication' used in EE experiments is to study the important question of how people learn in highly repetitive situations. The advantage of repetition is that it allows the experimenter to estimate whether the experimental outcomes are the result of players' confusion and inexperience.

1.2.2. Cooperative Game Theory (CGT) and EE

Experiments explore most research fields in Economics. More particularly, EE focuses on three Economic issues: rationality, markets and Game Theory. One of the favourite fields in EE is individual rationality. Through experiments, the hypotheses of the Theory of individual choices are tested in different ways. Particularly, individual choices are studied under certain, uncertain, or risky environment. Another field for EE applications is the study of markets. (Eber and Willinger, 2005).

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[2] The external validity refers to the ability to generalize the results obtained from the experiment to the real settings that the research intended to approximate (Loewenstein, 1999).

[3] The context issue will be developed deeply later in the text (cf. part 1.3.2.2.3).

Social interactions, which gather both individual choices and market situations, are also studied through EE experiments. Game Theory can be used to model the actions of individuals in a market situation simulated in a game. Games may be classified as cooperative or non-cooperative. This part presents cooperative games and the assumptions of Cooperative Game Theory (CGT) that are tested in such games. Some issues concerning the use of CGT and EE to treat water management problems are finally discussed.

1.2.2.1. The Cooperation between players in EE games.

Many experimental studies stressed cooperative behaviour whereas Game Theory predicts selfish behaviour. Typical experiments used to assess the cooperation issue, such as the prisoner's dilemma (PD) game, the public good game, also named voluntary contribution mechanism (VCM) game, (Gachter et al., 2004; Rege and Telle, 2004), or the common-pool resource (CPR) game (Cardenas, 2003). The common characteristic of such games is that they correspond to a social dilemma. A social dilemma is a situation in which the individual short-term interest leads to a collective long-term disaster (Pillutla and Chen, 1999). Among these games, the PD game (cf. table 2) is the most famous and the most used in Experimental Economics.

The PD game has been used to model cooperative behaviour (as opposed to competitive behaviour). Two participants are involved in the most widely used class of PD games. Each player has to choose independently between two options: *cooperation* (C) or *defection* (D). The payoff of one player depends upon the choice made by the other. The general form of the PD game can be represented in a 2*2 matrix:

		Player 2	
	Choice	C	D
Player 1	C	**R, R**	**S, T**
	D	**T, S**	**P, P**

The payoff to the left of the comma in each cell is the outcome of player 1, whereas player 2 payoff is given to the right of the comma.
R indicates "reward" for mutual cooperation, T denotes the "temptation" to defect, S refers to "sucker", and P is the "punishment" for mutual defection. The payoff structure presented in the matrix is a PD game if and only if the following inequalities are satisfied: **T>R>P>S** and **2R>T+S>2P** (Boone and Van Witteloostuijn, 1999; Dasgupta, 2007)

Table 2. General form of the prisoners' dilemma game

The VCM and the CPR games have also a great interest in studying social interactions. In both cases, there is the same conflict between individual and collective interests. The public good (VCM) and the CPR games can be conducted with several players who must choose between many strategies[4]. VCM and CPR games have a lot in common but with a basic difference. The public good game is designed around the participation in a common project, whereas the CPR game is framed around the extraction from a common pool (Willinger and Ziegelmeyer, 1999).

- A *public good* is a commodity that can be provided only if group members contribute something toward its provision whereas all persons (contributors and non-contributors) may use it (Pillutla and Chen, 1999). In that case, one contributor can consider the others' contributions as positive externalities on the public good (Willinger and Zigelmeyer, 1999).
- A *common pool* is accessible to all persons of a group, but one member's extraction reduces the potential benefits of the others. Then, one user can

[4] The VCM and the CPR games are played with more than the two players involved in the PD game and the several players have more than the two symmetric strategies (cooperate or defect) of the PD game (Eber and Willinger, 2005)

consider the others' activities as negative externalities on the common pool (Willinger and Ziegelmeyer, 1999). This kind of other members "exclusion" from the resource is an important difference with the classic public good definition (Cardenas and Carpenter, 2005; Eber and Willinger, 2005).

1.2.2.2. Cooperative Game Theory (CGT)

Game Theory studies strategic behaviour of decision-makers in situations where one player's decisions affect the other players. The basic assumption of Game Theory is that decision makers are rational players and take into account other decision-makers' rationality to build expectations on their behaviour (Parrachino et al., 2006a). There are two main branches of Game Theory, the first is Non-Cooperative Game Theory and the second is Cooperative Game Theory (CGT). This review focuses only on the second branch, as the model to be tested experimentally in our research is a CGT model. Unlike Non-Cooperative Game Theory, CGT does not focus on the coalition building among players but rather studies the possible results of cooperation. More particularly, CGT objective is to determine what coalition could be formed among the players in a game and how coalition gains are shared among its members. Specifically, CGT focuses on the solutions of the *grand coalition* that includes all the players. Cooperative models are generally framed as follows (Parrachino et al., 2006a):

Let N be a finite set of n players in a transferable utility game[5]. Let S and T be subsets of N. S and T are called partial coalitions and N is the *grand coalition* composed by all the players.
Let v be a real-valued function defined over all the subsets of N. Commonly, v is the payoff obtained, such as the payoff obtained by farmer i as singleton is noted v(i) and the payoffs for the coalitions S and N are $v(S)$ and $v(N)$ respectively.

Supposing that the players agree to work together on a certain objective, the main question in cooperative game models is how to allocate the earnings of a coalition among its members (Parrachino et al., 2006a and 2006b; Dasgupta, 2007). More specifically, the question is how the players divide $v(N)$ between all of them.

A distribution of $v(N)$ among the players is represented by a reward vector x such as the part of $v(N)$ received by farmer i is represented by x_i. If the players allocate all the amount of $v(N)$ among them, the efficiency principle is satisfied, meaning that $\Sigma x_i=v(N)$.

Different solution concepts of the payoff sharing issue are developed in CGT and could be provided as a subset or as a one-point (unique) solution.

- Subset solutions refer to a range of values that satisfy certain conditions and provide various possible solutions. The *core* is one example of a subset solution. A payoff vector x is in the core if it satisfies the following conditions (Tisdell and Harrison, 1992; Abbink et al., 2003; Parrachino et al., 2006a):
  - individual rationality; i.e. for all $i \in N$, $x_i \geq v(i)$

[5] A "transferable-utility game" is defined as follows: if a coalition can obtain a total utility, this utility can be divided among the members of the coalition in any possible way. Particularly, it is possible to transfer money among the players in order to reallocate the profit gained through the coalition (Parrachino et al., 2006a)

- group rationality; i.e. for all $i \in S$, for all S, $\Sigma x_i \geq v(S)$
- efficiency; i.e. $\Sigma x_i = v(N)$

Other subset solutions exist, such as the Kernel or the least core (Parrachino et al., 2006a). However, the set of vectors that forms such a subset solution is often too large to provide any usable information.

- ♦ A one-point solution is the unique solution that satisfies the conditions imposed by the solution definition. The *Shapley value* is a kind of one-point solution. The Shapley value solution vector satisfies individual and group rationality. It is defined such as each player's reward x_i equals a weighted average of the contributions the player makes to each coalition of which he is a member (Parrachino et al., 2006a). The Shapley value represents a "fair" payoff sharing, taking into account the players' strength and weaknesses (Tisdell and Harrison, 1992).

1.2.2.3. Water management issues

Despite the increasing competition around water resources, the level of negative externalities associated with water utilization is a big incentive to cooperate (Parrachino et al, 2006b). Cooperation over scarce water resources is possible under a variety of conditions. CGT and EE are useful tools to assess water management policies and to provide arrangements in water allocation.

1.2.2.3.1. CGT and water management issues

Issues of water resources, for example urban water supply, water pollution, or irrigation can be modelled with CGT. Particularly, CGT approach is useful in irrigation cases. Irrigation models are typical of transferable-utility situations where players can transfer resources or the benefits from using the common-pool resource (Parrachino et al., 2006b).

Tisdell and Harrison (1992) assessed the impact on social equity of two methods of water entitlement allocation. A model based on a real field situation in Australia was developed and the two water allocation alternatives were analysed using different CGT solutions. Particularly, Tisdell and Harrison (1992) studied the effect on the grand coalition payoff of the two different water allocation methods. They provided a useful tool for further water policy evaluations based on CGT.

1.2.2.3.2. EE and water management issues

Generally, Environmental Economics researches are conducted in the field and policies evaluation are developed from field observation. Ostrom (2006) asked *"what more can you possibly learn about institutions and resource governance from laboratory experiments that you have not already learned in the field?*". In field researches, environmental economists are never certain that the specific variable of their study is isolated. A good way to understand which components of a CPR situation affect agents' behaviour is to study a simplified version of a field experiment in the laboratory in order to control all variables (Ostrom, 2006).

Some water management policies are developed by using EE experiments in a laboratory. Cummings et al. (2004) present experiments that policymakers used to design and implement a policy in their environment. Their objective was to reduce water usage for irrigation and they compared total irrigation within different rules of water allocation. However, water management issues are not exclusively around quantity, but water quality is also approached through EE experiments. Willett and Sharda (1997) conducted in a laboratory an experiment as closely as possible to actual circumstances. They tested the impact and the effectiveness of two different policies and suggested some advices to improve water quality in the real situation.

1.3. Methodology of EE

This section presents the some methodological issues that arise when designing Economics experiments. An experiment is described in a protocol, which guides the experimenter who runs the game. The protocol must be precise in order to allow further replications of the experiment (either by the same experimenter or by other researchers). The instructions of a game are the framework that guides the players and also must be clear, in order to avoid mistakes in players' understanding of the game.

Sugden (2005a) stressed that from the beginning, Economics experimenters have been criticized for their methodology, and more particularly for the 'artificiality' of the laboratory experiments, unlike field experiments, which are more concrete. Laboratory environments exclude features of the world that are crucial for the workings of real Economic institutions. Among the methodological features representing critical points, Sugden (2005a) listed the following:

- *subjects* are unrepresentative of agents whose behaviour Economic Theory is designed to explain, and they do not have adequate opportunity to learn by trial and error how to act rationally in a way that Economic agents do in the field;
- *incentives* to optimise are smaller in the laboratory than outside;
- the abstract *context* of experimental tasks removes cues that, in the field, help people to orient themselves, and the social norms that guide interaction in the field are not adequately reproduced in the laboratory.

In this section, after a description of the procedures gathered under the term "protocol", these three points will be discussed focusing specifically on a) the characteristics of the participants of a game, b) the incentives that motivate them, c) the framing effect of the instructions on players' behaviour, and d) the importance of the experimental context.

1.3.1. The protocol and the instructions

As a preparatory task to an experiment, the researcher must design the framework of the experiment. The protocol is a set of procedures which includes the whole features of the experiment. It describes the categories of players who will participate, the instructions that the players will get, the incentives, the rules of the game and all the information needed in order to prepare the sessions. The experimenter may have different kinds of development around a same protocol. Each protocol version with a particular parameter is designed to study one kind of assumption. A treatment is a particular version of a given protocol, which relies on a specific pattern of parameters of a game. For example, in a game studying cooperative behaviour of the players, a first treatment could be a protocol version in which players cannot communicate each others and a second treatment could be a protocol version of the same game in which communication is allowed (Eber and Willinger, 2005)

The instructions provide the players all the relevant information needed to understand the rules. The instructions could be written either on a paper (more classically) or on a computer screen (when the experiment is run in an informatics experimental laboratory). At the beginning of the experiment, the participants read the instructions individually and then these instructions are read aloud by the experimenter. This stage is very important, because the players thus know that these instructions are a common knowledge for all the participants (Eber and Willinger, 2005).

The experimenter must be sure that the subjects understood the instructions. Actually, a player who does not understand the task could have a biased behaviour and his misbehaviour could introduce errors in the game, hampering the experimenters to conclude about the robustness of the results. The experimenter has different possibilities to insure a perfect understanding of the game by the players. He could give some examples of decisions to be made and the consequent results, directly written within the instructions in order to assist the subjects' understanding (Cardenas, 2003; Rege and Telle, 2004). Each participant could have to answer a short questionnaire that tests his understanding of the task. Certain subjects could reveal a lack of understanding. Then, they get a special individual tutoring before the experiment starts (Pillutla and Chen, 1999; Cooper and Kagel, 2003; Gachter et al., 2004; Rege and Telle, 2004). Another method is to play a first try before starting the game that will not count in the final calculation of the players' outcomes, in order to familiarize the participants with the task (Willinger and Ziegelmeyer, 1999; Cardenas, 2003). In case of games in which the players need to calculate their outcomes, the experimenter could give all the subjects a tool to help them in their calculations. Cardenas (2003) gave the players a same table of payoffs, function of individual choices and the choices of all the other participants in order to assist them in the decision-making procedures. He also notified in the instructions that this table of payoffs was common knowledge.

A granted rule, shared by all experimental economists, is that the instructions must provide information as honest as possible, in order to avoid deception[6] due to false instructions, as used sometimes in psychological experiment methodology. Nevertheless, some information could be hidden, such as the individual results of the other players, in case of games in which anonymity is required. Such anonymity is provided at the beginning of the game as common knowledge for all the players, thus there is no deception. Some other researches run experiments with a *surprise* re-start of the game (Cardenas, 2003; Akpalu, 2006). For example, at the beginning of the experiment, players are told to play individually a game in which talking is prohibited. Then, new instructions are distributed and communication between the players is allowed. The players did not know previously that there would be a re-start and discovered it "in live" when the experimenter announced it, but it is not a deception case because the experimenters do not manipulate the participants by changing the rules without informing them.

At the end of the experiment, the researcher generally gives a debriefing to explicit the experiment results and possibly pays the participants (in case of monetary

[6] In case of deception, the players believe they are playing some game but actually the experimenter is manipulating them. For instance the experimenter could involve a subject in a game in which the other players are not real players but either experimenter's accomplices or computers. The experimenter thus creates a false environment to test the subject's reactions (Eber and Willinger, 2005).

rewards, cf. part 1.3.2.2.1). A questionnaire could be distributed at the end of the experimental session, during the debriefing. The players answer questions about the game (i.e. about certain issues related to the study and the reasons of their choices during the game), and personal data on their Socio-Economic characteristics. This information could be used further by the experimenter for statistical analysis about the influence of players' characteristics (e.g. male/female; student/non-student) on their behaviour (Cardenas, 2003).

1.3.2. The main methodological issues of EE

1.3.2.1. Players

The experimenter, before the game, has to recruit subjects. According to the category of subjects he would use to run the game (e.g. students, local stakeholders, etc.), the researcher has different methods to contact people. For the games in which the players are students, the recruitment could be made by direct communication either through announcements in classes (Cooper and Kagel, 2003) or by approaching randomly people in the corridors of the university (Gachter et al., 2004). An email posted to diffusion lists is another possible way to contact directly people (Kuhberger et al., 2002). Posters placed on collective places (in the University or in the workplace if the players are students or non-students respectively) and flyers distributed during meetings are other methods for recruitment (Cooper and Kagel, 2003; Carpenter et al., 2004).

The more people participate to the experiment, the more robust the results. Nevertheless the number of participants depends on constraints that often hamper the experimenter to run the game with a large number of players[7]. Once the volunteers are chosen, the experimenter invites them to participate to the experiment and gather them in the experimental place.

1.3.2.1.1. Experiments with students

In the majority of the experiments, participants are students (Tversky and Kahneman, 1981; Carpenter and Cardenas, 2004; Brañas Garza, 2006; Akpalu, 2006). They are a convenient sample for academics because they are already within an academic environment, they could be motivated by a willingness to learn and could be curious about participating in the scientific research. In case of using monetary rewards to pay the participants, students could be motivated also by lower amount than other category of people, which is a relevant practical advantage. Students can be viewed as the standard subject pool used by experimenters (Harrison and List, 2004; Eber and Willinger, 2005).

The main criticism with respect to the students' samples is the potential biases introduced by the use of participants who are not representatives of the whole society (Benjamin and Robbins, 2007).

Some studies compared the results obtained by running experiments with both students and non-students samples. Gachter et al. (2004) studied the Socio-Economic

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[7] For instance, the constraints could be the capacity of the experimental room, the number of available computers of the experimental laboratory, or the available budget if the players receive monetary rewards at the end of the game.

impact on trust and voluntary cooperation. They conducted a VCM experiment (i.e. a voluntary contribution mechanism game, cf. part 1.2.2.1) with students and non-students people in rural and urban Russia. The results showed that non-students are more trusting and contributed more to the public good than students. Gachter et al. (2004) controlled for the Socio-Economic characteristics of the participants by submitting them a questionnaire at the end of the game. By analysing the players' responses, they found that Socio-Economic background matters for trust attitudes. According to their findings, the dominant Socio-Economic variable is age: older people exhibit more trust than younger people. The age mean, standard deviation and range within a students sample are lower than ones within the society. The impact on the results of the participants' age disappears when running experiments only with students. Moreover, Gachter et al. (2004) found that with respect to some Socio-Economic characteristics (e.g. membership in civic associations), the Russian student generation seemed to be closer to the American population investigated by Glaeser et al. (2002) than to the non-students of their own society. Consequently, it seems to be questionable to generalize to the whole society, characterized by particular features (e.g. culture, history), the results obtained with students who do not share totally the same features.

Some studies focused on such features of the society, comparing for example the effect of culture on people's behaviour. Carpenter and Cardenas (2004) were interested in cross-cultural comparisons of players' behaviour in experiments. Such a comparison was made after running the same experiment with people from different cultures in different locations. Carpenter and Cardenas (2004) proposed to allow participants from different cultures make decisions in the same experiment. Using Internet, they were able to run real-time experiments in which half of the participants were students from Colombia and the other half were students from US. The students played firstly a CPR game (i.e. a common-pool resource game, cf. part 1.2.2.1), facing the situation in which subjects extracted resources from a forest that also provided non-use (i.e. conservation) benefits. Secondly, the participants played a dictator game[8] by allowing them to voluntarily and anonymously donate any portion of their earnings from the CPR game to two real biodiversity conservation projects, one benefiting the *local community* and the other benefiting the *international community*.

The CPR results showed that American participants reacted by reducing forest extraction while the Colombian participants extracted significantly more when placed in groups with Americans. At the same time, the donation phase results (i.e. the dictator game) seemed to indicate that the Colombian students had a stronger preference for favouring the national (local) program and a weaker preference for global conservation than the American students. Cultural specificities seemed to influence the students' behaviour. However, these conclusions provided from experiments run with students remain questionable, as students are not representative of their own society. For example, it is impossible to conclude that Colombian people in general would extract more from a resource when faced with American people.

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[8] The dictator game is a variant of the ultimatum game. In the ultimatum game, one player proposes a second player a split of a sum of money. If the responder accepts the offer, the offer is implemented; if he rejects it, both players receive nothing. In the dictator game, the responder does not have veto power over the proposed split and simply receives whatever the proposer gives (Carpenter et al., 2004).

Boone and Van Witteloostuijn (1999) compared the impact of culture[9] and education on the competitive and opportunistic behaviour through a prisoner's dilemma game (cf. part 1.2.2.1) conducted with students. These authors confirmed Carpenter and Cardenas' (2004) results, indicating that cultural background influences players' behaviour. They also found that culture is much more firmly imprinted in an individual's mind than educational knowledge. Then the effect of culture seemed to dominate over the impact of education. The impact of education on behaviour was studied by Frank et al. (1993) who questioned if *"studying Economics inhibits cooperation"*. Frank et al. (1993) observed that students specialized in Economics behaved in more self-interested way than other students. They found that this difference seemed to result less from training in Economics than because people who chose to study Economics were initially self-interested. In other words, the exposure to lectures of self-interested models do not cause more self-interested behaviour, since it may be that economists were merely more interested by such models, and this was one reason why they chose to study Economics. This result confirmed that education is less influential than individuals' own characteristics (e.g. cultural background or academic preferences).

According to the previous examples, culture and age seem to be central in a society and seem to influence strongly people's behaviour. When using students to run experiments, researchers work with a sample where the variability of these two relevant characteristics is not representative of the whole society. Therefore the external validity of such experiments (i.e. the effects found in the laboratory are representative of the real world phenomena) remains controversial.

