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Introduction

On September 21-22, 2015, 6th International Scientific Conference "Quality of Life 2015. Human and Ecosystems Well-being" was held in Wrocław.

The conference was a part of the cycle of the conferences on the topic of quality of life that have been organized by the Department of Statistics (Wrocław University of Economics) since 1999. The aim of the cycle is to participate in the still rising all over the word wave of scientific studies on quality of life: ethical background and definitions of quality of life, investigating (how to measure it), presenting the results of differences of quality of life over time and space, its interdependences with natural environment, mathematical methods useful for the methodology of measuring quality of life and finally – possible methods of improving it. The conferences are meant to integrate the Polish scientific community doing research on these topics as well as to make contacts with foreign scientists.

This year our honorary guest was Professor Filomena Maggino, past President of International Society for Quality-of-Life Studies (ISQOLS), who presented a plenary lecture.

We hosted about 30 participants, among them scientists from Spain, Romania, Italy and Japan. We had 24 lectures on such a variety of topics as carbon footprint and mathematical properties of some estimators. The common background of all of them was to better comprehend, measure and possibly to improve the quality of humans' life.

The present volume contains the extended versions of some selected lectures presented during the conference. We wish to thank all of the participants of the conference for co-creating very inspiring character of this meeting, stimulating productive discussions and resulting in some potentially fruitful cooperation over new research problems. We wish also to thank the authors for their prolonged cooperation in preparing this volume, the reviewers for their hard work and for many valuable, although anonymous, suggestions that helped some of us to improve their works.

Finally, we wish to thank the members of the Editorial Office of Wrocław University of Economics for their hard work while preparing the edition of this volume, continuous kindness and helpfulness exceeding their duties of the job.

Katarzyna Ostasiewicz

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NATURAL DYNAMICS OF COMMON-POOL RESOURCES IN EXPERIMENTAL RESEARCH − CURRENT STATE AND PROSPECTS

NATURALNA DYNAMIKA WSPÓLNYCH ZASOBÓW W BADANIACH EKSPERYMENTALNYCH – OBECNE BADANIA I PERSPEKTYWY

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Summary: Sustainable use of natural resources is a key factor for survival of many small communities around the world. It creates problem called 'the tragedy of the commons', as it is assumed that people driven by their personal gains will tend to overuse the resource leading to its depletion. This idea led to creation of various experimental designs that introduced this characteristics, but were static, as they did not represent process of its natural regeneration. In the same time dynamics of this kind of resources such as fisheries or forests are critical element in the rational decision making. Difference between long-term sustainable use and short-time profits followed by poverty cannot be easily represented in static models. Therefore new designs were created aimed at capturing natural dynamics of such resources. They represent various types of ecosystems and were used in different countries and contexts. These designs are new addition to the field of experimental economics. There are many questions about their validity in the field and game theoretical characteristics. Nevertheless these questions create new areas for further investigation and research.

Keywords: tragedy of the commons, natural resources, ecosystems, experimental economy, game theory.

Streszczenie: Zrównoważone wykorzystanie zasobów naturalnych jest czynnikiem kluczowym dla przetrwania wielu niewielkich społeczności na całym świecie. Wiąże się ono z problemem „tragedii wspólnych dóbr", w którym zakłada się, że ludzie, dążąc do indywidualnych korzyści, będą nadmiernie wykorzystywać zasób, prowadząc do jego zniszczenia. Takie ujęcie problemu zaowocowało stworzeniem różnorodnych procedur eksperymentalnych, które zawierały opisany dylemat, ale miały charakter statyczny, ponieważ nie uwzględniały procesu naturalnej regeneracji zasobu. Dynamika zasobów takich jak łowiska czy lasy jest istotnym elementem w procesie podejmowania decyzji. Niestety modele statyczne nie są w stanie odwzorować różnicy pomiędzy jego długotrwałym, zrównoważonym wykorzystaniem a maksymalizacją krótkoterminowych zysków, prowadzącą do utraty źródła dochodu. Dlatego też zostały opracowane nowe procedury eksperymentalne, których celem jest przedstawianie dynamiki takich zasobów. Reprezentują one różne typy ekosystemów oraz zostały wykorzystane w różnych państwach i kontekstach. Tego typu procedury są nowym dodatkiem do obszaru ekonomii eksperymentalnej. Istnieje wiele pytań odnośnie ich trafności oraz charakterystyk opisywanych przez teorię gier. Zagadnienia te tworzą nowe obszary dla dalszych analiz oraz badań.

