A gaming approach to explore agricultural decision making

Case study on climate change adaptation

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Psalms 96:4

Abstract

Agricultural decision-making is essentially making land-use choices in a complex agro-ecological environment while facing risk and uncertainty. Role playing games present a way forward in realistically simulating the decision environment and its interactions as well as facilitating collective learning on the decision making processes. In this study we explored the influence of communication, leadership and relatedness on individual and collective land-use choice. In order to explore decision-making within a group we re-designed and modified the RESORTES board game slightly to develop a role playing game with aspect of climate change. Master students from Wageningen University and Research were drawn as participants to enact and explore the benefits and challenges of complex collective land-use decision-making in climate change adaptation. The role playing game reflected that land-use choices in rain-fed smallholder agriculture are based on climatic conditions. We found that communication positively influenced agricultural decisions on land-use choices for individual and collective benefit. Within a group the level of communication and the number of suggestions are significantly related to relationships of individuals as well as diversity of backgrounds of the individuals. High relatedness among individuals in a group leads to more suggestions made to each other. Leadership is essential in formulating a collective decision that encompasses both the collective and individual objectives. We found that multi-actor leadership leads to diverse land-use strategies while single-actor leadership results in limited strategies in land-use choices. Furthermore, we found that perceived leadership is not limited to the contribution of an individual. Our results reflected that in collective decision-making it is essential to consider the social dynamics of the group. Role playing games allow for in-depth study and co-learning on effective decision-making that leads collective benefit in social-ecological systems.

Key words: role-playing games, land-use choices, communication, relatedness, climate change adaptation, decision-making

1 Introduction

1.1 Background

Agricultural decision-making is essentially making land-use choices in a complex agro-ecological environment towards meeting farmer objectives (Wahab, 1996). The planning of mixed farming systems with an array of crops, animals and other resources is complicated since it involves management decisions on land-use choices and resource allocation (Groot *et al.*, 2012; Russell 2007). The variation in household management goals, objectives and choices has led to heterogeneous soil-crop-livestock interactions, resulting in different farming systems. Challenges of limited internal resource availability and competing claims to these resources in order to meet the farmer objectives have often led to conflicting schemes in decision making at the farm and community level (Giller *et al.*, 2008). Furthermore, challenges in agricultural decision making are exacerbated by the need for farmers to make decisions that deal with risk and uncertainty.

At farm level, farmers also face risk and uncertainty in decision making as a consequence of external constraints (e.g. bio-physical, economic, social components) that prevent the farmer from reaching their goals. Uncertainty is the existence of imperfect knowledge of the unpredictable occurrence of an event causing the inability to control outcomes, while risk is the exposure to a potential loss or a gain as a result of the uncertainty associated with pursuing a particular course of action (Hendrix, 1989). Uncertainty in farm-household decision making is created by three major types of factors, namely environmental, economic and social factors (Wahab, 1996). Variability in climatic conditions is one of the major uncertainties that farmers face and is projected to have a wide range of effects on smallholder farmers' livelihoods (Wardekker, 2011).

The bulk of the global agricultural production is mainly rain-fed agriculture, leaving it vulnerable to the unprecedented phenomena of climate change and increased climate variability (Kotir, 2010; IPCC, 2015). The projected trends in climate change and their potential negative impacts on agricultural production give urgency to addressing climate change adaptation in agriculture (Howden *et al.,* 2007). The need to adapt to climate change is now becoming widely recognized, due to undebatable evidence of the negative impacts of climate change on the natural, economic and social system (Wise *et al*., 2014). In the context of climate change, adaptation is defined as "the adjustment in natural or human systems in response to actual or expected climate changes or their effects, which moderates harm or exploits beneficial opportunities" (UNFCC, 2007; Government of Zimbabwe, 2013). Adaptation also includes responses and reactions from different sectors, from farm level to international level, aiming towards climate induced risk reduction (Howden *et al.*, 2007). Therefore, it is of paramount importance to align the scales (temporal, spatial and sectorial) and the nature of the decision to adapt to climate change (Howden *et al.,* 2007).

While there are different perspectives on the objectives and goals of climate change adaptation at farm level, the overarching goal of reducing the negative effects of climate change and increasing any possible benefits resulting from a hazard remains (Burton *et al.*, 1993). Adaptation to climate change highlights the importance of the interdependency of agents (e.g. individual farmers) through their relationships with each other, with the institutions in which they reside and with the natural resource base on which they depend (Adger *et al.*, 2003). Social and cultural values play a key role in aligning individual farmer activities and goals with the communal goals, as well as creating platforms to negotiate on the complexities arising from diverse goals and values. Positive effects of agricultural and natural resources management related groups have been observed in facilitating multi farm-level changes e.g. switching to improved seeds and response to market factors (Wood *et al*., 2014). In smallholder communities, where farmers manage a mosaic of plots, it is essential to coordinate agricultural activities at a communal level (Herrero *et al*., 2010). However, coordination can be quite challenging. Particularly, since individual farmers are influenced in their decision making by dilemma's and often conflicting schemes, such as economic incentives that might weaken collaboration among community members (Speelman *et al.*, 2014). In resolving these dilemmas, relationships of trust, reciprocity and exchange and collective action are core to decision making processes towards climate adaptation (Agder *et al.*, 2003). Therefore, the study of key factors that influence successful collaboration and coordination in agro-ecosystem design and land-use planning are paramount to climate change adaptation.

Agricultural decision making in complex socio-ecological systems involves numerous and diverse interactions between actors, as well as with their environment (Barreteau *et al*., 2007). Recent studies describe research methodologies that allow participants to safely enact and explore benefits and challenges of complex collective land-use decision-making processes (e.g., Speelman *et al.*, 2014, Villamor and Badmos, 2016; Kotir *et al.,* 2016). Games present a way forward in realistically simulating the decision environment and its interactions (Barreteau *et al*., 2007). These games have the potential within a system to facilitate collective learning on complex systems, foster a constructive dialogue among stakeholders and raise awareness of natural resources management. Furthermore, games can be used to explore agricultural decision making, address land-use coordination and observe social networks interactions and decision making processes that influence climate change adaptation.

1.2 Research context

Sub-Saharan Africa (SSA) is one of the most vulnerable regions to climate change (IPCC, 2015). Smallholder farmers' high dependency on rainfall for agricultural activities leaves them exposed to the negative impacts of climate change (Kotir, 2010). In Zimbabwe, 90% of agricultural land is under rain-fed agriculture and smallholder farmers own three quarters of this land (Nyagumbo *et al.*, 2007). The adverse impacts of climate change threaten to increase the vulnerability of the majority of smallholder farmers, who are already facing severe challenges of food insecurity and a declining natural resource base (Mapfumo *et al.*, 2013). Furthermore, climate change adaptation decisions are being made on the basis that is marred by incomplete knowledge and understanding on the impacts of implementing different adaptation strategies (Daron, 2014). Many of the problems stem from the absence of a cohesive framework that brings together technical and social threads during the process of decision making (Kellon and Arvai, 2010). Thus, it is paramount to examine key factors that influence decision making processes in land-use planning towards climate change adaptation.

1.3 Research objectives

The main objectives of this study are:

1. To explore individual and collective land-use decisions under distinct climate conditions,
2. To identify the role of influential factors (communication, leadership, relatedness) in agricultural decision-making processes.

The main objectives will be reached by addressing the following research questions:

1. How do farmers in Zimbabwe see climate change and adaptation options in their systems?
2. How does climate information relate to individual and collective land-use decisions?
3. How does communication, leadership, relatedness influence individual and collective land-use decisions?

2 Methodology

The research was divided into three main parts namely: 1) Game development 2) Data collection-game sessions 3) Data analysis (Figure 2.1). The three stages were used to develop and implement a gaming approach for exploring decision making processes in climate change adaptation, based on smallholder farming systems in Zimbabwe.

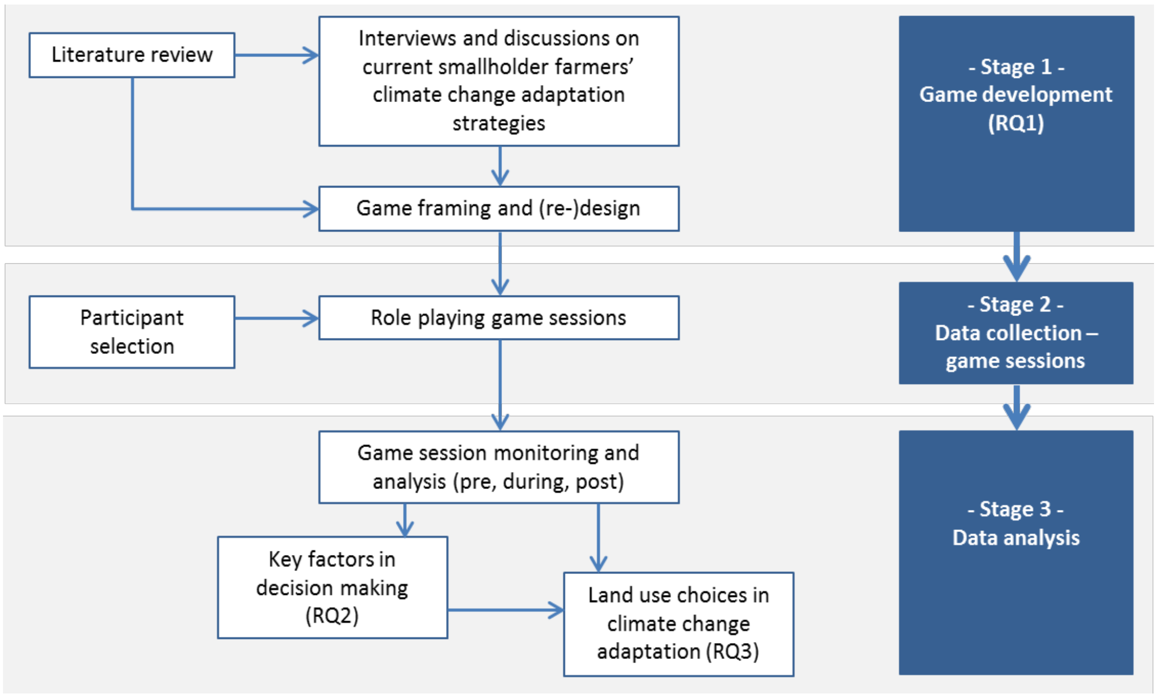

Figure 2.1: Schematic outline of the research study

The first stage in the research was to identify distinct climatic conditions and land-use choices in smallholder farming systems in Zimbabwe. Data on smallholder farming systems in Zimbabwe was collected through a combination of literature review, expert interviews and discussions with smallholder farmers in Zimbabwe. We conducted three focus group discussions (women only, men only and men and women combined) and interviews with extension workers, local researchers and community leaders. The collected data was used to design and develop a game that gave a realistic representation of the interactions in the smallholder farming system. The game was based on the RESORTES board game (Speelman *et al.,* 2014). The game was redesigned to contain elements of different climatic conditions, land-use choices and social interactions found in smallholder farming systems in Zimbabwe. Following the game development, a laboratory experimental method was used for game sessions to define and evaluate key factors in decision making (RQ2) and observe land-use choices in climate change adaptation (RQ3).

The laboratory experimental setting allows to observe and analyse human behaviour in decision making in a controlled environment (Kopelman *et al.,* 2002; Ostrom, 2006) (Figure 2.1, stage 2). The third stage involved analyses of motivations of the game participants towards the actions taken during the game. The third step led to inductive interpretations of how key decision making factors (RQ2) are related to land-use choices in climate change adaptation (RQ3) in real case scenarios.

2.1 **Game development**

Game framing is the process of defining how a situation is built up, the principles of organization that govern the events – at least social ones – and actor actions and their subsequent outcomes (Goffman, 1974). In this research, we developed a game based on smallholder farming systems in Zimbabwe, Mashonaland East province.

Using literature and expert interviews, we identified the distinct climatic conditions categories used by farmers in Hwedza. During discussions and interviews, farmers were asked about their perspective on climate change and the land-use choices they made in different climatic conditions. The collected information was used for designing a board game and assessment forms (pre-game interview, in-game questionnaire and post-game survey) to explore decision-making in climate change adaptation

The smallholder farming communities in the Eastern region of Zimbabwe are in the hotspots of climate change. We used Makwarimba village (18o 37’ S 31o 34’ E 1100 m.a.s.l.) in Hwedza District, Mashonaland East province as an example. In this farming community 90% of the farmers depend on rain-fed agriculture (Mapfumo *et al.,* 2015). Farming systems in Hwedza are mostly crop livestock farming systems. The main crops grown in the area are maize, groundnut and cowpea and the farmers mainly keep cows, goats and chickens for livestock production. The village is structured nucleating around a road to the nearest business centre (Hwedza Township). The homesteads form the epicentre of the community with the field plots surrounding the homesteads.

Smallholder farmers and extension officers from the Ministry of Agriculture concurred that climatic conditions being experienced in Makwarimba were now varying without any systematic pattern and was becoming more unpredictable than before. From the focus group discussions, we found that they categorized climatic conditions based on rainfall received per year into three distinct categories namely: wet year, dry year and normal year. Wet year was defined as a year with rainfall above what they are used to, while a dry year referred to a year with lower rainfall that they are used. Farmers in Makwarimba village acknowledged that they were experiencing climate change. However, their opinions differed on which agricultural activities to carry out for each distinct climatic condition. Using the information from smallholder farmers, we developed a role playing game.

2.1.1 **The role playing game**

The role-playing board game was developed based on the RESORTES board game (Speelman *et al.,* 2014). The RESORTES board game was re-designed to include climatic conditions affecting smallholder farmers in Zimbabwe. The role-playing (adjusted RESORTES) game was a cooperative, non-zero sum, goal seeking game developed to examine decision making on land-use choices for climate change adaptation. The game assessed players' decision making processes in the face of climate change as well as potential benefits from cooperation with other participants (Box 1).

