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Social dilemmas and individual/group coordination strategies in a complex rural land-use game

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Abstract: Strengthening ongoing bottom-up capacity building processes for local and sustainable landscape-level governance is a multi-dimensional social endeavor. One of the tasks involved – participatory rural land use planning – requires more understanding and more awareness among all stakeholders regarding the social dilemmas local people confront when responding to each other's land-use decisions. In this paper we will analyze and discuss a version of our game SIERRA SPRINGS that is simple to play for any stakeholder that can count to 24, yet entails a complex-coordination land use game – with an extensive and yet finite set of solutions – which can mimic in a stylized form some of the dilemmas landowners could confront in a landscape planning process where there livelihoods are at stake. The game has helped researchers and players observe and reflect on the individual coordination strategies that emerge within a group in response to these stylized dilemmas. This paper (1) develops a game-theoretical approach to cooperation, competition and coordination of land uses in small rural watersheds (2) describe the goal, rules and mechanics of the game (3) analyzes the structure of each farms' solution set vs. the whole watershed's solution set (4) derives from them the coordination dilemmas and the risk of coordination failure (5) describes four individual coordination

strategies consistently displayed by players; mapping them in a plane we have called Group-Level Coordination Space (6) discusses the strengths, limitations and actual and potential uses of the game both for research and as an introductory tool for stakeholders involved in participatory land use planning.

Keywords: Common pool resources, coordination dilemmas, coordination strategies, role playing game, rural land use planning

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1. Introduction

Multifunctional mountain landscapes with diverse and appropriate spatial distribution of forested and open land uses have been the basis of local livelihoods for centuries (García-Barrios and García-Barrios 1992, 1996) and are still critical for providing important services to local and external population (Jackson et al. 2009; Perfecto and Vandermeer 2010). Many mountain landscapes are quickly degrading and loosing these capacities (García-Barrios et al. 2010).

Rural landscape pattern and composition result – among other things – from how Individual land-holders' decisions affect each other and from how they are regulated by decentralized norms and centralized governance schemes (Parker and Meretsky 2004). A number of multi-scale social and ecological drivers represent new and evolving challenges for farmers and other stakeholders involved in coordinating land-use decisions in rural landscapes to reduce negative externalities derived from improper land use proportions and spatial distributions (Lewis et al. 2008).

Strengthening ongoing bottom-up capacity building processes for local and sustainable landscape-level governance is a multi-dimensional social endeavor (Taylor 2005). One of the tasks involved – participatory rural land use planning (Anta et al. 2006) – requires more understanding and more awareness among all stakeholders regarding the social dilemmas local people confront when responding to each other's land-use decisions, if land use coordination efforts are to be effective.

There are many traditional and new methods and approaches for engaging multiple stakeholders in rural land use planning experiences and for better understanding their decisions and behaviors. Cooperative game theory, spatially explicit lab and field CPR experiments, role-playing games, agent based models, companion modeling and policy simulation exercises are increasingly being used for this purpose. Each has its place, its own strengths and its own limitations. Some are highly controlled, generic, stylized and abstract while others are open-ended, context dependent and realistic. Some have been developed with the interest and the capacity to expose and understand the core social dilemmas and human behaviors involved in these and other CPR management situations. (For excellent recent reviews see Collectif ComMod 2006; Janssen and Ostrom 2006; Anderies et al. 2011.)

Since 2007, our team has been working with multiple stakeholders on a research project aimed at the participatory development of silvopastoral landscapes in the buffer zone of the La Sepultura MAB reserve in Chiapas, Mexico. The project involves participatory development of role-playing games and scenario simulators with active design and use by stakeholders. Among the first steps, we developed the spatially explicit board game SIERRA SPRINGS as the result of interactions with a diversity of stakeholders and researchers (GarcíaBarrios 2009). To date, the game has been successfully played in a couple of local multi-stakeholder workshops to introduce the concept of role playing games, and in local, national and international workshops by more than 140 graduate students interested in the topic.

In this paper we will analyze and discuss a version of SIERRA SPRINGS that is simple to play for any stakeholder that can count to 24, yet entails a complex-coordination land use game – with an extensive and yet finite set of solutions – which can mimic in a stylized form some of the dilemmas landowners could confront in a landscape planning process where there livelihoods are at stake. The game has helped researchers and players observe and reflect on the individual coordination strategies that emerge within a group in response to these stylized dilemmas.

The following chapters (1) develop a game-theoretical approach to cooperation, competition and coordination of land uses in small rural watersheds, (2) describe the goal, rules and mechanics of the game, (3) analyze the structure of each farms' solution set vs. the whole watershed's solution set, (4) derives from them the coordination dilemmas and the risk of coordination failure, (5) describes four individual coordination strategies consistently displayed by players; mapping them in a plane we have called Group-Level Coordination Space, and (6) discusses the strengths, limitations and actual and potential uses of the game. Methods and results are presented in each chapter as required.

2. A game-theoretical approach to cooperation, competition and coordination of land-uses in small rural watersheds

In many countries, watershed territorial management is formally governed by modern social institutions constructed on a set of constitutional principles that provide individuals with equal political, economic, and judicial opportunities (Carmona-Lara 2006; Corso 2010). Therefore, at least in principle, stakeholders could construct a symmetrical and equitable watershed society (Rawls 1971; Barry 1989). Such a social equilibrium is weak and stakeholders usually engage spontaneously in competition for land, land uses and other watershed resources and benefits leading to inequality (Binmore 2005). In the latter case, some agents, including the government, may be pursuing a Pareto improvement, either mildly inequitable and therefore acceptable for all players, or strongly inequitable and unacceptable, and leading to conflict and possible losses for everyone involved (Gintis et al. 2005). Alternatively, individuals may engage in a strong competition where pure gain for one player means pure loss for the other. Finally, economic, political and environmental externalities along with coordination errors can make everyone incur major losses in productivity and welfare (Bardhan et al. 2007).

