

Collective Action for Sustainable Farmer Water Management : The Case of the KILIMO NA MAJI Serious Game

Simulation and Gaming

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Collective Action for Sustainable Farmer Water Management: The Case of the KILIMO NA MAJI Serious Game

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Abstract

Background. Farmers in water scarce landscapes adapt in response to the erratic weather conditions. Adaptation through irrigation, depend on water access, while impacting on downstream water availability. Competition for **scarce water commons** among multiple users defines a **collective action** problem. Farmer land-, and water-use **decisions** are based on both economic rationality of cost-benefit expectations, and relational rationality of reconciling conflicting opinions of important person(s) in a farmer's social world, such as other water users, government, or spirits. **Serious games** that represent this duality of choices can help both players and interested others to analyze how **social relations** influence farmer decision-making.

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Intervention. Here we describe the generic design and early experiences with specific use of the KILIMO NA MAJI game. The game is designed to analyse effect of social relations as farmers individually and/or collectively explore alternative options for crop production in scarce water commons.

Methods. We designed and applied the game in the Mt. Kenya region; a semi-arid region, ranging across a gradient of upstream water abundance to downstream water scarcity. The design of the game was informed by literature, and information from local stakeholders. We analyzed data from the pilot game sessions to assess quality and effectiveness of the game using Likert scale and a 'solution space' which defines a bandwidth around the mean where tradeoffs between farm-income and water-use can be partially managed.

Results. Playing the game with local stakeholders showed that social relations that participants had with traders, agro-export companies and other important persons determined where their game outcomes were positioned within the solution space.

Conclusion. Playing KILIMO NA MAJI can help assess influence of social relations and support collective exploration of alternatives to crops production in water scarce landscapes.

Keywords

Collective action, farmer decisions, Mt. Kenya, serious games, scarce water commons, social relations

Background

Farmers in regions with seasonal droughts adapt their land- and water-use decisions to sustain crop production for food and income during dry season. They adapt in several ways which include farming drought tolerant crops, shifting planting seasons, and practicing irrigation (Kom et al., 2022; Ng'ang'a et al., 2021; Njinju et al., 2022; Peter & Imatari, 2019; Pilarova et al., 2022; Ratemo et al., 2020; Sindhu et al., 2019; Sollen-Norrlin et al., 2020; van Noordwijk, 2019). Although irrigation can sustain crop production over dry periods in certain areas, it meets with socio-economic, technical, and institutional challenges (Fanadzo & Ncube, 2018; Kanda & Lutta, 2022; Pilarova et al., 2022; Timothy et al., 2022). Unregulated irrigation from common water resources more often leads to conflicts among the multiple users who depend on the same common water resources. Governing the commons becomes a collective problem in instances where individual interests supersede shared goals (Janssen et al., 2023). Despite possible self-interests, individuals are capable of self-organizing and shifting focus from individual interests to shared goals (Ostrom, 1990). Collective action is built on trust and cooperation (Ostrom, 1990). It starts with understanding the impact of one's

actions and willingness to sacrifice own interests for the common good. Researchers and policy makers have used participatory approaches to create this understanding among stakeholders and to promote collective generation of local and sustainable strategies to management of resources (McConville et al. 2023). Such approaches include, among others, serious games. Serious games represent real systems in a simplified model that participants (community, researchers, and policy makers) can engage with on a shared-learning platform, experiment and experience impacts of their decisions, learn, reflect, build trust, and jointly identify alternative sustainable options in a safe environment (Biggs et al., 2021; Edwards-Jones, 2006; Falk et al., 2023; Fjællingsdal & Klöckner, 2020; Janssen et al., 2023; Kriz, 2017; McConville et al., 2023; Speelman et al., 2018, 2023; Toshiko et al., 2022; Van Noordwijk et al., 2020). Serious games have been developed and used in various fields including climate change, land, water, and environment management (García-Barrios et al., 2008; Janssen et al., 2023; Lairez et al., 2020; Rakotonarivo et al., 2021; Rooney-Varga et al., 2020; Sari et al., 2023; Sterman et al., 2015; Villamayor-Tomas & García-López, 2017; Villamor & Badmos, 2016; Villamor & Van Noordwijk, 2011). Serious games have also been used for diagnosis of a phenomenon; establishing a better understanding of land-use decisions and their impacts on water flow among local stakeholders; and instigating responses from external stakeholders including support to collective management of shared water resources (Edwards et al., 2019; Janssen et al., 2023; Toshiko et al., 2022; Van Noordwijk et al., 2020). In the context of farmer land and water decision making, relevant games include, RIPERWIN River Basin Game (Lankford et al., 2003), MEDTER game (Le Bars et al., 2004), Aquafej (Bars et al., 2014), FOWIS (Hertzog et al., 2014), Wat-A-Game (Ferrand et al., 2009), and CAPPWAG (Loudin, 2019). In a game session, participants are presented with rules to engage with the game, test possible interventions and explore alternative outcomes (Biggs et al., 2021; Edwards et al., 2019; Toshiko et al., 2022). However, it is not always that players play by the rules, other social and cultural factors can affect decision making processes in the game (Edwards et al., 2019; Hofstede et al., 2010; Van Noordwijk et al., 2020). Although serious games have been used widely to explore decision making process, there has been less emphasis on the effect of social relations compared to instrumental rationality (Githinji et al., 2023; Van Noordwijk et al., 2023a). Instrumental rationality places value on economic and ecological benefits while relational rationality weighs rationality from the perspective of relations that individuals have with their social world (Hofstede et al., 2019; van Noordwijk et al., 2023b). Social relations that individuals have with their reference groups affect their decisions. A reference group is an individual or group of individuals which a person considers while making decisions (Kemper, 1968, 2017). Reference groups can be alive (for instance neighbours), or dead (for instance ancestors); real or imagined (for example spiritual deities). An individual complies with the perceived preferences of a reference group either voluntarily (status-accord) out of respect, love, concern expecting to be accorded the same, and/or involuntarily to avoid power use for instance punishment, surcharge (Kemper, 1968, 2006, 2011, 2017). Accordingly, players may

make decisions that aim to meet individual or collective goals depending on salience of their reference groups.

In a game session, reference groups that are already existing in a player's mind (for instance family, or local market traders), in the room (for instance other players or participants), and/or those who emerge during a game session can influence the player's decision. A player may have multiple reference group; some more salient than others. Reference group can influence a player action depending on their relative salience compared to others. According to Kemper (Kemper, 2017), people who are wealthier, more educated and those in leadership positions are likely to be accorded more salience. Such people may become a salient reference group in a game session if other players are aware of their status-power standing in the society. Further, at times power wielded by an institution may be confused with power of an individual representing the institution (Kemper, 2017). Thus, other players may do the binding of such an individual. Some players may also gain status during a game session, for instance if they seem to understand the game better or if they make more profit. These players in turn may unintentionally affect decisions of others in subsequent rounds. Additionally, a game session can evoke emotions creating new reference groups whom players' feel the need to do their bidding. In a game session, players can observe the landscape as a whole; see and feel the impact of their action and that of others possibly generating an array of new emotions that can steer cooperation among players.