Słowa kluczowe: tragedia wspólnych dóbr, zasoby naturalne, ekosystemy, ekonomia eksperymentalna, teoria gier.

1. Common-pool resources

In literature common-pool resource (CPR) is defined as a type of good that is subtractable and it is costly to exclude potential users from using it. This means that if one of the users utilizes it, these units of the resource are no longer available for others. What is more, this person or group of people will be able to use this good even when a community or higher authorities do not allow it [Ostrom et al. 1994]. Sustainable use of CPRs is a key factor ensuring the long-time economic prosperity of many communities. This problem is not restricted to survival of small, rural communities that are dependent on forests, pastures or lake fisheries. Problems with management of CPRs are experienced in a similar way in developed countries when it comes to water pumping or the use of geothermal energy [Ostrom et al. 1994]. The same issues occur at a larger scale. For example in 2011 global fishery production in marine waters was estimated to 82.6 million tonnes [FAO 2014]. It represents an important part of global economy and worldwide food supply. Furthermore it can be argued that even Earth's atmosphere should be treated as a common-pool resource [Stonich et al. 2002]. This perspective shows that the importance of investigation into how they are managed cannot be underestimated.

This article is aimed at presenting current experimental research in this area. It concentrates on situations where there is a small group of clearly defined users. Furthermore it focuses on renewable resources that can regenerate in reasonable time, presenting how this regeneration can be introduced into experimental designs. As such dynamics are relatively new addition to the field, both opportunities and problems they create are presented in detail in the last part of the article.

2. Typical CPR experiments

The design of typical experiments in the area of common-pool resources management was heavily influenced by the idea of "tragedy of the commons". It was poetical description of the situation described by Garett Hardin [1968]. In his article he presented a hypothetical pasture which is used by multiple herdsmen. Each of them wants to maximize his own profits. If he adds one animal to his flock he gets full proceeds from it while all costs from overgrazing are shared equally among all users. Therefore it is rational for all herdsmen to do so. Hardin argued that this inevitably leads to overharvesting and depletion of the resource. Hence the "tragedy" – if individuals are rational they are not able to preserve the pasture and this fate that cannot be avoided.

There are many experimental designs aimed at investigating this problem. All of them are stylized versions of common pasture described by Hardin. A typical example of such a design was presented by Ostrom et al. [1994]. In this experiment participants can invest tokens they are given in one of two markets. First one gives a player a "safe" payoff proportional to the investment. The latter has the characteristics of the common-pool resource as described by Hardin. The payoff of participant *i* (π_i) from his investment (x_i) in the CPR can be calculated from the following equation:

$$\pi_i\left(x\right) = bx_i - ax_i(\Sigma x_i)^2. \tag{1}$$

In this case $\sum x_i$ is the sum of tokens invested by all players in the CPR while *a* and *b* are positive values that are parameters of the production function. It shows that participant's profit is proportional to his use of common-pool resource (bx_i). Costs, as in pasture described by Hardin, depend on decisions made by all users ($ax_i(\sum x_i)^2$). Participant's income in one iteration of the experiment is calculated as a sum of payoffs from both markets.

In this design the resource does not change throughout the whole procedure. The same set of decisions made by players always yields the same outcome regardless of their actions in previous iteration. Ostrom et al. [1994, p. 12] explained this problem in the context of resource dynamics: "One-shot games or time independent repeated games are adequate representation when the natural replacement rate is at least as great as current and foreseeable withdrawal rates so that the CPR is able to maintain itself.