The following game theory puzzle which we will call “The Little Watershed Game” provides an abstract but powerful representation of these situations. We will describe it through a specific example. Suppose two farmers, each one an independent producer, live in a watershed and have available two possible land uses: open pastureland for livestock and a low – income generating but sustainable forestry. A certain extent of forest is needed to assure common-pool drinkable water for farmers and livestock. Suppose that if the same activity is simultaneously dominant in both farms, neither farmer will be able to make a living due to insufficient income or to lack of quality water. Assume the farmers have seven pure land use strategies to manage their individual farms. Each strategy (A, B, C, D, E, F and G) represents an increasing proportion of the two possible land uses, such that strategy A means a 100 percent occupation of the farm with forestry, strategy D a 50–50 percent occupation of each land use, and G a 100 percent occupation of the farm with open pasture.

Formally, both farmers face the following symmetrical payoff matrix where a zero value means that a player does not achieve the required minimum-livelihood (defined as a benefit of 100).

	Farmer 2							
	Strategy	A	B	C	D	E	F	G
Farmer 1	A	0,0	0,0	0,0	0,0	0,0	0,0	0,200
	B	0,0	0,0	0,0	100,100	100,100	**100,160**	0,0
	C	0,0	0,0	0,0	100,100	**100,130**	100,100	0,0
	D	0,0	100,100	100,100	**100,100**	100,100	100,100	0,0
	E	0,0	100,100	**130,100**	100,100	0,0	0,0	0,0
	F	0,0	**160,100**	100,100	100,100	0,0	0,0	0,0
	G	200,0	0,0	0,0	0,0	0,0	0,0	0,0

“The Little Watershed Game” form has several distinctive structural properties. All of them are also present in the Sierra Springs Game (a much more complex game) and are characteristic of many complex socio-environmental situations:

I. Focal Point. The strategy combination **{DD}** is a “Pure Equality” Nash equilibrium corresponding to the only symmetric solution which satisfies a norm of equality both in strategy choice and in payoffs. However it is Pareto inefficient as other solutions produce a higher payoff for one farmer and a higher global payoff. (A Nash equilibrium occurs when each player is at its optimum value given the other player's choice, and has no incentive to change strategy.)

II. Multiple Equilibria. The "Pure Equality" equilibrium is not the only Nash equilibrium of the game. Other Nash equilibria run in the diagonal from {A, G} {G, A}.
III. Pareto Improvement. Players have the possibility of seeking other Nash equilibria and of deviating from the Pure Equality Nash equilibrium with a Pareto improvement, such as {F, B}, {E, C}, {E, C}, and {B, F}. (A Pareto improvement for a farmer implies that no other player is harmed.)
IV. Pure Conflict. There are (weak) Nash equilibria: {G, A} or {A, G} where the gain of one farmer means the loss of the other.
V. As in the "chicken game", only one of the players can obtain gains for deviating from the Pure Equality Equilibrium. If both deviate towards obtaining gains, their payoffs may be (0, 0). Pareto improvement, say {F, B}, or unilateral profit maximization, say {G, A}, require one player to dominate and the other to submit. Who dominates and who submits is a matter of "chicken competition." If no player is willing to submit, coordination will fail, and the weak Pure Equality equilibrium will become again the focal point for both players.
VI. Dis-coordination. The game is complex enough that coordination errors can exist. For example, while exploring for Pareto improvements in a competitive way (that is, a combination of good-will and mild greed), both players may deviate exactly in the same direction, by adopting, for example, strategy {C, C}, causing a mutual income disaster.

The two-player game we have just examined exposes several important social issues if the game is played simultaneously. The game is symmetrical and equality (equity) is available for both players. However, players can engage in a chicken-competition. In this case, they may pursue a non-equitable Pareto improvement, or they may engage in a strongly competitive situation in which pure gain for one means pure loss for the other. Finally, even when pursuing Pareto improvements that allow the other player a livelihood, coordination errors can cause everyone to loose.

Assumptions about the agent's kind of rationality are also relevant to the solution. For example, if Farmer 1 plays first and is an orthodox rational agent, then the only (weak) solution of the game is {G, A}. But suppose that there is a probability – probably high – that such an agent will not face another orthodox rational agent, but a strong reciprocator, that is, a most normal human being which seeks fairness and will punish *strong and severe* unfair intentions by choosing a strategy that either corrects injustice if possible, or if not will make her best to reduce any unjust agent pay-off to its minimum (see Gintis et al. 2005). Thus, if Farmer 1 chooses first Strategy G, Farmer 2 will retaliate by choosing any strategy but A, while if Player 1 chooses strategy F, she will choose strategies C or D to bring a fair pay-off (100, 100). Note that Player 2 could decide not to punish Player 1 if she mildly deviates from strategy D and chooses strategy E. In that case, we could assume Player 2 to conform and choose strategy C.

Another possibility is that both agents may play simultaneously but having bounded rationality without any information of the game other than the "Focal Point". Thus, they may need to "explore" the game to obtain "preferred" solutions (Pareto Improvements), in which case another structural characteristic: VII. Neutral Plurality will become relevant. This means that many strategy combinations (e.g. {D, B} and {B, E}) have the same pay-offs as the "Pure Equality" Solution, but are not Nash Equilibria. In situations in which information about the structure or pay-offs of the game is imperfect, such combinations may provide non-conflictive heuristic paths for joint exploration.

We will not explore any further the possibilities of this simple game, but it should be clear that once we consider the complexities of real human behavior a myriad of solutions are possible, and the possibility of committing an error because of biases in information or calculation are quite high. Why is territorial planning necessary in this context? Why should it be constructivist, participatory, and adaptive? In many social situations, complex spontaneous interactions among different agents may generate not only interests and normative conflicts, but also potential opportunities which are embedded or hidden within these same interactions. By fixing a collective vision and opening coordination and negotiation procedures for all stakeholders involved in complex watershed constructivist participatory planning may help them recognize their opportunities and avoid conflicts. However, participatory planning has it own problems and challenges (which may be managed via recurrent plan adaptation, in some cases). We will now engage in understanding some of these problems and challenges through the SIERRA SPRINGS game. For that purpose, we will consider the "simplest" possible case: Planning for sustaining livelihoods and the environment within a moral economy where nobody can be left destitute.

3. Sierra Springs' goal, rules and mechanics

The game board (Figure 1) represents a locale of 48 pristine forest sites (e.g. 48 single hectare plots) divided by 4 creeks into 4 quadrants.

There are 4 players, each of whom is assigned a quadrant and given a set of tokens that represent different land uses:

- 6 "F" tokens, representing managed forest;
- 6 "M" tokens (moderate cattle grazing);
- 6 "I" tokens (intensive cattle grazing).