Despite possible effect of social relations on a game's outcomes, most of the games that have been used to explore farmers' decision making have not explicitly explored the effect of social relations as a concept in decision making processes. More specifically, a game that can capture the effect of social relations in areas characterized by pressures to increase crop production amidst water scarcity, to our knowledge, does not exist yet. To address this gap, we designed and used a serious game to analyse the influence of social relations. This paper has two main objectives, i) to describe the design of KILIMO NA MAJI (meaning farming and water in Swahili language), a serious game designed to engage stakeholders in exploration of land and water management options that would sustain crop production in water scarce landscapes, and ii) present results from two game sessions providing insights into application of KILIMO NA MAJI game and analysis of game's outcomes from a social relations perspective. To achieve the objectives, KILIMO NA MAJI was developed and piloted in the upper Ewaso Ng'iro North River Basin in Mt. Kenya region. We hypothesized that the game will enable players (farmers) play out their actual behaviour and explore alternatives for sustainable land- and water use. Also, the design and setting of the game will help identify the effect of reference groups on farmers decisions not only in a game's outcome but also in reality.

Design of KILIMO NA MAJI

Game Objectives

The game has two main objectives i) provide a shared platform for stakeholders (farmers, regulators, policy makers, and researchers) to jointly experiment with various land and water options, observe impacts, reflect and generate alternatives to sustainably produce crop with scarce water; and ii) Support exploration of the influence of social relations on player decisions and game outcomes. To address these two objectives, we designed the game in two levels, that is, 1) the game itself with its spatial features of up-downstream gradient and resources availability, and 2) the social-relational model that represents the design on player interactions with reference groups. [Figure 1](#).

Game Design

The designing of KILIMO NA MAJI followed steps proposed by ([Etienne, 2014](#)) ([Figure 2](#)) that is, model development, experts review, companion modelling, re-modeling and finalization and game playing sessions (the game development process is comprehensively described in the [Supplementary Material](#)). Companion modelling with stakeholders from the Upper Ewaso Ng'iro North River Basin was done to ensure the game was as close to reality as possible. Such that players could relate to it and possibly reflect their actual behaviour in the game.

The Game Model

We used Actors, Resources, Dynamics, and Interactions (ARDI) Framework ([Etienne et al., 2011](#)) to design KILIMO NA MAJI. The *Actors* were farmers whose actions and/

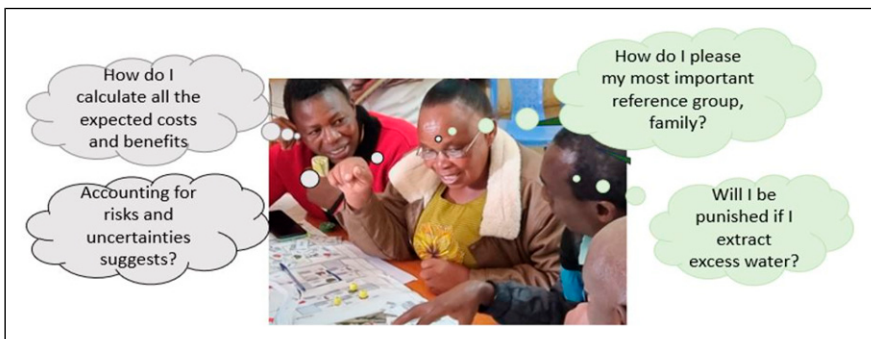


Figure 1. Players use KILIMO NA MAJI to identify feasible options to produce crops with the limited water. Thought clouds on the left indicate economic rationality while those on the right show social reactions rationality.

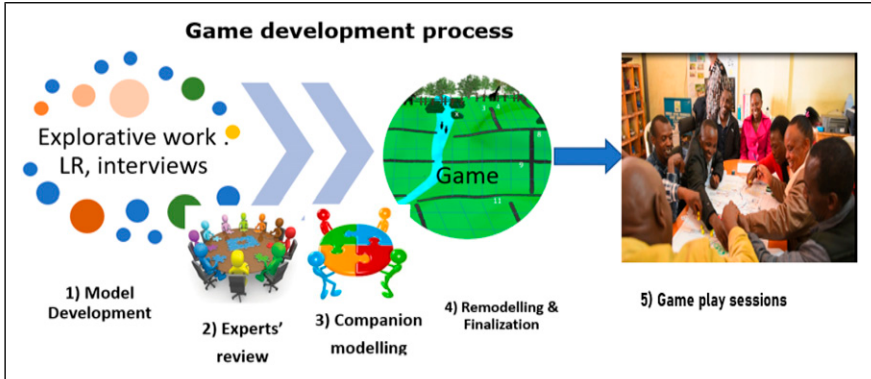


Figure 2. The game development process.

or decisions significantly impacted the landscape. Other actors were representatives from the Water Resource User Association (WRUA), playing their own role and that of government in water regulation. *Resources* were land, water, and finances. We tracked the impact of player actions on resources through two indicators, that is, amount of water extracted and farm-income. *Dynamics* were major processes that could affect the landscape or steer actions of the actors in a certain direction, for instance weather variations (dry and wet season), river flow changes, social cohesion, and collective action. Regarding *Interactions* players 1) Use knowledge/ rules/ relations to choose crops to farm, 2) Use money to buy seeds to plant 3) Use knowledge/ rules/ relations to decide whether to irrigate crops or not. Where, knowledge is both implicit (acquired by players over time such as crops that would produce better in their own locations), or explicit which the facilitator shares (such as amount of token required to irrigate different crops) or players share among themselves (such as the crops they should farm); rules include those provided by the facilitator (such as some water tokens cannot be extracted), or rules that players agree upon once they start collaborating.