This type of design is aimed at answering the question how people behave when they have to choose between individual and group rationality in the context described by Hardin [Cardenas et al. 2013]. The dynamic nature of natural resources such as fisheries or forests is omitted. Experiments are created to analyze how economic and social factors affect the decisions of the participants faced with this dilemma. They try, for example, to answer questions if cultural differences [Carpenter, Cardenas 2011] or payments for ecosystem services (PES) and communication [Midler et al. 2015] influence individual and group outcomes. The model itself does not match the exact nature of CPR but represents the core dilemma behind its use. These investigations are important, but they cannot answer the questions if and how the dynamic nature of natural resources influence the decisions of the participants.

3. Dynamics of natural resources

Renewable natural resources like fisheries or forests regenerate over time. The dynamics of such ecosystems are complex and their behavior is, in many cases, hard to predict [Scheffer et al. 1993; Hirota et al. 2011]. In reality this weighs heavily upon decisions made in natural resource management. Nevertheless, for many years, even the simplest dynamics of CPRs were not introduced into experimental research. As it was presented before, models were "static" as they did not change over time regardless of participants' decisions.

The process of natural regeneration can be modelled with the "dynamic" representations of the resource. A concept of these models is simple. When presented in discrete timesteps they should adhere to the following, abstract, model:

$$S_{t+1} = t\left(S_t, H\right). \tag{2}$$

The state of the resource (*S*) in timestep *t* + 1 depends both on state in previous round and harvest done by the users (*H*). The dynamics of the CPR are hidden within the transition function (*t*) which depends on characteristics of the modeled ecosystem. The nature of the resource state, harvesting effort and the transition function are not defined. This simple, abstract, description can be used to model complex ecosystems as well as representations behind simple games with few possible states of the CPR.

Adding natural dynamics to the model can introduce new concepts into the experiment. First of them is a stable state – it represents the case when the state of the resource does not change between timesteps. In reality such a situation happens if the action or inaction of users does not affect the CPR or it is able to return to its previous state. Furthermore there is social optimum. It is defined as a set of harvesting decisions that maximizes the group payoff from the resource use within given time [Cardenas et al. 2013]. As it refers to the group outcome as a whole it does not guarantee the equal share of the income among participants. Last, but not the least, there is the myopic Nash equilibrium. It is defined as a set of harvesting decisions that maximizes players' individual payoff in each one of timesteps [del Pilar Moreno-Sánchez, Maldonado 2010]. All these characteristics are not present in "static", iterated designs that are usually used in CPR research. Still, in simple models, these concepts can be understood by potential participants in the research. Therefore, during the experiment, they can make informed decisions about their resource use.

4. Fishery Game

Cardenas et al. introduced simple model representation of the fishery in one of their experiments [Cardenas et al. 2013]. In this design the resource can be in one of two states, high or low, that represent the availability of fish stock. In both cases each player can restrain himself from using the resource or decide how high or low fishing effort can be. Individual payoff in one iteration of the experiment depends both on state of the resource and player's decision as presented in Table 1.

Table 1. Payoffs in "A Fishery Game" designed by Cardenas et al. [2013]. Payoffs received by participants depend on the individual harvesting effort and state of the resource. The value connected with effort is used to calculate participant's sum of decisions

Resource	Individual effort		
	None (0)	Low (1)	High (2)
High (H)	0	7	8
Low (L1,L2)	0	2	3

Source: own work.

Total group fishing effort affects the state of the resource. When the availability of fish is high and participants' sum of decisions is at least 5 the fishery goes into low state. It is possible for resource to recover, but the total fishing effort has to be at most 1 for two subsequent iterations. The states and transitions of the resource are depicted in Figure 1. In every iteration of the experiment all participants have access to two fisheries that are not connected but share the same pattern of behavior.