Each player seeks to make a living (acquire 24 points) for himself by "developing sites" (placing tokens upon them). "F" tokens are worth 1 point; Ms and Is are worth 2 and 3, respectively.

All players must attain at least 24 points in their quadrants without damaging the collective creeks and spring; otherwise everyone loses.

Within a quadrant, the 8 inner-land-units are available only to the owner, while the 8 border land units (shared with two other players) will be owned by the neighbor who first colonizes them.

F tokens do not deforest the site; M and I tokens do.

In real life, the relation between forest cover and water quantity and quality is complex, contextual, scale-specific; and still debated (Bruijnzeel 2004). In this game, the hydrological balance is such that loss of forest cover beyond specific deforestation thresholds collapses drinkable water at the farm or at the watershed level.

In SS, colonization is restricted by four unforgiving environmental responses to land use decisions. They are not allowed on the board. (q.v. Figure 1):

a. More than 32 total deforestations dry the spring and creeks during the dry season. (All players and cattle have to leave the territory.)
b. More than 2 M or I tokens immediately surrounding the spring spoil the water during the dry season. All players (and their cattle) must leave the territory.
c. More than 2 deforestations on a creek dry it.
d. Contiguous I tokens trigger severe erosion, pest issues, or unfavorable microclimate.

Given that SS is played here as an adaptive planning exercise, moves are reversible, i.e. tokens can be removed or relocated at will. The owner of the token(s) must agree.

Players do not take turns; each can set tokens on his quadrant at his own pace.

Players are allowed to chat or work as a team, but the referee does not induce them to do so.

No monetary returns or other relevant rewards are offered to groups who achieve the goal.

4. The coordination dilemmas in Sierra Springs

The Sierra Springs game considered in this paper has a pre-established "moral economy" goal: nobody should lose his livelihood; everyone must have at least 24 points. Players are also aware that land use decisions at the quadrant level can sum up globally and/or interact at boundaries to produce a collapse of the common pool resources (water) and of livelihoods. These game preconditions resolve the issues of strong inequity in individual outcome and create a powerful incentive

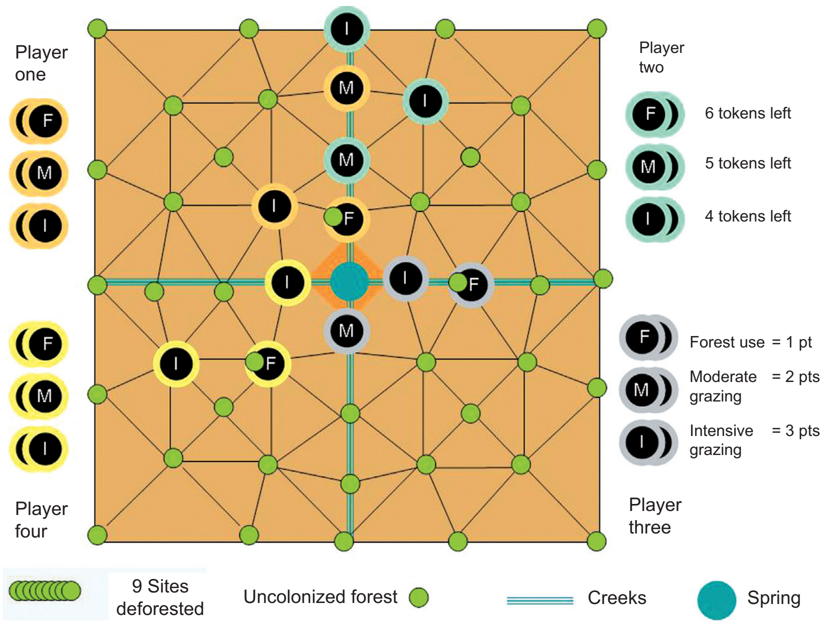

Figure 1: The Sierra Springs game board and tokens. The board has 48 forested land units (green tokens) that can be colonized. Each player gets six tokens each for the three land uses, and has access to a quadrant of the territory. Quadrants are separated by creeks. Within a quadrant, 8 inner land units are available only to the owner, while 8 border land-units (shared with two other players) will be owned by the neighbor who first colonizes them. In the figure, each player has selected 3 locations and placed 3 tokens on the board. Nine sites have been deforested and thereby, their forest tokens removed. Land use tokens have been placed to show examples of problematic situations: player 2 – as well as players 1 and 4 – have contiguous Is; players 1 and 2 have damaged their common creek; players 3 and 4 have damaged the community's spring.

for players to value coordination (as soon as they discover it is needed), and thus focuses on exposing players to the cognitive challenges and social dilemmas that emerge from the game-theoretical structure of the puzzle. This structure involves simultaneously a complex multiple-equilibrium coordination game and a competitive (chicken) game, prone to coordination failure.

We will briefly describe some properties of the solution set of SS that relate to this game-theoretical structure and its risks of coordination failure. They were derived by analyzing the game's list of 704 unique 4-player global solution vectors (GS's) of the form:

$([F_1\, M_1 I_1]\ [F_2\, M_2 I_2]\ [F_3\, M_3 I_3]\ [F_4\, M_4 I_4])$,

where letters represent the number of tokens of each type displayed by a player on his quadrant, and subindexes represent players (but not necessarily sequential quadrants). These 704 solutions have already been filtered for redundancy resulting from rotating the solved puzzle on the gaming table.

Parenthetically, most GS's allow some tokens in any quadrant's $[F_i\, M_i\, I_i]$ triad to be swapped in various ways without violating the game's spatial restrictions. For the analysis which follows, such additional level of spatial detail is unnecessary. The list of solution vectors as well as the geometric, algebraic and computational procedures to derive them are available upon request (Smith et al. 2011).

Let us first consider the potential conflict between a player's local (quadrant-level) solution and the need for a global (watershed-level) solution. A player has 8 pre-assigned "interior sites" available only to her and 8 "boundary sites" that can be colonized by her or his neighbors. She could set on the board as few as zero and as many as 16 tokens, with FMI triads ranging from [0,0,0] to [6,6,4]. This means he has 7×7×5=245 choices. Yet only 37 of these triads sum up to 24 points or more (with a maximum of 26 points), and constitute the set of local solutions (LS) available to the player.