The Reference Groups Modelling

We expounded the ARDI framework to include social relations of the players, thus R-ARDI (Figure 3). *Relations* were interactions between players and their salient reference groups. Noting that social relations are a key component of this game, the role of reference groups needed to be clear. A game can have three types of reference groups ‘visible’ (such as government, water regulatory body, agro-export company, brokers, NGO), the ‘invisible’ (such as ancestors and family) and ‘somehow visible’ (such as neighbors and downstream farmers). A facilitator can approach the role of ‘visible’ reference groups in three ways. Farmers play the role of the reference groups; real world reference groups, for instance local traders, play the game as themselves; or reference group exist entirely in the minds of the players. Where facilitator choose to have

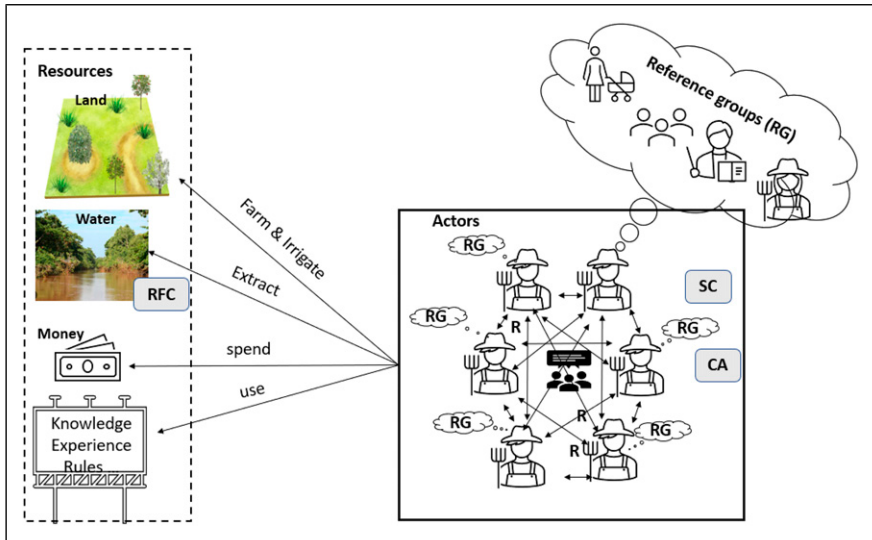


Figure 3. KILIMO NA MAJI conceptual framework: Farmers are the strategic actors (players) interacting with resources on the left (arrows shows Interactions). Interactions among players and between players and their reference groups i.e., Relations, are on the right. Each actor interacts with the resources and with own RG-reference groups that could include other actors in the room. Relations are indicated with double-edged arrows indicating status-power exchanges. The round cornered grey rectangles are the dynamics (SC- Social Cohesion, CA- Collective Action, and RFC River Flow Change).

farmers play the role of reference groups, these actors should be adequately briefed. Optionally, they can be allowed to have flexibility to simulate how they perceive reference groups. In our pilot sessions reference group existed entirely in the minds of the players. Pros and cons of each of these approaches is described in the [Supplementary Material](#).

Game Features

Game Board. The game board simulates a landscape occupied by smallholder farmers and a shared river that flows and serves up-, mid-, and then downstream communities ([Figure 4](#)). The landscape has farms; each farm has four plots equivalent to a quarter hectare and is managed by an individual household (player). The game board can be expanded or contracted to have more or less plots depending on the objectives of the user.

Cards & tokens. Kilimo Na Maji has info crop cards, tree models, water, and money tokens.

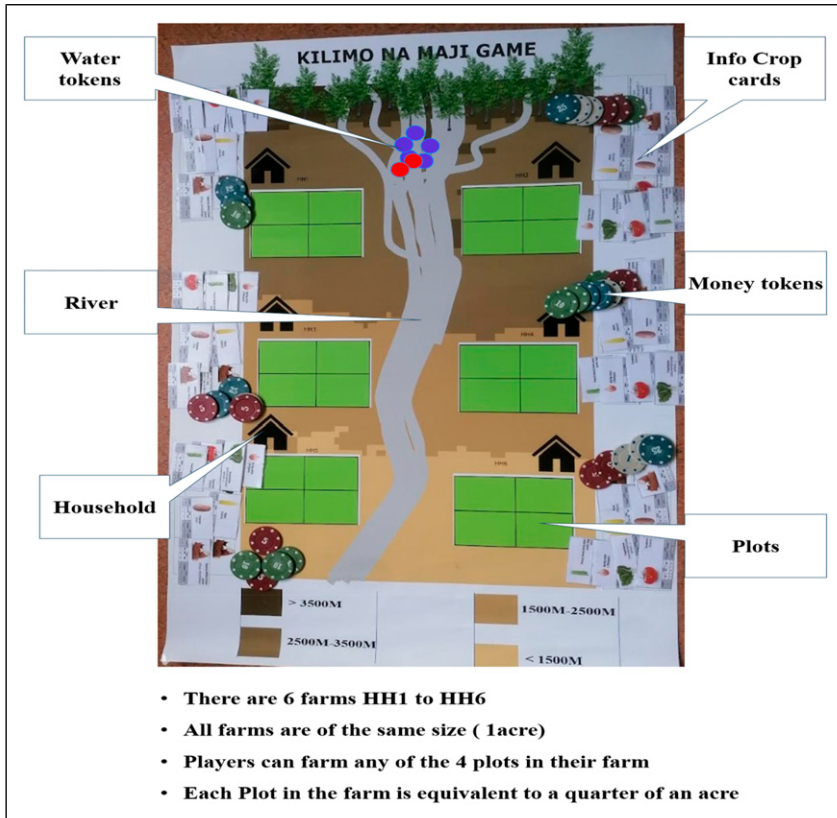


Figure 4. Board game simulating an up-downstream landscape. The board game has six (6) households with equal farm sizes. The game is played by placing the info crop cards on any of the four plots. Water and money tokens are utilized against some defined rules provided in the info crop cards and the supplementary material.

- a) Info crop cards (Figure 5) are in three categories - *Category A: High Water Requirement Crops (HWC)* for instance french beans, tomatoes, vegetables, and onions. These crops are highly profitable, but a farmer must irrigate to get a good harvest. *Category B: Medium Water Requirement Crops (MWC)* for instance maize, and potatoes. In this category, profits are lower than HWCs, crops can serve as family food, and do not have to irrigated. However, failure to irrigate the Medium Water requirement crops lowers their yield and profits (Figure 5). *Category C: Low Water Requirement Crops (LWC)* for instance cassava. These are crops may have low profit margin, but they can survive though seasons without irrigation.

Capital		Water			Profit	
		Jan	Feb	Mar	Irrigated	Rainfed
	2	1	1	1	2	1

Figure 5. Info Crop card. Each Player is issued with three types of cards: Low-, Medium, and high- water requirement crop cards. The info crop cards have the name of the crop with its translation in the local language, capital investment (in cash tokens) required to farm the crop, a crop's water irrigation needs per month (in water tokens), expected profit if crop is irrigated as required, and profit if the crop is not irrigated or is insufficiently irrigated.

- b) Tree models – usually given out for free by the government (the facilitator) in support of agroforestry.
- c) Water tokens – 1 token represents 300 MM of water volume. There are twelve sets of water tokens representing mean monthly river flow for every month of the year. At the beginning of each month, the facilitator places the monthly water tokens on the simulated river ready for any extraction by players. A table of coded river flow information from our pilot case study site is presented in [Supplementary Material](#).
- d) Money tokens – can be in terms of fake currencies, tokens of a certain value or made-up print outs of a specific value to allow transactions e.g., paying out the required capital.