The game was played on a board with four quadrants representing a communal landscape (Appendix Figure 2). Each game session comprised of six participants, enacting farmers with four plots each. In the first round of the game participants took turns to select plots with each player selecting a plot one at a time. Plots were selected once during the game and remained fixed for the rest of the round. Following the land selection rounds in each game session participants played four agricultural production rounds. Before each agricultural production round started a weather dice was rolled to determine the weather condition for that round. Thereafter participants selected land-use activities for their four plots, allocating one activity per plot. Land-use choices could be changed without limitation during agricultural productivity rounds. Land-use choices were selected between high-risk crop, low-risk crop, high-risk livestock or low-risk livestock. The points per round were determined once all plots had been allocated a land-use activity.

The participants during the game earned their points based on (i) land-use activities and (ii) coordination benefits among participants. The land-use activities were determined by a set of dice. We used a high risk and a low risk dice for the climatic condition for that round. The points for each climatic condition are shown below (Table 2.1). The average for all the dice was the same. The coordination benefits were additional points obtained by participants through the crop production additional points scheme (C.P.A.P) and/or the livestock production additional points scheme (L.P.A.P). C.P.A.P additional points were earned by participants with plots in a quadrant with eight crop based land-use activities. The additional points result from additional benefits that irrigation systems are easier to install on a smaller scale for fields clustered together. L.P.A.P additional points were obtained to participants with livestock plots if the total of livestock plots on the landscape summed up to ten or more. This is because with a number of livestock production activities it is easier and economical to install a central water supply infrastructure (e.g. borehole) to improve productivity. The points were summed up for each round to determine the overall winner of the game.

For this study, we focused on the additional points. This was because points from any of the four randomly scored land-use types have the same statistical expectancy (Speelman *et al*., 2014). The optimum strategy for a single player to obtain the highest was to occupy all four quadrants. The score could be attained through obtaining additional points through the L.P.A.P scheme and then free-riding on the C.P.A.P. (Calculation based on Speelman *et al.*, 2014).

Box 1: Detailed game description

Game goal

The player wins the game through accumulating the highest points

Game objective

(1) To discuss, practice and evaluate agricultural activities and decisions under varying climatic conditions.

(2) To observe and analyse

- Individual and collective decisions on land-use activities for different climatic conditions;
- Factors influencing collective decision-making (e.g. communication, leadership, relatedness).

Resources

The game requires

- Game board of 37 connected hexagons divided into four equal sized quadrants;
- 24 field selection cards (4 cards per player) of six different colours;
- 96 land-use activity cards – 4 sets of 24 cards;
- 1 Weather dice – a dice with 3 sets of 2 similar sides (D for dry year, N for Normal year, W for Wet year);
- 2 Score dice – 2 dice one with a large range and one with a larger range of numbers, the average of the two dice are the same;
- Score board.

Actors

The game can be played by six players, one facilitator and one assistant.

Game mechanics

Before the game starts the facilitator clearly explains the game rules to ensure all the players understand the rules of the game. The explanation of the rules is followed by an extensive practice session or round for all the players to familiarise them with the rules of the game via a thorough discussion. Following this the game starts with the players selecting field locations of their choice. The players take turns to select fields one at a time until all the players have selected four fields per player. Once all fields are selected, the last player to select the field location then rolls the weather dice to determine the weather condition for that round. Once the weather has been determined the players can start to select land-uses to the fields, one activity per field. The players can choose between high-risk (HR) crops (cereals), low-risk (LR) crops (pulses), LR livestock (small ruminants and poultry) and HR livestock (large ruminants). Before proceeding, all players need to be satisfied with their selected land-use activities. In the land-use allocation rounds, players do not take turns and changes can be made until they are happy with their choice. At the end of each land-use allocation round, the HR and LR dice are rolled. Then, the points per player are calculated and indicated on a scoreboard. The facilitator will highlight the round's source of additional points based on the land-use activities carried out by the players. In this study, all game sessions were played for four rounds. After the game, a debriefing took place where participants were asked to fill in an end of game questionnaire followed by a focus group discussion with all the participants.

Game rules

The facilitator administers the rules of the game to the players:

1. Players take turns to select fields. Each player selects one field on the board per round.
2. The field location is only selected once throughout the game and cannot be changed throughout the game.
3. Every round the players can allocate and change the land-use activities for as many times as they see fit on their four fields.
4. Points are earned based on the individual land-use decisions and additional points from cooperative and collaborative choices with the other players
5. There are additional points.

a. If on the whole board the total number of plots with livestock production activities (either HR or LR) sum up to ten and above four additional points per field with a livestock production activity are awarded.

b. If a quadrant has at least eight crop production activities (HR or LR) on its plots/fields all the players in the quadrant receive five additional points.

6. A weather dice is rolled first before players allocate land-use activities for their plots. The weather dice determines the weather condition for that round. After land-use choice allocation a high risk and low risk dice for the current weather in that round are selected and rolled. The two dice give point for high risk and low risk. The points vary per weather condition as illustrated in Table 2.1.

Table 2.1: Points on the different dice for different climatic conditions.

	Climatic conditions					
	Normal year		Wet year		Dry year	
	High risk dice	Low risk dice	High risk dice	Low risk dice	High risk dice	Low risk dice
	20	11	25	12	15	10
	15	9	17	9	11	8
	10	7	13	7	7	6
	0	3	0	4	3	4
	-5	1	-10	0	-1	3
	-10	-1	-15	-2	-5	-1
Average	**5**	**5**	**5**	**5**	**5**	**5**

2.1.2 Laboratory experiment - Game participant selection and data collection

The laboratory experiment study was performed between October 2016 and November 2016 at Wageningen University. We organized eight game sessions of each six participants. All game participants were recruited from the large pool of masters' students from Wageningen University. The participants were selected based on their willingness and availability to participate in the game sessions.

The eight sessions conducted in the laboratory experiment were composed of uniquely diverse combination of participants for each group. The participants' ages ranged between 22-43 years old (Table 2.3). Six (6) groups out of eight (8) groups had different gender combinations of participants. Only game session 2 was composed of only female participants, while group 8 had only male participants (Table 2.2). All the eight experiments comprised of participants from different nationalities. Participants in group 2 where from the same study major. However, the other seven sessions showed a variability in study specializations.

Table 2.2: Country of origin, study area and gender per game session.

Game Session	Country of origin	Study specialization	Gender	
			Male	Female
1	Nigeria (3), Uganda (1), Tanzania (1), Kenya (1)	Plant sciences (3), International Development (2), Environmental science (1)	4	2
2	China (3), Nepal (1), U.S.A. (1), Tanzania (1)	Organic agriculture (6)	0	6
3	Mexico (1), Ghana (1), Ecuador (1), Colombia (1), The Netherlands (1), Brazil (1)	Plant sciences (3), Organic Agriculture (3)	3	3
4	The Netherlands (5), Spain (1)	Animal Sciences (1), Organic Agriculture (1), Land and water management (1), Journalism (1), Plant Sciences (1), Information Technology (1)	3	3
5	The Netherlands (2), Italy (1), U.S.A. (2), Spain (1)	Biology (1), Health and Society (2), Animal Sciences (1), Management (1), Organic agriculture (1)	2	4
6	Tanzania (1), The Netherlands (3), Nigeria (1), Zimbabwe (1)	Organic Agriculture (3), Food and Nutrition (2), land and water management (1)	1	5
7	Indonesia (1), The Netherlands (1), Italy (3), Japan (1)	Plant Sciences (3), Management and Economics (2), Organic Agriculture (1)	5	1
8	Uganda (1), Ghana (5)	Environmental Studies (2), Land and Water management (2), Biotechnology (1), Management and Economics (1)	6	0

Table 2.3: The mean age, standard deviation and the age range of participants in each game session.

Game Session	1	2	3	4	5	6	7	8
Age Mean	30	26	28	31	25	27	26	30
S.D.	+/-1.97	+/-4.67	+/-1.72	+/-6.68	+/-2.26	+/-4.00	+/-2.42	+/-3.19
Range	8-32	23-33	26-31	25-43	22-28	22-32	24-31	28-35

2.1.3 **Game monitoring and analysis scheme**

A combination of quantitative and qualitative research techniques were used as analysing scheme for observing the different land-use choices selected by participants for different climatic conditions and to identify the key factors influencing these decisions. An in-depth analysis scheme composing of four elements was used to analyse the game dynamics:

1) Pre-game survey

The pre-game surveys were designed to establish the players' basic details (e.g. age, sex, field of specialization and country of origin), the relationships or relatedness of the players (trust) in each game session and their preferred field locations.

2) In-game questionnaires for participants

An in-game questionnaire was used to explore individual motivations for land-use choices in each round.

3) Post-game survey

A post-game survey was utilized to assess perceived leadership based on exemplary game play, suggestion and influence of other participants on a participant and the group.

4) Post game debriefing

Focus group discussions were conducted at the end of every game session to discuss how other players' suggestions and actions influenced decision-making. Furthermore, the group discussion after the game was conducted to assess how the participants evaluated the active participation of co-players and playability, enjoyability and functionality of the game.

All the games were recorded to qualitatively and quantitatively assess communication during the game. Individual and collective land-use decisions were analysed in relation to the associated climate conditions. We assessed each player's adaptation strategy in terms of (i) the number of crop and livestock plots allocated per player, (ii) the level of risk that each player takes and (iii) the diversity of land-use choices that each player selected. The adaptation strategies were assessed for all climatic conditions.

2.1.4 **Key decision making factors**

We assessed the influential decision making factors based on pre-identified factors from literature; communication, leadership and trust (Speelman *et al.*, 2014; Garcia-Barrios *et al.,* 2011; Janssen *et al*., 2010; Ostrom, 2004). Communication and leadership were assessed quantitatively and qualitatively. Due to the complex nature of assessing trust, we made the assumption that the value of relationship was a determinant of the level of trust (e.g. there is more trust in a high value relationship). Thus, we assessed the relatedness among the players.

2.1.4.1 Relatedness

We assed relatedness between players using the pre-game survey. The participants were asked to describe the nature of their association with the others in their game session. Relationships in this study were categorized as high value relationships or low value relationships. High value relationships were defined as relationships with strong connectedness among individuals with more cohesion and internally driven interactions. High valued relationships also included relationships where individuals shared personal interactions. The self-reported relationships by participants were used to plot network graphs for each group. The network graphs for each group were used to determine the relatedness index per player as the node normalized strength (Boccaletti, 2006; Speelman *et al.,* 2014).

$$\text{Relatedness index} = \sum \frac{\text{(Number of high value relationships) * 100\%}}{\text{(Number of players -1)}} \qquad \text{(Eq 1)}$$

*High value relationships include family, friendships

2.1.4.2 Communication

Using quantitative research evaluation of communication we determined (i) the total number of suggestions that were made related to decision making on climate change adaptation (ii) the total suggestions made by each player to either a single player or to all the players in influencing the land-use choices.

Qualitatively we assessed communication using an end of game questionnaire and the focus group discussion. Each individual player filled out the end of game questionnaire to determine the perceptions of the players on the players they felt made most suggestions and comments.

2.1.4.3 Leadership

We assessed leadership during the role-playing game session in two ways: perceived leadership and observed leadership. Perceived leadership during the game was based on the perceptions of the players on who was more influential during the game. Observed leadership was based on the counting the number of times a participant made a suggestion to both an individual player and the whole group.

Perceived leadership was assessed qualitatively using the post-game survey. A player was perceived to be a leader each time that is mentioned either as exemplary, making the most suggestions or making the most comments. Perceived leadership was assessed as a percentage of leadership equation (Eq 2).

$$\% \text{ Perceived leadership} = \sum \frac{(\text{Number of times player is mentioned}) * 100\%}{\text{Total number of possible leadership in the game}} \qquad \text{(Eq 2)}$$

Observed leadership was assessed quantitatively using the game recording. Observed leadership was measured by counting a player's suggestion to one or all of the players on action to take and issues to consider. Thus every time a player made a suggestion we recorded it as observed leadership during the game (Eq 3).

$$\% \text{ Observed leadership} = \sum \frac{(\text{Suggestions made by player during the game}) * 100\%}{\text{Total number of suggestions made during the game}} \qquad \text{(Eq 3)}$$

2.1.5 **Active participation**

This part of the study sought to understand how much the game engaged players to issues related to climate change adaptation both for the board game and real life situations. The following criteria was used to assess the game:

1. Active participation and playability: Were the players during the game actively discussing and deliberating on the land-use decisions?
2. Enjoyment and fun of the game: Did players enjoy the game and did they find the game entertaining?
3. Functionality and fostering group process: Were the players during the game driven towards discussing and collaborating their activities on the board?

The game was assed qualitatively through observations of how the participants played in the game. This was combined with the outputs from the group discussions after the game to determine the functionality of the game.

3 Results

3.1 Game outcome

During the land selection round, most of the participants allocated their plots in three of the four quadrants on the board (Table 3.1). Ten out of the 48 participants divided their plots over all four quadrants, which is the optimum individual strategy that allows for free riding. The plot allocation pattern on board was different per game session.

Table 3.1: Number of participants occupying different number of quadrants per game session.

Number of participants occupying	Game Session								Total
	1	2	3	4	5	6	7	8	
One Quadrant	1	1	0	0	0	1	0	1	4
Two Quadrants	1	2	3	3	0	1	3	0	13
Three Quadrants	2	2	3	3	5	3	3	0	21
Four Quadrants	2	1	0	0	1	1	0	5	10
Total	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**48**

In most game sessions participants reduced the percentage of plots selected for crop production activities and increased the plots for livestock production as the game progressed (Table 3.2, Appendix Table 1-3). In most game sessions, participants reduced the percentage of plots with low risk crops. However, for high-risk crop plots some game sessions increased the number of plots while other sessions reduced the plots. In the four rounds participants allocated more plots to high-risk livestock compared to low risk livestock. For most of the game sessions diversity was high, with a minimum of 46% average per session (Table 3.2). For most of the game sessions, diversity was higher in the first three rounds. Game session 1, 3 and 8 were characterized by a reduction in the diversity while game sessions 2, 4 and 6 had an increase in the land-use diversity.