Now, a local solution must be compatible with one or more global solutions. Each LS is a member of only a subset of all 704 global solution vectors. For example, one of the 37 local solutions is the FMI triad [4, 6, 3]. This triad appears at least once in 62 out of 704 global solution vectors. One of these 62 GS vectors is of the form $([4, 6, 3]\ [F_2, M_2, I_2]\ [F_3, M_3, I_3]\ [F_4, M_4, I_4])$.

Generalizing, each LSj is a member of a certain percentage (P_j) of the 704 GS's, so.

P_j=100×(number of GS's in which LSj appears at least once)/704. (j = 1…37)

Note that the sum of all 37 Pj is much higher than 100% as the subsets of GS's that are compatible with each LS overlap (i.e. because a four-triad global solution vector is formed by one or more of the 37 LS triads).

Thirty five out of the 37 LS have a P_j > zero, meaning that they are compatible with one or more global solutions. Of the thirty five, only 9 have a P_j between 20 and 36%. We will call them "easy to coordinate" local solutions (ELS). The other 26 LS have a P_j between 1 and 14%. We will call them "hard to coordinate" local solutions (HLS).

Hard and Easy refer to the lower and higher probability that other players' LS will be compatible with the player's choice of LS by mere chance. Now, strictly speaking, if P_j>0 and search time is infinite, coordination among the local solutions of each player will occur, and the puzzle will be solved. However, when a reasonable time limit to solve the puzzle is imposed on players, HLS have a higher probability of coordination failure.

Figure 2 displays in a ternary plot the 37 LS (according to their proportions of F,M and I tokens) and labels them with their P_j value. HLS's tend to concentrate towards the area with low F and high I proportions; while ELS's does the opposite. Yet, in all cases, ELS's are surrounded by HLS's and can pitfall into them if a player decides or is forced to change towards another LS with slightly different FMI proportions. So, in short, ELS are uncommon and "surrounded" by HLS, in what we could call a "nail-bed relation" between local and global solutions.

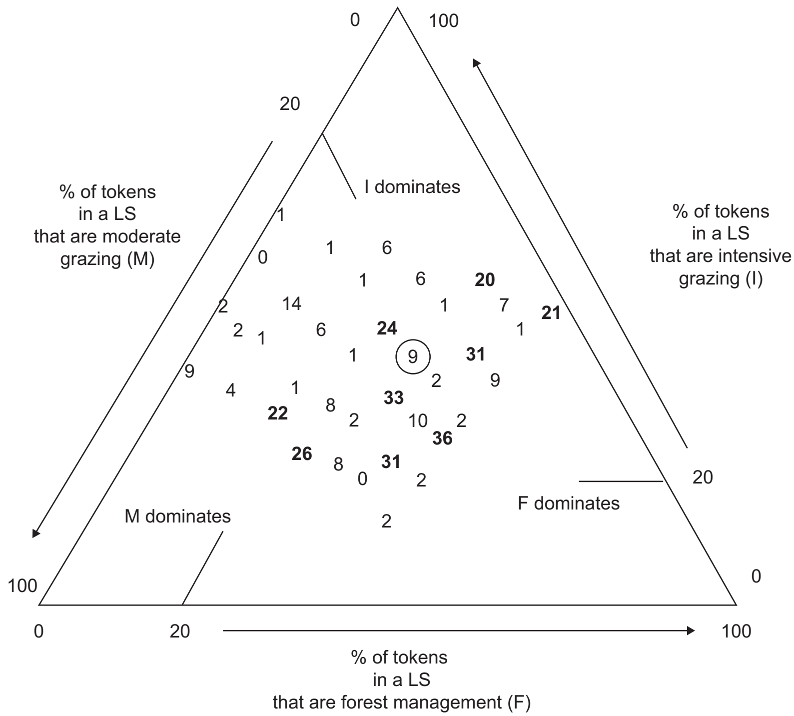

Figure 2: Each possible local solution (LS) on ,say, quadrant 1 is a [F, M, I] triad which can be described by its (percentual) proportions of F, M and I tokens, and by its P_j values (i.e. the percentage of the 704 global solutions (GS's) with which that triad is compatible). For example, the triad [4, 6, 3], is made of 31% F, 46% M, and 23% I, and it occurs in 9% of the GS's. Both attributes of this triad can be mapped on the ternary plot above (see circled number). The position of the circle represents the percentages of F, M, and I tokens in the triad, while the number inside it represents its P_j value. All 37 LS available to a player are similarly mapped on the plot, but the circles have been excluded to avoid crowding the figure. "Easy to coordinate solutions" (ELS) are in bold. Note that ELS will pitfall into "hard to solve solutions" (HLS; P_j<=14) or into non-solutions (P_j=0 or blank spaces) upon very small changes in FMI token proportions.

Let us now consider the interaction with other players in further detail by examining how ELS relate to the number of Is and boundary sites a player chooses or is forced to use. Intuitively, a player might consider that more Is reduce his contribution to deforestation (less open sites to reach 24 points) and his need to compete for boundary sites. This should contribute to relax coordination efforts.

Figure 3 shows that this is only partially true because the relation between factors that make an LS "easy to coordinate" are strongly non-linear. The relation between boundary sites required by an ELS and the specific percentage

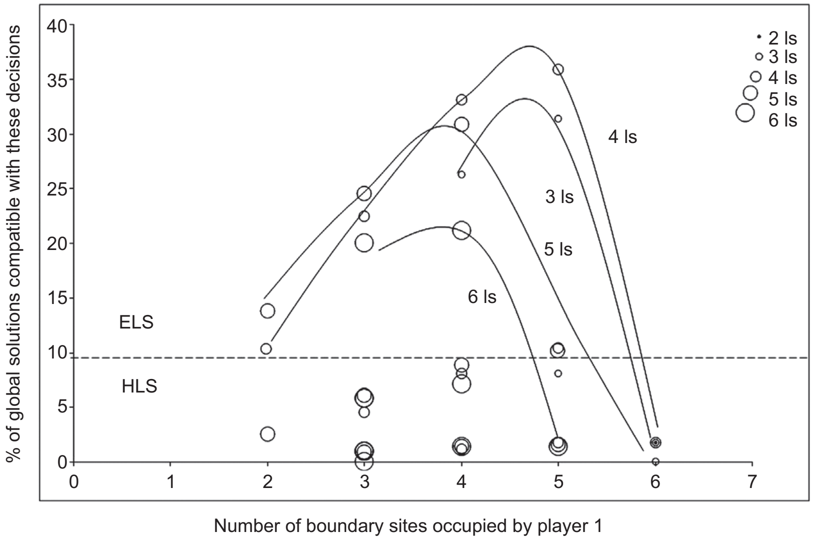

Figure 3: Possibility-Frontier Curves of local solutions (assumed to be player 1s) as a function of the number of I's in the solution, and of the number of boundary sites that it requires. ELS and HLS=easy and hard to coordinate local solutions, respectively.