Game Play Conditions

Playing the game requires a large room (or open space) with a table where the game board is placed. Players sit around the table and adjacent to their allocated plots. This is to allow easy access to their plots where they will be required to place their chosen info crop cards. Ideally, players should be seated throughout the game for their own comfort and for the facilitator to be able to get a better view of the whole game and players' actions. The board game printout is large enough to allow the six players to sit around the table comfortably, but also small enough to enable each player see the landscape as a whole; observe the actions of others; observe impact of own action; and listen to discussion of other players. This approach is specifically done to instigate possible emergence of other reference groups for instance other players in the room, and also possible formation of an 'all players' group for collective action.

Participants, players, and roles

- a) **Players** - The Kilimo Na Maji game has players playing the role of farmers making decisions on what to farm, whether to use irrigation, or whether to collaborate and with whom.
- b) **Policy maker** – the policy maker is the person in charge of administering set policies on water regulation. In the Kenyan context, this was chairperson of Water Resource Users Association (WRUA) or his representative. In the game, the person has three roles: a) regulate water use by prohibiting extraction of any more tokens or fine players for over-extraction of provided tokens; b) advice on water use c) in cases where players do not self-organize for better water management, the policy maker can initiate collective action discussions.
- c) **Logistics manager** - is charged with invitation of participants as per the researchers' requirements, organizing the game room to the comfort of the players and other logistics.
- d) **Facilitator**- is charged with briefing and debriefing of the participants. Before the game starts the facilitator explains the basics of the game, its objectives, how to play and the general conduct of all the participants in the room. The facilitator also explains and responds to any questions participants may have during the game playing session. Afterwards, the facilitator guides the debriefing session.
- e) **Observer**- Silently observes all the proceedings for later discussions during the debrief or for later discussions with the researcher.
- f) **Camera person(s)**- to record all the proceedings for later use by the researcher in the analysis.

Rules of the Game/Decision Tables

The Game has three tables representing the rules of the game. The most critical rules are also included in the info crop cards i.e., capital required, profits, and monthly irrigation requirements.

- a) Coded crop irrigation requirements – data for this table is generated using CROPWAT (Smith, 1992) based on climate data/ET, rainfall, crop requirements, soil type, cropping pattern, and proportion of acreage under a particular crop. The data is coded to manage the number of water tokens availed to the players and adjusted to account for farmers' perceived crop water requirements.
- b) Crop characteristics – maturity duration, capital investment, labour requirements, land rates (rent), profit margin with and without irrigation, price fluctuation. Although all this information increases representation of reality, it was noted that it can be overwhelming for players. In cases where time is limited, some of these elements can be omitted.
- c) Reference Groups (optional)– reference groups with pre-defined preferences, rules, incentive, and sanctions for non-compliance with their rules.

The Game processes

KILIMO NA MAJI game has three stages: stage 1 comprises of activities before the game, stage 2 is the Game playing session while stage 3 is the Debriefing session.

Stage 1: Before the game

- a) Players' demographic data is collected including, age, gender, economic activity, level of education, leadership, geographic location. The role of each player is noted i.e those who will play as farmers or those who will play the role of reference groups. Farmers' data is linked to the plots they will be allocated on the game board. Player's data is collected since it can give an indication if a player could be a salient reference group. A farmer's demographic data can be used as proxy indicators for status and power. According to (Kemper, 2017), a person's education, financial status, leadership position, age, gender may have an impact on their status-power standing. The facilitator should also find out if other participants are aware of each other's status and power by asking whether they knew each other before the game.
- b) Players are briefed on how to play, and the available land-, and water-use options. Options include trees, crops, and irrigation (done by picking the water tokens). Basic rules include: a farmer can choose more than one crop but may be limited by available resources; farmers can talk and discuss among themselves; reference groups (if in the room) can share their land- and water-use preferences with the farmers. The rules are also flexible enough for farmers to play the reality on the ground.
- c) Facilitator and players discuss on other possible decisions such as: repeating/ changing crop over the seasons, deforest/harvest/prune trees, expand land for crops, abandon/sell/fallow land, sub-division of land. This is to allow creativity of players as well as identify some options that could have been left out.
- d) Reference group players (if any) are briefed on their roles. Such roles include giving input subsidies; sanction for unacceptable behavior; advice on crops to adopt; buy crops. A sample of the reference group roles are presented in [Supplementary Material](#).

Stage 2: Playing the Game

Players are allocated plots on the game board, a set of info crops cards, and money tokens. One round represents a season (Figure 6). Each round has monthly sub-steps in which farmers choose to irrigate their crops or not. The session has six main steps with one round taking approximately 30 minutes.

This game is played by six smallholder farmers(players). After the briefing session, players assess their land and water use options and potential economic and ecological outcomes before making three main decisions i.e., what to farm; whether to irrigate; to

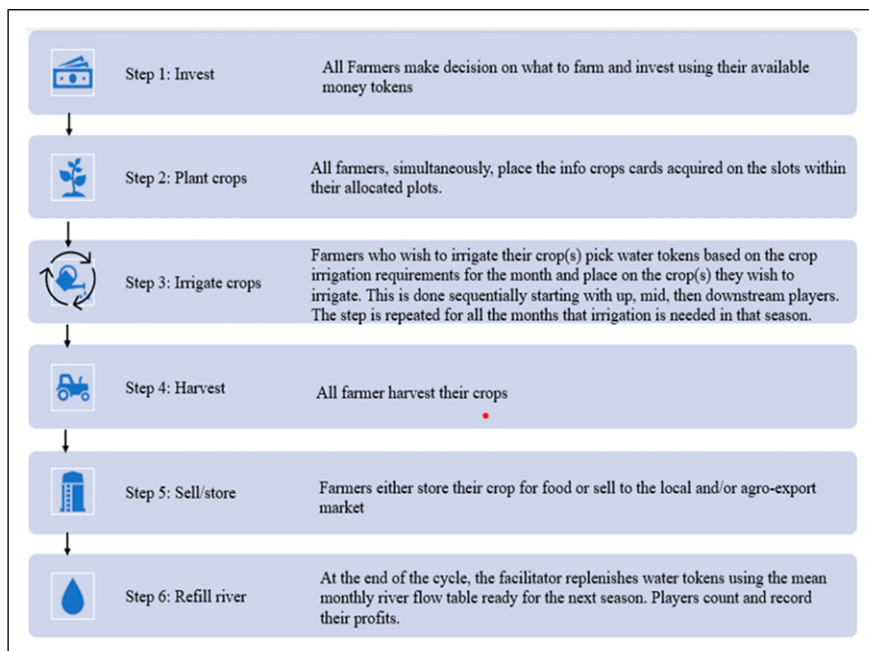


Figure 6. Steps in KILIMO NA MAJI game play session. These steps are repeated until players identify alternative options to sustainably produce crop amidst water scarcity. Subject to availability of water, step 3 is repeated for all months that irrigation is required, otherwise players move to the next step.

collaborate or not. At the beginning of each round, all players select crop(s) to farm, invest some money tokens on their choices and place these crops on their allocated plots. The next decision is whether to irrigate or not. Failure to irrigate crops that need irrigation leads to less profit. One round represents a season. Each round has monthly sub-steps for irrigation. At every sub-step, farmers interested in irrigation pick the available water tokens starting upstream, then midstream and finally downstream. At the end of the sub-step, facilitator refills the river with new water tokens as per the mean monthly river flow table. This step is repeated for all the months that crops need to be irrigated. At the end of each round, farmers harvest and sell their crops. Players earn income depending on the type of crop and whether the crop was irrigated as required. The target for each player is to earn a good income but also to avoid conflicts. Considering that water tokens are limited, irrigation by one player means less water tokens and profit for the other player. Therefore, players must decide on whether to collaborate and look for alternatives that would be acceptable to all players. The game continues until players are satisfied with their game choices and outcomes.