Table 3.2: Land-use choices selected by participants during the four game session rounds (mean % and range %).

Game Session		Game Round 1					2					3					4				
		HR.C	LR.C	HR.L	LR.L	DIV	HR.C	LR.C	HR.L	LR.L	DIV	HR.C	LR.C	HR.L	LR.L	DIV	HR.C	LR.C	HR.L	LR.L	DIV
1	Mean	33	21	29	17	88	17	21	25	38	71	8	33	33	25	71	25	0	46	29	46
	Range	25-50	0-25	25-50	25-50	50-100	0-50	0-25	0-50	25-75	50-100	0-25	0-50	0-100	0-50	25-100	0-50	0	0-100	0-75	25-50
2	Mean	17	42	21	21	67	17	38	21	25	75	29	17	29	25	83	29	17	29	25	83
	Range	0-25	0-75	0-75	0-50	50-100	0-25	0-75	0-50	0-50	50-100	25-50	0-25	0-50	0-50	25-50	25-50	0-25	0-50	0-50	25-50
3	Mean	25	21	29	25	79	21	46	13	21	71	21	21	25	33	75	4	29	33	33	58
	Range	0-50	0-25	0-75	0-50	25-75	0-50	25-75	0-25	0-50	50-100	0-25	0-25	0-100	0-50	25-100	0-25	0-50	0-100	0-75	25-75
4	Mean	4	29	21	46	50	63	17	13	8	54	25	13	50	13	63	25	21	33	21	71
	Range	0-25	0-75	0-100	0-100	25-100	50-75	0-50	0-50	0-25	50-75	0-50	0-25	0-100	0-25	25-75	0-75	0-50	0-75	0-75	50-100
5	Mean	29	4	42	25	63	33	25	25	17	79	33	21	21	25	83	29	13	13	46	58
	Range	0-50	0-25	0-100	0-50	25-75	0-75	0-50	0-50	0-25	50-75	25-50	0-25	0-50	0-50	75-100	0-75	0-25	0-75	0-75	50-75
6	Mean	21	17	25	37.5	58	12.5	33	33	21	75	25	33	8	33	67	21	17	42	21	71
	Range	0-50	0-50	0-75	0-75	50-75	0-25	0-75	0-50	0-25	50-100	0-50	0-75	0-25	0-75	50-75	0-50	0-25	25-50	0-50	50-100
7	Mean	17	17	38	29	63	29	21	33	17	71	46	25	21	8	63	33	4	29	33	58
	Range	0-50	0-75	0-75	0-50	50-100	0-50	0-75	0-50	0-25	50-100	25-100	0-50	0-50	0-50	25-100	0-50	0-25	0-50	0-75	50-75
8	Mean	33	17	29	21	88	21	21	42	17	67	33	8	54	4	58	13	4	75	8	46
	Range	25-50	0-25	25-50	0-25	75-100	0-50	0-50	0-75	0-50	50-100	0-50	0-25	25-75	0-25	50-100	0-25	0-25	25-100	0-50	25-75

HR.C=High risk crop selection, LR.C=Low risk crop selection, HR.L=High risk livestock selection, LR.L=Low risk livestock selection, DIV=Diversity

3.2 Additional points

In all sessions, all participants obtained additional points through one or both of the additional points schemes (Crop production additional points (C.P.A.P) and the Livestock production additional points (L.P.A.P) schemes). The total additional points per player ranged from 20 to 61 points. Only in four game sessions (session 4 – 7), participants managed to obtain additional points from the crop production additional points scheme (Figure 3.1).

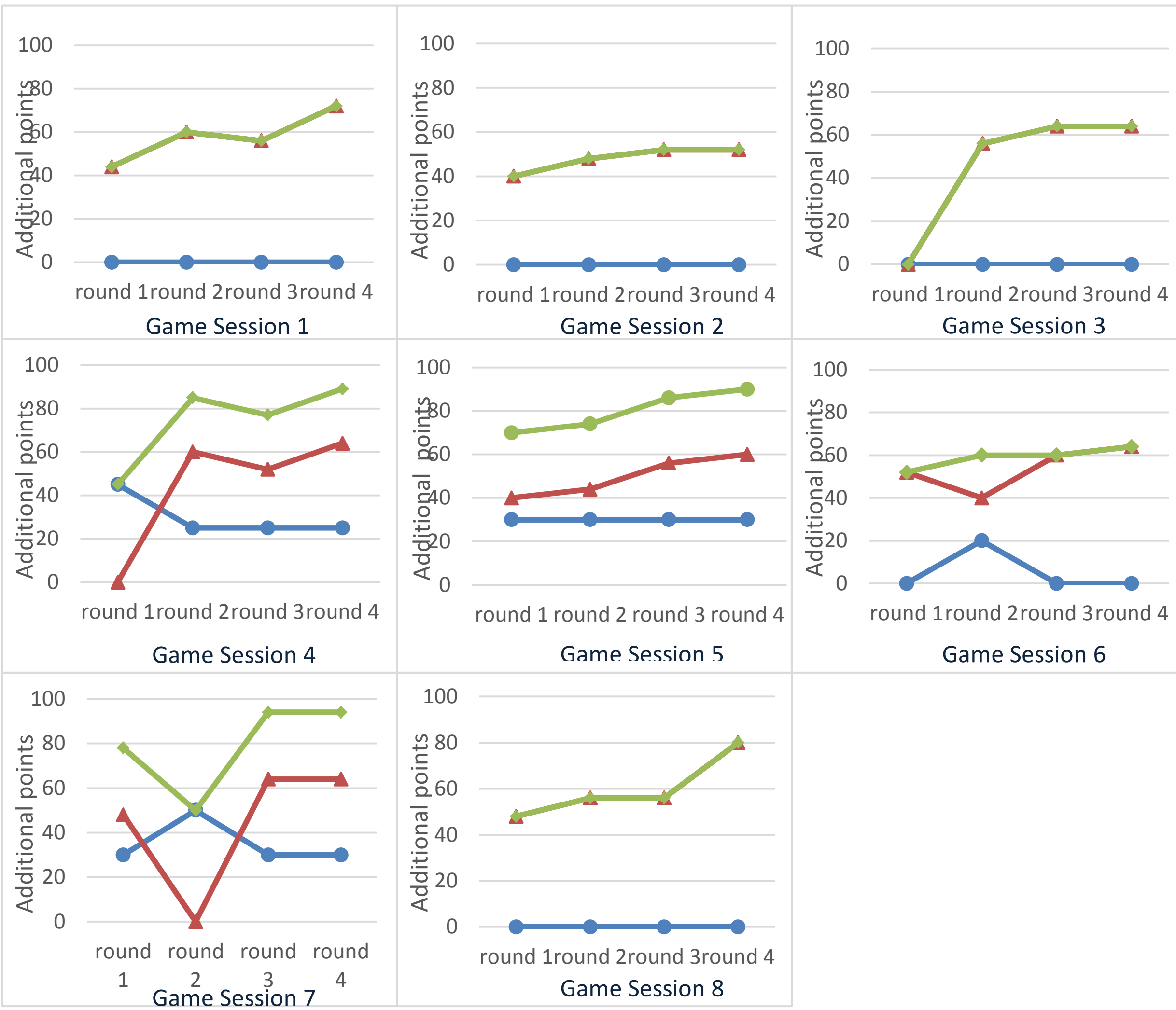

Figure 3.1: Total additional points obtained per game session for the four rounds played. Note: The total additional points (green line) results from C.P.A.P scheme (blue line) and the L.P.A.P scheme (red line).

3.3 **Key decision making factors**

3.3.1 **Relatedness**

Social relationships between session participants differed in strength and symmetry (same/different classification of relationship) (Figure 3.2). Group 7 and 8 participants had the most high value relationships with a relatedness index of 83% and 100% respectively (Figure 3.2; Table 3.3). Group 8 had only symmetrical high value relationships whereby all players related to each other in the same way as friends. Group 7 had almost all participants having symmetrical relationships except for player 2 with the rest of the players. Groups 2 and 6 had a high number of unrelated participants and many low valued relationships resulting in the lowest relatedness index. Game session 1 had a mixture of different relationships high and low value relationships as well as symmetrical and asymmetrical relationships. Thus, the range of the relatedness index was the widest among participants (Table 3.3).

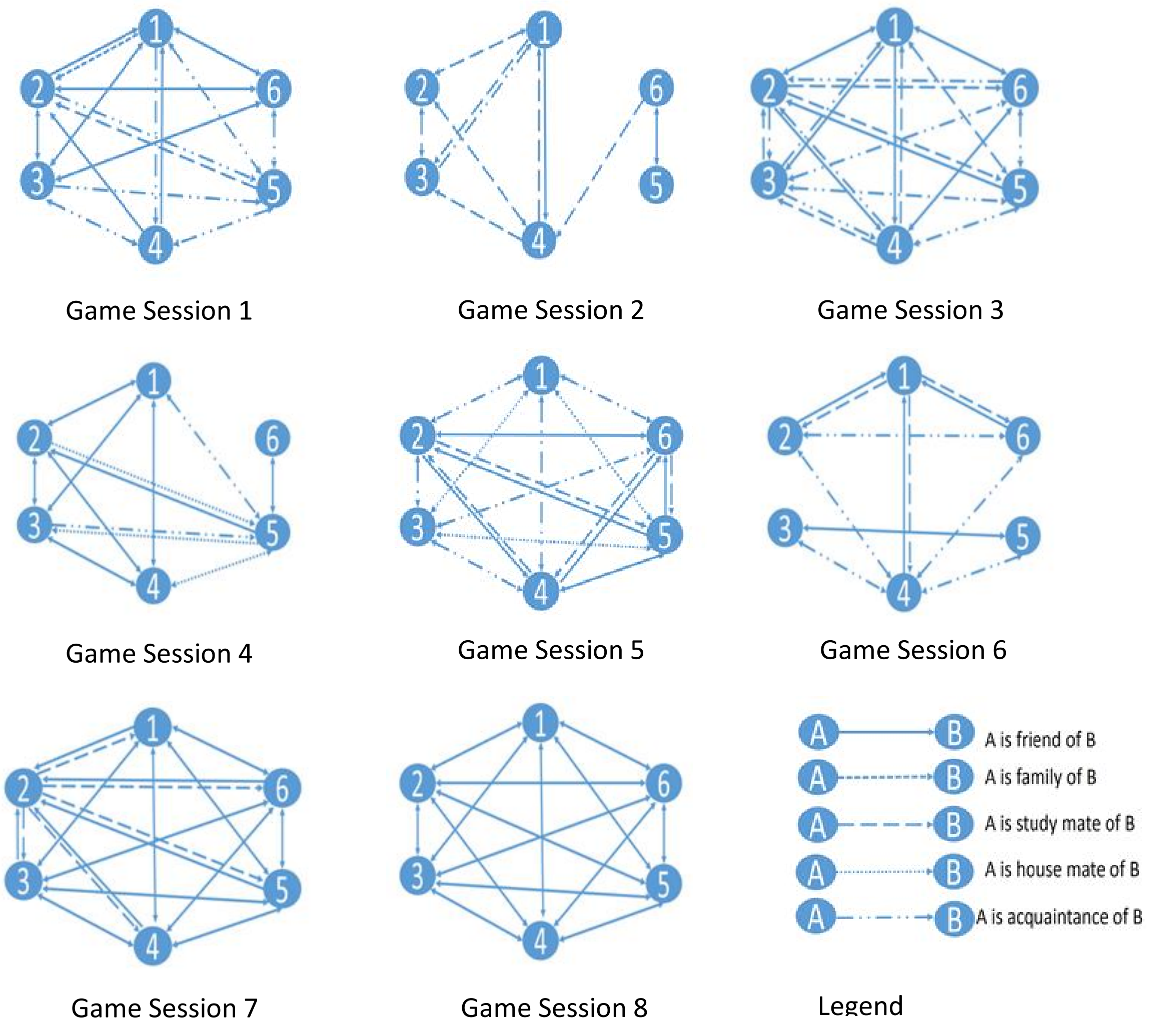

Figure 3.2: Social network graphs and legend showing the relationship between participants per game session.

Table 3.3: Participants mean relatedness index, standard deviation and range (%) per game session.

Game Session	1	2	3	4	5	6	7	8
Mean Relatedness Index	47	10	33	50	23	16	83	100
S.D.	+/-37.24	+/-10.95	+/-16.32	+/-24.50	+/-29.44	+/-23.38	+/-8.16	0
Range (%)	0-80	0-20	20-60	20-60	0-60	0-60	80-100	100

3.3.2 **Communication**

All participants contributed to discussions and made suggestions during the game. However, the number of suggestions per player differed strongly from 3 to 52 suggestions (Figure 3.3). Group 4, 7 and 8 had the highest mean number of suggestions made during the game sessions (Table 3.4).

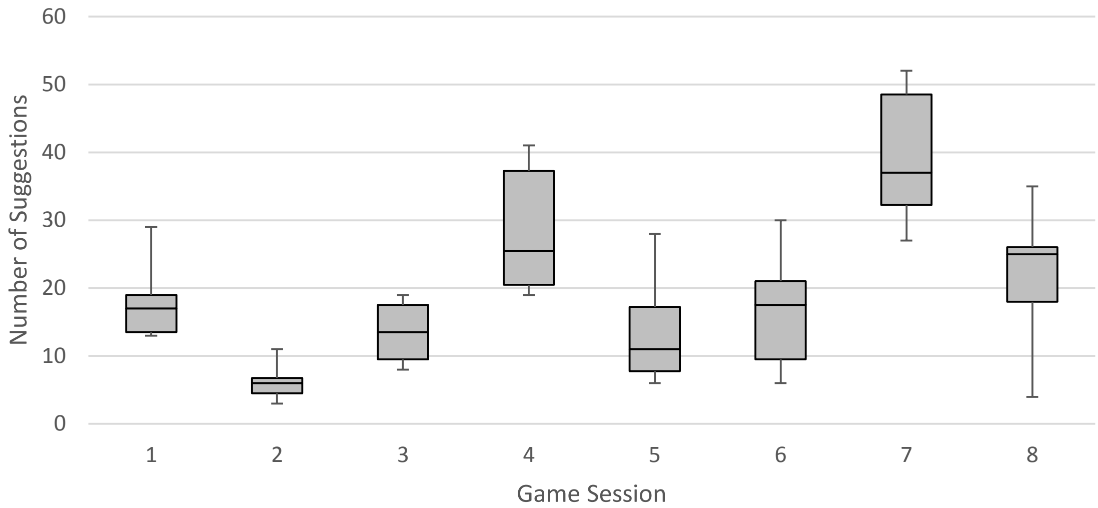

Figure 3.3: Suggestions made by participants per game session.