of compatible GS is hump-shaped. The higher the Is the lower the hump. Four I's and five boundary sites (one more than a player's fair share) produces the optimum LS; deviations in both directions become harder to coordinate. But this optimum LS can hardly be replicated by more than one player as only 6% of GS support it twice. This clearly exemplifies one of the coordination dilemmas of the game: most ELS imply a Pareto improvement as long as only one player adopts them; beyond that, the ELS becomes a HSL and the risk of coordination failure increases significantly.

The second coordination dilemma of SS arises when one player has created a serious threat of resource collapse, or remains trapped in a HLS, or when players seek simultaneously a Pareto improvement that will transform an ELS into a HSL. In such circumstances, who should reforest? Who should change his Is and/or reduce his boundary sites? Who will prevail and who will yield? Figure 4 shows a possible trajectory involving all four players: Pareto improvements by one player (AB) are followed by attempts to Pareto improve by a second player (CD), which leads to coordination failure (E). Subsequently, alternative chicken games can either restore (F1), improve (F2), or worsen the risk of failure (F3).

We may now derive the main lesson of these analysis. Reaching the equitable livelihood goal in a limited time while avoiding the four unfavorable environmental responses sets the need to properly combine and display land

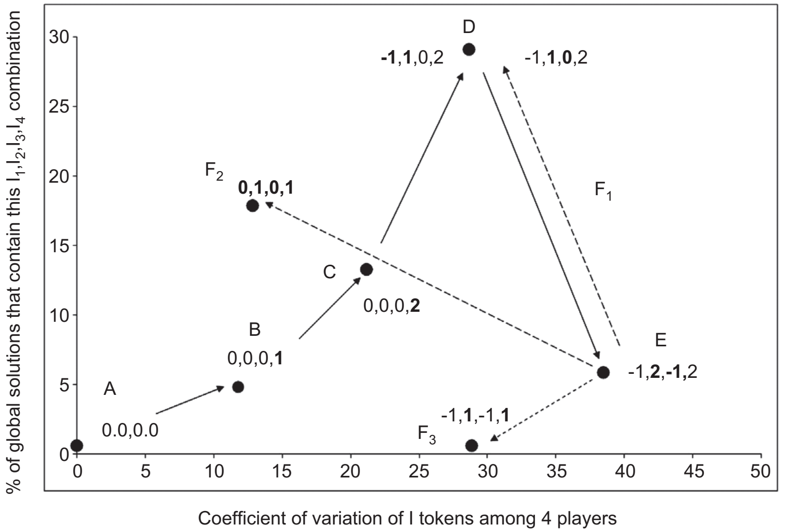

Figure 4: Pareto improvements, chicken interactions and risk of failure. The X axis is a measure of inequality in number of Is placed by each player on the board. Actual number of Is is not disclosed in the graph for the benefit of future players. At A, all players have an equal amount of I's on the board. In B and C, player 4 has improved his score and also made coordination easier for all. To follow up with player 4, player 2 has dominated players 1 and 3 at D and E respectively. Further interactions can restore D (F1), improve the situation (F2), or worsen it (F3). Bold numbers indicate what players interacted to produce the situation.

uses at different spatial and social scales (household, neighborhood and whole territory). In doing so, each individual "land owner" needs to discover that there may be a complex and strongly non-linear relation between (a) her zeal to either accumulate income in a competitive way or protect the common natural resources, and (b) the probability of finding a solution in which all the stakeholders can coordinate to acquire a sustainable livelihood. Most notably, near-symmetrical distributions of land uses within and among landowners demand less fine-tuned coordination efforts. Near symmetry requires individual restraint from preempting boundary sites, but individuals have incentives to pareto improve and play chicken games at these sites to increase or maintain there scores. A lack or an excess of collective will to engage in boundary site interactions will increase the probability of coordination failure, albeit in a complex way. Due to the complexity of the game – and of social life – such discoveries are not an easy task for any individual or group, and its lack of fulfillment can impede a global solution in a reasonable time. We will now focus on how different groups of individuals "negotiate" their way in trying to solve the complexities of such a planning problem.

Figure 5: Players engaged in the four individual level coordination strategies. S=Suggests; C=Controls; F=Follows; P=Plays Alone. The image has been obscured for anonymity.

5. Individual coordination strategies to overcome the social dilemmas

Before playing the land use coordination game with SS, participants play a competitive variant with the same rules, except that players take turns, varied by a random die. Whomever makes 24 points first "wins." Thus, the players gain familiarity with the game and become aware that their individual decisions are interdependent. Yet, when moving on to solve the coordination game, they can differ strongly in their urge to communicate, coordinate and lead the process.

Four stylized courses of action have consistently appeared among players in 40 sessions with agroecology and rural development students and with rural stakeholders: We named them Controls, Suggests, Follows, and Plays Alone (Figure 5). We will now describe them as strategies to overcome the social dilemmas of this interactive, adaptive planning exercise, and classify them according to trust, proactiveness in offering group solutions, and autonomy.

Social agents are seldom selfish rational individuals but rather learning and norm-adopting agents (Anderies et al. 2011). They bring many dimensions of human behavior both to the game and to real life land-use planning and land-use conflict resolution in rural areas (Cárdenas and Ostrom 2004). These complex-coordination processes mobilize both cognitive/rational abilities and emotional/social behaviors (Damasio 1994). In order to capture these dimensions in a stylized form, we describe and classify the four strategies as combinations of (a) the ability and will to communicate during the game and to offer solutions and suggestions to the group and (b) the level of trust in others' motivations (Ostrom 1998) and in self and others' abilities (Melaville et al. 1997). The way group members collaborate, coordinate and exert power in groups reflects different forms and issues of individual versus group autonomy (Janz et al. 1997; Langfred 2000; Hoegl and Parboteeah 2006). The way (a) and (b) combine in our classification also reflect these forms of autonomy.