1.3.2.1.2. Experiments with non-students

As stated above, experiments are generally run with students samples, also called "standard samples" (Harrison and List, 2004), but this kind of experiments showed some limits. In order to overcome these limits, the experiments could be run with "non-standard" samples (i.e. with non-students). Some researches focused on particular non-students samples, such as traders, managers or local stakeholders, in order to test the influence of their specific characteristics on behaviour (Eber and Willinger, 2005). Other researches run experiments with people in the field (i.e. in their own environment) and they do not focus on a particular Socio-Economic sample (Cardenas, 2003; Gachter et al., 2004). One particular advantage of running experiments in the field is the much wider variation for the skills and levels of understanding of the problem by participants, especially considering the different levels of schooling, and more particularly the lack of schooling (Cardenas, 2003). This lack of academic education is possibly balanced by non-students' experience.

Cardenas (2003) conducted an experiment in the field and focused particularly on the influence of people's wealth on people's behaviour. The game was the CPR game in which the participants had to manage a forest. The players were local stakeholders who manage a forest in their daily life. During the experiment, participants often drew parallels with their own experience. The experience gained using the local forest for

[9] *Culture* could have different meanings. Boone and Van Witteloostuijn (1999) presented *culture* as participants' nationality, but culture could be also viewed as the origins of people having the same nationality. People with origin from southern societies (such as Africa, Asia and Hispanic America) have the same collectivist cultural background, whereas people from individualist western societies (such as Northern America and Western Europe) are more individualist (Cox et al., 1991).

extracting firewood, fibres or food, was helpful to resolve the social dilemma of the game. Cardenas (2003) provided some methodological lessons from his experiment. In particular, there are advantages of bringing the experimental lab to the field and learn from observing the wider variance in certain characteristics of the participants in the subject pool (e.g. their wealth), if compared to college students as usually done. The results obtained by Cardenas (2003) also have more external validity because he conducted the experiment in the field with participants for whom cooperation is an important dilemma faced each day[10].

Even if it seems that the use of non-students samples provide more robust results, it has many constraints. If one advantage of running experiments with students is that they are available and have free-time, then for non-students time is a scarce resource. Moreover, non-students cannot go to the experimental laboratory, but rather the laboratory has to go to the participants. Carpenter et al. (2004) ran sessions with workers at the end of the workday to minimize the time commitment of the participants. They provided a summary of the instructions before the experiment when recruiting volunteers. This allowed the experimenters to keep the experimental time to half an hour on average.

1.3.2.1.3. Relationship between the players

Carpenter et al (2004) studied the impact on subjects' behaviour of the real-life social context[11] in which the laboratory (experimental place) is embedded. More precisely, they stated that the social context refers to the relationship players have with the other participants and with the experimenter, and to the set of norms and habits that dominate the life in the institution in which the experiment is run:

- *Workers* in the workplace see each other every day, often work together in teams, and can expect to continue working together for long periods of time.
- *Students*, even in a small campus, are more likely to be in competition for grades, are likely to have less frequent interactions, and know that their time together on campus is limited.

1.3.2.1.3.1. Anonymity

Loewenstein (1999) argued that the motives that could influence behaviour could include the desire to behave in an appropriate fashion, conform to the expectations of the experimenter, or with the willing to appear as a smart (or at least not stupid) and good person, or to be the "winner". Some experimental economists seem to believe that some of these motives can be eliminated through procedures that assure anonymity. People do behave differently when they believe they are being watched either by the experimenter or by the others players (Frank et al., 1993; Brosig, 2001).

Rege and Telle (2004) framed a public good experiment. People decided individually how much to contribute to the public good, and then the contribution of each player was communicated. The authors designed two treatments of the experiment. In the first "*approval*" treatment, each player at a time had to reveal his own contribution in sight of all the other participants. In the second "*no-approval*" treatment, anonymity was fully insured. The experimenter communicated the contributions without

[10] A response to the external validity issue when running games with students could be given by Akpalu (2006). In his experiments, made with students from Ghana, one of the characteristics of many participants was that their families were dependent on natural resources for their livelihood. His study did not focus on this issue but could provide a research question for the future.

[11] All the experimental context issues will be more detailed in part 1.3.2.2.3

revealing contributors identity. The authors found that people contributed less to the public good when playing anonymously, confirming the influence of anonymity on players' behaviour.

1.3.2.1.3.2. Communication among the players

In an Experimental Economics laboratory, the participants of the experiment are affected to a *box* with a computer. The players are isolated by separations between the boxes and they cannot see each other. Generally, communication is prohibited and the players make their decision individually (Eber and Willinger, 2005). However, in some researches, for example those studying cooperation among the subjects, communication between the players could be allowed.

In Cardenas' (2003) CPR game run in the field, groups of eight people were constituted and faced the decision to use a same resource (i.e. a forest). The decision had to be made privately and individually. The game was divided into two phases. During the first phase, individuals made their choices on each round without communicating with the others. After the first phase, the experimenters stopped the game and announced a new set of rules for the following rounds, in which the group would be allowed to have a 5 minute open discussion[12] before the decision for the next round. After the discussion, each member of the group returned to his individual desk and made his individual and still private decision. The results analysis showed that the introduction of face-to-face communication among group members had a positive impact on behaviour and earnings, despite the privacy of decisions.

The conversations were video recorded to analyse how communication influences the efficiency of cooperation around forest management. The videos showed that some groups had conversations where one could feel closeness among the players, while others had more formal and distant conversations. For the most efficient group[13], the communication was very "kind" from the very start of the second phase and was maintained over time. In other groups, the dialogue was much more difficult and cold, and the groups resulted less efficient. This result confirms the importance of communication on people's behaviour, and more particularly on cooperation. Moreover, when analysing the reasons of *kind* or *cold* communication within a group, Cardenas (2003) found that the group homogeneity with respect to the wealth level of the members was the main reason that affected communication. When playing the game, "poor" people in the real life were suspicious against "rich" people. This finding is consistent with Loewenstein (1999) and Carpenter et al. (2004) conclusions about the effect of relationship among players and of the social context on players' behaviour.

1.3.2.2. Experimental Design Features

Explanations and predictions by Economic theorists of people's choices in every day life are generally based on the assumption of human rationality. The definition of rationality is much debated. The normative definition of decision rationality derives from the use of the principles of the Utility Theory. It is assumed that the rational principle governing utility maximization ensures that decisions are logically coherent

[12] The face-to-face communication could be about anything the players wanted on the game, but must not include any kind of threats or promises of transfers of points or cash after the game.

[13] The most efficient group was the one which got the higher average earnings during the rounds divided by the maximum possible.

and consistent. One significant implication of this notion is that rational choice is uniform across all domains (Wang, 1996a). The choice is not affected by experimental content, it is not sensitive to context, and there are no specific features for processing particular kinds of tasks.

However, this viewpoint was strongly challenged on both theoretical and empirical grounds. Many scholars have converged to the notion that human cognition consists on several domain-specific mechanisms (Wang, 1996a). Experimental economists highlighted more particularly three experimental features influencing human cognition: the incentives provided to the subjects to maximize their utility function, the framing (phrased) of the instructions, and the context of the experiment.

1.3.2.2.1. Incentives

Among all the rules of Experimental Economics, perhaps the most enforced is the use of monetary payments, which is seen as a way of maintaining strict control over individual motivations. However, this rule is controversial and many researchers criticize it (Loewenstein, 1999; Rubinstein, 2001). One of them is Read (2005) who claims that there is no basis for requiring systematically the use of real monetary incentives[14] when doing Experimental Economics.

1.3.2.2.1.1. Why using monetary incentives?

Experimental Economists believe that the use of rewards allows them to control the incentives that operate in the experiments. As the Theory states, they follow the assumption that subjects are motivated by profit maximization. Therefore, with monetary rewards, it is expected that the players will behave in the sense of this theoretical claim (Loewenstein, 1999; Eber and Willinger, 2005; Read, 2005).

One reason to use incentives is to motivate players to do their best in understanding the task of the game, and to behave seriously, giving honest responses[15]. The experimenters pay the participants because they want them to think harder. It is argued that increased understanding drives behaviour in the direction of the "normatively-correct" response (Wilcox, 1993; Hertwig and Ortmann, 2001; Kuhberger, 2002). However, incentives are not necessarily better to increase players' understanding than other ways, such as writing better instructions with all the needed information or giving the players extra time (Read, 2005).

Read (2005) studied the relevance of the use of monetary incentives in Experimental Economics. He did not treat *whether* incentives work, but rather he considered the fundamental question of *how* the incentives work. Before deciding to use incentives, it is necessary to think about why the incentive is likely to have an effect[16], and what the alternative non-incentivised methods are.

[14] Real incentives are money in most of the experiments, but when players are students they could be also an improved mark for their exams (Brañas-Garza, 2006) or a reduction of the time to be spent in doing a task (Kuhberger, 2002).

[15] The players will invest cognitive effort to avoid making judgement errors (Hertwig and Ortmann, 2001).

[16] While real world decisions invariably implies real losses as well as gains, the use of monetary incentives in the laboratory rarely allows the imposition of real losses. Research on the house money effect shows that people tend to take more risk on house money (Thaler and Johnson, 1990).

Incentives might do more than push the players to do more of what they are doing already. They can also change what players do. Actually, people have strong intrinsic motivations to do their best. By paying the players, the experimenters give extrinsic motives. Even if this loss of players' motivation could be seen as a negative outcome, it might be exactly what the experimenter wants (Read, 2005). Intrinsic motivation is beyond the experimenter's control, and actions that maximize "intrinsic payoffs" may not be the ones that would maximize "economic payoffs". The extrinsic monetary incentive does not necessarily increase the level of motivation, but it might change its focus, thus making observed behaviour easier to interpret. Read (2005) stated this in more formal term:

> A monetary incentive is one of many sources of utility, among entertainment, altruism, self-esteem, etc. The decision-maker's goals can be summarized as follows:
>
> $$Max\ u(\$,EE)$$
>
> with
>
> Money: $\$=f(choice)$
> and everything else: $EE=f(choice)$
>
> By introducing monetary incentives, the weight put on money is increased. Ideally, the result is a single argument utility function $u(\$)$, so that if people are maximizing their earnings they are also maximizing their utility. One goal of using financial incentives, therefore, is to 'crowd out' other incentives.

As stated by Economic Theory, rational subjects look for optimising their economic payoffs (i.e. their profit or their income). If the experimenter's objective is to test the theoretical definition of players' rationality, then the use of monetary incentives is a good way to validate it. Monetary incentives in experiments could produce an illustration that if people are paid to do something, they are more likely to do it. Read (2005) suggested that it is not interesting to show that money can motivate people, but it is rather interesting to study if non-monetary motives (i.e. the "*everything else*" factor in the utility function) can also motivate decision-makers.

The use of monetary incentives could have a consequence on the reliability of the results. Hertwig and Ortmann (2001) considered that incentivised studies contain less error and are better than non-incentivised studies. They argued "*the benefits of being able to run many studies do not outweigh the costs of generating results of questionable reliability"*. Read (2005) answered that it is difficult to estimate at what point the benefit from doing many studies outweighs the benefits of generating 'better' ones. Monetary incentives is one of the tools researchers can use and the decision to employ monetary incentives, like any other research decision, should be made according to what the researcher wants to achieve using them.

1.3.2.2.1.2. How to calculate monetary incentives?

There are monetary costs when using monetary incentives. The use of monetary incentives increases the budget of the research, and limits the number of experiments conducted. The total amount of the monetary incentives could be so expensive that it could be a heavy constraint that decreases the possibility of replication of an experiment and then affects its external validity. The amount of the monetary incentives has to be chosen high enough to motivate the players and low enough to run many experiments.

A way to reduce the monetary cost of conducting experiments with monetary rewards is to pay randomly the participants at the end of the game. Among all the players, only one part will receive a payment at the end of the experiment (Eber and Willinger, 2005). Another method is to pay partially the players, only on a part of all the outcomes they obtained. Akpalu (2006) run an experiment divided in two games and he followed the "within-subjects" procedure (i.e. each player participated to the two games). He rewarded the players according to their outcomes only in one of the two games. At the end of the experiment, a toss with a coin designated for each participant which outcome would be the basis for the calculation of the monetary reward.

1.3.2.2.2. Framing effect

The term *framing* was introduced by Tversky and Kahneman (1981) and used to indicate the fact that simple and unspectacular changes in the wording of decision problems can lead to preference reversals. Kuhberger (1998) provided a deep analysis of the influence of framing on risky decisions, giving a survey over 15 years of research on the framing effect. He gave the term *framing* two definitions, a "strict" one and a "loose" one.

- the **strict** definition relates to the *wording* of a formally same problem, i.e. to a semantic manipulation of prospects whereby the exact same situation is simply re-described (Tversky and Kagel, 1981; Brañas-Garza, 2006).
- the **loose** definition of framing refers to an internal event that can be induced not only by semantic manipulations, but may result also from other *contextual* features of a situation and from individual factors, provided that problems are equivalent from the perspective of Economic Theory (Wang, 1996a; Willinger and Ziegelmeyer, 1999).

Among different framing problems, Tversky and Kahneman (1981) used the *life-death* decision model in which a certain number of people were described as being infected by a fatal disease. Two treatment plans were available. The first plan would result in a deterministic outcome that led to the *sure* survival for 1/3 of the patients. The second plan resulted in a probabilistic outcome that led to a 1/3 *probability* that the entire patient group would survive and a 2/3 probability that no one would survive. Subjects had to choose among the two treatment plans according to their preference for the outcomes associated with each plan.

Tversky and Kahneman (1981) (below called as TK) used a life-death decision problem that involved 600 anonymous hypothetical patients. When the choice was framed *positively* in terms of number of people who would be *saved*, 72% of their subjects chose the deterministic (sure) outcome. In contrast, when the choice outcomes were framed *negatively* in terms of number of people who would die, 78 % of the subjects chose the probabilistic (risky) outcome. This result demonstrates that seemingly inconsequent changes in the formulation of choice problems cause significant shifts of preference.

After a meta-analysis over a large number of publications on framing effect during 15 years, Kuhberger (1998) found that student samples dominate framing research. Students and non-students do not differ in their receptivity to the framing effect. Although students (considered as 'candid' persons) and experts might differ in a variety of ways, experts are also influenced by framing even if maybe to a lesser degree than students. Therefore, Kuhberger (1998) concluded that students are not misled, with respect to framing, when involved in an Experimental Economics exercise.

1.3.2.2.3. Context Issue

A common agreement among experimenters in the EE research field is to conduct experiments in a lab and to make the context of the experimental instructions as neutral as possible. It is argued that the experimenter looses control of the experimental parameters, since players have different interpretations of a real context. The reasoning is that a real context might contaminate behaviour, and then any observed behaviour could not be used to test general theories (Harrison and List, 2004; Eber and Willinger, 2005). The idea is that the players have a same perception of a general and neutral issue. For example each one could interpret differently an Economic context issue, such as two players respectively named 'seller' and 'buyer' in an auction or ultimatum game, or 'monopolist' and 'entrant' in a market game. In a context generalization, they become 'player A' and 'player B' in the experimental instructions (Cooper and Kagel, 2003). In their PD game design, Boone and Van Witteloostuijn (1999) did not use usual terms as "compete", "cooperate", "defect" and "sucker" to insure a neutral instruction setting.

However, it is not strictly true that subjects have the same perception of a neutral context. In the middle of the twentieth century some behavioural economists desired to expunge context conducting experiments in *" 'context free' temperature and sound-regulated white egg-shaped enclosures"* (Loewenstein, 1999). But an egg-shaped cage provides the same amount of context (with somewhat more alien) as any other environment. Cognitive Psychology states that all forms of thinking and problem solving are context-dependent, including tasks as language-comprehension. Instead, real referents can avoid subjects' confusion about the experimental task (Loewenstein, 1999). Loomes (1999b) claimed that "*the dangers of constructing experimental environments so stripped of context are that participants search desperately for cues about the kind of behaviour that might seem sensible, or that they think the experimenters might be looking for, with the result that they fail to process the tasks as they would do in the richer social environment that may be sought to model"*. In other words, subjects may seem like zero intelligence agents when they are placed in the unfamiliar and abstract context of an experiment. If the subjects do not understand what the experimental task is about, meaning that they do not know what actions are feasible and what are the consequences of different actions, then control is lost at a basic level (Pillutla and Chen, 1999). Nevertheless, it must also be recognized that inappropriate choice of field referents may trigger uncontrolled psychological motivations. The choice between an abstract context and one with field referents must be guided by the research question (Harrison and List, 2004).

1.3.2.2.3.1. The importance of experimental context

As a result of their experience with experimental games experimental economists are progressively gaining an appreciation of the importance of context effects. For example, the same game can be presented as a matter of selling and buying, or as a problem of resource allocation. The way the game is presented, though, may have a considerable impact on the players' behaviour. This is a direct consequence of the fact that each person has his own representation of a market or of a common pool resource (Eber and Willinger, 2005). There is a variety of alternatives to de-contextualise a game, such as describing a forest or a dam with water as being a "common pool" with tokens (Willinger and Ziegelmeyer, 1999), but sometimes there is no way to remove completely the context of a game. In the TK's life-death model, it is difficult to present the game without the disease, which is an important element of context. There is no really 'neutral' presentation of this game. If the experimenter removes the disease from the context of the game, then the experiment does not follow the life-death model and it is another game. Therefore, in such cases, the experimenters must attempt to understand the effect of the context more than eliminate it from the instructions.

In order to examine the real context effect underlying the subjects' preferences, Wang (1996a) did not remove the experimental context. Instead, he put a higher level of contextualization in the experiment. He introduced a social important contextual element, the *family* group, into the life-death decision problem, by specifying identities to patients of the small group (originally composed by "hypothetical anonymous" patients). The subjects were assigned to a more concrete situation where the 6 members of the group are relatives. Regardless of how the outcomes were framed (either positively or negatively), the majority of subjects in both situation (72% in saving-life case and 94% in losing-life situation) preferred the probabilistic (risky) outcome. This result showed that in a small group, deterministic outcome of certainly losing group members might be emotionally unacceptable, particularly when the members are relatives. The probabilistic outcome provides a "fair" chance, giving everybody in the family group an equal chance to survive. Decision rationality seems to be specific to the perception of the problem (familiar versus anonymous patients) and more generally, Wang (1996a) stated that decision rationality seems to be context-specific.

1.3.2.2.3.2. Weak and strong context effects

Cooper and Kagel (2003) studied the context impact on decision rationality by studying subjects' strategic play through a game based on the limit pricing model. In this game, a potential entrant faces a monopolist with either high or low costs. The entrant only wishes to enter the industry if he believes the monopolist has high costs. While the entrant cannot observe directly the monopolist's costs, he observes the monopolist's output decision before choosing whether or not to enter the industry. The monopolist has an incentive to strategically manipulate the output in order to change the entrants' beliefs about its true costs. Cooper and Kagel (2003) conducted two kinds of experiments, one articulated around an abstract context, and another in which the context is meaningful. In the "generic" treatments (i.e. with an abstract context), monopolists and entrants were described as respectively 'player A' and 'player B' and other terms were generalized in order to give the instructions a meaningless context. In the meaningful context, colloquial terms were used to avoid any "value laden" language. Thus the monopolist was referred to the "existing firm" and the potential entrant became the "other firm".

Cooper and Kagel (2003) postulated two possible effects of the context on the subjects' behaviour. They hypothesized a first effect of the context on a "low" level, where the context might serve as a catalyst, speeding up the learning process <u>without changing the reasoning process</u>. They called it the "*weak context effects*". They also hypothesized that there might exist "*strong context effects*", where the context not only speeds up the learning process, but also <u>impacts on subjects' reasoning processes</u>. The results were consistent with the presence of weak context effects. They also found some suggestion of strong context effects (the meaningful context seemed to stimulate more sophisticated reasoning) in the data, although this evidence was far from conclusive because it was observed on a relatively small amount of data.

They concluded that because of weak context effects, the use of meaningful context is likely to speed up convergence to equilibrium in Economic experiments. Consequently, sharper results are observed in a meaningful context, which is more representative of what is expected to be seen in the field. This result questions about the standard methodology of using generic context in Experimental Economics. Moreover, the external validity issue is not compatible with engaging in attempts to eliminate context in experimental instructions. The goal of external validity could be served by creating in a lab an experimental context that is similar to the one in which Economic agents will actually operate. One might be able to modify the lab experimental design to mimic the field contexts more reliably and then this contextualization would provide a more robust application to the experimental method in general (Loewenstein, 1999; Harrison and List, 2004). According to these observations, the use of contextualized experiments seems to be more useful to study agents' behaviour.

1.3.2.2.4. Comparing results of experiments

An important methodological issue concerns the choice of the treatment procedure when the experimental objective is to compare players' behaviour within different situations. The results obtained after running two treatments (i.e. protocol versions) could be compared through two procedures:

- The *between-subjects* procedure consists of comparing the results obtained through playing with two subjects' samples. Each subject faces only one treatment of the experiment (Wang, 1996a).
- The *within-subject* procedure consists of comparing the behaviour of a same sample in the two treatments. Each subject plays the two treatments (Kuhberger et al., 2002; Cooper and Kagel, 2003; Gachter et al., 2004).