During this stage, the facilitator takes note of any emerging social relations and its effects by observing player actions, and listening to discussions among players. For

instance, who is copying who, who is advising whom, whose actions caused a change in another player's action. This is because it is not always that people would be able to identify the relative importance of a reference group (which reference influenced their choices), but it can be reflected in the choices they make during a game session. While transiting from one round to the next, facilitator can choose to allocate plots differently in view of assessing any change in farmer decisions while placed in a different part of the landscape. The two options are:

Scene 1: Farmers play as their own selves at the landscape i.e upstream play as upstream farmers, and so does mid and downstream farmers. This setting represents the existing situation and helps understand the existing issues/ problems and their causes. In a landscape characterized by water related conflicts, players may be uncomfortable to play their own roles due to a possible infiltration of real-life frustrations in a game session. The facilitator should be weary of such cases and can avoid conflicts by opting to play scene two.

Scene 2: Farmers shift places. Balloting or a dice can be thrown to allocate farmers their lands. Farmers will only be allowed to draw ballots outside their actual locations. This setting is not only ideal for avoiding tension in an already water-conflicted landscape but can also be ideal in ensuring advantaged players experience and feel the impact of their actions and possibly generate empathy for the disadvantaged farmers. The scene may also make players understand how they are perceived by other players through their actions.

Stage 3: Debriefing Session

After the Game, the facilitator leads a debriefing session where players discuss the game, motivation for their choices, and extent to which players were able to learn from the exercise. In this stage, the facilitator should identify what kind of social relations impacted player decisions. specifically, the effect of already existing relations with reference groups in the minds of the players; effect of other participants in the room; and the effect of emerging relations during game play. Assessment on social relations can be obtained by asking players what informed their choice/who benefits from their choice of crop/ why they choose a certain practice. Other questions should be around the game quality: its functionalities, its representation of the actual context, the extent to which farmers are able to learn from the game and policy recommendations. A Likert scale questionnaire can be used to assess the quality of the game. The Likert scale and a sample of debriefing questions are provided in the [Supplementary Material](#).

Adaptation of the Game

KILIMO NA MAJI game is a generic game that can be adapted to different socio-ecological systems by changing the crop choices, crop irrigation requirements water tokens, reference groups, cash tokens, and sometimes the game board. A detailed procedure of 'how to' is provided as part of the [Supplementary Material](#).

Application of KILIMO NA MAJI

Using quantitative and qualitative analysis of two (2) pilot sessions, we tested the effectiveness of game in the Upper Ewaso Nyiro North River Basin. The pilot sessions were used to assess quality of the game: understability, playability, adequacy of time it takes to play, representation, its capacity to promote learning, and achieving its objective.

Methodology

The Upper Ewaso Ngíro North River Basin was used to inform the design of KILIMO NA MAJI game and test its effectiveness. The study site lies in the leeward side of Mt. Kenya. It forms part of the arid and semi-arid lands in Kenya with an average of 2000mm rainfall per annum in the upstream and less than 350mm per annum in the downstream (Kimwatu et al., 2021). Despite the limited rainfall, the region has high agribusiness potential supported by irrigation. The Government of Kenya with partners, implements several interventions to promote sustainable crop production while regulating water use. The interventions include a polycentric governance structure that manage water resources from national to community level. The governance structure includes a community-based water management institution known as the Water Resource Users Association (WRUA). WRUA manage specific water sheds with the main role of monitoring water use and curbing misuse. Despite this, a large amount of water is extracted for irrigation in the up and midstream region, leaving little or no water for downstream communities, often leading to water-related conflicts (Kiteme, 2020; Lesrima et al., 2021). In its application, KILIMO NA MAJI was adapted to incorporate features from the case study site to present an interactive game with the right amount of pressure for players as they make their land- and water-use decisions. Two sub-watersheds (*Nanyuki* and *Teleswani*) in the Upper Ewaso Nyiro North River Basin were used in the pilot sessions. Players' sociodemographic characteristics for each sub-watershed are shown in Table 1. 1st group comprised of members from *Nanyuki* sub-watershed while 2nd group were from *Teleswani* sub-watershed. Players were randomly selected within a stratified group that represented up-, mid-, and downstream zones. The two groups were objectively selected based on a prior study (Githinji et.al, 2024) that showed differences in land-use types between the two selected sub-water sheds. Hence the groups would be able to measure the extent to which representation of reality is reflected in the game play.

Data Collection

Data were collected from the two selected groups. All players and participants in the room gave written consent for use of their responses including written, verbal, photographs and videos in the analysis of data and any publications that could emerge from the game sessions. Our game sessions had three stages of data collection, before, during

Table 1. Players’ sociodemographic characteristics in the two application sessions.

	Group	Characteristics		
		Average	Min	Max
Age in years	1 st	36	27	42
	2 nd	53	45	65
Gender	1 st	Male (3), Female (3)		
	2 nd	Male (4), Female (2)		
Level of education	1 st	Secondary (5), tertiary (1)		
	2 nd	Primary (2), Secondary (4)		
Land size in hectares (owned)		Average	Min	Max
	1 st	0.5	0.0	2.4
	2 nd	1.2	0.4	2.0
Leadership	1 st	1 out of the 6 held different leadership positions		
	2 nd	All six held different leadership positions		

and after the game. Before the game, farmers’ characteristics were recorded, i.e., age, gender, level of education, land owned in hectares, positions of leadership held and location (up-, mid- or downstream farmer). During game playing stage, data on a player’s crop selection, use of irrigation or not and income were recorded on data sheets. Interactions among players and discussions during this session were also recorded, taking note of any undefined options that players introduced in the game. After the game (debriefing session), the facilitator used guiding questions (sample provided in the supplementary material) to guide a focus group discussion with participants. All game sessions were also video recorded, and photos taken to support analysis.