Strategies:

A **Plays Alone** (high trust in self with a low trust in others, unwilling or incapable to offer global strategies and solutions)

All approaches might include a short initial exploration of the quadrant with little interaction with others, but "Plays-alone" persists in his isolation as long as possible. If the player trusts his abilities and motivations more than others and does not "see" early on a global solution he can offer, the best strategy seems to continue to ignore others and solve locally, occupy as many sites as possible with high-value tokens, and later negotiate and coordinate changes with other players if strictly necessary and on a case-by-case basis. Ironically, this low level coordination strategy eventually demands very tight coordination and stressful negotiation to solve the puzzle. This player exerts his power as individual autonomy at the local level. Extreme attachment to a local solution can impede the global solution.

B **Controls** (high trust in self with a low trust in others, eager to offer global strategies/solutions)

This player trusts his abilities and motivations more than others. He is eager to control the coordination process because he "sees" early on what he thinks is a global solution or promising global heuristic, and/or because he is acutely aware of the risks of not coordinating and controlling the search process. This player exerts his power at the global level through leader-autonomy. Ironically, if control is too tight and the controller is wrong, then "group think" or strong resistance develop and solutions are not found in a reasonable time, if at all.

C **Suggests** (high trust in self and others, interested in offering global strategies/solutions)

This player trusts his abilities and motivations as much as others. He is aware of the need to coordinate but sees it as an adaptive process of continuous deliberation to select and accommodate others' suggestions and needs. He is confident that global solutions or promising global heuristic will emerge from the collaborative process. This player exerts his power at the global level through actively building group leadership and by balancing individual and group autonomy.

D **Follows** (low trust in self and high trust in others, feels incapable or uninterested in offering global strategies/solutions)

This player trusts leaders' motivations, and values their ability more than his own. He is passive and can be fascinated by controllers but also accommodates passively to group-level leadership. He lacks autonomy and exerts his power by "free-riding on the shoulders of giants".

6. Players perceptions of self and others coordination strategies

Forty groups of 4 persons played SS in 12 local, national and international workshops during 2009 and 2010. Once a group completed the puzzle, each player was assigned a visible ID number and received a written questionnaire which asked him to anonymously characterize his and other's predominant behavior during the game, using per player only one of the four following descriptions:

During the game, Player N:

A. Offered ways of solving the puzzle, insisted strongly on his (her) proposals and moved other player's tokens.
B. Offered ways of solving the puzzle, listened to other's suggestions and did not move other player's tokens.
C. Did not offer ways of solving the puzzle, followed other's suggestions and allowed others to move his tokens.
D. Did not offer ways of solving the puzzle, did not follow other's suggestions and played alone in his quadrant.

Thereby, each group of 4 players produced 16 perceptions on the individual behaviors during their game. The relative frequency (percentage) of each answer was calculated per group.

The 12 workshops and 40 board games ran smoothly. Players accepted the goal of the SS Game and found the rules reasonable. They agreed to the time limit and to the anonymous questionnaire.

We considered the possibility that performance might bias the group's perception of its own behaviors (i.e. there could be a positive correlation between them; Allison et al. 1996). For 15 groups that had external observers, we analyzed if there was a positive or negative difference in the number of (C+S) reported by players and observers, and if such difference was correlated with de-trended time. We found that: (1) players reported on average only 5% more (C+S) than observers. (2) Such bias did not correlate with time to solve the puzzle (R2=0.05; p=0.47). (3) Groups that did not finish reported also more (C+S) than observers.

Six hundred and forty reports were produced by 160 players. Overall, 51% of the reports were "Suggests," 23% "Follows," 14% "Controls" and 12% "Plays

Alone." Within groups, the Suggests reports ranged from 6% to 100% while all other ranged from 0% to 50%.

7. Towards an integrated description of coordination at the group level

When a group of players starts a game, each individual will have a propensity towards a particular coordination strategy, but we should expect players to adjust to how they perceive the group's composition, how the strategies interact, and how the game unfolds. Thus, we should expect the four individual coordination strategies (ICS) within groups to be correlated beyond the trivial fact that their relative frequencies sum up to 100.

An increase in the percentage of Suggest reports within groups significantly correlated with a decrease in all other strategies ($p<0.01$ in all three cases). An increase in the percentage of Control reports did not affect the percentage of Play Alone reports ($p=0.3$) and increased the percentage of Follow reports ($p=0.02$). Note that by the very nature of the data, an increase in percentage of one of the ICS will show a perfect (and trivial) negative correlation with its complement

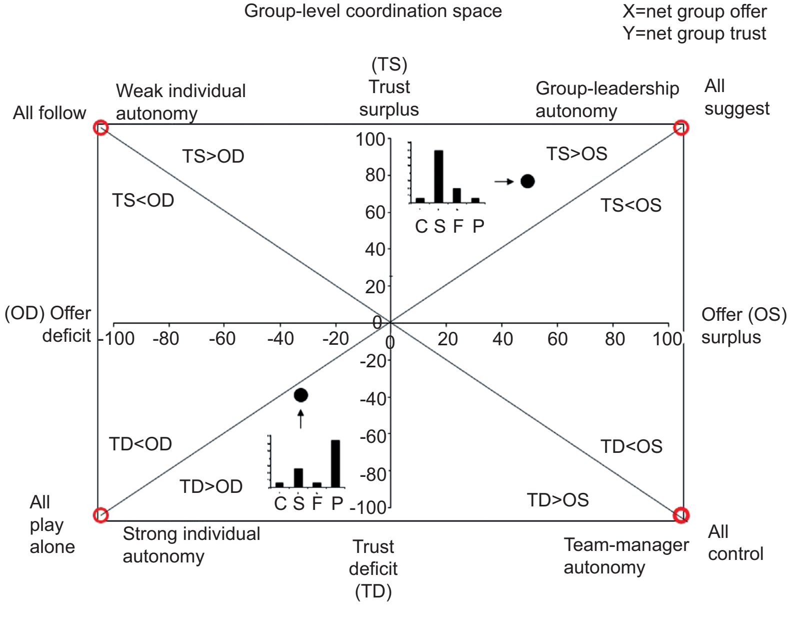

Figure 6: "Group-Level Coordination Space." The horizontal axis is the net proportion of perceived offerers in a group: X=(C+S)–(F+P). The horizontal axis is the net proportion of perceived trusters in a group: Y=(S+F)–(C+P). Thus, the frequency distribution of S F C P reports made by a group (small histogram inside the figure) is represented by a point. See the main text for further explanation.