The experimental protocol developed in this Master thesis (cf. Chapter 3) was designed by taking into account all the methodological aspects of EE presented in this part. We focused more particulalry on the context issue to answer the research question: can we use a RPG derived from a negotiation process as a *contextualized* laboratory experiment to test hypotheses? The simplified RPG will be used to test CGT hypotheses. The theoretical model that underlies the experimental design is presented in the following chapter (cf. Chapter 2).

Chapter 2: The CGT Model

The CGT model presented in this chapter derives from the one developed in the Kat River Basin (Dinar et al., 2006). Three farmers share water stored in a dam to irrigate their production of cabbage[17]. This chapter presents the model framework, the variables, the values and the functions tested during the second session (for the first version, cf annex A). The different calibrations of the CGT model and the hypotheses tested during the game are stated at the end of this chapter.

2.1. The CGT Model* (V2)[18]

Three farmers (i = 1,2,3) produce irrigated cabbage. Each farmer has a cultivated area of 20 Ha (S_{0i}). The annual amount of water/Ha to reach an optimum yield (Y_i) corresponds to (Wm) and it is the same for all farmers. Lower watering/Ha induces a reduction of Y_i following the response functions indicated in the following table. $Wm^* S_{0i} = W_{0i}$ is available to all farmers from rainfall plus water reservoirs present in each farm.

Production costs/Ha (C) are the same for all farmers and are independent of Y_i. Farmer's i profit/Ha (Π_i) is calculated as: $\Pi_i=Y_i*P-C_i$. Values for Y, P, C, Wm are provided in the following table.

	Y (Bags/Ha)	**Wm** (m^3/Ha)	**P** (ZAR)	**C** (ZAR/Ha)	**Response functions**
Farmer 1	3198	9100	6	16445	$Y_1=1200+0.2196*W_1$
Farmer 2	3198	9100	6	16445	$Y_2=600+0.2855*W_2$
Farmer 3	3800	9100	6	16445	$Y_3=1200+0.2857*W_3$

Table 3. CGT Model - Version 2 - Farmers' parameters

Each farmer can decide to extend his irrigated cabbage area, which becomes S_{1i}. A maximum additional area of 20 Ha/farmer can be allocated. This would bring the max total area/farm (S_{1i} max) to 40 Ha.

A dam with a capacity of 350 000 m^3 (D) can be used to irrigate increased surfaces cultivated at cabbage (S_{1i}). W_{1i} is the amount of water required by each farmer to irrigate S_{1i} . 250 000 m^3/year can be used for irrigation, whereas 100 000 m^3 represent the Reserve (R). R must be allocated to human consumptions and ecological purposes.

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[17] The context is more detailed below in the following chapter (cf. Chapter 3)

* This model was developed by S. Farolfi and F. Patrone. The mathematic formalization of this model is still provisional.

[18] The model version 1 (V1) is presented in the annex. V1 was tested during the 1st session of the laboratory experiment test and resulted in a game where players felt frustrated for not receiving all the information about the water allocation rules. The only difference between V2 and V1 is the rule of water allocation from the dam and the consequent assumption on the players' behaviour. In V1 players decide about areas to cultivate without having received from the dam manager precise information about the water they will be allocated from the dam. They therefore play in a situation of uncertainty. In V2, the players first ask for water and only after having received from the dam manager a reply on their water allocation from the dam.

Each farmer will base his decision to increase his irrigated surface by $S_{1i} - S_{0i} = \Delta S_i$, and therefore to increase Π_i, on the possible additional amount of water available for him from the dam ($W_{1i}-W_{0i} = \Delta W_i$).

Farmers can require water from the dam either individually, or forming coalitions (partial or grand). Every singleton or coalition will first require water from the dam. If the sum of all requirements is higher than 250 000 m^3, then each singleton or coalition will receive a maximum of water share corresponding to 1/3 (singleton) or 2/3 (partial coalition) of the 250 000 m^3 (19). Once received from the dam manager a confirmation of the water available from the dam for himself, each player will decide the surface to irrigate. When forming a partial coalition or the grand coalition, one farmer can transfer water to another member in order to irrigate the other's additional area.

Every player will consider other players to be rational and willing to maximize their profit, and therefore requiring at least 1/3 of the available water from the dam.
In this first model, water from the dam has no cost.

Side payments are allowed within coalition, meaning that the members can choose to share the profit obtained by the coalition between all of them.

The problem can be formulated as follows:

N = {1,2,3}

D = 350 000
R = 100 000

$S_{0i} = 20$
S_{1i} max = 40

$\Pi_{0i} = \Pi_i * S_{0i}$

Single Players:

v(1)[20] = $\Pi_{01}+X_1$; X_1 ($\Delta S_1, \Delta W_1$)
v(2) = $\Pi_{02}+X_2$; X_2 ($\Delta S_2, \Delta W_2$)
v(3) = $\Pi_{03}+X_3$; X_3 ($\Delta S_3, \Delta W_3$)
with X_i being the profit obtained by farmer i from cultivating additional area
Remaining Water in the Dam (WD) = R = 100 000

[19] In the version 2 played during the first test (12th June) it was: "*If the sum of all requirements is higher than 250 000 m^3, then each singleton or coalition will receive a share of the 250 000 m^3 proportional to the weight of his/her requirement on the total requirements*". It is interesting to note that if all players play "rationally", the two sub-versions 2 bring to the same result (e.g.: 1/3 of 250 000 m3 to each player when singletons and 2/3 to the partial coalitions).

[20] Coalitions and payoffs are noted as follows:

- the partial coalition formed by the farmers 1 and 2 is noted {1,2}, the one formed by farmers 1 and 3 is noted {1,3} and the last formed by farmers 2 and 3 is noted {2,3}; the grand coalition formed by the three farmers is noted {1,2,3}.
- payoffs of the singletons are noted as: v(1), v(2), v(3); payoffs of partial coalitions are noted as: v(1,2), v(1,3), v(2,3); payoff of grand coalition is noted as: v(1,2,3).

Partial Coalitions[21]:

$V(1) = \Pi_{01}+X_1$; $X_1\ (\Delta S_1, \Delta W_1)$
$V(2,3) = \Pi_{02}+\Pi_{03}+X_{2,3}$; $X_{2,3}(\Delta S_{2,3}, \Delta W_{2,3})$
with $X_{2,3}$ being the profit obtained by the partial coalition {2,3} from cultivating additional area
WD = R = 100 000

$V(2) = \Pi_{02}+X_2$; $X_2\ (\Delta S_2, \Delta W_2)$
$V(1,3) = \Pi_{01}+\Pi_{03}+X_{1,3}$; $X_{1,3}(\Delta S_{1,3}, \Delta W_{1,3})$
with $X_{1,3}$ being the profit obtained by the partial coalition {1,3} from cultivating additional area
WD = R = 100 000

$V(3) = \Pi_{03}+X_3$; $X_3(\Delta S_3, \Delta W_3)$
$V(1,2) = \Pi_{01}+\Pi_{02}+X_{1,2}$; $X_{1,2}(\Delta S_{1,2}, \Delta W_{1,2})$
with $X_{1,2}$ being the profit obtained by the partial coalition {1,2} from cultivating additional area
WD = 100 000

Grand Coalition:
$V(1,2,3) = \Pi_{01}+\Pi_{02}+\Pi_{03}+X_{1,2,3}$; $X_{1,2,3}(\Delta S_{1,2,3}, \Delta W_{1,2,3})$
with $X_{1,2,3}$ being the profit obtained by the grand coalition {1,2,3} from cultivating additional area
WD = 100 000

The interest in the grand coalition is to check: a) are the farmers able to maximize the payoff of the coalition (side payments); b) how do they allocate water among players in a coalition (bargaining?); c) how the payoff will be distributed among farmers? Will this correspond to the Shapley value of the CGT model?

[21] Interest here is to check: a) are they able to maximize the payoff o the coalition (side payments); b) how do they allocate water among players in a coalition (bargaining?).

2.2. Calibration of the model and expected results

The Shapley value is a one-point solution presented above in the text (cf. part 1.2.2.2).

Let *N* be a finite set of *n* players, *S* a subset of *N* composed by *s* players, and *v* the payoff obtained. Shapley proposed that there exists a unique value φ that satisfies the conditions of efficiency, dummy player property, anonymity and additivity (cf. Parrachino et al., 2006a). For all *i* € *N*:

$$\varphi_i(v) = \Sigma\ [s!\ (n-s-1)!]^*\ [\ v(S \cup \{i\}) - v(S)\ ]\ /\ n!$$

The Shapley value could be interpreted as follows:
Considering any permutation *π* of the set *N* and any player *i* € *N*. If P(i, π) is the set of players that precede *i* in the permutation *π*, M(i, π) = v(P(i, π)∪{i}) – v(P(i, π)) is the marginal contribution of i to the coalition P(i, π). The Shapley value will be:

$$\varphi_i(v) = 1/n!\ \ \Sigma\ M(i, \pi)$$

Considering a situation with *n* players agreeing to meet in a certain room, imagine the *n* players entering one at a time into that room in a random order (specified by the permutation *π*) and that each player, as soon as he enters and reaches the coalition S created by the players arrived before him, receives a reward equal to v(S∪{i})-v(S), that is his marginal contribution.

The Shapley value is the mean marginal contribution, averaged on all of the n! permutations *π*.

Adopting the parameters indicated and considering the players are rational and profit takers, the following results can be expected in terms of payoffs:

	value of the coalition	sum of Shapley values for players in the coalition	
V(1)	79958	87524	In the Core
V(2)	79958	87524	In the Core
V(3)	185258	209362	In the Core
V(1,2)	159944	175048	In the Core
V(1,3)	298320	296886	Not in the Core
V(2,3)	298320	296886	Not in the Core
V(1,2,3)	384410	384410	In the Core

Table 4. Theoretical payoffs and the corresponding Shapley values (with farmer 3 more productive)

In table 4, the Shapley values are $\varphi_1 = \varphi_2 = 87\ 524$ and $\varphi_3 = 209\ 362$.Therefore, we have $\varphi_{1,2} = \varphi_1 + \varphi_2 = 175\ 048$, $\varphi_{1,3} = \varphi_1 + \varphi_3 = \varphi_{2,3} = \varphi_2 + \varphi_3 = 296\ 886$.
In this example, the Shapley values are calculated as follows (cf. table 5):

	Marginal contribution of player j to the coalition		
Permutation	1	2	3
123	79958	79986	224466
132	79958	86090	218362
213	79986	79958	224466
231	86090	79958	218362
312	113062	86090	185258
321	86090	113062	185258
Total	525144	525144	1256172
Shapley value	**87524**	**87524**	**209362**

Table 5. Calculation of the Shapley value

Considering the first permutation π = 123:

- M(1, 123) = v(1) – v(Ø) = v(1) = 79 958
- M(2, 123) = v(1,2) – v(1) = 159 944 – 79 958 = 79 958
- M(3, 123) = v(1,2,3) – v(1,2) = 384 410 – 159 944 = 224 466

In that case, there are 6 equi-probable permutations π. The Shapley value is the mean on the marginal contributions:

- $\Phi_1(v) = 1/6\ \Sigma M(1, \pi)$ = 525 144 / 6 = 87 524
- $\Phi_2(v) = 1/6\ \Sigma M(2, \pi)$ = 525 144 / 6 = 87 524
- $\Phi_3(v) = 1/6\ \Sigma M(3, \pi)$ = 1 256 172 / 6 = 209 362

If we look at the results when farmer 3 is even more productive (response function for farmer 3: Y_3=1200+0.4500*W_3), the following results can be expected in terms of payoffs:

	value of the coalition	sum of Shapley values for players in the coalition	
V(1)	79958	106273	In the Core
V(2)	79958	106273	In the Core
V(3)	446724	530664	In the Core
V(1,2)	159944	212546	In the Core
V(1,3)	641961	636937	Not in the Core
V(2,3)	641961	636937	Not in the Core
V(1,2,3)	743210	743210	In the Core

Table 6. Theoretical payoffs and the corresponding Shapley values (with farmer 3 even more productive)

In both calibrations, the conditions of super-additivity of this game are respected, as:

- v(1) + v(2) = v(1,2); v(2,3) ≥ v(2) + v(3) and v(1,3) ≥ v(1) + v(3);
- v(1,2,3) ≥ v(1) + v(2) + v(3); v(1,2,3) ≥ v(1,2) + v(3); v(1,2,3) ≥ v(1,3) + v(2) and v(1,2,3) ≥ v(2,3) + v(1).

Nevertheless, in this CGT model, the Shapley values are such that $\varphi_1 + \varphi_3 < v(1,3)$; and $\varphi_2 + \varphi_3 < v(2,3)$. Therefore the Shapley value does not belong to the core (cf. tables in annex C10). Note, however, that the core is non-empty. For example, the allocation *(90 000, 90 000, 563 210)* is in the core, as can be easily checked.

Because farmer 3 is more productive, the fact that the two coalitions including farmer 3 would have interest in staying out of the grand coalition seems quite obvious.

In fact, the same result is obtained if the game is calibrated with farmer 3 less productive.

If farmer 3 is less productive (response function farmer 3: Y_3=1200+0.2* W_3), the following results can be expected in terms of payoffs:

	value of the coalition	sum of Shapley values for players in the coalition	
V(1)	79958	81596	In the Core
V(2)	79958	81596	In the Core
V(3)	48908	55378	In the Core
V(1,2)	159944	163192	In the Core
V(1,3)	138557	136974	Not in the Core
V(2,3)	138557	136974	Not in the Core
V(1,2,3)	218570	218570	In the Core

Table 7. Theoretical payoffs and the corresponding Shapley values (with farmer 3 less productive)

If farmer 3 is even less productive (response function farmer 3: Y_3=1200+0.19* W_3), the following results can be expected in terms of payoffs:

	value of the coalition	sum of Shapley values for players in the coalition	
V(1)	79958	82430	In the Core
V(2)	79958	82430	In the Core
V(3)	32987	42790	In the Core
V(1,2)	159944	164860	In the Core
V(1,3)	127636	125220	Not in the Core
V(2,3)	127636	125220	Not in the Core
V(1,2,3)	207650	207650	In the Core

Table 8. Theoretical payoffs and the corresponding Shapley values (with farmer 3 even less productive)

The results therefore indicate that, provided that players play rationally and are profit takers, the game is always super-additive, but the Shapley allocation is not in the core. An interesting feature is represented by the fact that in all cases (farmer 3 more productive and less productive) the two coalitions including farmer 3 would have a slightly higher payoff by staying alone compared with the Shapley value they would receive in the grand coalition.

The experimental set-up that follows aims at testing the Cooperative Game Theory hypotheses that lie behind these results.

The experiments will be specifically designed to test:

1) Players' rationality (selfishness) and profit maximization;
2) Players' capacity to take advantage of the side payments in coalitions;
3) Players' behaviour in terms of resources (water, land) allocation within a coalition;
4) Players' choice to stay in partial or grand coalition (because of the particular case of this game);

5) If players stay in the grand coalition, allocation of coalition's payoff in comparison with the Shapley values.

Chapter 3: The contextualized experimental protocol building

Most Experimental Economics exercises aim at testing hypotheses derived from a theoretical model. The objective of this study is to test Cooperative Game Theory (CGT) hypotheses. A CGT model derived from a Role-Playing Game used in a development project (Kat Aware) was designed by S. Farolfi and F. Patrone (cf. chapter 2) and was the basis to build an experiment articulated around the water management issue. The overall research question treated by this study is whether such contextualized experiment is useful to test theoretical hypotheses. The water management context was therefore maintained in the experimental design.

In the game used for the experiment and described here below, water is used for irrigation, domestic uses and ecological purposes. The subjects of the experiment play the role of farmers. They have to make decisions implying the allocation of commonly owned water and the choice of cultivated areas. Farmers play alone at the first stage of the game, then they play within partial coalitions and finally together in a grand coalition.

The experiment is specifically designed to test the CGT hypotheses presented in the previous chapter (cf. Chapter 2)

As the experiment is based on a CGT model, the CGT vocabulary is used in the following text. However, the players were not faced with this vocabulary. The theoretical terms were changed into more colloquial words. For example, terms as ‘partial coalition’ and ‘grand coalition’ were named respectively “informal group decision” and “irrigation board” (cf. instructions in annexes B1, B2 and B3).

3.1. The Experiment

The experiment consists in a water resource management game. Water is stored in a dam. Three farmers, cabbage cultivators, can require water from the dam to irrigate more area than their initial endowment.

The game was a one-shot round, meaning that the farmers play only one period, corresponding to one year.

The farmers have the same initial area endowment (20 Ha) but they had different production functions. Each farmer may increase his cultivated area to a maximum of 40 Ha (initial 20 Ha + additional 20 Ha). If a farmer chooses to increase the cultivated area, he needs water from the dam. In that case, he must ask the dam manager (played by the experimenter) the amount of water needed.

Therefore, the farmer’s decision is made at two, interrelated, levels: the additional area to cultivate and the amount of water needed from the dam.

The dam has a capacity of 350 000 m^3 of which 100 000 m^3 must be preserved for domestic consumption and the ecological reserve.

The experiment is composed of three phases.

During the **first phase**, the three farmers play as singletons. They choose the area to cultivate and the corresponding water required without communication with the other farmers (cf. instructions in annex B1).

During the **second phase**, two farmers play together in a partial coalition whilst the third farmer still plays alone. The partial coalition is presented to the farmers as an "informal group" (cf. instructions in annex B2). The farmers forming the partial coalition choose together the area cultivated by each one and the amount of water they required. The profit obtained is common between the two farmers and side-payments[22] are allowed.

The second phase is composed of three independent rounds:
Round 1: farmer 3 plays alone whilst farmers 1 and 2 play in a coalition.
Round 2: farmer 2 plays alone whilst farmers 1 and 3 play in a coalition.
Round 3: farmer 1 plays alone whilst farmers 2 and 3 play in a coalition.

Finally, in the **third phase**, the three players play together in a grand coalition. The same cooperative principle as in the second phase with two farmers is generalized to the group including all the farmers. The grand coalition is presented to the players as an "irrigation board" (cf. instructions in annex B3), and consequently the farmers in the board manage collectively the water available from the dam.

After having played the three phases, the players receive the results from each phase in terms of profit. On the basis of these results, they choose whether they prefer to be in a coalition or not and, if all the players want to be in the grand coalition, they are required to share the corresponding payoff.

3.2. First Test Session - 12th of June 2007

The test session was conducted the 12th of June 2007 by two researchers (the experimenter and an assistant) in a classroom with 6 Master students of the University of Pretoria. One week before, a first presentation of the game was given to the students. Each student received a copy of the instructions and the farmers' roles were distributed. Therefore, the students already knew the general framework of the game before coming to the real test session.

The following scheme (Figure 1) was drawn on the black board. The scheme indicates that the three farmers, each getting initially 20 Ha and having the possibility to extend the area to cultivate cabbage up to a maximum surface of 40 Ha, are connected to the dam by an individual channel. The dam contains 350 000 m^3 of water, of which

[22] The side-payments theory is based on the assumed assumption than "the coalitional utility function is expressed in units of a divisible commodity which stores utility, and which can be transferred without losses to the players". If a coalition can obtain a total utility, this utility can be divided among the members of the coalition in any possible way. It is possible to transfer money among the players in order to reallocate the profit gained through the coalition. Such games satisfying these assumptions are called "transferable-utility games" (Parrachino I., Zara S., Patrone F. – 2006 - *Cooperative Game Theory and its application to natural, environmental and Water resource issues: 1. Basic Theory,* World Bank policy research working paper 4072).

250 000 are available for irrigation. No upstream-downstream effect is observable in the game set-up.