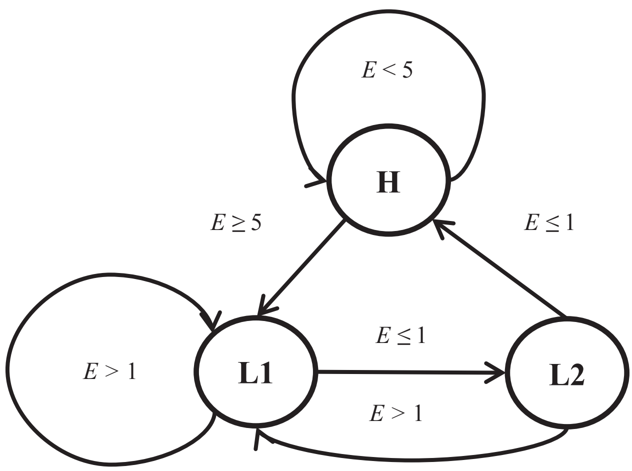

Figure 1. Graph representing possible states of resource in "A Fishery Game" designed by Cardenas et al. [2013]. Values of represent the total fishing effort that leads to the transition into next state

Source: own work.

Even though this model of the CPR is very simple it contains the main features of the dynamic representations that were mentioned before. When fishery is in high state and total group effort does not exceed 5, it remains in stable state. Social optimum means keeping the resource in this state for the most of the experiment. It represents the sustainable use of the CPR. Still, in the last iteration of the experiment, participants should maximize their effort to get the most from the fishery. On the other hand myopic Nash equilibrium leads to the depletion of the CPR in the first iteration. In the end if all participants follow this decision pattern it results in lower total payoff throughout the experiment compared to social optimum.

The game was used by Cardenas et al. in Thailand and Bolivia, where it was checked how simple institutions and monitoring system affects decisions regarding the use of CPRs [Cardenas et al. 2013]. Furthermore the design was adapted by Prediger et al. [2011] to investigate how cultural differences between communal farmers in Namibia and South Africa influence their decisions. In this case the basic dynamics of the model remained intact but fisheries were changed into grazing areas. Other use of this design were experiments conducted by del Pilar Moreno-Sanchez and Maldonado [2010] in the Colombian Caribbean. Treatment used in this research concentrated again on how institutional arrangements affect the outcomes of groups using CPRs. It introduced a complex model of the resource with non-linear payoff and regeneration functions. Still, for the simplicity, in the experimental research it was reduced into representation with two possible states of CPR and payoff matrix similar to the original version of the design.

5. Forestry Game

Other design created by Cardenas et al. [2013] is "Forestry Game". It represents forest consisting of 100 trees that are divided into 10 rows. In each round players have an opportunity to decide how many of them they want to cut. Their payoff is proportional to a harvesting decision and these trees are removed from the forest. After that there is a regeneration phase. One new tree is added to the forest for every row that was left intact. Even though the description of the dynamics is simpler than in "Fishery Game" the system itself is much more complex. In this case in each iteration the CPR can be in one of 101 different states that represent the size of the forest.

Social optimum for this design means that the forest should be used in sustainable way for at least some part of the experiment. It means keeping it in the stable state that will enable the CPR to regenerate into its maximal size. As presented in Figure 2, when the experiment lasts for 10 iterations, after the fifth round a forest use should increase. This relates to the definition of social optimum − a set of harvesting decisions that maximizes the group payoff from the resource within given time. If players know the duration of the experiment they should increase their profit by increasing the harvest in a way that they will cut down the forest completely in the last round of experiment. When a number of iterations increases the sustainable use of the resource should last longer. On the other hand, myopic Nash equilibrium leads to the depletion of the resource by sixth round. In this case there is no row of 10 trees present in the forest. It means that, by regeneration rule, it will remain in this state till the end of the experiment. No new trees will be added to the forest – the CPR have been completely depleted.