Table 3.4: Mean number of suggestions, standard deviation and the range (%) per game session.

Game Session	1	2	3	4	5	6	7	8
Mean Number of Suggestions	18	6	14	29	14	17	39	22
S.D.	+/-6.03	+/-2.79	+/-4.76	+/-9.93	+/-8.40	+/-9.07	+/-10.44	+/-10.63
Range (%)	13-29	3-11	8-19	19-40	6-28	6-30	27-52	4-35

In almost all sessions, most suggestions were made in the first round (Figure 3.4). In the first round that sessions with more suggestions took more time, as compared to the rounds with less suggestions. The suggestions and comments in the first round were mostly centred on formulating an overall goal, collaboration and land allocation. In the proceeding rounds land allocation could not be changed, thus there were no suggestions on it. Only in game session 2, the number of suggestions increased by a very small margin as the game progressed.

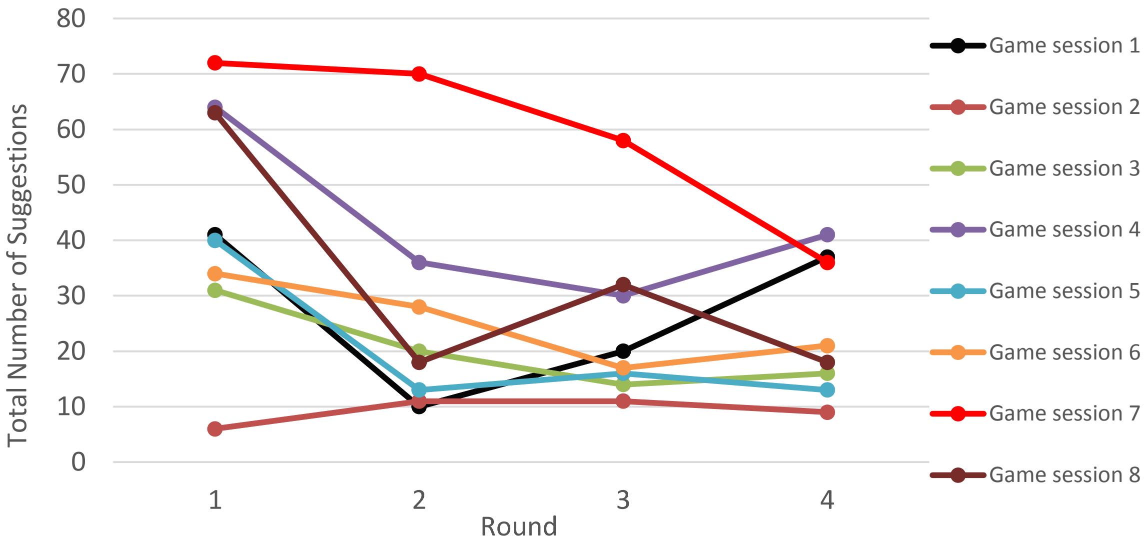

Figure 3.4: The trend and total number of suggestions made per round per game session.

During the game sessions, the majority of the suggestions made were related to collective decision-making and landscape configuration planning for mutual benefit. Suggestions were made on various topics with most suggestions related to collaboration (23%), land-use choices (18%) and land allocation (13%), while the topic of low risk (5%) and high risk (8%) were least discussed (Figure 3.5). However, the topic of the suggestions differed per game session.

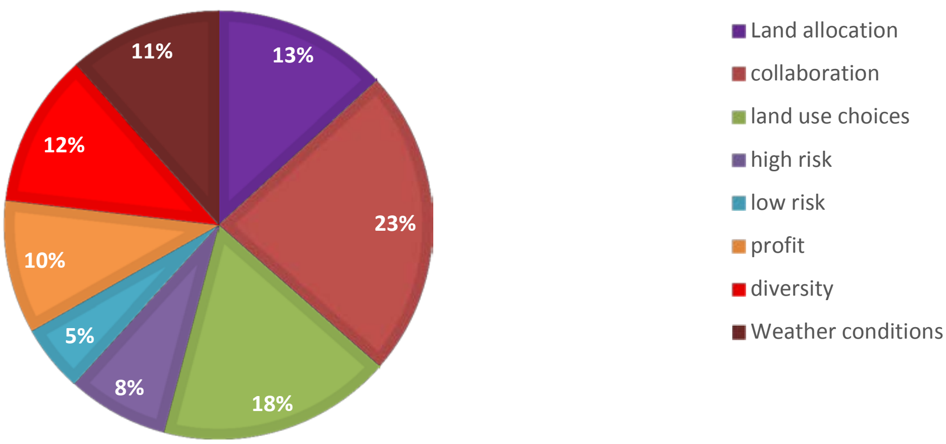

Figure 3.5: Pie chart representing the percentage of suggestions made during all game sessions.

The most suggestions for different topics were made in game sessions 4, 7 and 8. Group 7 made the largest number of suggestions in total (Figure 3.6). Suggestions related to weather conditions were made in all groups.

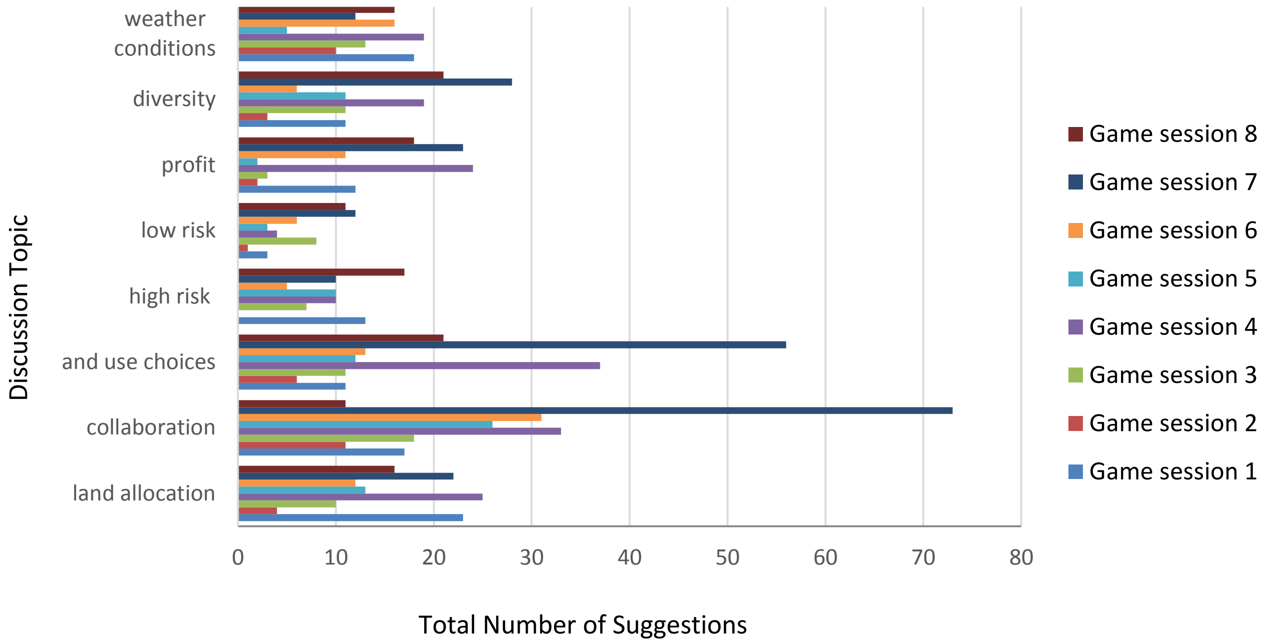

Figure 3.6: Number of suggestions per discussion topic per game session.

3.3.3 **Leadership**

In all game sessions, there was a discrepancy between perceived and observed leadership (Figure 3.7). During game sessions 3, 4, 7 and 8 there was more than one participant with overall observed leadership during the game. However the participants perceived there was only one participant demonstrating overall leadership during these game sessions (Figure 3.7). The perceived leadership and observed leadership in most game sessions showed that there was difference on the level of leadership between observed and perceived leadership for different ranks. The participants ranked first in leadership had a higher level of perceived leadership compare to observed leadership. However, participants with a lower rank had a higher level of observed leadership compared to the perceived leadership.

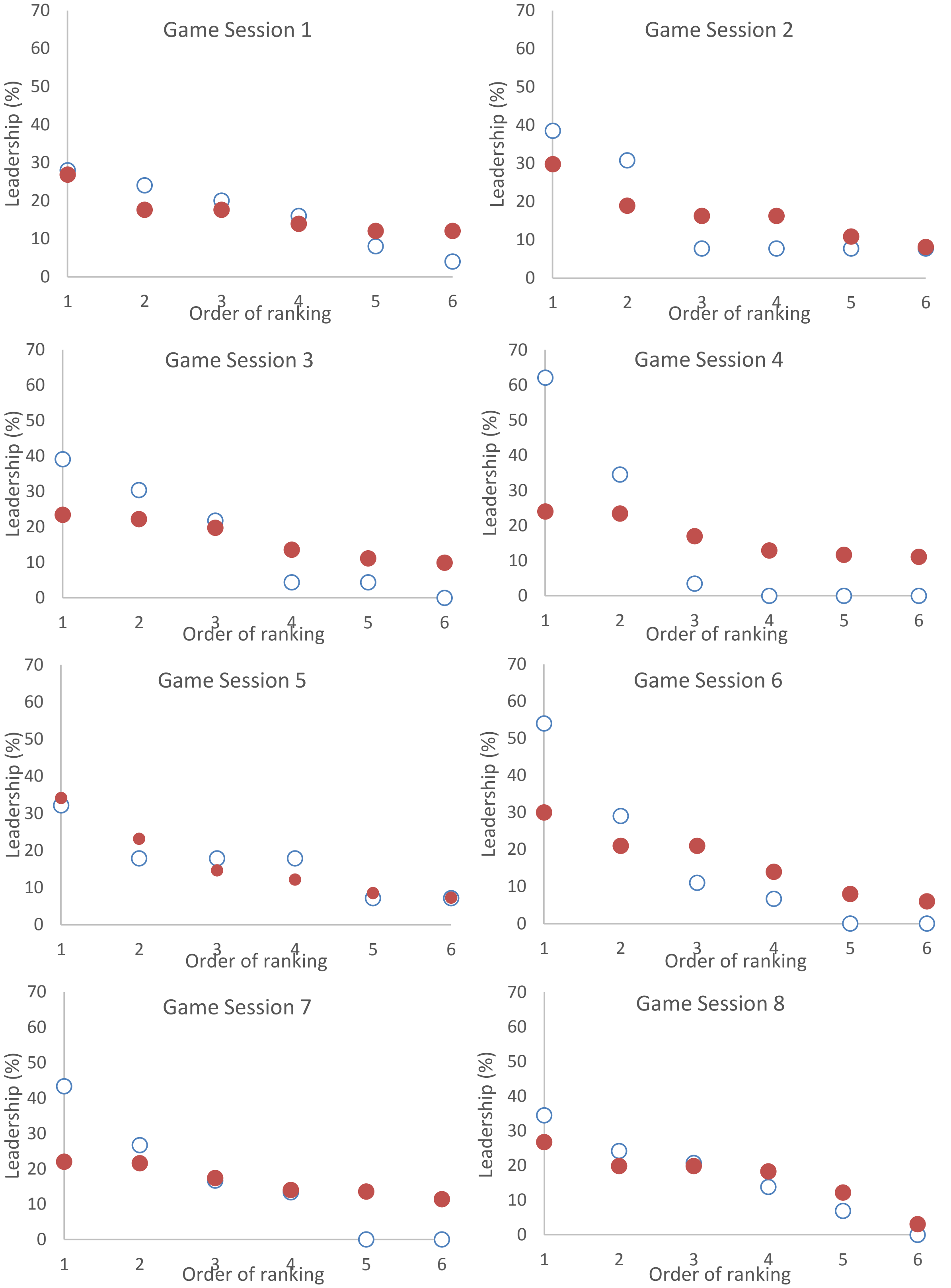

Figure 3.7: Perceived leadership (blue) and observed leadership (red) order of rank for the participants per game session (%).See Appendix 1 figure 1 for participant and exact ranking

The player rankings in terms of perceived leadership and observed leadership where different for all the game sessions. However in game sessions 1, 2, 3, 4, 5, and 7 the same player was ranked as the overall leader during the game. However the rest of the participants the rank on perceived leadership varied with the observed leadership rank (Appendix Figure 1). However, it was observed that at a lower perceived leadership participants demonstrated more leadership than was perceived and vice versa (Figure 3.8).