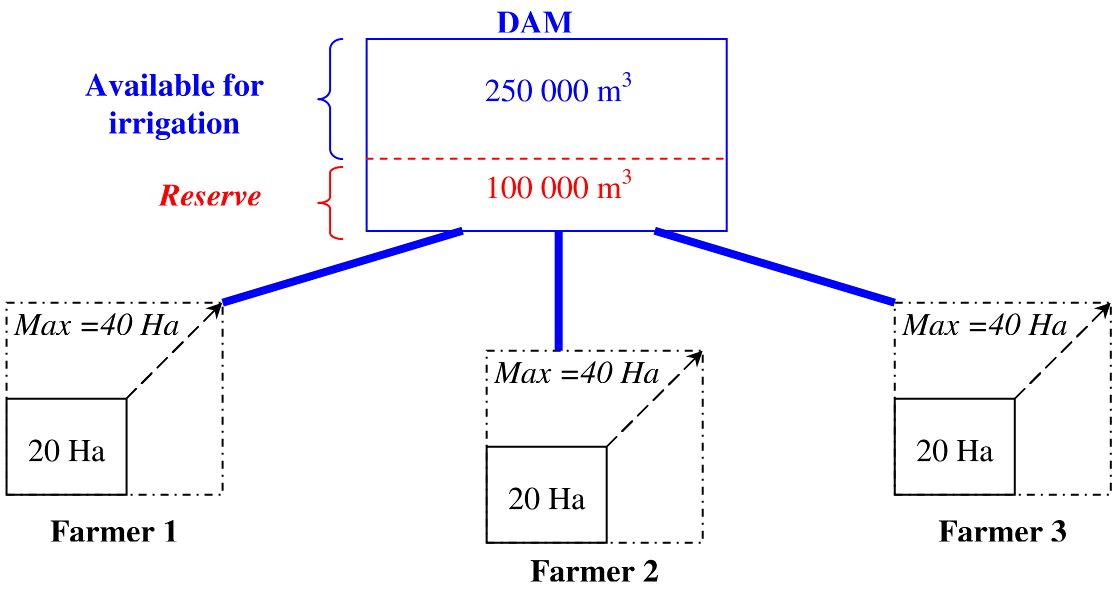

Figure 1. Scheme of the game

The six participants were divided into 3 groups of two persons each (cf. pictures in annex B8). Each group played the role of a farmer and was located at three corners of the laboratory (the classroom).

Each group had a laptop open on a simple excel program prepared by the experimenter to help the players making their decisions. The experimenter also got a laptop with an Excel program to follow the game and to calculate the payoffs according to the farmers' choices.

The farmers could calculate their profit by introducing the additional area they wanted to cultivate and the water required from the dam in the corresponding cells of the program. The program calculated automatically the profit (cf. the Excel sheet in annex B5). The players therefore could produce different scenarios modifying the irrigated surface and the corresponding water needs. After having tested different scenarios, players made their choice.

The farmers' decision was communicated to the experimenter through an individual decision sheet (one per farmer). The decision sheet was a piece of paper composed by two cells; one was reserved for the farmer's water request, and the other for the additional area the farmer wanted to cultivate (cf. annex B4). A new decision sheet was distributed before the beginning of each phase and was collected after the farmers made their decision. The information contained in the decision sheet was used by the experimenter to calculate the total amount of required water, the consequent water allocation following the allocation rules (cf. part 3.2.1), and the profit obtained by the three farmers.

During the first phase, the farmers played alone as singletons all in the same room and at the same time.

During the second phase, the two farmers forming the partial coalition remained in the main room, while the third player was accompanied by the assistant to another room and played alone. This was repeated three times (rounds) to allow all possible combinations.

During the third phase, all the farmers played together in the grand coalition.

Every singleton or coalition was allowed to use the Excel tool prepared by the experimenter to help him or her in making his or her decision.

3.2.1. The two versions of the game

Two versions of this game were tested the one after the other with the same 6 students. The difference between the two versions lies on the mechanism of water allocation followed by the dam manager and the uncertainty in the decision made by the farmer.

In the **first version**, the dam manager allocated the water required by the farmers with the only constraint represented by the maximum capacity of the dam. The respect of the domestic and ecological “reserve” was not compulsory. The farmers did not know how the dam manager would allocate water. The only rule the farmers knew was that there was a priority order and that they probably would not be the first to be supplied. Therefore, the farmers chose how much additional area to cultivate without knowing if they would obtain the whole amount of water needed to irrigate it. The farmers had to choose if and how much to increase the irrigated area under uncertainty.

In the **second version**, the dam manager’s allocation rules were transparent and known by the farmers. Unlike in the first version, the domestic and ecological reserves were respected. The allocation rule was as follows: if the total water required by the three farmers was lower than the amount of water available (i.e. 250 000 m^3), each farmer would receive exactly the amount of water required. If the total water required was higher than the amount of water available, the dam manager distributed the water available among the three farmers proportionally to their original demand.

For example, if the requests for farmers 1, 2 and 3 were respectively 50 000 m^3, 100 000 m^3 and 150 000 m^3, the total amount of water required is equal to 300 000 m^3 (which is higher than the 250 000 m^3 available). Consequently, the dam manager would divide the 250 000 m^3 available proportionally to their requests among the three farmers. Therefore the amounts allocated would be 41 666 m^3, 83 333 m^3 and 125 000 m^3 for farmers 1, 2 and 3 respectively.

Unlike in the first version, the farmers required first water from the dam, and then they were informed on the amount they would receive. Only at this point the farmers decided whether or not to extend their cultivated area. Farmers’ choice regarding the extension of cultivated areas took place with no uncertainty in this version.

The following table (table 8) summarizes the common framework for the two versions of the experiment. The differences between the two versions are highlighted at the bottom of the table. A detailed description of the test phases is provided in annex B6.

The first version was video-recorded to save a copy of the experiment.

Common framework of the experiment			
Phase	**Name**	**Round**	**Description**
1	**SINGLETONS**		Farmers 1, 2 and 3 played alone
2	**PARTIAL COALITIONS**	**1**	Farmers 1 and 2 played together; Farmer 3 played alone
		2	Farmers 1 and 3 played together; Farmer 2 played alone
		3	Farmers 2 and 3 played together; Farmer 1 played alone
3	**GRAND COALITION**		Farmers 1, 2 and 3 played together

Differences between the two versions of the experiment	
First version	**Second version**
Dam water allocation rules	
Unknown priority order in water allocation ➔ The farmers did not know the water allocation rules followed by the dam manager	Proportional water allocation ➔ The farmers knew the water allocation rules followed by the dam manager
Farmers' decision making process	
The farmer's water request and the decision on the additional area to cultivate were formulated at the same time ➔ Uncertainty on the farmers' choice	The farmer first formulated the water request, and then the dam manager informed the farmer about water allocation. Only at this point the farmer decided about the additional area to cultivate. The decision was made in two steps ➔ No uncertainty behind farmers' choice

Table 9. Common framework and differences between the two versions of the first test session

3.2.2. Results

3.2.2.1. General observations

The first version of the experiment lasted 81 minutes (1h21) and the second one 61 minutes (1h01) (cf. details in annex B7). The participants did not receive monetary rewards at the end of the test. Generally the participants understood quickly and completely the game. The Excel program proved to be a useful tool to help the players in their decision-making process. There were no problems with the numbers or the calculations. Only one mistake was observed. The players also allocated properly (i.e. as predicted in the model) water within coalitions, considering the different production (response) functions of each farmer.

The CGT model makes the assumption of rationality of the players, which are profit takers. By comparing the results of the test session with the "theoretical" results obtained through the model (see tables in annexes B10 and B11), it can be observed that in both versions of the experiment, unlike in the theoretical model, the result was not super-additive[23], but for different reasons.

3.2.2.2. Non super-additivity analysis

In the first version, the dam manager's criteria for the water allocation were unknown by the players, which made their decisions under uncertainty. The players asked for water even when playing as singletons. They were either optimistic on the probability of receiving water, despite the indications contained in the instructions, or, if they believed in the instructions, they did not expect the other players to ask for the full amount of water, or they went for a free riding of the reserve. Actually, only one player (farmer 3) out of three asked for the maximum amount of water. As a consequence, the domestic and ecological reserve was always preserved, except when the coalition by the farmers 1 and 2 played. In the partial coalitions phase, the farmers increased progressively their water (and surface) demand from less than expected in the theoretical model (63 700 m^3) to all the water available (250 000 m^3). This result could be due to a learning effect appearing through the replication of the same situation (Loewenstein, 1999; Eber and Willinger, 2005).

Because, unlike what the theoretical model predicted (cf. annex B10), singletons and partial coalitions attempted anyway to ask for water, and the dam manager allocated what they asked for, it happened that $v(1)+v(2)>v(1,2)$, $v(1)+v(3)>v(1,3)$ and $v(2,3) + v(1) > v(1,2,3)$, making the game not super-additive.

In the second version, if the total demand was higher than the 250 000 m^3 available, the dam manager distributed the 250 000 m^3 among the players proportionally to their request. Therefore, water allocation to each player depended also on what the other players required. The reserve was always preserved.

Unlike the assumption of rationality of the model, most players did not ask the total amount of water they could, even if in this case they did not risk anything by asking the maximum. Therefore, due to the water allocation rule, those who asked more water in a phase or round got proportionally more than those players that played conservative (e.g. farmer 3 required more than farmers 1 and 2). For the same reason the partial coalition {1,3}, asking the maximum and being faced with a low request from farmer 2, was able to have a profit v(1,3) that summed to v(2) is higher than v(1,2,3). For this reason, the second version results were not super-additive.

3.2.2.3. Payoff sharing

During the second phase of the first version, players were asked, after they played the partial coalition round, how they would share the payoff obtained. This is not relevant information to compare with the theoretical results, but it represented complementary information. In the three cases, unlike the logical expectation of payoff sharing that follows the different productivity of the three farmers, the players chose an equal allocation between the two of them (50% each).

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[23] Let N be a finite set of n players in a transferable utility game. Let S and T be subsets of N (S and T are coalitions). Let v be a real-valued function defined over all the subsets of N. In the present experiment, v is the payoff obtained.
A transferable-utility game is super-additive if for all S, T included in N, with $S \cap T = \emptyset$
$v(S \cup T) \geq v(S) + v(T)$

During the final debriefing after having conducted the two versions of the game, the experimenter asked why the participants chose such a sharing. Farmers 1 and 2 who had a worse response function than farmer 3 had an interest in the equal sharing. The question was to know why farmer 3 accepted such repartition. Farmer 3 did not answer. It seemed that the two players playing farmer 3 role did not remember why they chose the equal repartition. They might have considered the equal sharing as a fair choice without having assessed the different farmers' contribution to the final profit.

The experimenter only communicated the payoffs obtained in the second version. Once the players knew all the profits obtained in the three phases they were asked whether they wanted to be in the grand coalition and, if yes, to share the grand coalition payoff. The following table (table 9) presents the results obtained in the second version.

Phases	Coalitions	Payoff values (ZAR)
Singletons	{1}	49 768
	{2}	72 909
	{3}	218 421
Partial coalitions	{1,2}	145 385
	{1,3}	177 913
	{2,3}	298 305
Grand coalition	{1,2,3}	384 163

Table 10. First test session - second version results

As the game was not super-additive, farmer 3 did not want to participate to the grand coalition whereas farmers 1 and 2 had interest to play in the grand coalition. After negotiation, farmers 1 and 2 convinced farmer 3 to join them in the grand coalition by leaving to farmer 3 the same payoff as the one obtained in the first phase (singleton). Then, farmers 1 and 2 shared the remaining profit equally between the two of them (table 10).

	Coalitions	Payoff values (ZAR)
Farmers	{1}	82 821
	{2}	82 821
	{3}	218 421
Total	{1,2,3}	384 163

Table 11. First test session – second version: grand coalition payoff sharing

3.2.3. Lessons

This first test session provided some lessons that represent a basis to develop a new version of the game. The second version was better perceived than the first one because it was more transparent in terms of instructions. Particularly the rules of water allocation were perfectly known by the players. The second version will therefore be the basis to build the new instructions. The new version (version 3) was tested in a second session test (mid July).

3.2.3.1. The new instructions

The second session test was not conducted with students but rather with staff members of the University of Pretoria. The players discovered the instructions at the beginning of the session without knowing previously the experimental framework. Consequently, the instructions had to be more detailed. For instance, the scheme drawn on the black board during the first session test would be included in the instructions. More detailed instructions should not require oral explanations and this fact is crucial when homogeneity among sessions and reduction of external biases is sought. According to some authors, with a homogeneous set of information given to the participants, replications of the game could be conducted in different places and different times (Rege and Telle, 2004; Eber and Willinger, 2005).

In the first session, the second phase (partial coalitions) instructions were given aloud at the beginning of each round, whereas the third singleton farmer was already in the next room. It would be preferable to give the instructions at the end of the first phase, before asking to farmer 3 to leave the laboratory. Consequently, all the players will have the same information at the same time.

The decision sheet will be inspired by the following model (table 11).

Water request from the dam	*Dam manager's water allocation decision* ***Reserved to the experimenter. Do not fill***	Additional cultivated area	*Profit obtained* ***Reserved to the experimenter. Do not fill***
…………….. m^3	m^3	……………. Ha	ZAR

Table 12. The new decision sheet

An example of how to fill the decision sheet was given either in the instructions or directly in the decision sheet.

The Excel program would be the same as used during the first session test. The explanation of the program and some examples would be written in the instructions.

The payoffs presentation at the end of the session can be formalized and made as much neutral as possible. The resuming table of all payoffs obtained along the three phases of the game can be drawn on the black board as in the first session or an Excel table can be video-projected. In order to reduce the bias among different experiments, all the instructions regarding the grand coalition payoff sharing can be written. According to this, the experimenter then read aloud the instructions and then, the players could begin to play/negotiate.

3.2.3.2. The new water allocation rules

To increase the probability of super-additivity in the experiment, and therefore to have a meaningful share of grand-coalition payoff, the following water allocation rule was adopted.

Each singleton or coalition will first require water from the dam. If the sum of all requirements is higher than 250 000 m^3, then each singleton or coalition will receive a maximum of water share corresponding to 1/3 (singleton) or 2/3 (partial coalition) of the 250 000 m^3 [(24)]. Once received from the dam manager a confirmation of the water available from the dam, each player will decide how much surface to irrigate.

3.3. Second Test Session - 18th of July 2007

The second test session was conducted the 18th of July 2007 in a meeting room at the Department of Agricultural Economics of the University of Pretoria. The game played during this second test session simulated the same water management problem as in the first test session. The original situation[25] and the structure of the game with three phases[26] were maintained. However, some modifications were made following the lessons learned during the first test session. These modifications are illustrated in the following section.

3.3.1. Differences between the two test sessions

This second test session was not run with students as the previous one, but with three researchers of the Department of Agricultural Economics. The three players, who discovered the game framework only at the beginning of the session, were located at three equidistant places of the central table of the meeting room (cf. pictures in annex C9). Unlike in the first test session where each farmer was played by a group of two students, each participant of the second session played the role of one farmer. As in the first test session, the farmers had a laptop open on a simple Excel program prepared by the experimenter to help them making their decisions (cf. the Excel sheet in annex B5).

The instructions were modified (cf. Annexes C1, C2 and C3) to provide more written information than the original instructions used during the first test session[27]. As suggested after the first test session, the scheme (cf. figure 1 page 39) and details about the Excel program and the decision sheet were provided directly in the instructions.

However, the main difference with respect to the original instructions consisted in the new dam water allocation rules, that look now as stated in part 3.2.3.2.

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[24] In the version 2 played during the first test it was: If the sum of all requirements is higher than 250 000 m^3, then each singleton or coalition will receive a share of the 250 000 m^3 proportional to the weight of his/her requirement on the total requirements. It is interesting to note that if all players play "rationally", the two sub-versions bring to the same result (e.g.: 1/3 of 250 000 m^3 to each player when singletons and 2/3 to the partial coalitions).

[25] Three farmers, each having an initial endowment of 20 Ha, have the possibility to extend their area where to cultivate cabbage up to a maximum of 40 Ha, and are connected to a dam (having a total capacity of 350 000 m^3, of which 250 000 m^3 are available for irrigation) by an individual channel.

26 During the first phase, the three farmers play as singletons. During the second phase, two farmers play together in a partial coalition whilst the third farmer still plays alone. Finally, in the third phase, the three players play together in a grand coalition.

[27] This choice was made in order to reduce the biases coming from oral presentations that are inevitably different session after session.

Some examples of water demand were provided to the players in the instructions to illustrate the application of the water allocation rules (cf. instructions in Annex C1).

Like in the second version of the first test session, the farmers made their decision in two steps: 1) they first formulated their water request, and then the dam manager (still played by the experimenter) informed them about water allocation. 2) Only at this point the farmers decided about the additional area to cultivate. They still used a decision sheet to communicate with the experimenter. However, the decision sheets were modified following the model presented in the lessons learned from the first test session, and they were different in each phase of the game (cf. annexes C4, C5 and C6).

During the **first phase** (singletons), the decision sheet was exactly the one suggested in the lessons of the first test session, with four cells corresponding to the two decision process steps[28] (cf. annex C4).

During the **second phase** (partial coalitions), water demands were formulated individually in the same decision sheet, meaning that each farmer within the coalition made his own water request. Actually, the sum of the individual demands is the criterion followed by the dam manager to decide how to allocate water among the farmers. Each farmer of the partial coalition indicated his water demand in the same decision sheet[29] (cf. annex C5). Water allocation was calculated and communicated by the dam manager, and then the farmers shared between the two of them the total water allocated. They indicated in their decision sheet how much area each farmer wanted to cultivate *and* how much water was used to irrigate it[30]. The experimenter calculated the partial coalition payoff and communicated it to the farmers; farmers where finally asked to share the obtained payoff between the two of them.

During the second phase, the farmer out of the partial coalition left the experimental room. Unlike in the first test session, the third farmer did not play "actively", whereas his water demand was taken into account in the round played by the two others when requiring water from the dam. During this phase, the experimenters considered the third farmer always rational (selfish) and profit-taker and therefore requiring the maximum amount of water for one singleton.

During the **third phase** (grand coalition), the three farmers formed the "Irrigation Board". They became themselves responsible for the dam management. Therefore, the first decision process step (i.e. water demand) disappeared, meaning that, after negotiation, the farmers decided directly how much area each one would cultivate *and* how much water would be used to irrigate it. Consequently, the decision sheet was simplified (cf. annex C6).

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[28] The two decision process steps are: (1) water demand; (2) additional area to cultivate. Each decision step was divided in two moments: (a) farmer demand or decision on one hand, and (b) dam manager response. Therefore, the decision sheet was divided in four cells.

[29] Instead of one decision sheet per farmer in the first test session, only one decision sheet was distributed to the two farmers forming the partial coalition during the second test session.

[30] During the first test session, the farmers in the partial coalition only had to communicate the area to cultivate without specifying how much water would irrigate it.

Among all the parameters of the game, there was only one modification between the two test sessions. In the second test session, the productivity of farmer 3 was higher than in the first test session[31].

A detailed description of the phases is provided in annex C7. Unlike the first test session, the second session was not video recorded.

All the differences between the two test sessions are summarized in the following table (cf. table 12).

[31] This change was introduced to amplify the difference between the repartition of payoffs among players when they play singletons and the corresponding repartition of the grand coalition payoff according to Shapley.

Game features	First test session (12/06/2007)	Second test session (18/07/2007)
The players	Students	Researchers
	A group of two students played the role of one farmer	One researcher played the role of one farmer
	Players already knew the framework of the game before the session (oral presentation one week earlier)	Players did not know previously the game framework
Water allocation rules	*(Second version)* if Σ(water demands) > 250 000 m^3 → proportional water allocation among players	if Σ(water demands) > 250 000 m^3 → quota: allocation at the maximum of 1/3 for a singleton (2/3 for partial coalitions) of 250 000 m^3
Decision sheet	The same decision sheet model was used for the three phases. One decision sheet per farmer at each phase	Each phase was played with a specific decision sheet model
Instructions		The instructions were more detailed, with more information about the Excel program and the decision sheet, and with water allocation examples
Partial coalition	The third player out of the partial coalition played separately in another room	The third player left the experimental room but did not play "actively"
	The partial coalition payoff was shared only "informally" between the two farmers	Partial coalitions were formally required to share their payoff
Farmer 3 productivity	When well irrigated, farmer 3 productivity was 3 800 bags/Ha	When well irrigated, farmer 3 productivity was 5 295 bags/Ha

Table 13. Differences between the first and the second test sessions

3.3.2. Results

3.3.2.1. General observations

The second test session of the experiment lasted 159 minutes (2h39) (cf. details in annex C8). If compared with the duration of the two versions tested with students during the first test session (81 and 61 minutes for version 1 and version 2 respectively), the second session was longer. A major reason for this is that more time was left to the participants at the beginning of the experiment to read and understand the instructions and the rules of the game.

Except the water allocation rules (cf. part 3.2.3.2) and a higher productivity for farmer 3, the same CGT model as in the first session test (second version) backed the game.

The observed players' behaviour was very close to the rational one assumed in the model, and this determined a high correspondence between the results of the game and those of the model (cf. tables in annex C10). It can be observed that the game resulted super-additive and that Shapley values payoffs stay within the core (cf. part 1.2.2.2).