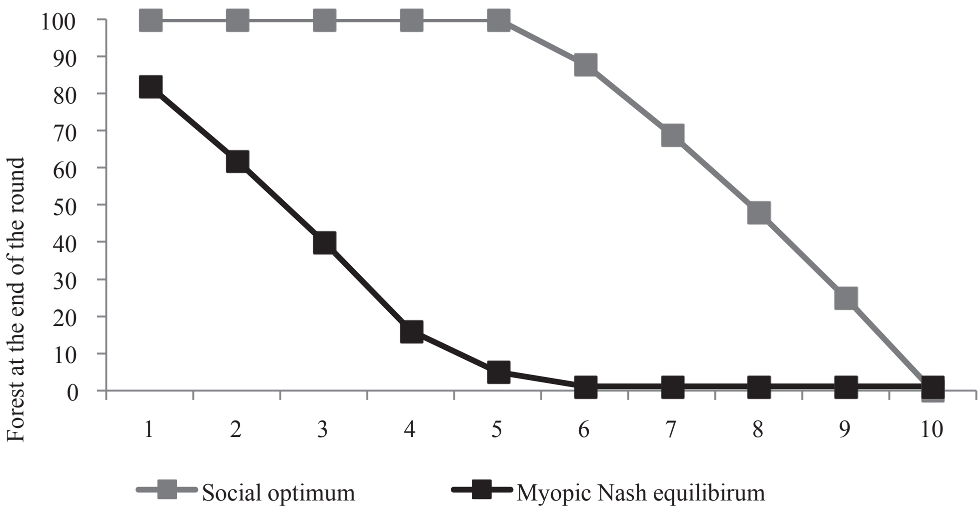

Figure 2. Social optimum and myopic Nash equilibrium in "Forestry Game"

Source: own work.

In the original design created by Cardenas et al. [2013] participants from Thailand and Colombia were able to use simple institutions and monitoring mechanisms. It was checked how they had affected their management of the common forest. Similar design was also reproduced by Slavíková et al. [2011] in the Czech Republic, Slovakia and introduced by Magnuszewski et al. [2014] in Bolivia and Uganda. In the last case there were no restriction on the communication during the experiment and participants could create their own institutions, perform monitoring and sanction other members of the community. Furthermore the "Forestry Game" was used by Ghate et al. [2013] as a base for their research conducted in India. First the experiments used original design with communication and no-communication treatments. In others forest resources were separated into timber, fodder and fuelwood. Each type had its own size and had regeneration rate of 10% as in the original design. Still all of these forest resources should sum up to 100 units.

6. Spatial design

Janssen et al. [2008] in their design introduced not only dynamics of the CPR but also its spatial distribution. This experiment was conducted using computer simulation. It represented a grid with 20x50 cells that was partially filled with tokens representing the resource, as shown in Figure 3. The simulation took place in real-time and players used their avatar to harvest the resource in real time.

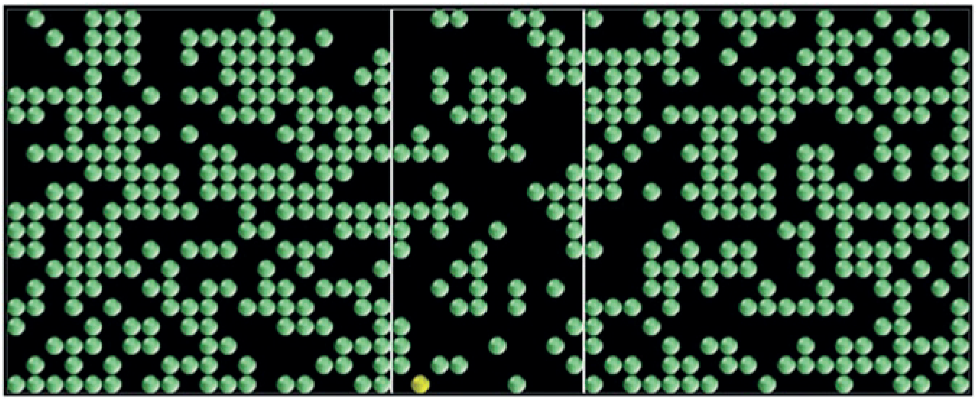

Figure 3. Graphical representation of the resource in experiment by Jansen et al. [2008]. Green tokens represent the resource, yellow token is the avatar of the player

Regeneration happens in fixed moments during the experiment. Therefore it is done in discrete timesteps as opposed to the real-time harvesting decisions by participants. In this type of the experiment regeneration is stochastic and depends on the location within the game area. This creates additional complexity connected with simulating natural resources that was absent in designs presented before. In this experiment regeneration rule determines the probability of a new unit of CPR appearing on empty space *c* at timestep *t*. It is defined by the equation:

$$p_c(t) = r\frac{n_c(t-1)}{N}. \tag{3}$$

Such a probability (p_c) depends on regeneration parameter (r) and the number of neighboring cells containing resource token in previous timestep (n_c) divided by the total number of neighboring cells (N).