– the algebraic sum of all other ICS percentages. However, each ICS does not have to correlate negatively with all others taken separately. These results show that the effects on other ICS of increasing Suggest and of increasing Control are qualitatively different.

When bringing to the table sets of four players, the studied ICS can combine in many different ways. If we assume that these ICS can be somewhat synergistic or somewhat antagonistic, then distinct combinations of ICS (say C-S-F-P versus C-C-P-P) might differ in their "net proportion of trusters" and/or "net proportion of offerers." A first step in analyzing these combinations is building a way to map them onto a meaningful group-level coordination space. For this purpose, we devised a Cartesian plane which we will call "Group-Coordination Space" (GCS) (Figure 6) where the horizontal axis is the net proportion of offerers in a group: *X=(C+S)–(F+P)*. The horizontal axis is the net proportion of trusters in a group: *Y=(S+F)–(C+P)*. (C equals percentage of Controller reports; S equals percentage of Suggest reports;

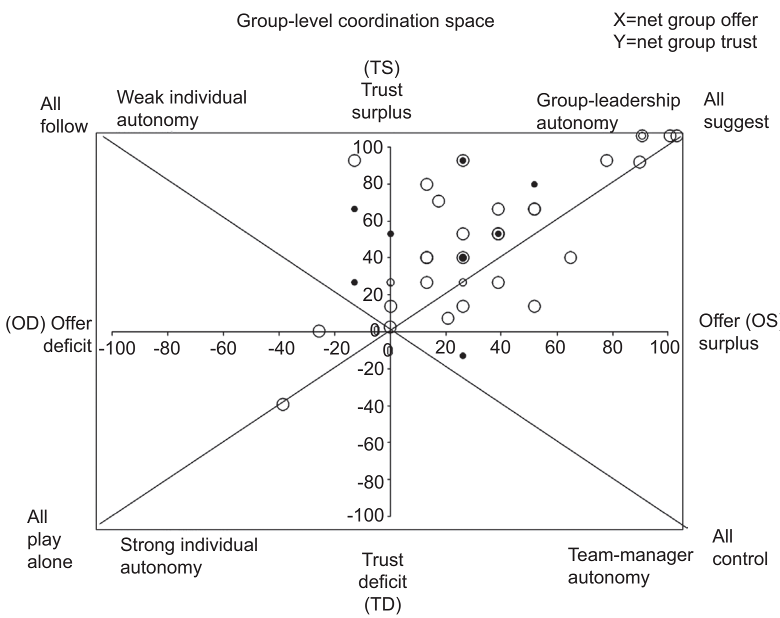

Figure 7: The position of the 40 groups in "Group Coordination Space." Big open circles=Agroecology and rural development students (undergraduates to PhDs, but mainly MScs). Small open circles=Seasoned rural sociologists and graduate students in RPG workshop. Small filled circles=Multiactor groups (farmer leaders, government officers, NGOs, researchers) in a RPG workshop. The three subsets of players did not differ statistically in their XY position in GC space. See the main text for further explanation. Some points fall on the same x,y coordinates.

F equals percentage of Follow reports; P equals percentage of Play Alone reports within a group.)

Each group (i) of 4 persons playing the game has coordinates (Xi, Yi) in this space. In our study, these coordinates were defined by calculating what percentage of the 16 reports made by group (i) fell under each ICS.

The center (0,0) represents a balance between trust versus mistrust and between offers versus no offers reports. The diagram is divided into 8 subspaces that describe qualitatively the type of imbalance between the net trust and the net offer of the groups that fall in each of them. For example, a group with 25% "Control" reports and 75% "Follow" reports would fall under "offer deficit > trust deficit," while a group with 75% "Suggest" reports and 25% "Control" reports would fall under "offer surplus > trust surplus."

The corners in the graph represent those groups with 100% of a single coordination strategy (say, all suggest), with the impossible case "all follow" included for completeness. The other three corners represent "all suggest," "all control" and "all play alone" which are contrasting group-level coordination strategies (group leadership autonomy, manager-type autonomy and strong individual autonomy, respectively).

Figure 7 displays the results from 40 groups in Group-Coordination Space. These were divided into three subsets according to different social composition of groups: (1) Agroecology and rural development students (undergraduates to PhDs, but mainly MScs). (2) Mixed-generation rural development scholars in an RPG workshop (seasoned rural sociology researchers from major Mexican universities, and graduate students). (3) Multiactor groups (farmer leaders, government officers, NGOs, researchers) in RPG workshops. The three subsets of players did not differ statistically in their X and Y position in GC space.

"X=Net Trust" and "Y=Net Offer" in the GCS showed a significant positive linear correlation (R=0.64; p<0.01) but not to the point of being redundant explanatory variables (R2=0.41). Most groups fell within the upper quadrant (Surplus Offer, Surplus Trust) in Group-Level Coordination Space. Values at or near corners were only found for the "All Suggest" group coordination type. Groups with different socio-cultural conditions (graduate students, mixed generations of rural development scholars, actual watershed stakeholders) did not differ significantly (p>0.5) in their position in GCS.

8. Discussion

A large literature has emerged on what could be the paths towards sustainable rural societies. Some of it (e.g. Gunderson and Holling 2002; Taylor 2005; García-Barrios and García Barrios 2008; Ostrom 2010) has focused critically on the assumptions of "top to bottom," techno-scientific approaches, that describe modern socio-environmental processes from the perspective of controllable processes and systems. Serious attempts have been made to construct a local notion of sustainability, based upon the concept of strategic cooperation, which allows redefinition and organization of public activity as a gradual process of social construction from the bottom to the top in a perpetual win-win dynamic. However, new institutional economic literature (Bowles 2005) has extensively reviewed several profound dilemmas of strategic cooperation. We presented a theoretical framework and a simple representation of the various dilemmas that may be expected in watershed distributed management, in order to help understand some of the issues that arise when considering participatory planning as a means of formation of shared expectations.