3.3.2.2. Water demand analysis

Like in the second version of the first test session, the decision process was divided into two steps: Players first demand water from the dam and then they decide the area to cultivate. Then, there was no uncertainty behind farmer's choice of areas and there was an incentive for the farmers to ask for the maximum.

During the **first phase** (singletons), two players asked for the water needed to cultivate the 20 Ha representing the maximum possible area extension (i.e. 182 000 m^3) as expected by the theoretical model and one asked for 83 333 m^3 (probably anticipating the response from the dam manager). The three farmers received 83 333 m^3 and chose correctly their cultivated area in order to maximize their singleton payoff[32].

During the **second phase**, the partial coalitions always required 250 000 m^3, corresponding to the total available water from the dam. As a result of the repartition of the coalition demand between the two farmers, though, while coalition {1,2} got the expected 166 666 m^3 corresponding to 2/3 of the available water, coalitions {1,3} and {2,3} got only 151 333 m^3. The following table (table 13) summarizes the partial coalition water demands and the corresponding allocations.

[32] Only marginal approximation adjustments in the calculations of the irrigated areas were observed at this stage.

	Partial coalition {1,2}		Partial coalition {2,3}		Partial coalition {1,3}	
	Water demand (m^3)	Water allocation (m^3)	Water demand (m^3)	Water allocation (m^3)	Water demand (m^3)	Water allocation (m^3)
Farmer 1	100 000	83 333	**68 000**	**68 000**		
Farmer 2	150 000	83 333			**68 000**	**68 000**
Farmer 3			182 000	83 333	182 000	83 333
Partial coalition	250 000	166 666	250 000	**151 333**	250 000	**151 333**
Third farmer	182 000	83 333	182 000	83 333	182 000	83 333
Partial coalition + the third farmer	432 000	250 000	432 000	234 666	432 000	234 666

Table 14. Second test session - phase 2 (partial coalitions): experimental water demands and allocations

Once the farmers received their water allocation from the dam, they chose properly the additional area to cultivate and the corresponding water for irrigation (cf. tables in annex C10). Apart from the capacity of the players to calculate properly, this could be an argument in favour of the Excel program and the graph provided in the annex of the instructions as good tools to help the players making their decisions on the area to cultivate.

In the **third phase** (grand coalition), the players felt the responsibility of becoming managers of the dam ("we have a new role now"), and played accordingly. They used the whole water available (250 000 m^3) but did not intake the reserve. They also were able to allocate the irrigation water in order to get the maximum productivity (20 Ha to farmer 3 and the remaining 7 Ha to either farmer 1 or 2). Marginal differences between the cultivated areas in the experiment and the theoretical ones were also observed at this stage.

3.3.2.3. Payoffs sharing

During the **second phase** (partial coalitions), players were asked specifically, after they played each round, how they would share the payoff obtained. This information is not taken into account in the comparison with the theoretical results, but it represents complementary information for both the experimenters and the farmers. By sharing concretely the payoff obtained at this stage, players learn how to share a payoff with another farmer before the final negotiation that will take place in the grand coalition.

The first round involved farmers 1 and 2 who have exactly the same yield when they irrigate properly (9 100 m^3/Ha) the cultivated area. As expected, the payoff obtained was equally shared between the two of them (cf. table 14). Then farmer 1 left the experimental room and farmer 3 played the second round with farmer 2. Farmer 3 productivity is higher than farmers 1 and 2 ones. Consequently, farmer 3 contributes more in the payoff obtained by a better production function. Therefore, farmer 3 has an advantage on farmers 1 and 2 when sharing the partial coalition payoff. However, at the end of the second round, the payoff obtained by the partial coalition {2,3} was equally shared between farmers 2 and 3 without taking into account the higher productivity of farmer 3 (cf. table 14). This might be due to the fact that farmer 2 already shared the partial coalition payoff with farmer 1 during the first round. Consequently, farmer 2 had an advantage on farmer 3 because of the experience gained.

During the third round, farmers 1 and 3 already shared once a payoff; consequently they had the same level of experience. The profit obtained was shared this time according to farmer 3 productivity. Farmer 3 probably learned from the second round, when playing the partial coalition with farmer 2, and now took advantage of his higher productivity when sharing the payoff obtained together with farmer 1 (cf. table 14).

The following table (table 14) summarizes the payoffs obtained during the second phase (partial coalitions) and the repartitions of the payoffs between the two farmers of the corresponding partial coalition.

	Partial coalition {1,2}		**Partial coalition {2,3}**		**Partial Coalition {1,3}**	
Payoff obtained *(ZAR)*	159 094		612 794		612 794	
Repartition	**Farmer 1**	**Farmer 2**	**Farmer 2**	**Farmer 3**	**Farmer 1**	**Farmer 3**
(ZAR)	79 547	79 547	306 397	306 397	500 000	112 794

Table 15. Second test session - phase 2 (partial coalitions): payoffs sharing

At the end of the **third phase**, the experimenter communicated the payoffs obtained during all the three phases. Once the farmers knew all the profits obtained in the three phases, it was asked them whether they wanted to be in the grand coalition and, if yes, to share among the three of them the grand coalition payoff. The following table (cf. table 15) presents all the results obtained during the session and the theoretical ones calculated by the CGT model.

Phases	Coalitions	Experimental Payoff (ZAR)	Theoretical Payoffs (ZAR)
Singletons	{1}	79 547	79 958
	{2}	79 547	79 958
	{3}	444 599	446 899
Partial coalitions	{1,2}	159 094	159 917
	{2,3}	**612 794**	642 037
	{1,3}	**612 794**	642 037
Grand coalition	{1,2,3}	741 921	743 210

Table 16. Second test session: the three phases payoffs and theoretical predictions

The notations used for the analysis of the results are the same as the ones used previously in this text (cf. part 1.2.2.2).

A transferable utility game is defined by giving a finite set *N* of *n* players and a real-valued function *v* defined over all the subsets of *N*. In the present experiment, *N* is a set of three players and *v* is the payoff obtained by the various groups of players in the different phases of the experiment.
N is said to be the *grand coalition*. We shall refer to other coalitions *S*, different from *N*, as *partial coalitions*.

In the game, the payoffs of the singletons are noted *v(1)*, *v(2)*, *v(3)*, the payoffs of the partial coalitions are noted *v(1,2)*, *v(1,3)*, *v(2,3)* and the payoff of the grand coalition is noted *v(1,2,3)*.

We are interested in the way in which the players share *v(N)* between themselves. In the experiment, the three players share *v(1,2,3)* between the three of them The part of the grand coalition payoff received by farmer *i* is represented by x_i such as: $\Sigma x_i = v(N)$. The vector whose coordinates are x_i is said to be an allocation.

We remind a couple of theoretical definitions (cf. part 1.2.2.2 and Parrachino et al., 2006a):
- a game is *super-additive* if for all *S*, *T* included in *N*, with $S \cap T = \emptyset$, $v(S \cup T) \geq v(S) + v(T)$
- The *core* of the game is the set of all vectors *x* such that:
  - for all $i \in S$ and for all *S*, $\Sigma x_i \geq v(S)$ (rationality)
  - $\Sigma x_i = v(N)$ (efficiency)

The results of the second test session provided:
- v(1) + v(2) = v(1,2); v(2,3) ≥ v(2) + v(3) and v(1,3) ≥ v(1) + v(3);
- v(1,2,3) ≥ v(1) + v(2) + v(3); v(1,2,3) ≥ v(1,2) + v(3); v(1,2,3) ≥ v(1,3) + v(2) and v(1,2,3) ≥ v(2,3) + v(1).

The super-additivity conditions were therefore respected.

In our theoretical CGT model, the coordinates of the Shapley value are such that $\varphi_1 + \varphi_3 < v(1,3)$; and $\varphi_2 + \varphi_3 < v(2,3)$. Therefore the Shapley value does not belong to the core (cf. part 2.2 and tables in annex C10).

In the game resulting from the experiment the Shapley value lies in the core (which therefore will be non empty). The reason for this resides in the way farmers required water during the second phase. A lower water allocation to the partial coalitions {1,3} and {2,3} resulted in a payoff lower than expected by the model (cf. table 15 and the tables in annex B10) and also lower than the corresponding Shapley allocations in the experiment.

As the game was super-additive and all Shapley allocations were in the core, the three farmers had no reason to stay out of the grand coalition. The grand coalition payoff was therefore shared between the three farmers as presented in the following table (cf. table 16). The rate $\mathbf{V_i}$ of the payoff as a singleton for farmer ***i*** is given by $\mathbf{v(i)/\Sigma v(i)}$ (cf. tables in annex C11 and table 16). The rate $\mathbf{X_i}$ of what farmer ***i*** receives from the repartition of v(1,2,3) is given by $\mathbf{x_i/v(1,2,3)}$ and the repartition following Shapley's predictions is given by the rate $\mathbf{Sh_i}$ (cf. tables in annex C11 and table 16). For each farmer i, X_i is closer to V_i than to Sh_i.

	Value (ZAR)	Rate X_i (%)	Rate V_i (%)	Rate Sh_i (%)
Farmer 1	x_1=100 575	13,5	13,2	15
Farmer 2	x_2=100 346	13,5	13,2	15
Farmer 3	x_3=541 000	73	73,6	70
Total	v(1,2,3)=741 921	100	100	100

Table 17. Second test session: the grand coalition payoff sharing

Players actually declared during the debriefing to have followed as reference for the redistribution of v(1,2,3) the relative distribution of payoffs when they played as singletons.

The small difference in the allocation between player 1 and 2 is merely due to calculation issues. The benchmark for players 1 and 2 in order to stay in the grand coalition was represented by 100 000 Rand. They did not pay a lot of attention to the small amounts they received above this threshold.

3.3.3. Lessons and perspectives

As the players said at the end of the game, the instructions were really self-explanatory. When the experimenter proposed the players to read the instructions aloud, the players answered that it was not necessary. According to them, the instructions were clear and they understood quickly the objective of the game. This could be due to either the quality of the instructions or the ability of the players, knowing that players were researchers in Economics.

The transition between the first phase (singletons) and the second phase (partial coalitions), as well as the transition between the second phase and the third one (grand coalition) must be prepared previously and more accurately. When distributing new instructions between two phases, the experimenter must introduce orally the new situation indicating for instance that from that moment onwards all previous decisions do not count anymore and that the new phase is like a "new year" where everything starts again from scratch.

The water allocation to farmers in partial coalitions follows the rule of 1/3 max of available water to each farmer. This resulted in the allocation of 68 000 m^3 of water to those farmers requesting this amount (lower than 1/3) even if the total amount of water requested by the coalition was 250 000 m^3. In the next version of the game it will be introduced the rule of 2/3 max for the coalition as a whole. An improved explanation of the possibility to share the water among allocation's members is also required.

It could be useful to compare the grand coalition payoff allocation V_i with other theoretical benchmarks other than the Shapley value, such as for example the Nucleolus or the τ-value (cf. Parrachino et al., 2006a).

Another question about farmer 3 productivity remains. So far, the game was only played with farmer 3 more productive than farmers 1 and 2. A possible change could consist in having farmer 3's productivity lower than farmers 1 and 2. Such version of the game was prepared to be tested during the second test session, but was not played because of the length of the first version.

In order to provide an incentive for players to "play rational", most experiments use economic incentives. Even if no payment was provided to players during these two test sessions, the research group is planning to introduce some form of economic incentive in the future sessions. An idea would be to define "performance indexes" for each player based on players' payoffs differentials in various phases of the game. For instance, $IP_i = (P_{1i}-P_{0i})/P_{1i}$ would take the difference between the payoff player i obtains in the coalition he agrees to stay (P_{1i}) and the initial endowment (P_{0i}) and then relate it to the first term. In the played session, this would bring the following IP for the three players:

- 0.453 for player 1;
- 0.453 for player 2;
- 0.434 for player 3.

These indexes, always < 1, could be multiplied by 100 ZAR or 10 Euro in order to calculate the individual monetary reward for each player.

As they are constructed, these indexes reduce to 0 the productivity differences among players. The problem is that, if players play rational as singletons, these indexes could push players to aim at the repartition of the grand coalition payoff following the distribution of the singletons' rates (V_i of table 16) instead of the Shapley allocation (Sh_i of table 16), as this repartition would provide the same monetary reward to all players.

Further discussion will take place to define the right method to calculate the possible economic incentives to players.

Finally, to simplify calculations, rounded figures will substitute the current ones.

Chapter 4: Conclusion and research perspectives

This Master thesis is part of a research project that was inspired by a participatory work on water governance in the Kat River Basin (Eastern Cape, South Africa). During this participatory project, a Companion Modelling (ComMod) approach was implemented. Stakeholders played a role-playing game (RPG) articulated around water management in order to understand the complexity of the local system and to build up a catchment strategy within the local water users association. The ComMod approach exhibited some regularity in the stakeholders' behaviour that seemed worth further investigation. The outcomes of the RPG conducted with local stakeholders in the field were first compared with theoretical results predicted by a Cooperative Game Theory (CGT) model calibrated on the same data. Some similarities in the grand coalition payoff sharing appeared and suggested to deepen this comparison through an *experimental* use of a simplified version of the RPG to test a certain number of hypotheses made by the CGT. The EE approach was chosen because, unlike the ComMod approach used in the Kat, it provides the possibility to reproduce many times the same experiment in order to gather data and capitalize knowledge. However, EE commonly develops experimental protocols which are decontextualized. Consequently, the overall question treated by this research project is whether a contextualized experiment is useful to test theoretical hypotheses, and particularly how to simplify or adapt the real context to run valid experiments.

A CGT model derived from the original RPG played in the Kat River was designed by S. Farolfi and F. Patrone and was the basis to build a contextualized experiment articulated around a water management issue. The results obtained through a repeated use of the contextualized experiment will be compared with those of the CGT model and then with a decontextualized version of the same experiment.

The comparison of the results obtained is likely to provide insights on the correspondence between hypothetical and real behaviour of players when facing a situation of common pool resource (water) allocation in different conditions of cooperation. Experiments will be conducted with "candid players" such as university students first, and then with real stakeholders (water users, farmers, public decision-makers), to observe the effect of experience on the behaviour of players. Experiments will finally be conducted modifying certain parameters, particularly those sensitive to policy tools, to observe how the adoption of specific water policies could influence local stakeholders' behaviour.

During the 4 months of stage at University of Pretoria, this Master focused more particularly on the preparatory work of this research project with the objective of designing and testing a contextualized experimental protocol. After the design phase, two test sessions were conducted, the first with students (12th of June 2007) and the second with researchers (18th of July 2007). These sessions provided some very important lessons to improve the protocol.

However, the experimental protocol is not completely definite. Some context aspects remain to be discussed. Particularly, in the present game, water is required for free from the dam. We chose this game characteristic to simplify the experiment, but this characteristic (i.e. water provided for free) does not exist in any real context. Another change to proceed is about the decision sheet used during the second phase (partial coalitions). It will be modified to take into account the "anticipation" of the water allocation between the members of the coalition, as observed during the second test session (cf. part 3.3.2.2).

Some marginal changes will also be needed to improve the protocol before it can be adopted in an experimental context. Firstly, the duration of each phase of the game must be specified in order to limit the total length of an experimental session. Secondly, we will round the parameters of the game to simplify calculations. Thirdly, monetary incentives could be introduced to motivate the players.

Once the experimental protocol is set-up in a satisfactory way, experiments will be conducted with candid players and experts. Two aspects of the experimental context, namely the decontextualized version of the game and the use of the game with candid and expert players were discussed within the research group. Some perspectives related to these aspects are summarized here below.

4.1. The decontextualized experiment

To get insights about the capacity of a contextualized game (CE) to test theoretical hypotheses, the results obtained through this CE must be compared with the results obtained through a decontextualized one as suggested by most authors in EE, following the between-subjects procedure (Wang, 1996a).

The decontextualized experiment (DE) could be built in three phases as the CE - 1) singletons; 2) partial coalitions; 3) grand coalition - but with abstract terms instead of water management specific terms. For instance, the dam could be designed as a "common-pool", water could become "tokens" and the farmers could be generic "players". However, there is another way to decontextualize the game by providing directly to the participants of the DE all the payoffs obtained during the three phases of a CE (previously played by other subjects). The participants of the DE must share the grand coalition payoff without knowing on what all the information they get is based. Particularly, they do not know that the payoffs were obtained by playing a game articulated around a water management issue. They also do not have the same level of experience on payoff sharing as the players of the CE, who learned by sharing the partial coalitions payoffs. The experiment is then decontextualized by involving players only in the last step of the game, without presenting them all the three contextualized phases of the CE. The DE protocol remains to be built in the following stage of the research project.

4.2. The players

After having played both CE and DE with "candid players" represented by university students, a further step of the research consists in playing with "real" stakeholders involved in water management (farmers, water managers, decision makers). The objective of opening the experimental research toward the field aims at isolating the "experience" complexity component that influences players' behaviour. Moreover, the external validity issue will be resolved by involving stakeholders in the experiment (Harrison and List, 2004).

A further development of this research project could be also to evaluate the impact of *cultural background* on agents' behaviour by conducting the CE and DE with both students and stakeholders in South Africa and in France. Other features of the real complexity, such as History or the importance of water issues in each society could be evaluated by comparing the experimental results obtained by South-African and French samples (Carpenter and Cardenas, 2004). The translation of the experimental protocol should be made with many care, particularly to provide exactly the same information to all the players in both countries.

Consequently, the research project could be viewed as a 2*2*2 experiment (2 countries * 2 categories of players * 2 experimental contexts) and could provide 8 sets of data to compare.

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Annexes

Annex A
The version V_1 of the CGT Model

Three farmers (i = 1,2,3) produce irrigated cabbages. Each farmer has a cultivated area of 20 Ha (S_{0i}). The annual amount of water/Ha to reach an optimum yield (Y_i) corresponds to (Wm) and it is the same for all farmers. Lower watering/Ha induces a reduction of Y_i following the response functions indicated in the following table. $Wm* S_{0i} = W_{0i}$ is available to all farmers from rainfall plus water reservoirs present in each farm.

Production costs/Ha (C) are the same for all farmers and are independent of Y_i. Farmer's i profit/Ha (Π_i) is calculated as: Π_i=Y_i*P-C_i.

Values for Y, P, C, Wm are provided in the following table.

	Y (Bags/Ha)	**Wm** (m^3/Ha)	**P** (ZAR)	**C** (ZAR/Ha)	**Response functions**
Farmer 1	3198	9100	6	16445	Y_1=1200+0.2196*W_1
Farmer 2	3198	9100	6	16445	Y_2=600+0.2855*W_2
Farmer 3	3800	9100	6	16445	Y_3=1200+0.2857*W_3

Table 18. CGT Model – Version 1: Farmers' parameters

Each farmer can decide to extend his irrigated cabbage area, which becomes S_{1i}. A maximum additional area of 20 Ha/farmer can be allocated. This would bring the max total area/farm (S_{1i} max) to 40 Ha.

A dam with a capacity of 350 000 m^3 (D) can be used to irrigate increased surfaces cultivated at cabbage (S_{1i}). W_{1i} is the amount of water required by each farmer to irrigate S_{1i} . 250 000 m^3/year can be used for irrigation, whereas 100 000 m^3 represent the Reserve (R). R must be allocated to human consumptions and ecological purposes.

Each farmer will base his decision to increase his irrigated surface by S_{1i} - S_{0i} =ΔS_i, and therefore to increase Π_i , on the possible additional amount of water available for him from the dam (W_{1i}-W_{0i} =ΔW_i).

Farmers can require water from the dam either individually, or forming coalitions (partial or grand). Every singleton or coalition will consider themselves to be the last to have right to require water and will consider other players rational and willing to maximize their profit.

In this first model, water from the dam has no cost.

Side payments are allowed within coalitions.