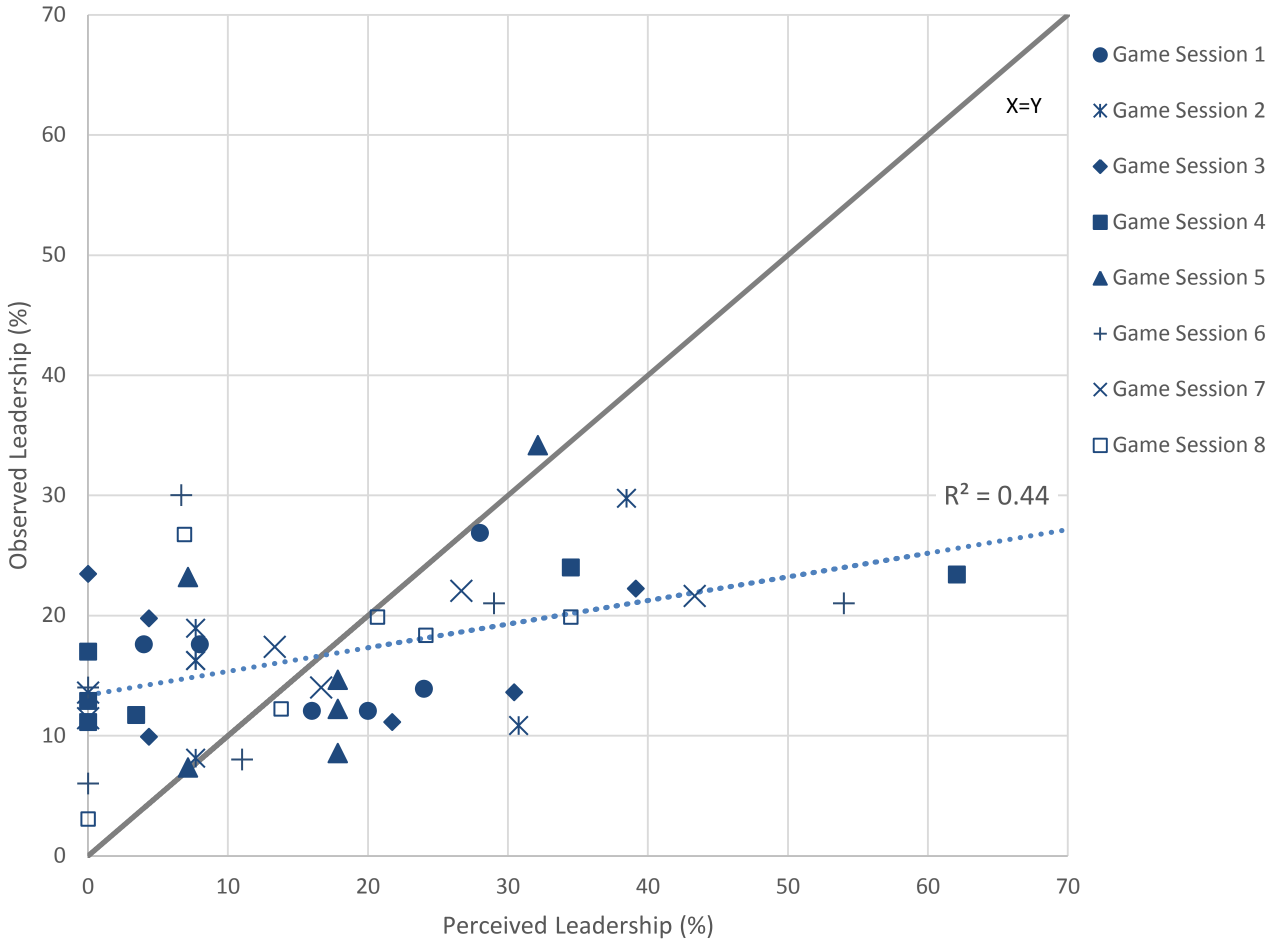

Figure 3.8: The relationship between perceived and observed leadership per game session (%). Note: The x=y line shows when perceived leadership (%) is equal to observed leadership (*P*=0.00158) (%).

3.3.4 **Active participation**

We observed that all participants for the sessions participated during the discussions on the strategies to use during the game. In game sessions 4, 5, 6 and 7 before plot selection, players agreed to first share their goals and objectives for the game. Results from the in-game questionnaire showed that player contributions were considered more often than individual game plan during the game (Table 3.5). The in-game questionnaires indicated that weather conditions were a top consideration for the players in decision-making. In the end of game focus group discussions players from all the sessions highlighted that decision making was a result of a combination of factors and not just a single factor. During the focus group discussions players also highlighted that individual decision-making was influenced by other players directly through other player suggestions and indirectly by their land-use activities during the game.

Table 3.5: Total number of top considerations by the players per game session that influenced land-use activities. Note: These considerations were recorded by players as the game progressed.

Game Session	Top considerations				
	Weather Conditions (#)	Field location (#)	Land-use activities of other players (#)	Player suggestion (#)	Individual game plan (#)
1	18	8	10	10	7
2	13	13	6	17	0
3	17	8	6	13	6
4	12	5	14	7	7
5	10	13	12	3	6
6	20	3	2	5	8
7	16	16	9	6	10
8	20	7	6	9	7
Mean	16	9	8	9	6
S.D.	+/-3.7	+/-4.5	+/-3.9	+/-4.6	+/-2.9
Range (%)	10-20	3-16	2-14	3-17	0-10

During the focus group discussions the players indicated they enjoyed the game. The players highlighted that collaboration and collective decision making are important in ensuring climate change adaptation. In group 8, there was a consensus that the dice was a good representation of how climate has been changing over the past years. However, players felt that the game needed to introduce some of the negative outcomes from certain choices during the game. This element was essential to balance livestock and crop interactions during the game and closely simulate real case scenarios.

3.4 Game analysis

3.4.1 Weather

The climatic conditions for the four rounds in each game session were randomly selected as the game progressed. In most game sessions we also observed that land-use choices varied with climatic conditions for the rounds in each session.

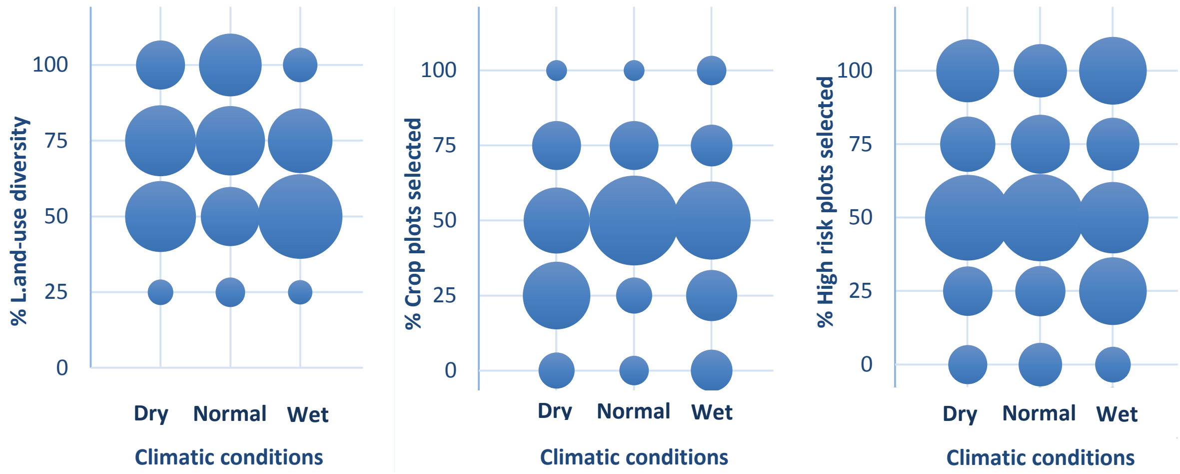

Figure 3.9: Diversity in land-use choices (%), crop plots selected as a percentage of total plots per participant (%) and high-risk plots selected as a percentage of total plots per participant (%) under different climatic conditions. Diversity is expressed as land-use allocated as a percentage of total possible land-use choices.

Most participants had high diversity in land-use choices for their plots (Figure 3.9). However, there was less diversity in wet year scenario. In a dry year, fewer plots were selected for crop production. In a normal year for most participants land was equally shared between crops and livestock. The level of risk for the three climatic seasons was diverse among participants. However, most participants had 50% plots selected for high risk in a dry and normal year. In a wet year, participants were more skewed towards high risk compared to low risk land-use choices (Figure 3.9, Appendix I, Table 1-3).

3.4.2 Relatedness

We identified a significant positive relationship (p=0.011) between number of plot selection changes per player and the relatedness index. Most players (65%) allocated their plots in different quadrant location as compare to their preferred locations indicated before the game. The players with a higher relatedness index adjusted their plots more from their originally preferred plots (Figure 3.10). Most players with more high value relationships had more plot changes observed. In most sessions before and during the land allocation round all the groups discussed on the best possible strategy. However, group 4, 5, 6, 7 and 8 agreed on a clear landscape configuration goal. This resulted in most of the participants changing from their preferred plot selection.

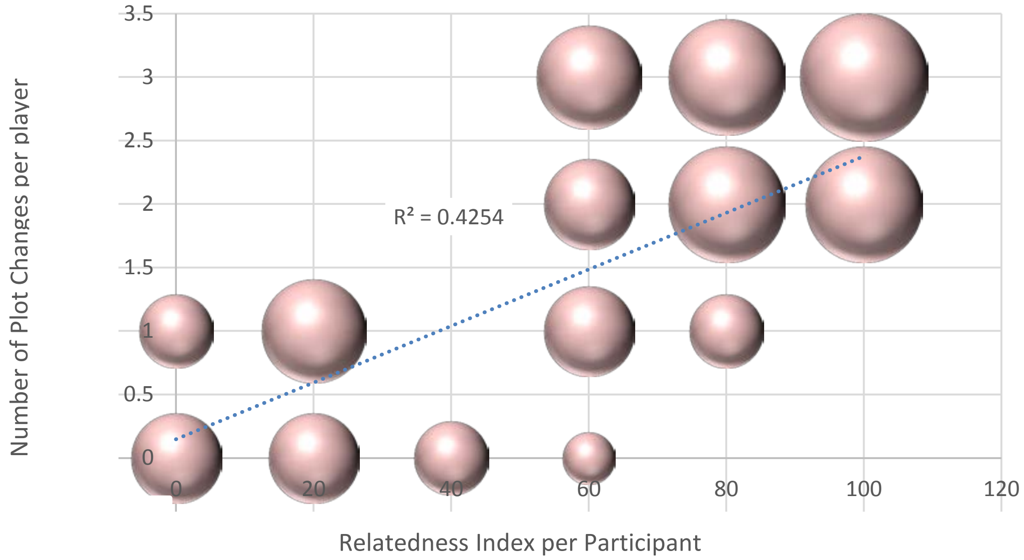

Figure 3.10: The relationship between relatedness index per player and the number of plot changes per player between preferred plot location and the actual selected plot location on the board.

A higher mean relatedness index corresponded to higher total additional points and a higher number of suggestions made during a game session (Figure 3.11 and Table 3.3).

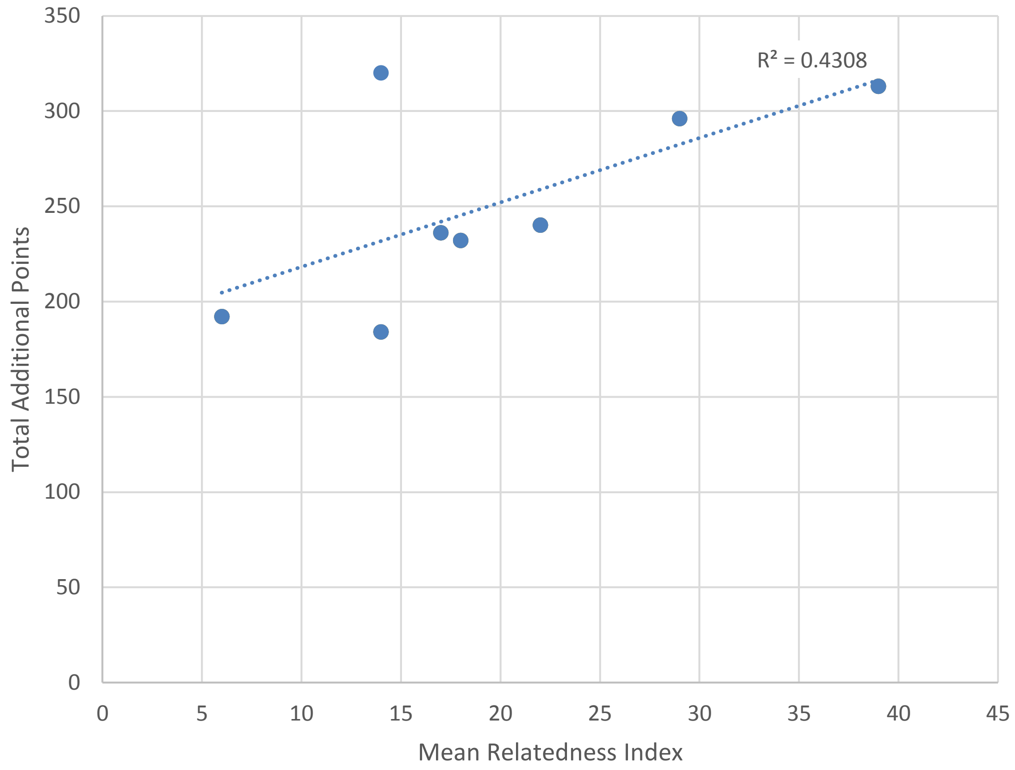

Figure 3.11: The relationship between total additional points and the average relatedness index of participants per session. The R^2=0.43 for all the game sessions and R^2=0.887 without group 5.

3.4.3 **Communication**

There was a significantly positive relationship (*p*=0.041) between relatedness index and the total number of suggestions made and also there was also a significantly positive relationship between the total number of suggestions and the diversity of specializations among game session participants. The game sessions comprising of participants with high value relationships as well as diverse backgrounds made more suggestions (Figure 3.12). Participants with high value relationships made suggestions to each other on allocation of plots and discussed more in-depth on collaboration to achieve maximum benefit. The diversity of backgrounds among participants was an essential element for a diversity of topics discussed in the sessions (Figure 3.12b).