Data Analysis Using the ‘Solution Space’

To test the capacity of the game in achieving its main objectives, we used the ‘solution space’. In KILIMO NA MAJI, farmer decisions could lead to different land and water use choices with direct impact on farm-income and water availability. This gives a wide range of possible outcomes, ‘the Solution space.’ The solution space was developed by running 1000 random choices thereby generating 1000 possible outcomes; equations used to generate the solution space are provided in the supplementary material. There is a bandwidth around the mean that suggests tradeoffs can be partially managed, for instance by limiting water use in dry season, or by increasing water availability through water harvesting. Two variations of the solution space were i) players make random choice of crops but follow water sharing rules i.e., extract only the amount of water required by each crop starting with upstream players, followed by midstream and

finally downstream (Figure 5 a, b, c); ii) players make random land and water choices without following any rules (Figure 5 d, e, f). In the first option, the outcomes in the solution space were further disaggregated by different player groups i.e up-, mid-, and downstream. The solution space showed that in a dry season only the upstream players benefit (Figure 7 a), while a dry season with water harvesting is like a wet season where everyone benefits since there is enough water. (Figure 7 b, c).

To test one of the objectives of the game i.e., providing a shared platform for participants to jointly experiment and generate alternatives to sustainably produce crop with scarce water, results from a game session are mapped into the solution space. If the results are within this space, then this is an indication that the objective is achieved. The other objective of the game i.e., assessment of the effect of social relations, we incorporated a discussion session to identify relations that players have with reference groups that could have placed the outcomes at specific points of the solution space. Further, we analyzed player's socio-demographic data as proxy indicators of player's status and power as possible reference groups during a game session. Furthermore, before the game, players ranked reference groups that had been identified as salient reference groups in the region by Githinji et.al (2024), using a scale of -3 to 3 (where -3 is least important, and 3 most important).

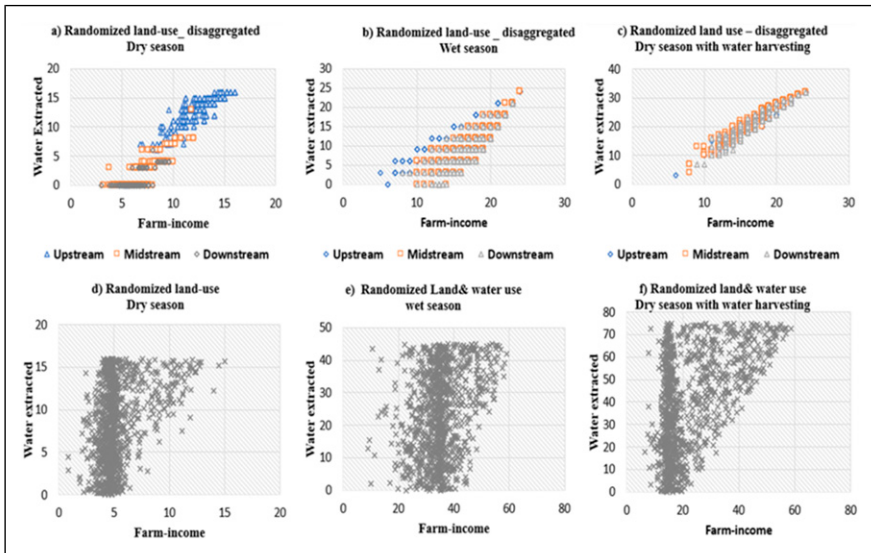


Figure 7. Shows a solution space for both dry and wet seasons. a, b, and c show all possible game outcomes on farm-income versus water extracted for random choices within strict water use. i.e., a crop is irrigated with the exact amount of water needed for maximum yield. Figure d, e, and f shows all possible outcomes on farm-income versus water extracted for random choices without restricted water use.

Results from the Pilot session

Effectiveness of the game

Overall, KILIMO NA MAJI game was rated at 4.2 and 4.5 against a possible 5, by the 1st and the 2nd group respectively with objectivity, representation and understandability being ranked as the best qualities of the game. (Figure 8). These three qualities ranked highly among players since they felt the game was a close reflection of their landscape, land use choices and pressures around water scarcity and water governance. Thus, it was easy to relate with the game, understand its rules and collectively explore alternative options. Some of the players felt the game took too long to play but also highlighted that this was understandable considering the complexities of the system that had to be included.

Game outcomes

While the solution space provided all possible outcomes of the game, playing KILIMO NA MAJI with people added the influence of social relations on player actions and outcomes of the game. In both groups, players started off with high-water requirement crops to get higher profits. Since upstream players accessed water first, they made more money in the first round of the game (Figure 9 a and b). This was followed by the realization that water is not enough for all and pressures from those who did not get water. Resultantly, a reference group comprising of all players emerged. Players collectively defined rules (opinions) for this new group which included water harvesting for the 1st group and equal water sharing for the 2nd group. Under collective action, the difference on farm-income reduced across up-, mid-, and downstream players

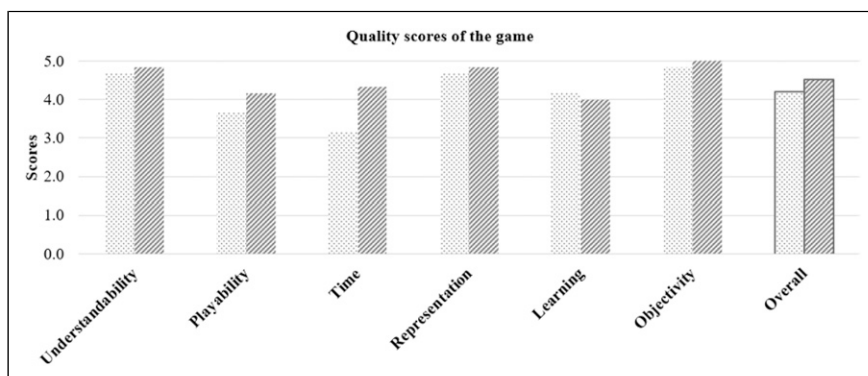


Figure 8. Player's scores on the quality of KILIMO NA MAJI in both first and second group. Scores range from 1 (lowest) to 5 (highest). The last columns show the average rating of different qualities of the game by the two groups.

(Figure 9 c and d). Opinions for the ‘all players’ reference group significantly impacted the game outcomes, such that the 2nd group which did not harvest water, got much lower farm-income compared to players from the 1st group. (Figure 9 c).

Salience of Reference Groups

Results showed that on average, family was the most important reference group while ancestors, government, and peers were not important in both groups. Downstream communities and agro-export companies were not important for the 1st group but were considered salient in the 2nd group (Figure 10).