The problem can be formulated as follows:

N = {1,2,3}

D = 350 000
R = 100 000

$S_{0i} = 20$
$S_{1i}\ max = 40$

$\Pi_{0i} = \Pi_i * S_{0i}$

<u>Single Players</u>:

$$\left\{\begin{array}{l} \mathbf{v(1) = \Pi_{01}} \\ \mathbf{v(2) = \Pi_{02}} \\ \mathbf{v(3) = \Pi_{03}} \\ \\ \text{Remaining Water in the Dam: WD} = 350\,000 \end{array}\right.$$

<u>Partial Coalitions</u>:

$$\left\{\begin{array}{l} V(1) = \Pi_{01} \\ \mathbf{V(2,3) = \Pi_{02}+\Pi_{03}+X\ ;\ X(\Delta S_{2,3}, \Delta W_{2,3})} \\ \qquad\qquad\qquad \text{with X being the profit obtained by cultivating additional area} \\ WD = 282\,000 \end{array}\right.$$

$$\left\{\begin{array}{l} V(2) = \Pi_{02} \\ \mathbf{V(1,3) = \Pi_{01}+\Pi_{03}+X\ ;\ X(\Delta S_{1,3}, \Delta W_{1,3})} \\ \\ WD = 282\,000 \end{array}\right.$$

$$\left\{\begin{array}{l} V(3) = \Pi_{03} \\ \mathbf{V(1,2) = \Pi_{01}+\Pi_{02}+X\ ;\ X(\Delta S_{1,2}, \Delta W_{1,2})} \\ \\ WD = 282\,000 \end{array}\right.$$

<u>Grand Coalition</u>:

$$\left\{\begin{array}{l} \mathbf{V(1,2,3) = \Pi_{01}+\Pi_{02}+\Pi_{03}+Z\ ;\ Z(\Delta S_{1,2,3}, \Delta W_{1,2,3})} \\ \qquad\qquad\qquad \text{with Z being the profit obtained by cultivating additional area} \\ WD = 100\,000 \end{array}\right.$$

Annex B
First test session - 12th of June 2007

Annex B1

Instructions - phase 1: "singletons"

NB: When it is not specified, the instructions were the same in both versions 1 and 2 of the game.

FARMER

You are a farmer producing irrigated cabbage (2 cycles per year). You are part of an irrigation scheme with other 2 farmers having the same area and producing cabbage like you. Your farm has an area of 20 Ha. The other farms have 20 Ha too.

The water requirements for your cabbage are 9 100 m^3/Ha. If you irrigate properly your cabbage, your annual yield/Ha corresponds to

[*farmer 1*: 3 198 bags of cabbages (20 Kg each).]
[*farmer 2*: 3 198 bags of cabbages (20 Kg each).]
[*farmer 3*: 3 800 bags of cabbages (20 Kg each).]

Market cabbage price, production costs and other technical information to allow you calculating your profit are available in the attached table.

If you provide more water than 9 100 m^3/Ha, your yield will not improve, whereas if you provide less than 9 100 m^3/Ha, your yield will decrease following the response function that has been provided to you, whilst your costs will remain constant.

This year very little rainfall is foreseen, but your storage facility allows you to collect efficiently this scarce water and to irrigate your initial 20 Ha. You and the other farmers can extend your area cultivated at cabbage up to a maximum of 20 additional Ha, for a total area of 40 Ha per farmer. But the only water available to irrigate your additional area comes from a dam that you share with the other 2 farmers.

This dam contains 350 000m^3 of water. 250 000m^3 are available for irrigation whilst 100 000m^3 (the Reserve) must be allocated to human consumption and environmental uses.

[**Version 1**: You can ask the dam manager for a water allocation, but you have no insurance to be satisfied. In fact you may well be the last (i.e. the 3rd) to be satisfied, as you are part of the irrigation scheme only since last year and do not know the criterions of the dam manager for water allocation. If the other farmers want to maximize their profit, you can expect that they will ask for all the water available for irrigation from the dam (250 000 m^3) to cultivate 27.5 additional Ha between the two of them. In the case you are the last to be satisfied, this will leave you without available water from the dam besides the Reserve. If you get water from the dam, it is for free.

Please, fill-up your decision sheet indicating: a) how many additional Ha of cabbage you intend to cultivate; and b) how much water you require from the dam. If you decide not to increase your area, just indicate 0 Ha and 0 m^3.]

[**Version 2**: You can ask the dam manager for a water allocation, but you have no insurance to be satisfied. Your request for water cannot exceed your real needs. If the sum of the water requests will be lower than 250 000 m^3, then you will get the water you have requested. If the sum of the water requests is higher than 250 000, then you will get an amount of water lower than what you requested and corresponding to the proportion of your request on the total water demanded. If you get water from the dam, it is for free.

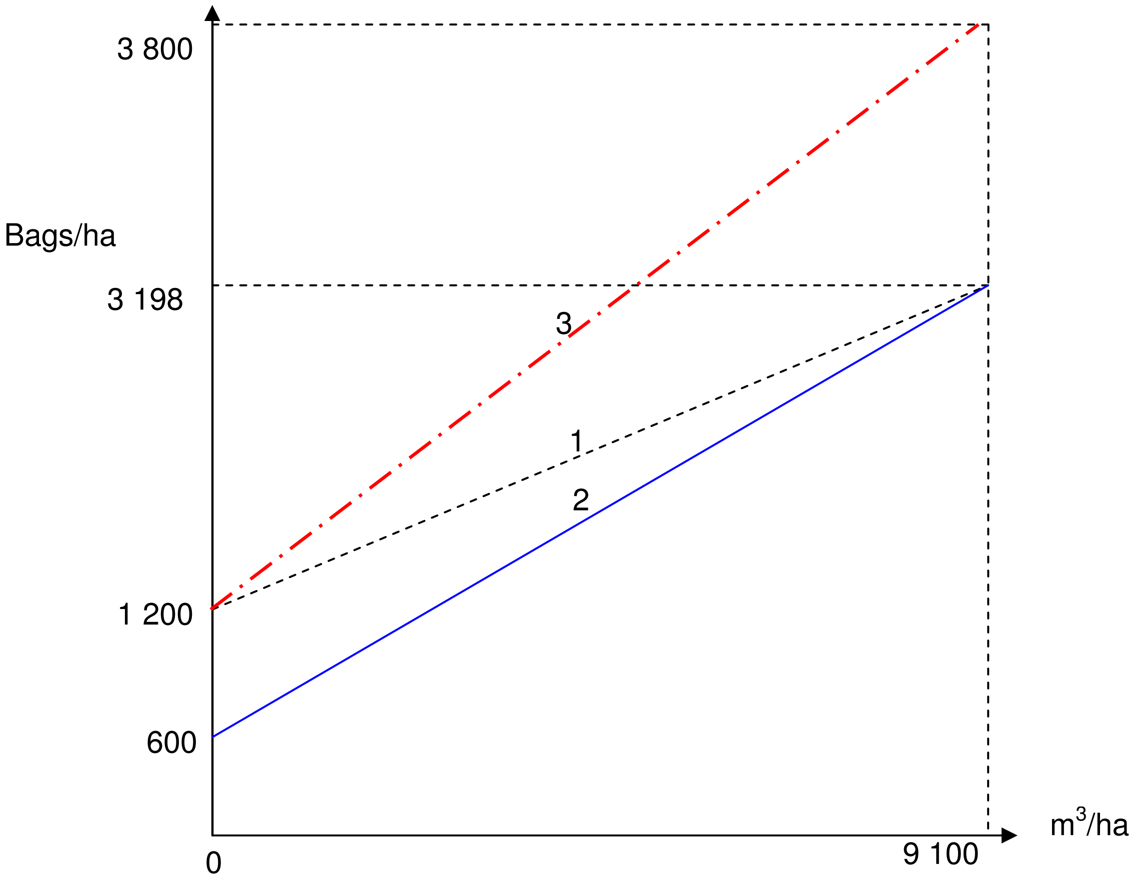
Please, fill-up your decision sheet indicating:
a) How much water you require from the dam;
After you know how much water you will get from the dam, please indicate:
b) How many additional Ha of cabbage you intend to cultivate;. If you decide not to increase your area, just indicate 0 Ha and 0 m³.]

To facilitate your profit calculations, a simple Excel model is provided. Through it you can explore different scenarios regarding the areas to cultivate and the corresponding water required.

Parameters for profit calculations for all farmers

Water requirement for cabbage (m^3/Ha)	Market price for Cabbage (ZAR/bag)	Production cost (ZAR/Ha)
9 100	6	16 445

Cabbage yield response to water for the three farmers



NB:
* 1=farmer 1; 2=farmer 2; 3=farmer 3.
* Farmers are heterogeneous: they have different response functions to water = different productivity of their land.
* Some production is possible with no additional water (1200 bags/Ha for 1 and 3; 600 bags/Ha for 2).

Annex B2

Instructions - phase 2: "partial coalitions"

NB: When it is not specified, the instructions were the same in both versions 1 and 2 of the game.

INFORMAL DECISION GROUP

You have now the possibility to define a strategy to cultivate cabbage using water from the dam with one of your colleague farmers (informal decision group). You can decide together how much water to ask from the dam and then how many Ha to irrigate as a group.
You can choose to irrigate your own area, your colleague's one or both. The coalition's profit will be shared between you and your colleague using an agreed allocation scheme at the end of the season.

[**Version 1**
Your group will be allowed requiring water from the dam, but again with no insurance of being satisfied by first. In fact your coalition may well be second on the list of priority as you and your colleague are new in the irrigation scheme and do not know the criteria of the dam manager for water allocation.

If the remaining (3^{rd}) farmer wants to maximize his profit, you can expect him to require the full amount of water needed to irrigate his 20 Ha of maximum additional surface (182 000 m^3). If your group is second to be satisfied, this will leave you with 68 000 m^3 available from the dam besides the Reserve.

After having discussed your common strategy within your group, please fill-up your decision sheet indicating: a) how many additional Ha of cabbage you intend to cultivate; and b) how much water you require from the dam. If you decide not to increase your area, just indicate 0 Ha and 0 m^3.

After having received your results, please indicate how you would share between you and your colleague your group's profit.]

[**Version 2**
Your group will be allowed requiring water from the dam, but again with no insurance of being completely satisfied. If the sum of the water requests will be lower than 250 000 m^3, then your group will get the water you have requested. If the sum of the water requests is higher than 250 000, then you will get an amount of water lower than what you requested and corresponding to the proportion of your request on the total water demanded.

After having discussed your common strategy within your group, please fill-up your decision sheet indicating:

a) how much water you require from the dam;

After you know how much water you will get from the dam, please indicate:

b) how many additional Ha of cabbage you intend to cultivate; If you decide not to increase your area, just indicate 0 Ha and 0 m^3.

After having received your results, please indicate how you would share between you and your colleague your group's profit.]

Annex B3

Instructions - phase 3: "grand coalition"

NB: When it is not specified, the instructions were the same in both versions 1 and 2 of the game.

IRRIGATION BOARD

You can now define a strategy to cultivate cabbage using water from the dam together with the other two farmers in the irrigation scheme (irrigation board). You can therefore use all the 250 000 m^3 to irrigate your extended cultivated area or your colleagues' ones. The coalitions' profit will be shared between you and your colleagues using an agreed allocation scheme at the end of the season.

[**Version 1**:
After having discussed your common strategy with your colleagues, please fill-up your decision sheet indicating: a) how many additional Ha you intend to cultivate at cabbage; and b) how much water you require from the dam. If you decide not to increase your area, just indicate 0 Ha and 0 m^3.]

[**Version 2**:
After having discussed your common strategy with your colleagues, please fill-up your decision sheet indicating:

a) how much water you require from the dam;

After you know how much water you will get from the dam, please indicate:

b) how many additional Ha of cabbage you intend to cultivate; If you decide not to increase your area, just indicate 0 Ha and 0 m^3.]

* * *

After the results of all game phases are provided to all players:

Now please share the commonly obtained profit among the three members of the Irrigation Board.

Annex B4

The decision sheet

Session………….. Phase………….

Farmer n. ……………

Water Requirements (m^3)	Additional Area to Cultivate (Ha)

…………………………….

Annex B5

The Excel program for each farmer

farmer 1

Initial area (Ha)	Additional area (Ha)	0	
20	Additional water (m3)	0	
Total water (m3)			Irrigation water/Ha
182000			9100
Total area (Ha)			Total cabbage production (bags)
3198,0001			63960
3198			Total profit (Zar)
			54860

Table 19. Excel sheet for farmer 1

farmer 2

Initial area (Ha)	Additional area (Ha)	0	
20	Additional water (m3)	0	
Total water (m3)			Irrigation water/Ha
182000			9100
Total area (Ha)			Total cabbage production (bags)
3197,99995			63960
3197,99995			Total profit (Zar)
			54860

Table 20. Excel sheet for farmer 2

farmer 3

Initial area (Ha)	Additional area (Ha)	0	
20	Additional water (m3)	0	
Total water (m3)			Irrigation water/Ha
182000			9100
Total area (Ha)			Total cabbage production (bags)
3799,999857			76000
3799,999857			Total profit (Zar)
			127100

Table 21. Excel sheet for farmer 3

Annex B6

Description of the game's phases

First version: priority in water allocation unknown

Total first version of the game duration = 1h21. The step duration details are given in the table in annex B7.

In the first version context, the farmers did not know the criterions of the dam manager for water allocation (see instructions in annexes B1, B2 and B3).

Introduction
A first oral presentation of the experiment was provided to the participants. The instructions were read aloud. Sometimes, some examples or precisions were given whereas they were not written in the instructions.

Phase 1: Singletons
After the introduction, the experimenter gave time to allow the players to read individually the instructions. The experimenter had individual talks with each farmer in order to be sure that the players understood the instructions and to explain how the Excel program works. An individual tutoring was given in case of misunderstanding.
After the individual explanations, the experimenter gave time to make the decision. The decision sheets were collected.

The data were treated by the experimenter who took note of the results in a table (see annex B9). Each farmer's payoff (profit) was individually communicated.

After the first individual phase, two players were asked to stay in the experimental classroom while the third farmer was accompanied by the experimenter assistant to a next room with a laptop.

Phase 2: Partial coalitions
For the first round, farmer 3 in the next room still played individually, like in the first singleton phase; the instructions did not change for him. In the experimental classroom, new instructions were distributed to farmer 1 and farmer 2 who played together in a partial coalition. The instructions were read aloud. Then, the experimenter left time the players to make their decision. The decision-making procedure of the group was video-recorded.
Farmers 1 and 2 did not give a common decision sheet. They did not have the same production function, so they chose the area cultivated by each one and the amount of water required to be shared between the two of them. Therefore, two decision sheets were collected for the partial coalition.
The three decision sheets were collected. Farmer 3 came back to the laboratory while the experimenter treated the data. The payoff obtained by the partial coalition was communicated to farmers 1 and 2. It was asked how they would share the profit obtained.

For the second round, farmer 2 left the experimental classroom. Farmers 1 and 3 formed the partial coalition. Farmer 3 did not know the new instructions for the "informal group" (partial coalition); therefore they were read aloud one more time.
The same procedure was conducted as in the first round. The three decision sheets were collected. Farmer 2 came back to the experimental room while the experimenter treated the data. The profit obtained by the informal group was communicated to Farmer 1 and Farmer 3. It was asked how they would share the profit obtained.

For the third round, farmer 1 left the experimental classroom and then farmers 2 and 3 formed the partial coalition. All the farmers had already known the instructions. Therefore the experimenter did not read the instructions aloud.
The same procedure was still conducted. The three decision sheets were collected. Farmer 1 came back to the experimental room while the experimenter treated the data. The profit obtained by the partial coalition was communicated to farmers 2 and 3. It was asked how they would share the profit obtained.

After the three partial coalition rounds, the third phase began. The three farmers joined around a laptop in the experimental classroom. The three farmers played together and managed themselves the water from the dam. They formed an "irrigation board" and played what the CGT name as the "grand coalition".

Phase 3: Grand coalition
The new instructions were read individually before the experimenter read them aloud. The farmers still decided the area cultivated by each one and the amount of water required from the dam for the irrigation. The farmers did not have the same production function, so the farmers had to decide the area cultivated by each one and the corresponding water to require from the dam.
The three decision sheets were collected.

Second version: proportional water allocation

Total second version of the game duration = 1h01.

In the second version context, the dam manager's allocation rules are known by the farmers (see instructions in annexes B1, B2 and B3)

This second version was not video-recorded.

Introduction
The instructions were read aloud, focusing particularly on the change made from the first version. The new mechanism of water allocation and the split of the farmers' decision-making process in two moments were highlighted.

Phase 1: Singletons
After the introduction, the experimenter left time the players to make individually the decisions. Firstly, the farmers required the amount of water to the dam manager. The decision sheets containing the water requests were collected.

The experimenter treated the water demands and communicated individually to each singleton the amount of water allocated. Then, the farmers knew how much water they could use to irrigate their additional area. They chose the area to cultivate. The decision sheets containing the choices on cultivated area were collected.

The experimenter calculated the payoffs (profits) for each farmer and communicated the results individually.

After the first individual phase, two players were asked to stay in the experimental classroom while the third farmer was accompanied by the experimenter assistant to a next room with a laptop.

Phase 2: Partial coalitions
As the players already knew the principle of the second phase and the new water allocation system, the instructions were not read aloud

For the first round, farmer 3 went to the next room, whereas farmers 1 and 2 stayed in the experimental classroom. Firstly, farmers 1 and 2 together chose the amount of water required to be shared between the two of them. Farmer 3 chose also the amount of water but individually. The decision sheets were collected.

The experimenter treated the water demands and communicated the amount of water allocated to the partial coalition and to the farmer 3. Then, the farmers knew how much water they could use to irrigate their additional area. They chose the area to cultivate. Farmers 1 and 2 do not have the same production function, so they chose the additional area cultivated by each one. The three decision sheets were collected.

The experimenter calculated the payoff for each farmer, while farmer 3 came back to the experimental classroom. Farmer 2 went to the next room with the experimenter assistant.

For the second round, farmers 1 and 3 played together within the partial coalition while farmer 2 played individually. The same decision-making process was conducted. The experimenter treated the water demands and then the farmers chose the area to cultivate.

For the third round, farmers 2 and 3 played together within the partial coalition while farmer 1 played individually. The same decision-making process as in the first and second rounds was conducted.

For the last phase, the farmers formed the irrigation board (grand coalition). The three farmers joined around a laptop.

Phase 3: Grand coalition
The new instructions were not read aloud. Farmers 1, 2 and 3 played together within the grand coalition and chose the amount of water required to be shared between the three of them. The decision sheets were collected. The experimenter treated the water demands and communicated the amount of water allocated to grand coalition. Then, the farmers knew how many water they could use to irrigate their additional area. The three farmers decided the additional area cultivated by each one. The decision sheets were collected

The experimenter treated the data and gather the whole results obtained through the second version of the experiment.

The payoffs obtained by the farmers individually in the first singleton phase and those obtained by the partial coalitions were presented before giving the payoff obtained by the grand coalition.

After the presentation of all the payoffs, the experimenter asked the players what situation they preferred between playing alone (singleton), playing in the informal group (partial coalition) or playing all together (grand coalition). Each farmer answered.

Then, the experimenter asked them to share the payoff obtained through the grand coalition. The players negotiated during 5 minutes and gave the experimenter their grand coalition payoff sharing among the three of them. Decision sheets were not used at this stage.

At the end of the second version, the experimenter leads a debriefing on what happened during the two versions of the experiment. Some comments about the results were given and the players could detail the reasons of the different choices made along the experiment.