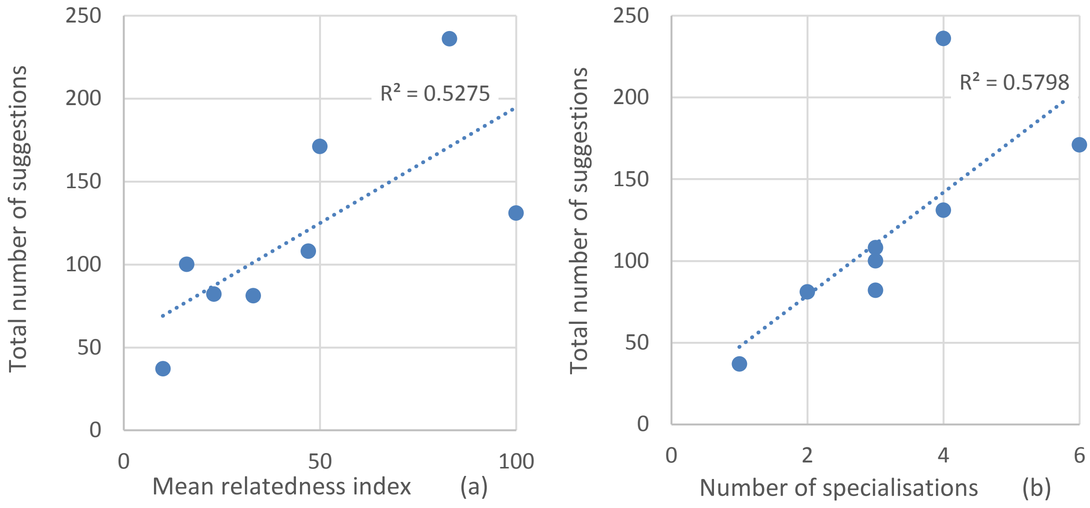

Figure 3.12: Relationship between the mean relatedness index (a) and number of participants' study specialization (b) to the total number of suggestions per game session.

The game sessions that had more suggestions during the session attained more additional points (Figure 3.13). There was a significant positive relationship (*p*=0.011) between total number of suggestions and the total additional points attained. Through making suggestions to each other they were able to come up with most beneficial land-use choices. In game session 5 there were high number of additional points (320), though there were not a lot of suggestions (236). This was as a result of participants agreeing on a clear game plan in the beginning. Most participants that attained most points and had more suggestions demonstrated shared leadership. The results showed that participants in game session 4, 5, 6 and 7 had more shared leadership. This resulted in more suggestions and, subsequently, more additional points.

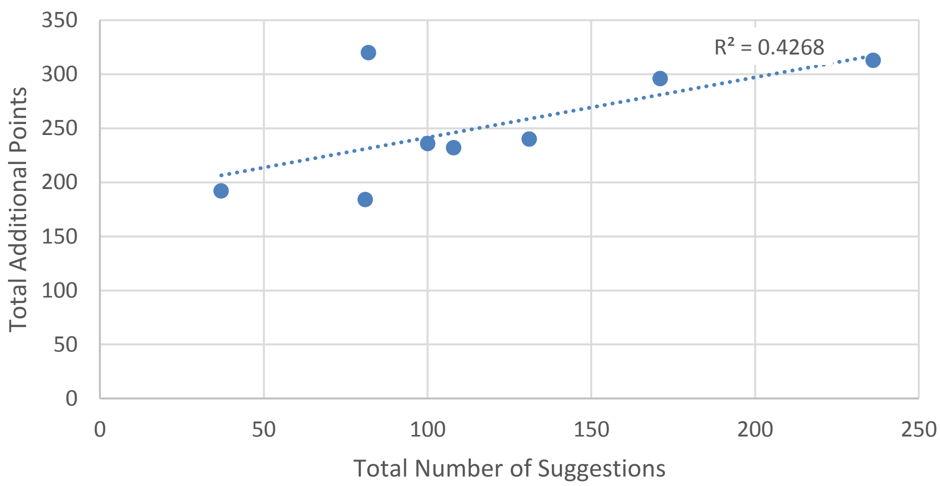

Figure 3.13: The relationship between total additional points and the total number of suggestions per game session.

3.4.4 **Leadership**

The game sessions comprised of overall individual leadership or multi-actor leadership (Appendix 1 Figure 1, Figure 3.7). Game sessions 4-7 had multi-actor leadership and they had more in-depth discussions on the plot configuration as well as the land-use choices during the different rounds. The game sessions with multi-actor leadership utilized both additional point schemes during the four rounds. On the other hand, game sessions 1-3 and 8 had a single overall leader in the group and attained additional only from the L.P.A.P scheme. Most groups with single leadership had fewer comments within the group. Furthermore, most of these participants were also ranked high in observed leadership. However, we could not relate the rank or level of leadership within game session to the relatedness index for all the participants.

4 Discussion

The role playing game reflected agricultural decision-making in climate change adaptation and it allowed for an in-depth study of influential factors in decision-making. The game inferred the importance of social dynamics in collective decision-making while considering individual objectives.

During the land selection round most participants did not manage to achieve the optimum individual strategy. Thus most participants could only obtain suboptimal additional points throughout the game. Most participants allocated their plots in three quadrants. We observed that this resulted in unevenly distributed additional points among the participants. We identified a positive relation between the relatedness among players (i.e. relatedness index) and their land allocation. Most game sessions participants discussed before the land allocation round on their individual plan and how to formulate an overall plan. Results suggest that landscape configuration for the eight sessions was dependent on game plan discussed and relatedness of the participants. Speelman *et al.* (2014) also indicated that the level of group coordination during the field allocation determines the individual and group optimum strategies which can be biased towards diversified or homogeneous landscapes and equal or unequal division of additional points. We found that during the sessions that participants discussed on locating plots in different quadrants for collaboration to achieve additional points.

Wiseman (2015) highlighted that social relations play an important role in organizing communities. According to Wiseman (2015), people in society try to settle near to those that they are close to socially. We found a positive relation between relatedness and the plot changes by participants. Furthermore, Verdery *et al.* (2011) stated that the degree of relatedness between individuals correlates with the distances between dwelling units. We observed that most participants with symmetrical, high value relationships selected plots close to each other. We found that participants preferred selecting different plots and move to quadrants where collaboration was quicker. In game sessions with the RESORTES board game, Speelman *et al.* (2014) identified a moderately positive correlation between a player's individual relatedness index and the number of adjusted field locations. However, they did not identify a clear relation between field allocation pattern and relatedness pattern.

Most participants selected more high-risk land-use activities in a wet year compared to either a dry year or a wet year. Furthermore, the percentage of diversity of land-use choices that were selected in a wet year was lower than for the other climatic conditions. In a dry year most participants selected more diversity of land-use choices. Results suggested that participants perceived less chance of failure in a wet year, and a dry year to be more risky. These results were supported by the comments of most participants in the debriefing. By allocating land to more high-risk land-use activities the participants perceived a higher possibility of gain. Furthermore, it was observed that in a dry year, less crop land-use choices were selected. However, in a normal year and wet year more plots were allocated to crop production. The participants perceived that in a dry year crops were more likely to fail compared with livestock. This is in line with findings of Mapfumo *et al.* (2013) who highlighted smallholder farmers depend on rain-fed agriculture and they perceive unavailability of rainfall as the major constraint to productivity. Climate change adaptation studies have highlighted and advocated many different adaptation strategies including diversification (Lin, 2011; Kelly and Adger, 2000) and low risk agricultural production (Mapfumo *et al.,* 2013). In our study participants selected more low-risk land-use choices in a dry year and diversified land-use activities as well.

In this study, we observed that the total number of suggestions was positively related to the relatedness of participants in the game sessions. All participants made suggestions during the game sessions of which most were focused on agreeing to collaborate, the landscape configuration for the game and the overall game plan. For all the game sessions the participants mostly made suggestions on collaboration (23%), land-use choices (18%) and land allocation (13%). Speelman *et al.* (2014) found that a strong social network and high relatedness among players was correlated to in-depth communication among participants. We found that game sessions with higher relatedness index had a high average number of suggestions covering diverse topics of discussion. Furthermore, game sessions with higher number of suggestions achieved more additional points. The numbers of suggestions and total additional points were positively related. Thus, the game sessions showed that through communication most participants were able to collaborate to achieve high additional points.

Several studies using experimental research have shown that communication makes a positive influence on the outcomes, and is key in decision-making (Ostrom, 2000; Poteete *et al.,* 2010; Jansen *et al.,* 2010; Andreli *et al.*, 2011). In collective decision-making, increased communication among participant increased performance (Poteete *et al.*, 2010) and low communication were linked to low game outcomes (Jansen *et al*., 2010). Most game sessions with high suggestions attained high additional points. This resulted in selection of land-use choices to achieve high additional point. The game sessions with more suggestions had in-depth discussions on individual and collective goals. Poteete *et al.* (2010) stated that for participants who did not know each other, in the first rounds there was no substantial cooperation and consequently pay-off was low. However, as the game progressed participants became familiar with each other which enabled participants to gain sufficient trust to collaborate. We found similar results in the game session with the lowest relatedness index. In this session, communication increased as the game session progressed. As a result also the additional points increased over time. However, game session 5 formed an exception. This session showed that high additional points was not necessarily only a consequence of high communication and high relatedness. This game session was characterized by moderate number of suggestions and a mixture of high and low value relationships among participants but achieved highest additional points. This suggests that additional points could also be achieved through efficient quality communication and suggestions.

Furthermore, we also observed that game sessions with participants from diverse backgrounds resulted in more communication. Participants with diverse backgrounds were observed to share more suggestions compared to game sessions with participants from only one specialization. In group decision-making, Dreu and West (2011) stated that different knowledge backgrounds with sufficient overlap among individuals is essential to ensure effective communication. We found that game sessions with participants with diverse backgrounds in a game session corresponded to high additional points. We also observed that the suggestions in these were not only by one person but rather by several people resulting in collectively agreed upon land-use decisions.

In this study, we assessed observed leadership of participants during the game session based on the participation of each individual specifically suggestions to others individually or as a group. We found that there was a discrepancy between perceived and observed leadership. We found that at top ranked participants were perceived to demonstrate a higher level of leadership than the observed leadership. The actual performance of perceived top leaders in the sessions was lower than was assumed by other participants. However at a lower ranking the observed leadership was higher than the perceived leadership. The results showed observed leadership was not directly equivalent to perceived leadership. Perceived leadership was not only assessed by performance of participants during the session. We found no direct relationship between observed and perceived leadership. Overall rate of participation is a "prime index of leadership in the eye of other group members" on production, problem solving and discussion tasks (Hackman and Morris, 1969). However, Hackman and Morris (1969) also indicated that high participation was not a sufficient condition for perceived leadership but there could also be verbal and non-verbal characteristics and activities associated with good group performance. Van Vught (2006) stated that leadership is not limited to the characteristics and skills of leaders but is also shaped by interactions among participants. Speelman *et al.* (2014) identified there was a mismatch between perceived leadership and observed leadership. In this study we observed that perceived leadership was not only based on suggestions but also overall communication and exemplary land-use selection during the game. We observed that players that were highly ranked in leadership were participants with high relatedness index in the group and had more symmetrical connections with other participants. The results highlighted that participants perceived leadership based on the individual's capacity to make suggestions and facilitate a decision-making process that is in line with their individual goal.

Studies have shown that, over the years role playing games have been developed with the interest and capacity to expose and understand the core social dilemma and human behaviors in land-use planning and common resource management (Garcia-Barrios *et al*., 2011). Thus, the use of role playing games offers an opportunity to explore decision making in agricultural decision making. Speelman *et al.* (2014) highlighted that the RESORTES land-use planning board game, has proved to be a useful tool to actively involve smallholder farmers in an exercise in the designing of more sustainable agricultural landscapes through land-use planning. Though the RESORTES board game was designed as an explorative model for farmers Jansen *et al.* (2011) has shown that a laboratory experiment and farmers in the field tend to make the same decisions when spatially explicit dynamics are included. Furthermore, laboratory experiments enable unpacking complex problems to examine effects of different components on outcomes and to replicate results with diverse participants (Jansen *et al.,* 2010). Games have been widely used to explore decision-making and resource allocation towards climate change adaptation (e.g Kotir *et al.,* 2016; Villamor and Badmos, 2016). In d'Aquilo *et al.* (2013), results showed that in a study in West Africa with smallholder farmers, participants varied their land-use choices and resource use based on climatic conditions. Though we used a laboratory experiment, the impact of climate variability had a strong influence on the participants' land-use choices.

In this study, we put emphasis on the influence of participants' background i.e. study specialization's influence on decision-making but however did not account for background knowledge and cultural orientation. Poteete *et al*. (2000) stated that in selecting preferences as well as in communication the individual's inclination is significantly influenced by one's culture. However, Briley *et al.* (2000) highlighted that there is a need to consider the dynamic account of cultural influence. They also highlighted the need to consider decision making in situations where influence of culture is activated or suppressed. This furthermore raises a notion that the participants within a group might not necessarily cooperate with everyone in the same way. In the study we looked into relatedness and how it would influence location of plots and how it influences number of suggestions. Speelman *et al.* (2014) used follow up interviews for further debriefing with farmers, this can be used in the research design to investigate other elements related to the individual participant's decisions on land-use choices. This would be an essential step needed for this research, to conduct more in-depth discussions with the participants to understand their drivers in decision making.

Adger *et al*. (2005) highlighted that climate change involves the temporal and spatial variation in weather conditions. In the study we looked at climate change based on seasonal variation. However, Niang *et al.* (2014) also highlights that climate change also influences includes intra-seasonal variability e.g. mid-season dry spells, rainfall intensity. All these factors of climate change variability influences the performance of crops and livestock differently. In the game we did not include the element of intra-seasonal variability in decision making in climate change adaptation. Furthermore the variability of seasonal can influence crop and livestock performance differently. Thus, further development of the game can be done to include the intra-seasonal variability element to the game.

5 Conclusions

In complex social-ecological farming systems, effective decision making is critical for smallholders to manage uncertainties especially in the light of climate change. Exploring agricultural decision-making using role playing games can generate insights into the impact of important decision-making factors on individual and collective decision-making. However, role playing games have not yet been widely embraced in research on agricultural decision-making for climate change adaptation.