Effect of reference groups on game outcomes

The decisions (on what to farm, whether to irrigate, to collaborate or not and when) placed a game’s outcomes in a particular position on the solution space. To a large extent, the results showed that players carried along their social status, power, and

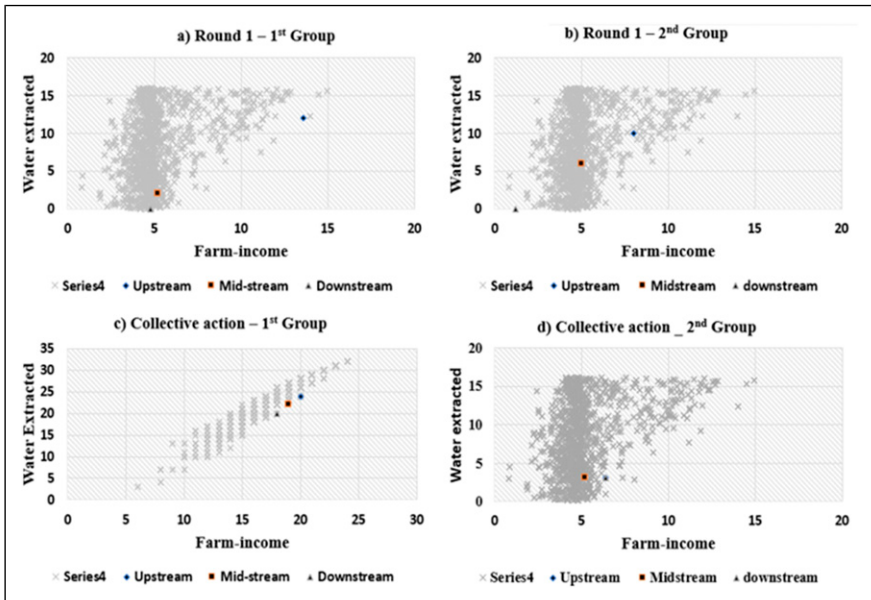


Figure 9. (a) and (b) shows impacts of individual land-use choices on water and household income for both groups within the possible solution space of randomized land- and water-use choices without water harvesting. (c) shows results of collective decisions in the first group within all possible solutions of randomized land-use choices during dry season with water harvesting while (d) shows results of collective action for the 2nd group during a dry season without water harvesting.

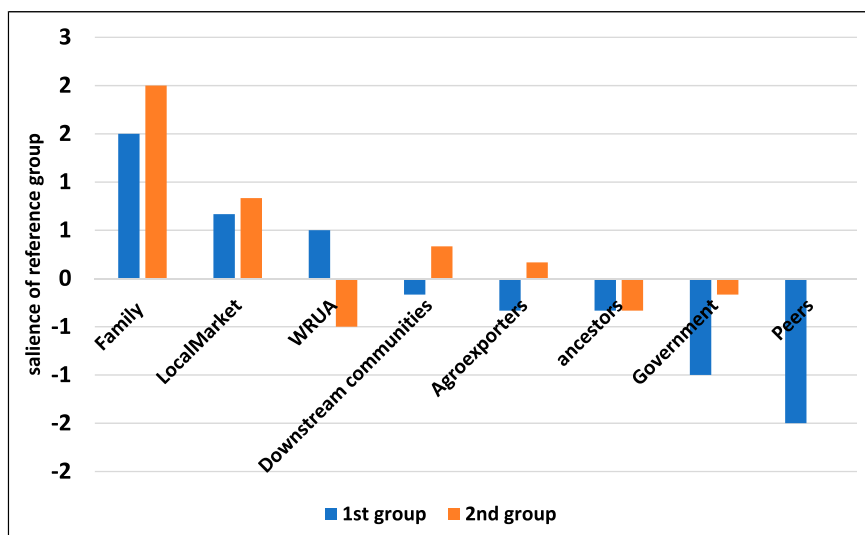


Figure 10. Salience of reference groups as averaged across players in the two groups.

voices from their salient reference groups to the game sessions. Although the identified pre-game relative importance of reference groups was not fully reflected in the game sessions, there were instances where player decisions seemed to be aligned to perceived preferences of their reference groups. For instance, from the debrief session we found that players prioritized crops that could ensure food for their families and income; noting family was the most salient reference group. The influence of local market traders and agro-export companies created a significant difference between choices made by the two groups. The 1st group constituted of farmers influenced by local market traders in real lives; hence they chose crops that could sell in the local market such as vegetables, tomatoes, and potatoes. The 2nd group constituted of farmers in contract farming with agro-export companies; they chose crops for export for instance French beans.

During the game, other reference groups emerged including a high-status individual in the 1st group and ‘all-player’ reference group in both game sessions. Players in the 1st group were not familiar with each other nor each other’s status-power standing. However, early in the game session, the only player with leadership position (a proxy indicator for status-worthiness- power), in society exerted his status and claimed more status by issuing suggestions, opinions and non-verbally through his sitting position and confidence in addressing other players. Results showed that this player benefitted more from the shared water resources causing a gap in water-use and farm income between upstream players and other players. In the 2nd group, players were well known to each other and held leadership positions in their respective communities. Each player felt he/she had and deserved a higher status than the other. The game session was

therefore characterized by less asking but more status claiming: giving, opinion, or suggestions. Additionally, any sense of status deficit, for instance through water overextraction by upstream or mid-stream players, was countered with an equal status claiming force from afflicted players leading to intense disagreements until a compromise was achieved.

Discussion of Pilot Sessions

Application of KILIMO NA MAJI was meant to assess its effectiveness in achieving its objectives. We first discuss results against these two objectives and then other observed results from the game sessions.

Objective 1: Catalyze Collective Exploration of Alternatives for Crop Production. We found that KILIMO NA MAJI did indeed prompt different interactions and player decisions in the two game sessions. KILIMO NA MAJI was simple enough for players to understand, relate with and prompt collective water management discussions as should be in a serious game (Edwards et al., 2019; Falk et al., 2023; Fjellingsdal & Klöckner, 2020; Janssen et al., 2023; Kriz, 2017). Resultantly, players identified alternative options to water scarcity including 1) strengthening water regulatory institutions 2) increasing water supply through water harvesting; and 3) managing available water by shifting planting seasons and type of crops. According to results from the game session, players' statements and actions showed that they were able to relate the game to reality (results of game evaluation are provided in supplementary material). For instance, a player who in reality harvested water, proposed doing so in the game; this option is not provided in the briefing session of the game. However, although in most cases players are expected to play according to the rules provided (Biggs et al., 2021; Edwards et al., 2019) there may be other undefined rules that can emerge as participants interact with each other in the game. This provides an opportunity for facilitator-player and player-player learning.