Annex B7

Detail of the durations

<table>
<tr><th colspan="3"></th><th colspan="2">Version 1</th><th colspan="2">Version 2</th></tr>
<tr><th>Phase</th><th colspan="2">Round</th><th></th><th>Time (minutes)</th><th></th><th>Time (minutes)</th></tr>
<tr><td rowspan="6" colspan="3">1 Singletons</td><td>Introduction</td><td>14</td><td>Introduction</td><td>6</td></tr>
<tr><td rowspan="2">Tutoring +Decision</td><td rowspan="2">14</td><td>Decision Water</td><td>3</td></tr>
<tr><td>Treatment +Decision Area</td><td>4</td></tr>
<tr><td>Treatment</td><td>2</td><td>Treatment</td><td>3</td></tr>
<tr><td>Transition</td><td>2</td><td>Transition</td><td>2</td></tr>
<tr><td>Phase 1</td><td>32</td><td>Phase 1</td><td>18</td></tr>
<tr><td rowspan="11">2 Partial Coalitions</td><td rowspan="3">1</td><td rowspan="3">{1,2} & {3}</td><td rowspan="3">Decision +Treatment</td><td rowspan="3">14</td><td>Decision Water</td><td>4</td></tr>
<tr><td>Treatment +Decision Area</td><td>4</td></tr>
<tr><td>Round treatment</td><td>1</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">{1,3} & {2}</td><td rowspan="3">Decision +Treatment</td><td rowspan="3">13</td><td>Decision Water</td><td>3</td></tr>
<tr><td>Treatment +Decision Area</td><td>3</td></tr>
<tr><td>Round treatment</td><td>1</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">{2,3} & {1}</td><td rowspan="3">Decision +Treatment</td><td rowspan="3">6</td><td>Decision Water</td><td>2</td></tr>
<tr><td>Treatment +Decision Area</td><td>4</td></tr>
<tr><td>Round treatment</td><td>1</td></tr>
<tr><td colspan="2"></td><td>Transition</td><td>3</td><td>Transition</td><td>2</td></tr>
<tr><td colspan="2"></td><td>Phase 2</td><td>36</td><td>Phase 2</td><td>25</td></tr>
<tr><td rowspan="5" colspan="3">3 Grand coalition</td><td rowspan="2">Decision +Treatment</td><td rowspan="2">13</td><td>Decision Water +Treatment +Decision Area</td><td>4</td></tr>
<tr><td>Treatment</td><td>3</td></tr>
<tr><td>Payoffs presentation</td><td>0</td><td>Payoffs presentation</td><td>6</td></tr>
<tr><td>Negotiation</td><td>0</td><td>Negotiation</td><td>5</td></tr>
<tr><td>Phase 3</td><td>13</td><td>Phase 3</td><td>18</td></tr>
<tr><td colspan="3"></td><td>Version 1</td><td>81</td><td>Version 2</td><td>61</td></tr>
</table>

Table 22. First test session – Versions 1 and 2 – Detail of the durations

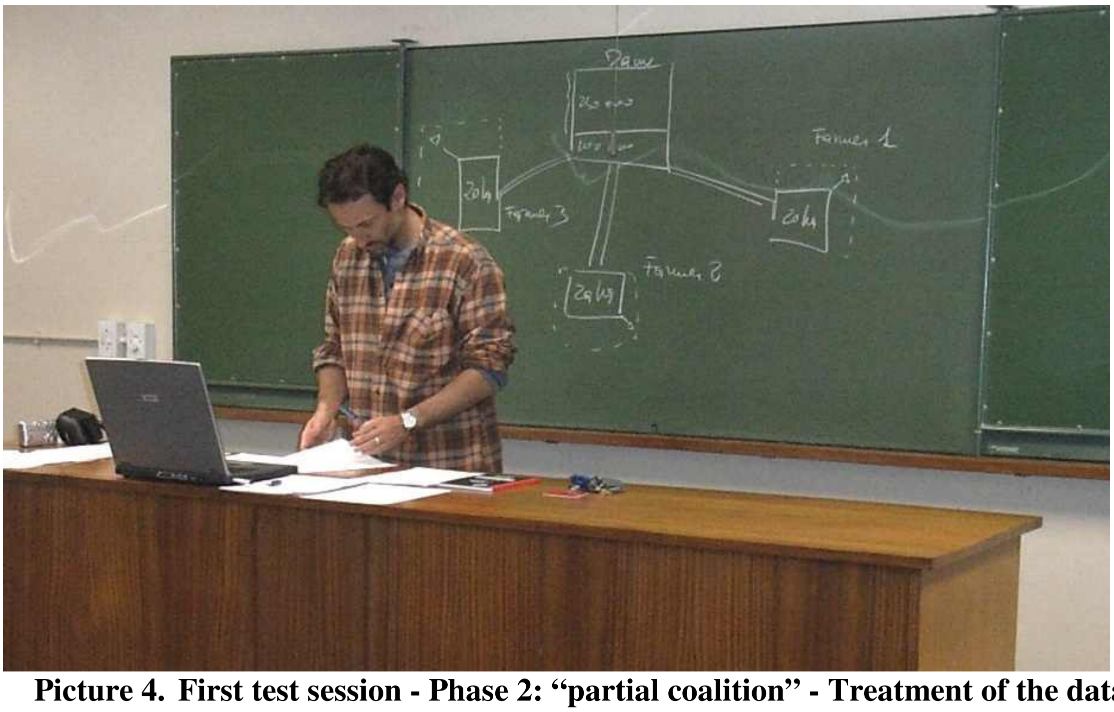
Annex B8

The pictures
(Version 1 & Version 2)

Picture 1. First test session - Phase 1: "singletons" - Location of the players
The three groups were located at the three corners of the experimental classroom. At the back of the classroom, the experimenter was tutoring farmer 3.

Picture 2. First test-session - Phase 2: "partial coalition" - Partial coalition
Round 3: farmers 2 and 3 played together within a partial coalition.

Picture 3. First test session - Phase 2: "partial coalition" - Third farmer
Round 3: farmer 1 played individually in the next room



Picture 4. First test session - Phase 2: "partial coalition" - Treatment of the data
After having collected the decision sheets, the experimenter treated the data.

Picture 5. First test session - Phase 3: "grand coalition" - Grand coalition
The three farmers played together within the grand coalition

Picture 6. First test session - Phase 3: "grand coalition" - Presentation of all the payoffs
The experimenter provided the participants all the payoffs obtained through the three phases of the game on the blackboard

Annex B9

Experimenter's payoffs following-up table

INDIVIDUAL PROFITS	(IN ZAR/Year)
Farmer 1	
Farmer 2	
Farmer 3	
INFORMAL DECISION GROUPS	
Farmer 1+ Farmer 2	
Farmer 1+ Farmer 3	
Farmer 2+ Farmer 3	
IRRIGATION BOARD	
Farmer 1+ Farmer 2 +Farmer 3	

Table 23. Experimenter's payoffs following-up table

NB: the table was the same for the versions 1 and 2 of the game

Annex B10

Results and Theoretical predictions
Version 1

Version 1

Phase	Farmers	Water Request (m^3)	Additional area (Ha)	Profit (ZAR)	Super-additivity	Water request (3rd farmer)	Remaining water in the Dam	Shapley Value in Grand Coalition	In the core
1 Singletons	{1}	45500	5.0	68575	**No**			60346	**No**
	{2}	45500	5.0	68575	Yes			70632	Yes
	{3}	182000	20.0	254200	**No**		77000	253514	**No**
2 Partial Coalitions	{1,2}	63700	7.0	128921	Yes	0	286300	130978	Yes
	{1,3}	182000	20.0	309060	Yes	83333	84700	313860	Yes
	{2,3}	250000	27.5	329632	**No**	63700	36300	324146	**No**
3 Grand Coalition	{1,2,3}	250000	27.5	384492			100000	384492	Yes

Theoretical case of the version 1

Phase	Farmers	Water Request (m^3)	Additional area (Ha)	Profit (ZAR)	Super-additivity	Water request (3rd farmer)	Remaining water in the Dam	Shapley Value in Grand Coalition	In the core
1 Singletons	{1}	0	0.0	54860	Yes			99560	Yes
	{2}	0	0.0	54860	Yes			99560	Yes
	{3}	0	0.0	127100	Yes		350000	185291	Yes
2 Partial Coalitions	{1,2}	68000	7.5	130210	Yes	0	282000	199119	Yes
	{1,3}	68000	7.5	229432	Yes	0	282000	284850	Yes
	{2,3}	68000	7.5	229432	Yes	0	282000	284850	Yes
3 Grand Coalition	{1,2,3}	250000	27.5	384410			100000	384410	Yes

Table 24. First test session – Version 1 – Experimental results and theoretical case

Annex B11

Results and Theoretical predictions
Version 2

Version 2

Phase	Farmers	Water Request (m3)	Additional area (Ha)	Profit (ZAR)	Super-additivity	Water request (3rd farmer)	Remaining water in the Dam	Shapley Value in Grand Coalition	In the core
1 Singletons	{1}	59295	9,0	49768	Yes			73437	Yes
	{2}	59894	6,6	72909	Yes			76430	Yes
	{3}	130809	14,4	218421	Yes		100000	234260	Yes
2 Partial Coalitions	{1,2}	119190	13,0	145385	Yes	130810	100000	149903	Yes
	{1,3}	203443	22,4	315533	**No**	46557	100000	307733	**No**
	{2,3}	166666	18,3	298306	Yes	83333	100001	310690	Yes
3 Grand Coalition	{1,2,3}	250000	27,5	384163			100000	384163	Yes

Theoretical case of the version 2

Phase	Farmers	Water Request (m3)	Additional area (Ha)	Profit (ZAR)	Super-additivity	Water request (3rd farmer)	Remaining water in the Dam	Shapley Value in Grand Coalition	In the core
1 Singletons	{1}	83333	9,2	79958	Yes			87524	Yes
	{2}	83333	9,2	79958	Yes			87524	Yes
	{3}	83333	9,2	185258	Yes		100000	209362	Yes
2 Partial Coalitions	{1,2}	166666	18,3	159944	Yes	83333	100000	175048	Yes
	{1,3}	166666	18,3	298320	Yes	83333	100000	296886	**No**
	{2,3}	166666	18,3	298320	Yes	83333	100000	296886	**No**
3 Grand Coalition	{1,2,3}	250000	27,5	384410			100000	384410	Yes

Table 25. First test session – Version 2 – Experimental results and theoretical case

Annex C
Second test session - 18th of July 2007

Annex C1

Instructions - phase 1: “singletons”

FARMER

You are participating in an economic experiment. The instructions you are about to read are self-explanatory. The experiment is to proceed in silence. Talking is prohibited. Please raise your hand, if you have any question or if there is anything that is not clear to you.

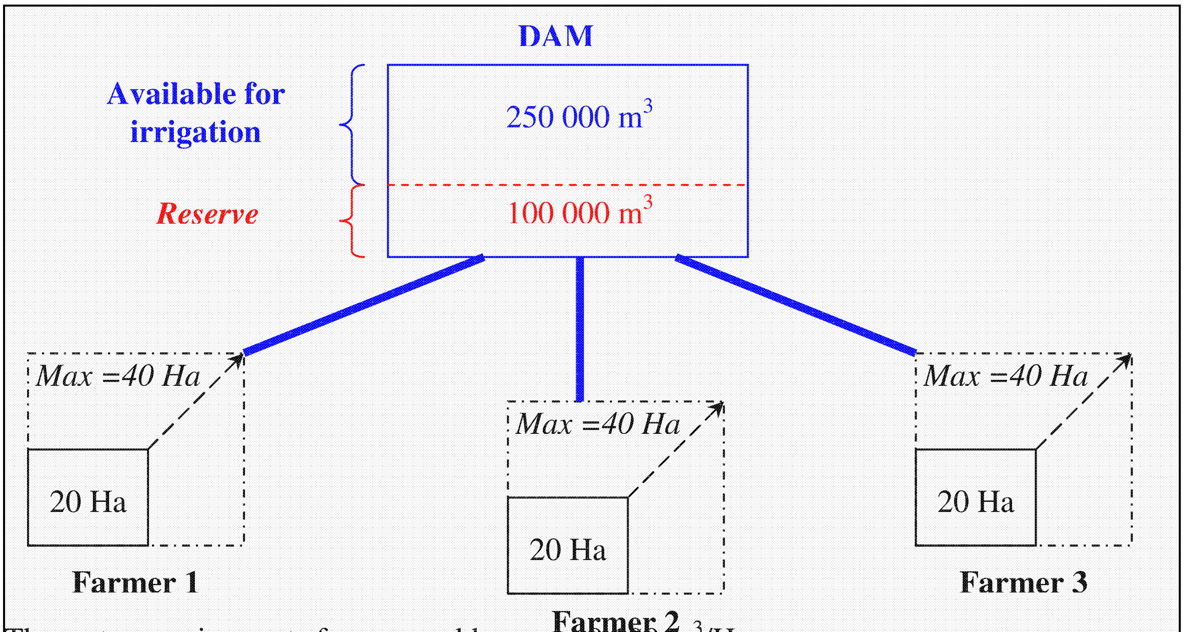
In this experiment, you are playing with two other people, meaning that your group consists of three members. You and the two other participants are farmers. You are part of an irrigation scheme with the two other farmers having the same area (20 Ha) and producing irrigated cabbage (2 cycles per year) like you. You will make a decision for only one cultivating season.

You and the other farmers can extend your area cultivated at cabbage up to a maximum of 20 additional Ha, for a total area of 40 Ha per farmer.

This year very little rainfall is foreseen, but your storage facility allows you to collect efficiently this scarce water and to irrigate your initial 20 Ha. The only water available to irrigate your additional area comes from a dam that you share with the other two farmers. If you cultivate your initial 20 Ha, you do not need water from the dam, if you conversely choose to cultivate more than 20 Ha, you must ask the dam manager for a water allocation to irrigate your additional area.

The dam contains 350 000 m^3 of water. 250 000 m^3 are available for irrigation whilst 100 000 m^3 (the Reserve) must be allocated to human consumption and environmental uses.

The figure below synthesizes the game context.



The water requirements for your cabbage are 9 100 m^3/Ha.

- If you irrigate properly your cabbage, your annual yield/Ha corresponds to:
  [*farmer 1*: 3 198 bags of cabbages (20 Kg each).]
  [*farmer 2*: 3 198 bags of cabbages (20 Kg each).]
  [*farmer 3*: 5 295 bags of cabbages (20 Kg each).]
- If you provide more water than 9 100 m^3/Ha, your yield will not improve, whereas if you provide less than 9 100 m^3/Ha, your yield will decrease following the response function that you find in the annex, whilst your costs will remain constant.

Market cabbage price, production costs and other technical information to allow you calculating your profit are available in the attached table (cf. annex). If you get water from the dam, it is for free.

You can ask the dam manager for a water allocation, but you have no insurance to be satisfied. You cannot require water in excess of your crops' real needs.
- If the sum of the water requests by all farmers will be lower than 250 000 m^3, then you will get the water you have requested.
- If the sum of the water requests by all farmers will be higher than 250 000 m^3, then each farmer will get at the maximum 1/3 of the 250 000 m^3 (i.e. 83 333 m^3).

The amount of water you will receive depends therefore on the choices that you and the other farmers make during the water allocation process.

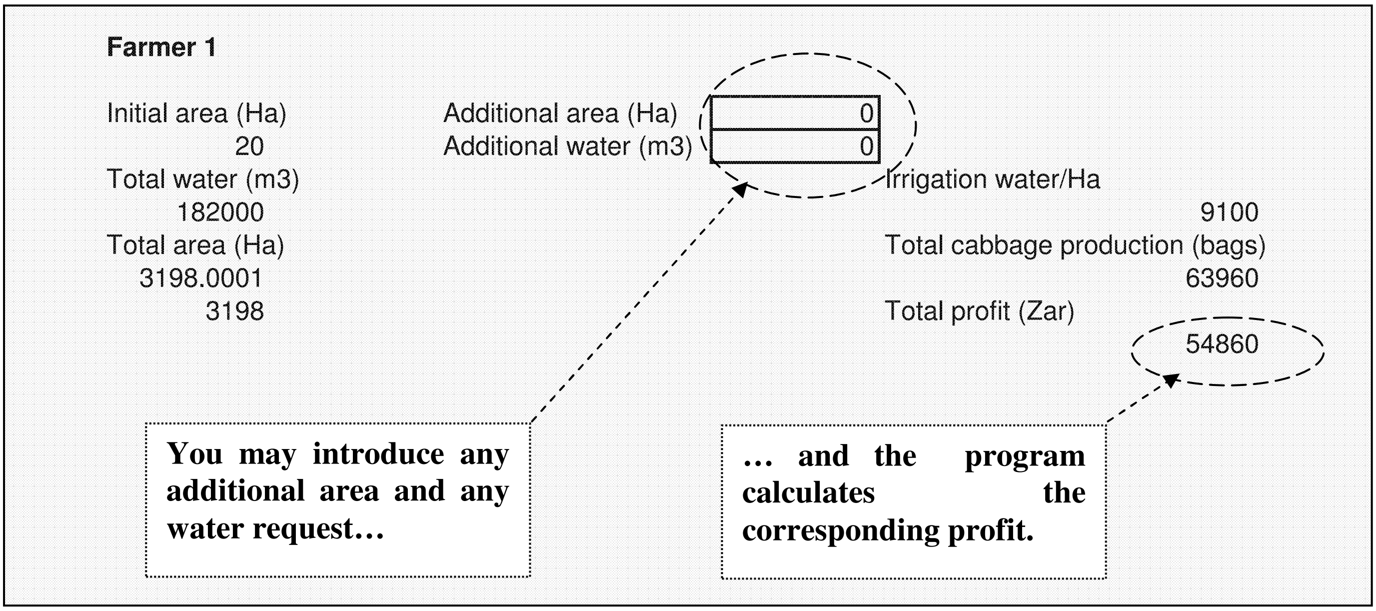
Examples of water allocation following the rules of the dam manager as described above:

- If none of the three farmers requires water from the dam, the available 250 000 m^3 for irrigation will stay in the dam. Each farmer will earn the profit obtained through cultivating the initial 20 Ha.
- If none of the two other farmers requires additional water and you ask for the maximum amount of water you can require from the dam that is 9 100 m^3/Ha * 20 Ha = 182 000 m^3, the sum of water requests is equal to 182 000 m^3, which is lower than the available 250 000 m^3. You will then receive your expected amount of water equal to 182 000 m^3.
- If every farmer chooses to extend the cultivated cabbage area up to the maximum additional 20 Ha, each farmer will ask for 182 000 m^3 from the dam. The sum of the water requests is then equal to 546 000 m^3, which is higher than the 250 000 m^3 of water available for irrigation. Each farmer will then only get 1/3 of the 250 000 m^3, equal to 83 333 m^3.
- If one farmer chooses to extend the cultivated cabbage area up to the maximum additional 20 Ha and consequently asks for 182 000 m^3 from the dam, while the other two farmers ask for only 50 000 m^3 each, the total water requirements will reach 382 000 m^3, which is higher than 250 000. In this case, the farmer that required 182 000 m^3 will have only 1/3 of the available water = 83 333 m^3, while the two other farmers will have what they have requested = 50 000 m^3 each.

After having received by the dam manager an answer on the amount of water allocated to you, you will decide how many additional Ha you want to cultivate.

To facilitate your profit calculations, a simple model constructed in Excel is provided. Through it you can explore different scenarios regarding the areas to cultivate and the corresponding water required. The Excel model is calibrated on the technical and financial parameters shown in the annex.

The Excel program looks as follows:



To get started with the Excel program, you can try to calculate the profit corresponding to the scenarios provided above in the examples. If you have any question, please raise your hand, an experimenter will attend you.

You will receive a decision sheet like the one here below. Please, follow the instructions contained in the boxes to fill the white fields of the table. Grey fields are reserved to the experimenters.

Water request from the dam	*Dam manager's water allocation decision* ***Reserved to the experimenter. Do not fill***	Additional cultivated area	*Profit calculated* ***Reserved to the experimenter. Do not fill***
…………….. m^3	m^3	……………. Ha	ZAR

1) Indicate here how much water you require from the dam…

…After you know how much water you will get from the dam…

…2) Indicate here how many additional Ha of cabbage you want to cultivate

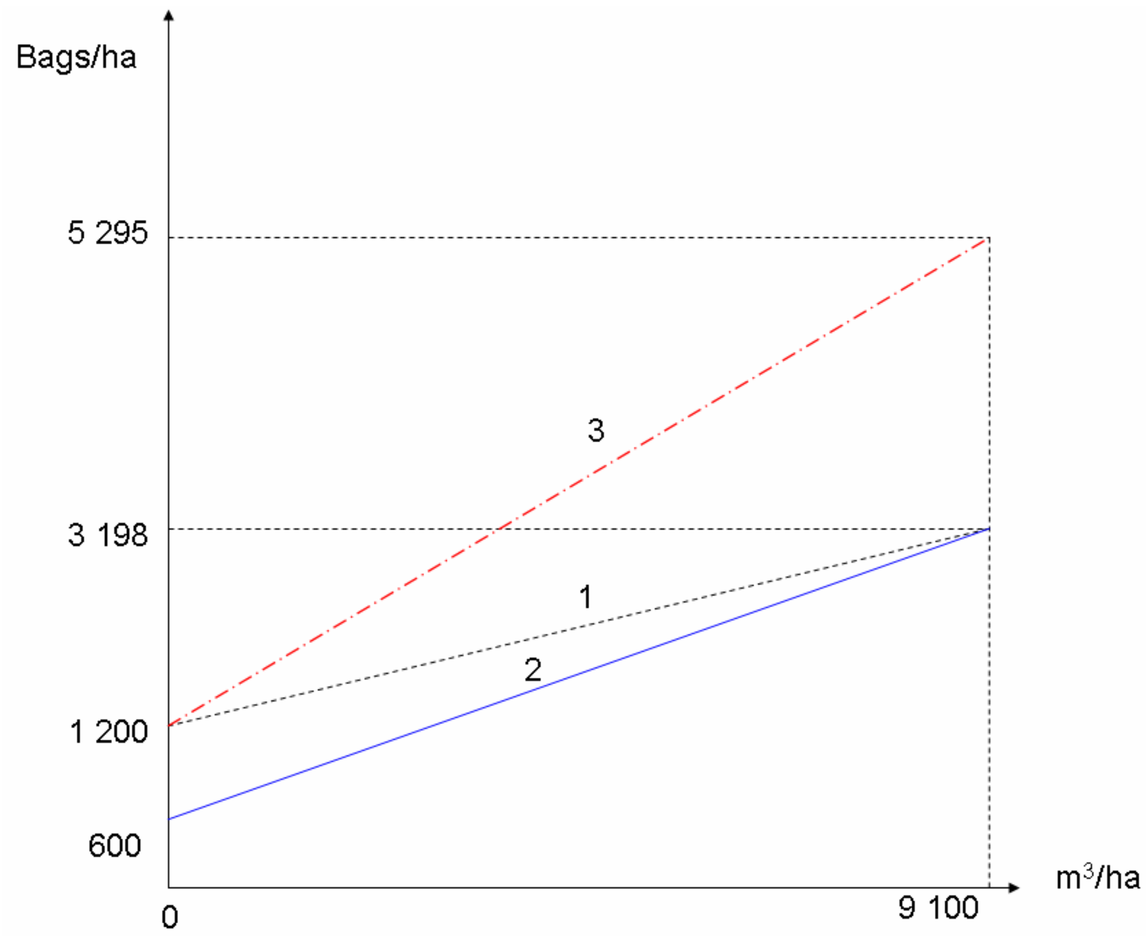
➔ ***If you decide not to increase your cultivated area, just indicate 0 m^3 and 0 Ha.***

Annex

Parameters for profit calculations for all farmers

Water requirement for cabbage (m^3/Ha)	Market price for Cabbage (ZAR/bag)	Production cost (ZAR/Ha)
9 100	6	16 445

Cabbage yield response to water for the three farmers



NB:

* 1=farmer 1; 2=farmer 2; 3=farmer 3.
* Farmers are heterogeneous: they have different response functions to water = different productivity of their land.
* Some production is possible with no additional water (1200 bags/Ha for 1 and 3; 600 bags/Ha for 2).