In this study, we explored the impact of key decision making factors; communication, relatedness and leadership, on individual and collective land-use choices. We developed a laboratory experiment with MSc students from Wageningen University in which a slightly modified version of the RESORTES land-use board game (Speelman *et al.*, 2014) was used to research decision-making processes. Through effective decision making individuals could select land-use choices less affected by climate change. Through diversified land-use choices individuals benefit from different land-use schemes towards climate change adaptation. We showed that communication and relatedness among players positively influenced successful collective decision-making. Game sessions in which more suggestions were made resulted in significantly more additional points. Communication is essential in formulating a landscape configuration plan and selecting land-use choices that integrate individual and collective goals. Also, sessions with a high relatedness among players resulted in significantly more additional points. High relatedness among individuals in a group seemed to establish a level of trust that created a conducing environment for communication. Communication was also significantly higher within a group with more symmetrical and high valued relationships. Diversity in player's background allowed for more in-depth discussions and consensus building, which resulted in high collective benefits. Diversity of backgrounds among individuals can possibly lead to multi-actor leadership in a group. A group with multi-actor leadership has more diversity in land-use choices and attains benefit from different schemes. We found that groups with one-actor overall leadership used a single benefit scheme and focused on one main land-use strategy. Individuals with more high value relationships are perceived to be top ranked leaders in a group.

Further research is still needed to explore decision making under real life conditions where by the game is played by actual farmers not students. It is important to assess the influence of different group dynamics in smallholder communities e.g. institutional leadership on collective decision making. In agricultural decision making social dynamics play a key role in influencing land-use choices, whereby communication, leadership and relatedness can positively lead to mutual benefit.

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Appendix I

Table 1. Percentage and average of selected crop production land-use choices as a percentage of the total plots for each participant per round, per player and game session.

Game Session 1 Player	Quadrants Occupied	Round 1 Normal (%)	Round 2 Wet (%)	Round 3 Normal (%)	Round 4 Wet (%)	Average player^{-1} (%)
1	1	50	25	50	50	43.75
2	2	50	25	50	50	43.75
3	4	50	50	50	0	37.5
4	3	75	75	50	50	62.5
5	4	50	50	50	0	37.5
6	3	50	0	0	0	12.5
Average		**54**	**38**	**42**	**25**	**40**
Game Session 2 Player	**Quadrants Occupied**	**Round 1** Dry (%)	**Round 2** Dry (%)	**Round 3** Normal (%)	**Round 4** Normal (%)	**Average player^{-1}** (%)
1	3	100	75	25	50	62.5
2	2	25	50	50	25	37.5
3	2	50	50	50	50	50
4	3	25	0	50	25	25
5	1	75	75	50	50	62.5
6	4	75	75	50	75	68.75
Average		**58**	**54**	**46**	**46**	**51**
Game Session 3 Player	**Quadrants Occupied**	**Round 1** Dry (%)	**Round 2** Dry (%)	**Round 3** Normal (%)	**Round 4** Normal (%)	**Average player^{-1}** (%)
1	3	75	50	50	75	62.5
2	2	50	50	75	50	56.25
3	3	50	50	0	0	25
4	2	100	50	25	50	56.25
5	3	75	50	50	25	50
6	2	50	0	0	0	12.5
Average		**67**	**42**	**33**	**33**	**44**
Game Session 4 Player	**Quadrants Occupied**	**Round 1** Wet (%)	**Round 2** Wet (%)	**Round 3** Wet (%)	**Round 4** Dry (%)	**Average player^{-1}** (%)

1	3	50	25	75	25	43.75
2	3	100	25	25	25	43.75
3	2	75	50	50	50	56.25
4	2	100	75	50	50	68.75
5	2	100	0	0	0	25
6	3	50	50	75	50	56.25
Average		**79**	**38**	**46**	**33**	**49**

Game Session 5 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Wet (%)	Normal (%)	Wet (%)	Wet (%)	
1	3	100	75	75	25	68.75
2	3	50	50	25	25	37.5
3	3	50	50	50	50	50
4	3	50	50	25	25	37.5
5	3	50	50	50	75	56.25
6	4	50	50	25	25	37.5
Average		**58**	**54**	**42**	**38**	**48**

Game Session 6 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Dry (%)	Dry (%)	Dry (%)	Dry (%)	
1	1	25	75	25	0	31.25
2	2	75	75	25	50	56.25
3	4	25	25	25	0	18.75
4	3	50	25	50	75	50
5	3	75	100	50	50	68.75
6	3	25	50	50	25	37.5
Average		**46**	**58**	**38**	**33**	**44**

Game Session 7 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Normal (%)	Normal (%)	Wet (%)	Dry (%)	
1	2	50	100	50	50	62.5
2	3	50	75	50	50	56.25
3	2	75	75	25	25	50
4	2	75	75	50	25	56.25
5	3	25	50	25	25	31.25
6	3	25	50	25	50	37.5
Average		**50**	**71**	**38**	**38**	**49**

Game Session 8 Player	Quadrants Occupied					Average player^{-1} (%)
		Dry year (%)	Normal year (%)	Wet year (%)	Dry year (%)	
1	4	25	50	25	25	31.25
2	4	75	50	50	0	43.75
3	4	50	0	25	25	25
4	1	50	50	50	25	43.75
5	4	50	50	50	0	37.5
6	4	50	50	50	25	43.75
Average		**50**	**42**	**42**	**17**	**38**

Table 2. Percentage and average diversity of selected land-use activities under different weather conditions per round per player and game session. The diversity is a percentage of the total possible land-use choices per participant.

Game Session 1 Player	Quadrants Occupied	Round 1	Round 2	Round 3	Round 4	Average player^{-1} (%)
		Normal year (%)	Wet year (%)	Normal year (%)	Wet year (%)	
1	1	50	75	100	50	68.75
2	2	100	50	75	50	68.75
3	4	100	75	100	50	81.25
4	3	75	75	75	50	68.75
5	4	100	100	50	25	68.75
6	3	100	50	25	50	56.25
Average		**88**	**71**	**71**	**46**	**69**
Game Session 2 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Dry year (%)	Dry year (%)	Normal year (%)	Normal year (%)	
1	3	50	75	75	100	75
2	2	75	100	100	75	87.5
3	2	100	100	100	100	100
4	3	50	50	75	50	56.25
5	1	50	50	50	75	56.25
6	4	75	75	100	75	81.25
Average		**67**	**75**	**83**	**79**	**76**
Game Session 3 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Normal year (%)	Wet year (%)	Wet year (%)	Normal year (%)	

1	3	50	75	50	50	56.25
2	2	50	75	75	50	62.5
3	3	100	100	50	25	68.75
4	2	50	100	75	100	81.25
5	3	75	75	75	50	68.75
6	2	100	25	25	25	43.75
Average		**71**	**75**	**58**	**50**	**64**
Game Session 4 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}**
		Wet year (%)	Wet year (%)	Wet year (%)	Dry year (%)	(%)
1	3	50	75	75	75	68.75
2	3	50	75	75	75	68.75
3	2	50	75	75	50	62.5
4	2	50	75	100	100	81.25
5	2	50	25	50	25	37.5
6	3	75	50	50	50	56.25
Average		**54**	**63**	**71**	**63**	**63**
Game Session 5 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}**
		Wet year (%)	Normal year (%)	Wet year (%)	Wet year (%)	(%)
1	3	50	75	50	50	56.25
2	3	75	75	50	50	62.5
3	3	50	75	50	50	56.25
4	3	100	100	75	75	87.5
5	3	100	100	75	75	87.5
6	4	100	75	50	50	68.75
Average		**79**	**83**	**58**	**58**	**70**
Game Session 6 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}**
		Dry year (%)	Dry year (%)	Dry year (%)	Dry year (%)	(%)
1	1	75	75	75	50	68.75
2	2	50	50	75	50	56.25
3	4	75	75	75	50	68.75
4	3	100	50	50	50	62.5
5	3	75	50	100	100	81.25
6	3	75	100	50	75	75
Average		**75**	**67**	**71**	**63**	**69**

Game Session 7 Player	Quadrants Occupied	Round 1	Round 2	Round 3	Round 4	Average player^{-1} (%)
		Normal year (%)	Normal year (%)	Wet year (%)	Dry year (%)	
1	2	50	25	50	50	43.75
2	3	100	75	50	50	68.75
3	2	75	75	75	75	75
4	2	50	75	50	50	56.25
5	3	75	50	75	75	68.75
6	3	75	75	50	75	68.75
Average		**71**	**63**	**58**	**63**	**64**
Game Session 8 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Dry year (%)	Normal year (%)	Wet year (%)	Dry year (%)	
1	4	75	50	50	75	62.5
2	4	75	75	50	25	56.25
3	4	100	50	50	50	62.5
4	1	100	100	100	50	87.5
5	4	75	50	50	25	50
6	4	100	75	50	50	68.75
Average		**88**	**67**	**58**	**46**	**65**

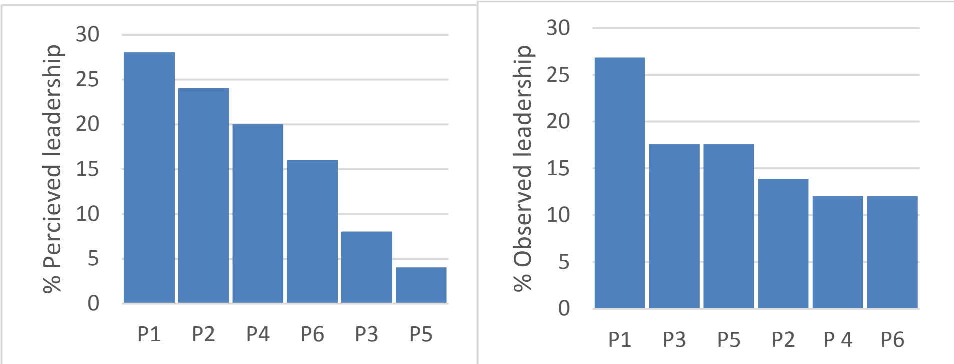
Table 3. Percentage and average of high-risk land-use choices selected out of the total land-use choices by the participant, for different weather conditions per player and game session

Game Session 1 Player	Quadrants Occupied	Round 1	Round 2	Round 3	Round 4	Average player^{-1} (%)
		Normal year (%)	Wet year (%)	Normal year (%)	Wet year (%)	
1	1	100	75	50	100	81.25
2	2	50	0	25	50	31.25
3	4	50	25	50	25	37.5
4	3	75	50	25	100	62.5
5	4	50	50	0	100	50
6	3	50	50	100	50	62.5
Average		**63**	**42**	**42**	**71**	**54**
Game Session 2 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player^{-1}** (%)
		Dry year (%)	Dry year (%)	Normal year (%)	Normal year (%)	
1	3	25	50	75	50	50

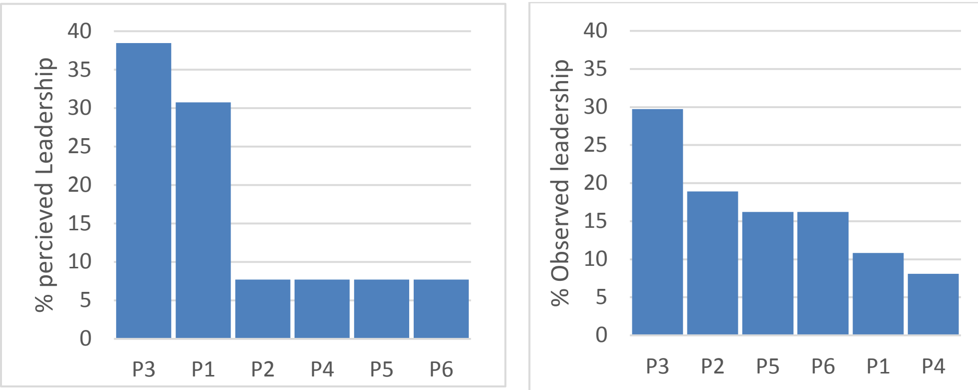
2	2	25	50	50	25	37.5
3	2	50	50	50	50	50
4	3	100	50	25	100	68.75
5	1	0	0	100	75	43.75
6	4	25	25	50	25	31.25
Average		**38**	**38**	**58**	**54**	**47**
Game Session 3 Player	**Quadrants Occupied**	**Round 1** Normal year (%)	**Round 2** Wet year (%)	**Round 3** Wet year (%)	**Round 4** Normal year (%)	**Average player^{-1}** (%)
1	3	0	25	0	0	6.25
2	2	0	25	25	0	12.5
3	3	50	50	25	0	31.25
4	2	50	50	50	50	50
5	3	50	25	25	0	25
6	2	50	100	100	100	87.5
Average		**33**	**46**	**38**	**25**	**35**
Game Session 4 Player	**Quadrants Occupied**	**Round 1** Wet year (%)	**Round 2** Wet year (%)	**Round 3** Wet year (%)	**Round 4** Dry year (%)	**Average player^{-1}** (%)
1	3	100	75	50	50	68.75
2	3	75	50	50	75	62.5
3	2	75	75	75	50	68.75
4	2	50	50	50	50	50
5	2	75	100	25	100	75
6	3	75	100	100	100	93.75
Average		**75**	**75**	**58**	**71**	**70**
Game Session 5 Player	**Quadrants Occupied**	**Round 1** Wet year (%)	**Round 2** Normal year (%)	**Round 3** Wet year (%)	**Round 4** Wet year (%)	**Average player^{-1}** (%)
1	3	75	50	75	100	75
2	3	25	25	0	0	12.5
3	3	100	75	100	100	93.75
4	3	50	50	50	25	43.75
5	3	50	50	25	25	37.5
6	4	50	75	0	25	37.5
Average		**58**	**54**	**42**	**46**	**50**

Game Session 6 Player	Quadrants Occupied	Round 1	Round 2	Round 3	Round 4	Average player-1
		Dry year (%)	Dry year (%)	Dry year (%)	Dry year (%)	(%)
1	1	50	50	50	75	56.25
2	2	25	0	25	50	25
3	4	75	50	50	75	62.5
4	3	50	0	100	0	37.5
5	3	25	50	50	50	43.75
6	3	50	50	100	75	68.75
Average		**46**	**33**	**63**	**54**	**49**
Game Session 7 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player-1**
		Normal year (%)	Normal year (%)	Wet year (%)	Dry year (%)	(%)
1	2	100	100	100	100	100
2	3	50	50	100	100	75
3	2	75	75	50	75	68.75
4	2	0	50	50	100	50
5	3	75	100	50	50	68.75
6	3	75	25	25	75	50
Average		**63**	**67**	**63**	**83**	**69**
Game session 8 Player	**Quadrants Occupied**	**Round 1**	**Round 2**	**Round 3**	**Round 4**	**Average player-1**
		Dry year (%)	Normal year (%)	Wet year (%)	Dry year (%)	(%)
1	4	75	50	75	25	56.25
2	4	75	25	100	100	75
3	4	50	75	100	100	81.25
4	1	50	50	50	100	62.5
5	4	75	100	100	100	93.75
6	4	50	75	100	100	81.25
Average		**63**	**63**	**88**	**88**	**75**

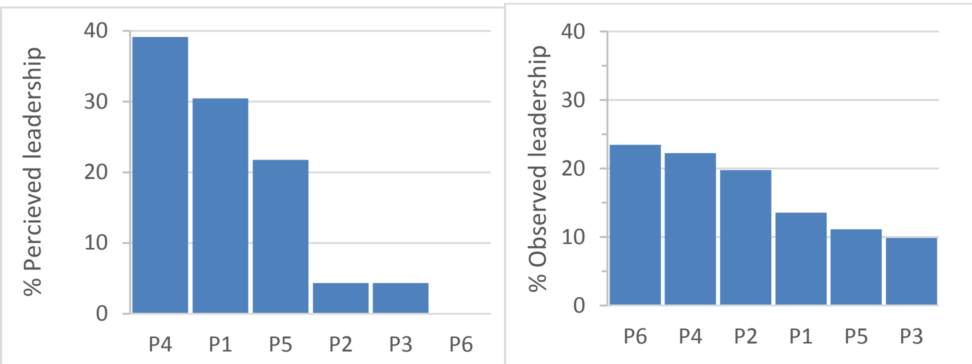
Figure 1: Perceived leadership(%) and observed leadership (%) per participant per game session.