Objective 2: Assess Influence of Social Relations on Game Outcomes. In both game sessions, water inequalities and hence farm-income raised concern and complains among some of the players. Since players are relationally rational, i.e. rational within the context of their social world (Hofstede et al., 2019), choices that seemed economically rational at the beginning of a game session were socially irrational in subsequent rounds. This led to conflicts among players and ultimately collective action. Collective action was driven more by pressure from other players (Van Noordwijk et al., 2023a). Each of the two groups formed an 'all-players' reference group that was salient to all players, the pleasing of whom was more important than other reference groups. In the 1st group, WRUA representative led other players to collective action and they jointly agreed on harvesting water to increasing income for all players. In the 2nd group, collective action could be considered to have been self-organized; emerging from the players after intense arguments over water resources. In both cases, the game was critical in

visualizing the problem and for jointly looking for options. In reality, collective action may take many forms and lead to varied outcomes depending on, a society's cultural orientation; motivation; rules, monitoring systems, incentives, and sanction (Hofstede et al., 2010; Hofstede & Liu, 2020; Kemper, 2017; Nordman, 2021; Ostrom, 1990; Toshiko et al., 2022; et al., 2023). Whatever the outcome, under collective action players make what they perceive to be socially rational choices.

Limitations of the Study and Future Research

Despite the capabilities of KILIMO NA MAJI, the game has limitations that are experienced in most serious games. Among them, 1) limited number of players against the population represented, presenting a possible bias of results; and 2) limited time for playing the game leading to inadequate exploration of all scenarios (Biggs et al., 2021; Edwards-Jones, 2006). Due to time limitations and to reduce complexities, there are various scenarios we could not try out. For instance, unexpected weather conditions, reference groups with varied opinions, introduction of a new government policy, diverse cultural orientations. These could be options that can have significant effect on a player's actions and possibly of interest to some researchers. While these can be included in future cases, another option that can facilitate exploration of many scenarios could be programming the game in Agent Based Modelling (ABM). ABM can be used to explore variations in different study sites, and viable solutions while making individual or collective decisions. Despite the reduced complexity, some players felt that the game sessions were still too long. Thus, for future research, we would recommend prioritization of elements that are a 'must-have' depending on the objective of the user of the game.

One limitation of analyzing influence of social relations from the Kemper's perspective is that the analysis heavily depends on the capacity of the researcher in analyzing player's actions, their discussion during the game session and responses in the debrief session. The data collection is also faced with difficulties in identifying reference group that motivated a certain action. Kemper (2017) notes that individuals may not always be aware of their reference groups; additionally, some actions may have been motivated by more than one reference group and it may become difficult to identify which reference group motivated which action. We further note that two game sessions may not have been adequate to comprehensively analyses the full capability of the game, but was enough to assess capacity of the game in achieving its objectives.

Possible Uses of the Game

KILIMO NA MAJI can be adapted and used to support management of scarce water commons in different landscapes. Possible users of the game can be policy makers, research institutions, water regulatory bodies, local communities among other. The game can be used to engage local stakeholders in co-production of alternatives to sustainably produce crops amidst water scarcity; to experiment and assess impacts of

policy interventions in a safe environment; training on farm water management; exploring influencers of farmer decisions; and visually demonstrate workings of a socio-ecological system to its members.

As first step, users of the game need to adapt various components to their objectives. For instance, for a researcher that wish to demonstrate different irrigations strategies and their impact on water availability and food production, more specific measurements of the crop irrigation need and impact on production may be needed; while for a stakeholder that wishes to inform local communities of the impact of their actions on others, exact measures may not be necessary. The next steps would be to understand the processes of applying the game and analysis of results.

Conclusion

In this study, we describe the design and show application of KILIMO NA MAJI as a serious game that can be used i) to engage farmers in understanding and exploring options for sustainable crop production during dry periods, and ii) to assess effect of social relations on farmer decisions. Over the years, there has been an increase in the use of games in various kinds of socioecological systems such as environment, water, land, climate change. However, to our knowledge, none of the games have provided for capturing and analysis of social relations as a factor that affect farmer decisions. In this paper therefore we present the design of a game that captures the effect of social relations, and its application in Mt. Kenya region. In the methodology and results, we present and assess game outcomes using a 'solution space' and further use the theory of status-power theory of emotions to discuss the effect of social relations on a game's outcome. We find that game outcomes can end up in different positions in the solution space; varying from high to low water consumption and low to high farm-incomes depending on relations that players have with important others in their social world. Therefore, the game can be used by stakeholders (policy makers, farmers, researchers) to explore alternatives to sustainably produce crops in scarce water commons. KILIMO NA MAJI is generic with capability to be adapted to fit any other water-scarce region. The concept of the game can also be used to design an Agent Based Model that explores diverse options.

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Supplemental Material

Supplemental material for this article is available online.

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Author Biographies

Margaret Githinji is a researcher in diverse fields but with a special interest in exploring socio-ecological systems in tropical landscapes. Her methodologies delve into participatory approaches to gain a better understanding of local stakeholders' perspectives on their social-ecological systems and options for sustainable use of natural resources. Her publications henceforth highlight social impacts on the social-ecological systems and rich stakeholders-centered opinions on better management of the system.

Erika N. Speelman is an associate professor of Spatial gaming and Simulation at Wageningen University. Erika is a (tropical) agronomist by training with a strong inter- and trans-disciplinary focus. Her work centers largely around contested tropical landscapes. She has been developing and implementing gaming and simulation tools to explore and facilitate (social) learning about the complex dynamics in social-ecological systems.

Meine van Noordwijk is an ecologist who has worked on and published systems that range from roots interacting with soil via multifunctional landscapes to social-ecological-political systems on tropical forest margins. Currently, he works as a Distinguished Senior Fellow at CIFOR-ICRAF, based in Indonesia, and as a Professor (em.) of agroforestry at Wageningen University, where he is Co-PI of the Scenario Evaluation for Sustainable Agroforestry Management (Serious games for the forest-water-people nexus) Programme that supported the current research.

Prof Catherine Muthuri is currently the Country Director- Kenya and Regional Convener, East Africa for CIFOR-ICRAF and prior to that the regional coordinator for ICRAFs' East and Southern Africa Region at ICRAF. Catherine holds a PhD in Ecophysiology/agroforestry from Jomo Kenyatta University of Agriculture & Technology- JKUAT under an ACU split site scholarship at Nottingham University UK.

Catherine has worked successfully within multidisciplinary research teams comprising International, national and policymakers in conceptualising, designing, and implementing research in development focusing on agroforestry –water-food-people nexus and land restoration for improved food security and resilient landscapes and livelihoods. She is a widely published <https://scholar.google.com/citations?user=MicFkDUAAAAJ&hl=en>, a world-class researcher, and has participated in many scientific events and made presentations in international fora.

Gert Jan Hofstede (1956) is emeritus professor of Artificial Sociality at Wageningen University, the Netherlands. With a background in biology, information systems, and national culture, he studies the emergence of patterns in social systems. He published widely on culture (e.g., *Cultures and Organizations*, *Exploring Culture*), and simulation gaming (e.g. *Why Simulation Games Work – in Search of the Active Substance*). His recent work includes agent-based modeling and artificial sociality (e.g. *Artificial Sociality Manifesto*). Find more at <https://geerthofstede.com/news>