There is strong debate over the effectiveness of “bottom-up” vs. “top-down” approaches to rural land use planning (Agrawal and Gibson 1999). Within advocates of local participatory processes, some cast doubts about those supposedly participatory approaches that end up empowering the already powerful (Rudqvist and Woodford-Berger 1996; Barnaud et al. 2007). Participatory role playing game designers are keen to avoid such situations (Barnaud et al. 2007) by trying to make them instruments that effectively promote inclusion, communication, reflection and social learning among stakeholders in conflict.

We are currently developing companion modeling experience in a locality in Chiapas, Mexico. We have found that the process can be strengthened by incorporating simple stylized and generic games such as SS that explicitly address and expose in safe and instructional environments the dilemmas stakeholders confront and the emergent human behaviors that obstruct cooperation and coordination. We are trying to avoid a situation where reflection over these dilemmas and behaviors remain implicit, lost in details, or as mere anecdotes in debriefing sessions.

SS was specifically tailored to generate coordination dilemmas. Its tractability allowed us to derive the solution set, and the torturous relation between individual and collective solutions produces a complex, risk prone, but solvable coordination-dilemma game. Further analysis of this solution set can be a powerful resource to design new rules for relevant lab and field experiments.

The game’s strong focus on coordination exposed four individual strategies that appeared consistently in groups of players. Cooperative human behavior as a means of addressing coordination and cooperation has many dimensions. From a collective action perspective, Ostrom (1998) focuses on human behaviors related to communication, coordination, reciprocity, trust, shared norms, reputation, incremental sanctions and other conditions leading to cooperative performance. Cárdenas and Ostrom (2004) identify individual, group context, and material payoff dimensions that affect the actual cooperative behaviors and decisions a player “brings to the game”. Other fields of research (e.g. social psychology, business management, learning) also identify multiple dimensions in cooperative human behavior and focus on team roles (Belbin 1993), individual and group autonomy (Hoegl and Parboteeah 2006), and leadership (Zaleznik 1992). We attempted to explain the four observed behaviors by integrating well established elements of these different research fields and frameworks, with emphasis on trust and forms of leadership and autonomy.

The game's generality allowed it to be played repeatedly with a stable survey protocol and to describe a robust distribution of coordination strategies. Three quarters of reports were S+F (positive net trust) and 2/3 were S+C (positive net spontaneous engagement in communicating and offering solutions). Significant correlation among the frequencies of some strategies were found; Suggest reduced Follows and Plays Alone while Controls increased them. This conforms to previous findings by Samuelson (1991).

Eighty-five percent of the groups fell within the upper right quadrant in Group Coordination Space. Yet, 15 percent of groups could not properly coordinate their actions in the 45 minute time limit, and few groups approximated and perceived full "cooperative-leadership" coordination where all or most suggest. This means that there is opportunity for players (both multi-stakeholder groups and students) to develop this capacity.

Allison et al. (1996) warn that in some cases performance might bias the group's perception of its own behaviors, but we did not find significant bias. Concerns were raised whether players would admit – even anonymously – that their strategy was "I offered ways of solving the puzzle, insisted strongly on my proposals and moved other player's tokens." Underestimation of "controls" could have occurred but for the opposite reason. In a recent set of 22 groups playing a variant of the SS game we separated self and other's descriptions; controls appeared more frequently as a self description than as a description by fellow players.

We proposed a simple, linear way of mapping in 2D the profiles of coordination strategies at the group level (GCS), to observe their diversity and frequency. Yet, fully understanding the group-level coordination dynamics that emerges and how it relates or not with various dimensions of performance awaits further work. This includes playing the game with groups of farmers and applying more detailed monitoring and surveys.

Rigorous and carefully crafted lab and field experiments incorporating spatially explicit resource dynamics have found that the intensity and equity of communication among players correlates with the capacity to harvest a CPR sustainably (Janssen 2010). Such studies have also found that students in the lab and farmers in the field tend to make similar decisions when spatially explicit dynamics are incorporated (Janssen et al. 2011). This latter is in line with our finding that graduate students and actual multistakeholder groups were not significantly different in Group Coordination Space. Overall, this suggests that it could be useful to further develop the social experiment protocol of SS. One of the authors (A.W.) has recently finished an online virtual version of the game and is developing automatic processes to capture, as the game unfolds, token movements, player chat and context-specific questions, along with the compliance and anonymity of players, as suggested by Anderies et al. (2011).

9. Conclusions

We have shown that SIERRA SPRINGS is a complex-coordination game that explicitly addresses in a stylized way relevant land-use coordination dilemmas and exposes interactions between individual coordination strategies that could positively or negatively affect participatory land use planning.

CPR investigators currently strive to understand why many social groups self organize at different scales to sustain resources and governance institutions while others do not. They consider that research needs be advanced at three interrelated levels: (a) the broader social-ecological context, (b) the micro-situation impinging on individuals in a collective action situation, and (c) individual human behavior (Poteete et al. 2010).

Companion Modeling and similar approaches are generating an increasing diversity of role playing games, including water sharing and land use adaptive planning at the watershed level. (Collectif ComMod). Many powerful RPGs are more realistic than lab experiments and deal with these questions with an extensive number of rules, variables and stakeholders in a very adaptive and open-ended way. The cost is that it becomes difficult to reproduce the results and to make systematic comparisons as many factors are uncontrolled (Bousquet et al. 2002).

The SS game described here could counter this tradeoff by being used with rigorous research protocols of second generation lab and field experiments. For example, SS could further the analysis of coordination dilemmas and behaviors that are increasingly arising in small-holder rural settings where collectively held land has been privatized but where remaining CPR are negatively affected by decisions – now righteously defended as each farmer's private matter – about land use proportions and distribution.

We and many researchers (e.g. Barnaud et al. 2007; Sandkler et al. 2010) expect an increasing need for landscape-level cooperation and coordination in order to strengthen adaptive co-management and governance of social-environmental processes. While developing more sophisticated RPGs and scenario simulators, we have continued to find SS to be both a promising research tool and a good introduction to coordination dilemmas and strategies for those stakeholders involved in building and/or using more realistic role playing games in the context of participatory rural land use planning.

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