This design was used to explore how property arrangements such as private property or open access affected the outcomes of the group and state of the resource. There were several research activities that used this design but none of them was performed in the field with real resource users [Janssen et al. 2008; Janssen et al. 2010; Janssen, Ostrom 2008].

7. Issues and prospects – discussion

Three basic experimental designs that have already been presented in this article introduce various approaches at modelling dynamic CPR. All of them are relatively recent and innovative in this field of research. Cardenas et al. [2013] even describe them as “new wave” of experimental designs. As they are new addition to the field they can generate controversies. At the same time they present completely new opportunities.

First of all, an ecologist may argue that these models of CPR bear only little or even no resemblance to real-life ecosystems. From their perspective they are not simple but simplistic. They lack many basic features possessed by systems. In the designs presented in this article the resource is discrete and homogenous. Its spatial distribution is taken into account in only one of these experiments. In reality fisheries or forests are complex ecosystems that are home to various animal and plant populations that interact with each other. Heterogeneity, feedbacks within the system and spatial distribution is a key factor to understand their behavior. Furthermore the nature of possible human interventions into the CPRs and their potential results adds even more complexity to this problem. These aspects are key factors in resource management and, in presented designs, are addressed in a version that may be viewed as oversimplified.

Therefore it is crucial to incorporate at least some of these characteristics when creating new designs. It may give a researcher insight into the interactions between human communities and natural resources systems. Addressing this complexity in new designs is an opportunity, but it also creates additional problems. Firstly, the main feature of the experiments should be simplicity. “Fishery Game” and “Forestry Game” are designed to be as simple as possible. It is due to the fact that they were conducted in the rural societies of CPR users. More complicated design with advanced mechanics may be more realistic but it can be too complex for the participants to understand. If they cannot predict how their actions affect state and behavior of the model they cannot make informed decisions that can be based on further analysis.

Another problem comes directly from the dynamic nature of presented designs. As it was mentioned before, decision environment changes over time due to the decisions of participants and natural processes reproduced in the model. The range of possible actions and their consequences may be different in each iteration of the experiment. It creates a question how people react to such changes. For example we can assume that participants can do specific actions when they are faced with the scarcity of the resource. It can be theorized that they can lower their decision to let the CPR regenerate. Alternatively they can increase harvest to secure for themselves at least some of the payoff assuming that others will follow the myopic Nash equilibrium. Unfortunately experiments that have been presented in this article do not address such questions. When statistical analysis is applied, it is based on simple tools using mean payoffs in two treatment groups as their input. This gives information which group was able to earn more from the CPR. Basing on models’ characteristics, it can be translated to information which group was able to sustain it longer, but does not give any information about harvesting dynamics. Multiple decision patterns, driven by various rationales, can yield the same final result and they will be undistinguishable. Introducing designs and statistical methods that can help investigate this problem is a necessary step in this area of research.

Last, but not the least, the key to understand the dynamic context of decision patterns in these experiments can be game theory. Its tools and methods are well established in economy as a way of analyzing actions undertaken by rational individuals. Experiments presented in this article use concepts based on game theory such as social optimum and myopic Nash equilibrium. Regrettably presented designs represent only a superficial analysis of this subject. A good example of this problem is "Forestry Game" where both of these decision patterns were calculated (see Figure 2). First of all the set of actions that is labelled as social optimum is only one of possible sequences that fulfill its definition. This is due to the discrete nature of the resource and regeneration rule. Therefore, in this and similar designs, researchers should present social optima rather than others. Furthermore there is an important question of myopia of Nash equilibrium. In "Forestry Game", in one iteration, Nash equilibrium is indeed harvesting maximum possible number of resource. However, it may not be the case for the game as a whole. In the presented experimental designs there was no attempt at calculating Nash equilibrium for the duration of the experiment. This can be interpreted as the approximation of the discount factor. Following this argument people concentrate on their current payoff and do not think about the future income from the CPR. It may be the case, but it is hard to argue that prospect profits do not count at all. What is more, there is also a problem with the complexity of calculating Nash equilibrium for the whole game. This exceeds current and foreseen computational capabilities of computers. Calculating it requires developing or adapting existing approximation methods that are used in "static" games. It still requires research and joint effort by mathematicians and economists.