Annex C2

Instructions - phase 2: "partial coalitions"

INFORMAL DECISION GROUP

*The instructions you are about to read are self-explanatory and similar to those of the first phase, except that **you have now the possibility to define a strategy** to cultivate cabbage **with one of your colleague farmers** using water from the dam. You will then form an informal group of two farmers.*

You and your colleague can decide together how much water to ask from the dam and then how many Ha to irrigate as a group. You can choose to irrigate your own area, your colleague's one or both, trying to achieve the best result **collectively**.

Your group can require water from the dam, but again with no insurance of being completely satisfied. The following rules will apply.
- If the sum of all water requests is lower than 250 000 m^3, then your group will get the water you have requested.
- If the sum of all water requests is higher than 250 000 m^3, then each farmer will get at the maximum 1/3 of the 250 000 m^3. Your group will receive therefore a maximum of 166 666 m^3 of water.

After having discussed your common strategy within your group, please fill-up your decision sheet indicating:

	Water request from the dam	Dam manager's water allocation decision *Reserved to the experimenter. Do not fill*	Additional cultivated area	Water to irrigate the additional area	Profit obtained by the group *Reserved to the experimenter. Do not fill*
Farmer …	…………… m^3	m^3	…………Ha	…………m^3	*ZAR*
Farmer …	…………… m^3	m^3	…………Ha	…………m^3	
		TOTAL			

1) Indicate here how much water you require from the dam….

…After you know how much water your group will get from the dam…

…2) indicate here how many additional Ha of cabbage you want to cultivate…

… 3) and how many m3 you will use to irrigate your additional Ha.

➔ ***If you decide not to increase your area, just indicate 0 m^3 and 0 Ha.***

Annex C3

Instructions - phase 3: "grand coalition"

IRRIGATION BOARD

The instructions you are about to read are self-explanatory and similar to those of the previous phase, except that ***you have now the possibility to define a strategy*** *to cultivate cabbage* ***together with the other two farmers*** *in the irrigation scheme using water from the dam (irrigation board).*

You are now part of an Irrigation Board composed by all three farmers in the irrigation scheme. You are now responsible for the management of the dam, which has the same capacity and reserve as in the previous phases. You can use the water from the dam to irrigate your extended cultivated area or your colleagues' ones, trying to achieve the best result **collectively**.

After having discussed your common strategy within your group, please fill-up your decision sheet indicating:

	Additional cultivated area	Water to irrigate the additional area	Profit obtained by the group *Reserved to the experimenter. Do not fill*
Farmer 1	…………..Ha	…………. m^3	
Farmer 2	…………..Ha	…………. m^3	ZAR
Farmer 3	…………..Ha	…………. m^3	
		TOTAL	

1) indicate here how many additional Ha of cabbage you want to cultivate…

… 2) and how many m3 you will use to irrigate your additional Ha.

➔ ***If you decide not to increase your area, just indicate 0 m^3 and 0 Ha.***

Annex C4

Decision sheet - phase 1: "singletons"

Session…………….. Phase……….

Farmer …………

Water request from the dam	*Dam manager's water allocation decision* ***Reserved to the experimenter. Do not fill***	Additional cultivated area	*Profit calculated* ***Reserved to the experimenter. Do not fill***
…………….. m^3	m^3	……………. Ha	ZAR

Annex C5

Decision sheet - phase 2: "partial coalitions"

Session…………….. Phase……….

	Water request from the dam	Dam manager's water allocation decision *Reserved to the experimenter. Do not fill*	Additional cultivated area	Water to irrigate the additional area	Profit obtained by the group *Reserved to the experimenter. Do not fill*
Farmer …	…………… m^3	m^3	…………Ha	…………m^3	*ZAR*
Farmer …	…………… m^3	m^3	…………Ha	…………m^3	
		TOTAL			

Annex C6

Decision sheet - phase 3: “grand coalition”

Session…………….. Phase……….

	Additional cultivated area	Water to irrigate the additional area	Profit obtained by the group *Reserved to the experimenter. Do not fill*
Farmer 1	…………..Ha	…………. m^3	
Farmer 2	…………..Ha	…………. m^3	ZAR
Farmer 3	…………..Ha	…………. m^3	
		TOTAL	

Annex C7

Description of the game's phases

Total second test session duration = 2h39. The step duration details are given in the table in annex C8.

Introduction
The instructions and the decision sheets were provided to the participants. They did not know previously the game. Consequently a long time was left for an individual reading. The participants raised the hand when questions arose during the individual reading. The answers were given collectively to provide the same information to all the players. After 23 minutes, the experimenter asked them if they needed to read together aloud the instructions. The players answered that no, therefore the instructions were not read aloud and the first singletons' decision process step (i.e. the water demand) began immediately after the individual reading.

Phase 1: Singletons
After the introduction, the experimenter left time the players to make individually the decisions. The players did not understand that the decision had to be made in two steps (i.e. the *water demand* firstly, and after receiving the water allocation from the dam manager, the *area to cultivate* secondly). Consequently, some players already were calculating the area to cultivate. The experimenter explained the decision process, and then the farmers only required the amount of water to the dam manager. The decision sheets containing the water requests were collected.

The experimenter treated the water demands and communicated individually to each singleton the amount of water allocated. Then, the farmers knew how much water they could use to irrigate their additional area. They chose the area to cultivate. The decision sheets containing the choices on cultivated area were collected.

The experimenter calculated the payoffs for each farmer and communicated the results individually.

After the first individual phase, the experimenter explained the objectives of the second phase. At the same time, new instructions were distributed.

Phase 2: Partial coalitions
The new instructions were read individually by the three farmers. Once there were no more questions, farmer 3 left the experimental room for the first round. Farmers 1 and 2 stayed in the experimental room. Farmer 3 did not play actively and stayed outside waiting for the end of the first round.

Firstly, farmers 1 and 2 together chose the amount of water required to be shared between the two of them. The decision sheet was collected. The experimenter treated the water demands and communicated the amount of water allocated to the partial coalition. Then, the farmers knew how much water they could use to irrigate their additional area.

Secondly, they chose the area to cultivate. Farmers 1 and 2 do not have the same production function, so they chose the additional area cultivated by each one *and* the corresponding water for irrigation. The decision sheet was collected.

The experimenter calculated the payoff for each farmer, and communicated it to the two farmers asking them how they would share it between the two of them. They communicated their payoff sharing and farmer 3 came back to the experimental room. Farmer 1 left the room and the second round was played with farmers 2 and 3 forming the partial coalition.

The same decision-making process was conducted. The experimenter treated the water demands and then the farmers chose the area to cultivate and the corresponding water for irrigation. At the end of the round, farmers 2 and 3 shared the partial coalition payoff.

For the third round, farmers 1 and 3 played together within the partial coalition while farmer 2 left the experimental room. The same decision-making process as in the first and second rounds was conducted.

For the last phase, the farmers formed the irrigation board (grand coalition). New instructions were distributed with the grand coalition decision sheet.

Phase 3: Grand coalition
The experimenter explained the new objectives and the new instructions were read individually by the players. Farmers 1, 2 and 3 played together within the grand coalition and managed the dam. Consequently they chose the amount of water required to be shared between the three of them, without asking the dam manager for the water allocations. The decision sheet was collected.

The experimenter treated the data and gather the whole results obtained through the experiment.

The payoffs obtained by the farmers individually in the first singleton phase, those obtained by the partial coalitions and the payoff obtained by the grand coalition were presented by the experimenter in a video projected table.

After the presentation of all the payoffs, the experimenter asked the players what situation they preferred between playing alone (singleton), playing in the informal group (partial coalition) or playing all together (grand coalition).

The players negotiated during 17 minutes and gave the experimenter their grand coalition payoff sharing among the three of them. A decision sheet was not used at this stage and the grand coalition payoff repartition was communicated orally by the three farmers.

At the end of the session, the experimenter leads a debriefing on what happened during the experiment. Some comments about the results were given and the players could detail the reasons of the different choices made along the experiment.

Annex C8

Detail of the durations

<table>
<tr><th colspan="4">Phase</th><th></th><th>Time (minutes)</th></tr>
<tr><td rowspan="5">1</td><td rowspan="5" colspan="3">Singletons</td><td>Distribution of instructions & decision sheets +individual reading</td><td>23</td></tr>
<tr><td>(collective reading) Possibly questions</td><td>1</td></tr>
<tr><td>Water demand</td><td>8</td></tr>
<tr><td>Treatment + Decision (Area +Water)</td><td>3</td></tr>
<tr><td>Treatment</td><td>1</td></tr>
<tr><td colspan="4"></td><td>Phase 1</td><td>36</td></tr>
<tr><td rowspan="15">2</td><td rowspan="15">Partial Coalitions</td><td colspan="2">Round</td><td>Distribution of instructions & decision sheets +individual reading</td><td>9</td></tr>
<tr><td rowspan="4">1</td><td rowspan="4">{1,2} & {3}</td><td>Water demand</td><td>7</td></tr>
<tr><td>Treatment + Decision (Area +Water)</td><td>2</td></tr>
<tr><td>Round treatment</td><td>1</td></tr>
<tr><td>Profit sharing</td><td>1</td></tr>
<tr><td colspan="2"></td><td>Transition</td><td>1</td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">{2,3} & {1}</td><td>Water demand</td><td>7</td></tr>
<tr><td>Treatment + Decision (Area +Water)</td><td>9</td></tr>
<tr><td>Round treatment</td><td>1</td></tr>
<tr><td>Profit sharing</td><td>1</td></tr>
<tr><td colspan="2"></td><td>Transition</td><td>2</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">{1,3} & {2}</td><td>Water demand</td><td>2</td></tr>
<tr><td>Treatment + Decision (Area +Water)</td><td>3</td></tr>
<tr><td>Round treatment</td><td>1</td></tr>
<tr><td>Profit sharing</td><td>6</td></tr>
<tr><td colspan="4"></td><td>Phase 2</td><td>53</td></tr>
<tr><td rowspan="7">3</td><td rowspan="7" colspan="3">Grand coalition</td><td>Distribution of instructions & decision sheets +individual reading</td><td>2</td></tr>
<tr><td>Decision (Area +Water)</td><td>28</td></tr>
<tr><td>Round treatment</td><td>2</td></tr>
<tr><td>Payoffs presentation</td><td>4</td></tr>
<tr><td>Negotiation</td><td>17</td></tr>
<tr><td>Treatment</td><td>3</td></tr>
<tr><td>Restitution (Debriefing)</td><td>14</td></tr>
<tr><td colspan="4"></td><td>Phase 3</td><td>70</td></tr>
<tr><td colspan="4" rowspan="2"></td><td rowspan="2">Total</td><td>159</td></tr>
<tr><td>2h39</td></tr>
</table>

Table 26. Second test session - Detail of the durations

Annex C9

The pictures

Picture 7. Second test session - Phase 1: "singletons" - Location of the players
The three farmers were located at three distant places of the central table of the room

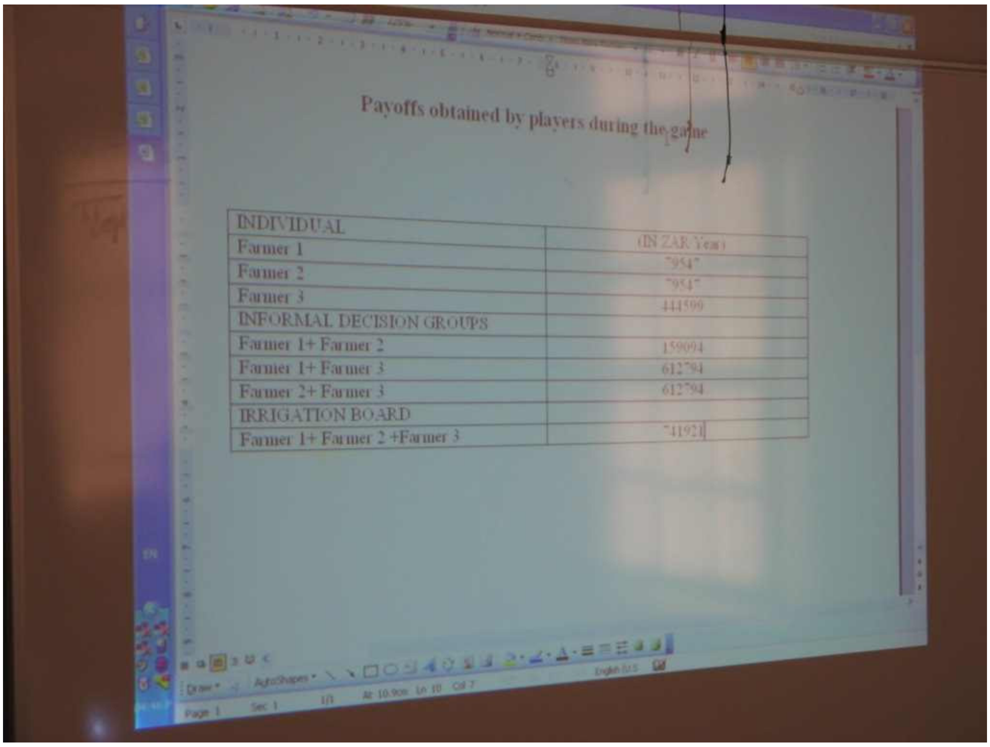
Picture 8. Second test session - Phase 2: "partial coalition" - Round 1
Farmers 1 and 2 played together within a partial coalition.

Picture 9. Second test session - Phase 2: "partial coalition" - Round 2
Farmers 2 and 3 played together within a partial coalition

Picture 10. Second test session - Phase 3: "grand coalition" - Grand coalition
The three farmers played together within the grand coalition.

Picture 11. Second test session - Phase 3: "grand coalition" - Presentation of all the payoffs

All the payoffs obtained through the three phases of the game were video projected



Picture 12. Second test session - Phase 3: "grand coalition" - Projection of the payoffs

The video-projection of all the payoffs obtained through the three phases of the game

Annex C10

Results and theoretical predictions

Second test Session

Phase	Farmers	Water Request (m3)	Additional area (Ha)	Profit (ZAR)	Super-additivity	Remaining water in the Dam	Shapley Value in Grand Coalition	In the core
1 Singletons	{1}	83333	9,0	79547	Yes		110848	Yes
	{2}	83333	9,0	79547	Yes		110848	Yes
	{3}	83333	9,0	444599	Yes	100001	520224	Yes
2 Partial Coalitions	{1,2}	166666	18,0	159094	Yes	100001	221697	Yes
	{1,3}	151333	17,0	612794	Yes	115334	631073	Yes
	{2,3}	151333	17,0	612794	Yes	115334	631073	Yes
3 Grand Coalition	{1,2,3}	245700	27	741921		104300	741921	Yes

Theoretical case

Phase	Farmers	Water Request (m3)	Additional area (Ha)	Profit (ZAR)	Super-additivity	Remaining water in the Dam	Shapley Value in Grand Coalition	In the core
1 Singletons	{1}	83333	9,2	79958	Yes		106227	Yes
	{2}	83333	9,2	79958	Yes		106227	Yes
	{3}	83333	9,2	446899	Yes	100000	530757	Yes
2 Partial Coalitions	{1,2}	166666	18,3	159917	Yes	100000	212453	Yes
	{1,3}	166666	18,3	642037	Yes	100000	636983	**No**
	{2,3}	166666	18,3	642037	Yes	100000	636983	**No**
3 Grand Coalition	{1,2,3}	250000	27,47	743210		100000	743210	Yes

Table 27. Second test session - Experimental results and theoretical case

Annex C11

Shapley values and the three phases' payoffs

Coalition Values --------->

Coalition	Value
v(1)	79547
v(2)	79547
v(3)	444599
v(1,2)	159094
v(1,3)	612794
v(2,3)	612794
v(1,2,3)	741921

v(1)+v(2)+v(3)= 603693

(Rate) **V**
0,132
0,132
0,736

Marginal contribution of farmer j to the coalition

Permutation	**1**	**2**	**3**
123	79547	79547	582827
132	79547	129127	533247
213	79547	79547	582827
231	129127	79547	533247
312	168195	129127	444599
321	129127	168195	444599
Total	665090	665090	3121346
Shapley value	**110848**	**110848**	**520224**
(Rate) **Sh**	**0,15**	**0,15**	**0,70**

Shapley value ---------->

percent of overall profit ------>

Table 28. Second test session - Shapley values and the three phases' payoffs

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Mathieu Désolé

Testing Cooperative Game Theory through a Contextualized Role-Playing Game about Irrigation Water Management

Summary

This Master thesis is the first step of a researh project and is based on the work of construction and test of an experimental protocol, adopting a simplified Role-Playing Game (RPG) to test hypotheses issued from Cooperative Game Theory (CGT). The RPG context refers to the case of common property water allocation among farmers and derives from observations made during a participatory project on water governance in the Kat River Basin (Eastern Cape, South Africa). The adoption of the simplified RPG for experiments triggers the following research question: can we use a contextualized Role-Playing Game in a laboratory to test theoretical hypotheses? To provide insights on the issue of game contextualization, some CGT hypotheses can be tested through both contextualized and de-contextualized versions of the RPG. Two test sessions of the contextualized game (CE) protocol were run and provided lessons to improve it before it will be adopted in a real experimental context. The de-contextualized experiment (DE) protocol remains to be built in the following stage of the research project.

Key-words

Cooperative Game Theory; Experimental Economics; Protocol; Context; Water management;

Test de la Théorie des Jeux Coopératifs à travers un Jeu de Rôles Contextualisé autour de la Gestion de l'Eau d'Irrigation

Résumé

Ce mémoire de Master est la première étape d'un projet de recherche et repose sur la construction et le test d'un protocole expérimental, basé sur un Jeu de Rôles (JDR) simplifié, pour tester des hypothèses dérivées de la Théorie des Jeux Coopératifs (TJC). Le contexte du JDR se réfère à l'allocation d'eau en propriété commune entre des agriculteurs, et dérive des observations faites pendant un projet participatif sur la gouvernance de l'eau mené dans le bassin versant de la rivière Kat (Eastern Cape, Afrique du Sud). L'adoption d'un JDR simplifié pour faire des expériences pose la question suivante : peut-on utiliser un JDR contextualisé pour tester des hypothèses théoriques ? Pour répondre au problème de la contextualisation du jeu, des hypothèses issues de la TJC peuvent être testées à la fois à travers une version contextualisée et une décontextualisée du JDR. Deux sessions ont été conduites pour tester la version contextualisée du protocole du JDR et ont permis son amélioration avant son adoption dans un vrai contexte expérimental. La version décontextualisée du JDR reste à construire dans les prochaines étapes du projet de recherche.

Mots-clés

Théorie des Jeux Coopératifs; Economie Experimentale; Protocole; Contexte; Gestion de l'Eau

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