Game session 1



Game session 2



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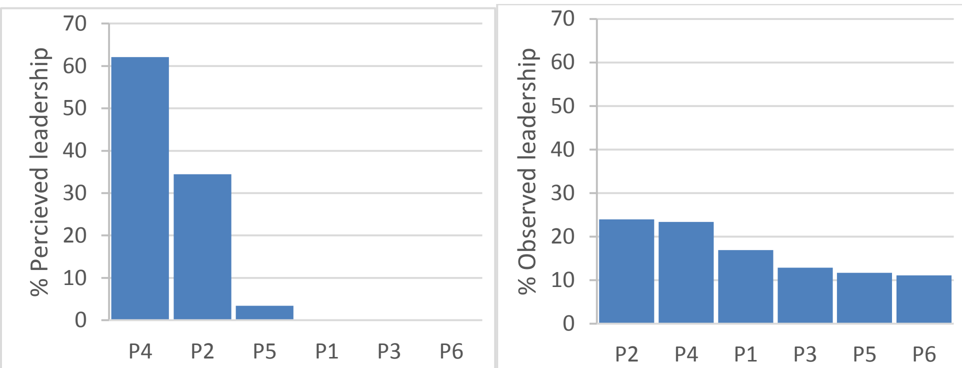

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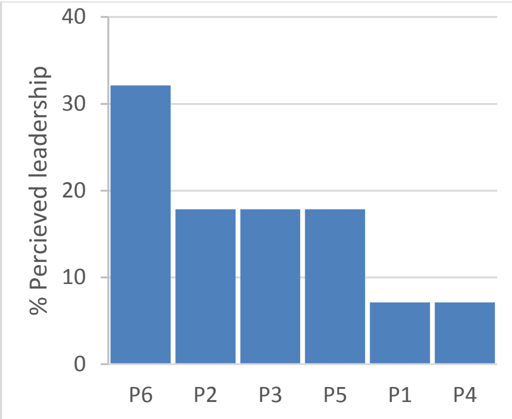

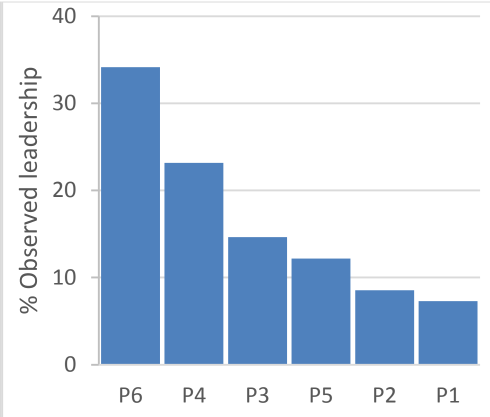

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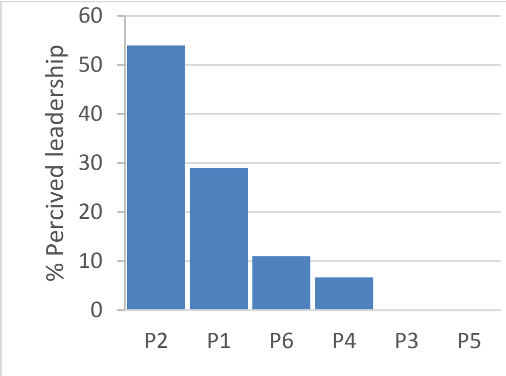

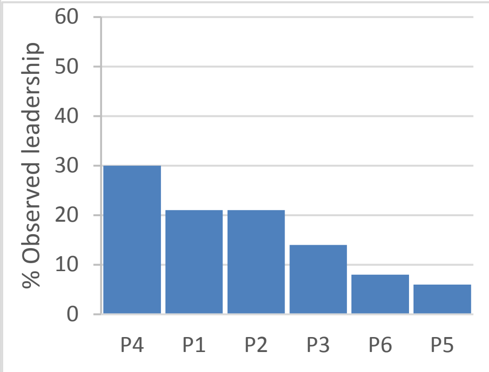

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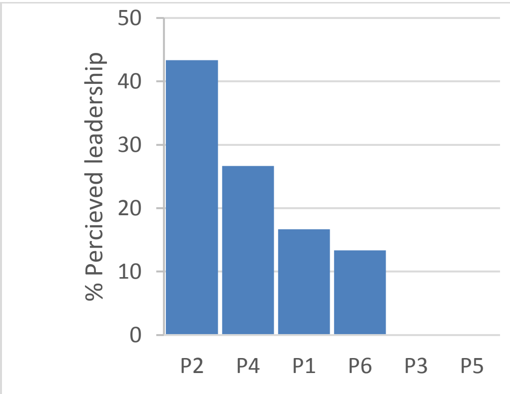
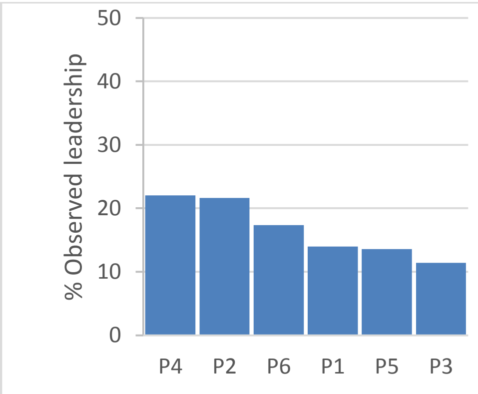
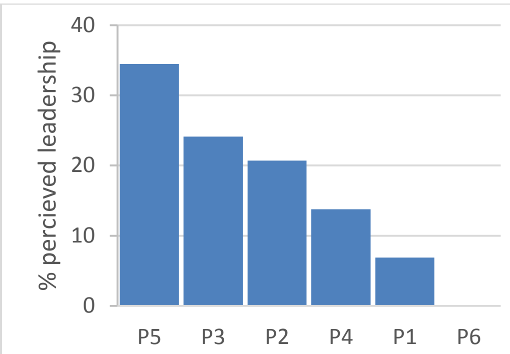
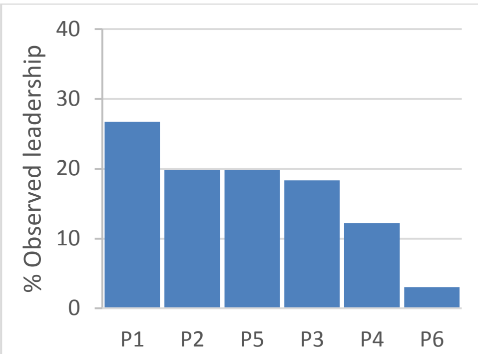




Game Session 7





Game session 8

Pre-game questionnaire

Name ...

Age......

Nationality.....

Study programme.........

Relatedness to other players

What is the nature of your relationship with other players?

1. **Player 1....(Name....)..............**
   a) Friend
   b) Family relative
   c) Study mate
   d) Acquaintance
   e) Not related
   f) ....

2. **Player 2....(Name ...)..............**
   a) Friend
   b) Family relative
   c) Study mate
   d) Acquaintance
   e) Not related
   f) ....

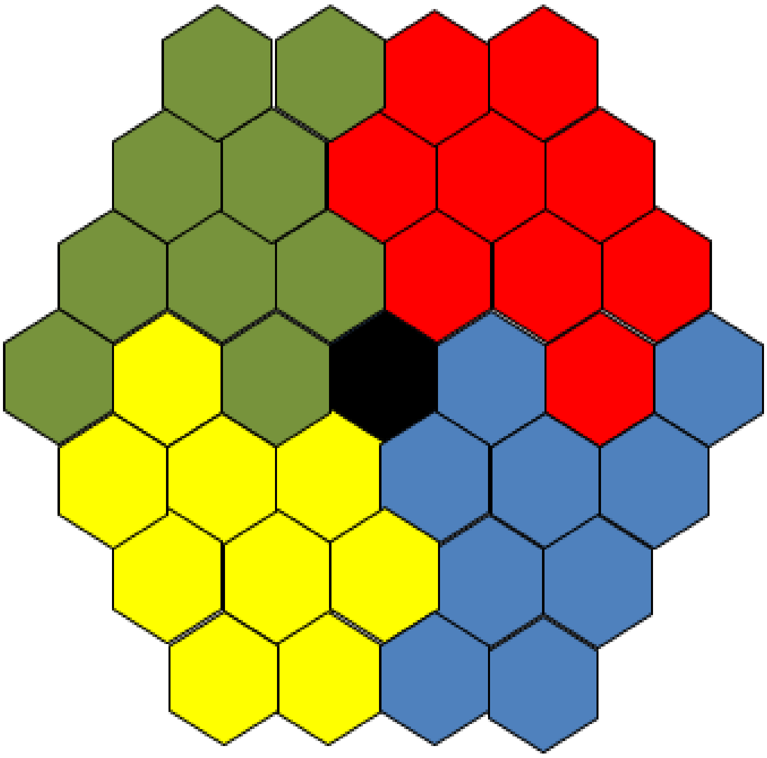
3. **Player 3....(Name....)..............**
   a) Friend
   b) Family relative
   c) Study mate
   d) Acquaintance
   e) Not related
   f) ....

4. **Player 4....(Name....)..............**
   a) Friend
   b) Family relative
   c) Study mate
   d) Acquaintance
   e) Not related
   f) ....

5. **Payer 5....(Name....)...............**
   a) Friend
   b) Family relative
   c) Study mate
   d) Acquaintance
   e) Not related
   f) ....

6. **Player 6....(Name....)..............**
   a) Friend
   b) Family relative
   c) Study mate
   d) Acquaintance
   e) Not related
   f) ....

In the game where would you prefer to locate your fields?



In-game questionnaire

Name....

Game.........

1. What is your overall game plan?

2. What's your plan in this round to achieve the overall game plan?

	Round 1	Round 2	Round 3	Round 4
a) Use high risk land-use activity b) Use low risk land-use activity c) Use individual game plan d) Use common plan with others e) Consider weather condition data *f) Other*				

3. How many land-use activities do you plan to implement on all your plots?

	Round 1	Round 2	Round 3	Round 4
a) one activity b) Two different activities c) Three different land-use d) Four different activities				

4. What are you top considerations in making land-use choices in this round?

	Round 1	Round 2	Round 3	Round 4
a) weather information b) field location c) other players activities d) personal game plan e) contributions of other players f) Other................................				

Last round questionnaire (at the end)

1. What was the biggest reason(s) to make decisions about land-use in the game?
   a) weather conditions
   b) productivity of crops in different weather conditions
   c) other player's opinions
   d) the price risk of land-use choices
   e) the players result
   f) other................................

2. Who made more suggestions during the game **in general**?
   a) Player 1
   b) Player 2
   c) Player 3
   d) Player 4
   e) Player 5
   f) Player 6

3. Who made the most suggestions **to you**?
   a) Player 1
   b) Player 2
   c) Player 3
   d) Player 4
   e) Player 5
   f) Player 6

4. Who was strongest in influencing the direction of the game and give their opinions **in general**?
   a) Player 1
   b) Player 2
   c) Player 3
   d) Player 4
   e) Player 5
   f) Player 6

5. Who was stronger to **give you** opinions or in trying to influence **you**?
   a) Player 1
   b) Player 2
   c) Player 3
   d) Player 4
   e) Player 5
   f) Player 6

6. Who was an exemplary during the game?
   a) Player 1
   b) Player 2
   c) Player 3
   d) Player 4
   e) Player 5
   f) Player 6

Focus group discussion

The focus group discussion will be used to discuss the views, observations and interpretations of the players from the game. The focus group discussion will be framed to base the discussion on different thematic topics. The thematic topics will be

1) The game

Q1 Did you enjoy the game?
Q2 What do you think was the objective of the game?

2) Climate change adaptation

Q3. What were the different land-use choices you used for different weather conditions and why?
Q4. What was the best way to address the variability of the weather conditions in the game?
Q5. What do you think is the best adaptation strategy in the face of climate change?

3) Decision making

Q5. What were the major influences in your decision making process?
Q6. Please expand on each influence?

4) Social network

Q6. Who did you decide to work with and why?
Q7. Was it beneficial to work the way you did?