Summing up, experimental games with dynamic representation of the resource give researchers an opportunity for more detailed insight into decision making process of the CPR users. Current research is based on simple models and is the first step to establish such games as valid area of scientific exploration. They still require further analysis to answer methodological issues that emerge from these designs.

References

Cardenas J.C., Janssen M., Bousquet F., 2013, *Dynamics of rules and resources: three new field experiments on water, forests and fisheries*, [in:] *Handbook on Experimental Economics and the Environment*, List J., Price M. (eds.), Edward Elgar Publishing, Cheltenham, pp. 319-345.

Carpenter J., Cardenas J.C., 2011, *An intercultural examination of cooperation in the commons*, Journal of Conflict Resolution, no. 55 (4), pp. 632-651.

del Pilar Moreno-Sánchez R., Maldonado J.H., 2010, *Evaluating the role of co-management in improving governance of marine protected areas: An experimental approach in the Colombian Caribbean*, Ecological Economics, no. 69 (12), pp. 2557-2567.

FAO, 2014, *The state of world fisheries and aquaculture*, http://www.fao.org/3/a-i3720e.pdf (access 10.10.2015).

Ghate R., Ghate S., Ostrom E., 2013, *Can communities plan, grow and sustainably harvest from forests?*, Economic and Political Weekly, no. 48 (8), pp. 59-67.

Hardin G., 1968, *The tragedy of the commons*, Science, no. 162 (3859), pp. 1243-1248.

Hirota M., Holmgren M., Van Nes E.H., Scheffer M., 2011, *Global resilience of tropical forest and savanna to critical transitions*, Science, no. 334 (6053), pp. 232-235.

Janssen M.A., Goldstone R.L., Menczer F., Ostrom E., 2008, *Effect of rule choice in dynamic interactive spatial commons*, International Journal of the Commons, no. 2(2), pp. 288-312.

Janssen M.A., Holahan R., Lee A., Ostrom E., 2010, *Lab experiments for the study of social-ecological system*s, Science, no. 328 (5978), pp. 613-617.

Janssen M.A., Ostrom E., 2008, *TURFS in the lab: institutional innovation in real-time dynamic spatial commons*, Rationality and Society, no. 20 (4), pp. 371-397.

Magnuszewski P., Stefanska J., Andersson K., Salk C., Pajak M., Wright G., Chazdon R.L., Lopez M., Ostasiewicz K., Sendzimir J., 2014, *A gaming activity to study the emergence of adaptive governance arrangements for tropical forest ecosystems*, presentation on: Workshop on the Ostrom Workshop 5.

Midler E., Pascual U., Drucker A.G., Narloch U., Soto J.L., 2015, *Unraveling the effects of payments for ecosystem services on motivations for collective action*, Ecological Economics, no. 120, pp. 394-405.

Ostrom E., Gardner R., Walker J., 1994, *Rules, Games, and Common-pool Resources*, University of Michigan Press.

Prediger S., Vollan B., Frölich M., 2011, *The impact of culture and ecology on cooperation in a common-pool resource experiment*, Ecological Economics, no. 70 (9), pp. 1599-1608.

Scheffer M., Hosper S.H., Meijer M.L., Moss B., Jeppesen E., 1993, *Alternative equilibria in shallow lakes*, Trends in Ecology & Evolution, no. 8 (8), pp. 275-279.

Slavíková L., Kováčb U., Kluvánková-Oravská T., Malýa V., 2011, *Sustainable forest management as experimental study from the Czech and Slovak Republics*, Prognostické práce, no. 3 (4), pp. 337--355.

Stonich S., Stern P.C., Dolsak N., Dietz T., Ostrom E., Weber E.U. (eds.), 2002, *The Drama of the Commons*, National Academies Press.