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Getting Ahead of the Game: Experiential Learning for Groundwater Governance in Ethiopia

CRAFTING COMBINATIONS TO GOVERN GROUNDWATER (GUEST EDITORS: R. MEINZEN-DICK & B. BRUNS)

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ABSTRACT

Groundwater management is highly complex, with many users sharing the same resource often with limited understanding of their interconnectedness. Behavioral experiments (games) that simulate real-life common-pool resource use have shown promise as an experiential learning tool for improving resource governance. This study pilots an experiential learning intervention in Ethiopia using a groundwater game to help raise awareness of groundwater over-extraction and improve understanding of the importance of collective action in governance. In the Meki River catchment in Ethiopia, small-scale irrigation is expanding, but overextraction and competition over groundwater have not yet reached alarming levels. The groundwater game, adapted from India and including the addition of a rule-making round, was played in 15 villages with 30 groups. The game was accompanied by subsequent community-wide debriefing in each village to reflect on the experience and lessons learned, which stimulated discussions about groundwater governance. We surveyed participants to capture individual mental models regarding groundwater use and management, as well as any immediate learning effects. Focus group discussions in each village prior to the intervention and again six months after the intervention assessed possible lasting effects. The findings indicate cognitive, normative and relational learning, including increased understanding of groundwater dynamics (such as the joint effect of diverse water uses and users), the importance of collective action in resource management, and the benefits of communication. We find gendered differences in decision-making about resource extraction in the game and development of group-level resource management, confirming the need for gender-responsive approach to sustainable groundwater management interventions. We discuss community-wide learning and institution-building, and considerations for future intervention designs. We recommend embedding experiential learning, facilitated by local extension officers and other practitioners, in intervention packages that include both technical assistance on water-conserving technologies and groundwater management approaches and support in building communities' institutional capacity.

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INTRODUCTION

The importance and effectiveness of self-governance and community-level institutions and collective action for the sustainability of natural resources is well known (Ostrom, 1990; 2000). Yet limited awareness of resource dynamics and lack of user cooperation contribute to resource overuse and degradation (Zhang et al., 2022). Understanding the biophysical and systems' characteristics of natural resources, the social dilemmas in common-pool resource (CPR) management, and the need for shared solutions are important steps that allow communities to embark on forming institutions for regulating resource use and effectively addressing governance challenges.

Groundwater is a key freshwater source for drinking, domestic and productive uses while serving important ecological functions (Closas and Molle, 2016). It is under pressure from climate change and increased demand from human activities (Nagaraj et al., 1999). With the characteristics of CPR including high subtractability and low excludability, combined with low visibility of aquifers' response to extraction, groundwater resources are particularly prone to over-extraction and depletion. As users interact with and impose externalities on each other, institutions are needed to coordinate resource use and create trust and incentives for sustainable management (Meinzen-Dick et al., 2018). But effective governance of groundwater to prevent over-extraction is further compounded by the difficulty of coordinating among large numbers of water users, many of whom often do not realize their interconnectedness or have limited understanding of the factors affecting water tables.

Group dynamic games that simulate real-life resource use and multi-user interactions and connect social dilemmas to action situations have shown promise as an intervention tool for experiential learning about sustainable CPR management (Becu et al. 2017, den Haan & van der Voort, 2018; Ferrero et al., 2018). A growing body of literature explores the use of group games to facilitate engagement with communities to improve understanding of socio-ecological systems and stimulate discussions about the need and options to improve natural resource governance (Falk et al. 2023). They are useful for identifying patterns in thinking and behavior, testing management options, as well as shaping "mental models" and understanding of relationships both among users and between users and the resource. Abstract games usually have the intent to bring about a specific management or cooperation challenge and are useful in a wide range of situations, while games based on detailed site-specific systems dynamics are less scalable (Janssen et al. 2023).

In India, the piloting of a semi- abstract experiential learning game that simulated crop choices and impacts on aquifers has improved community members' understanding of groundwater conditions (Meinzen-Dick et al. 2018). It also improved understanding of the need for coordination and adoption of rules for effective resource management, thus aiding collective action and decision making. Participating communities were significantly more likely to adopt rules governing groundwater use, compared with control communities (Meinzen-Dick et al., 2018). While such games are not a silver bullet, they can complement other capacity support to shape mental models around groundwater resources and empower communities to strengthen local governance (Falk et al., 2023).

Africa has seen a substantial increase in smallholder farmer-led irrigation in recent decades (Wiggins and Lankford. 2019). Small-scale groundwater irrigation in particular has been increasing in extent and importance in arid and semi-arid areas of Sub-Saharan Africa (Giordano et al., 2012). However, most of the existing water institutions fail to integrate governance of groundwater sources (Lefore et al., 2019), creating the risk of not achieving the full potential of groundwater irrigation and leading to undesirable social and environmental consequences (de Fraiture and Giordano, 2014).

In Ethiopia, groundwater irrigation development is still at an early stage (Bryan et al., 2020) despite private and public support (Namara et al., 2013). Groundwater resources in the Southern Nations, Nationalities, and Peoples' Region (SNNPR) of Ethiopia are considered abundant to support irrigation expansion, if managed sustainably, with high potential to improve incomes, livelihoods, and food and nutrition security for millions of people (Xie et al., 2021). Small-scale irrigation in SNNPR has been rapidly expanding in recent years (FAO and IFC, 2015), increasing pressures on groundwater resources, which largely remain unregulated. Experiential learning interventions on groundwater governance thus present a unique opportunity to get ahead of the game and plant the seeds for collective action on groundwater management that can help prevent groundwater depletion in the future before reaching critical levels (Kemper, 2007).

This paper presents results from piloting an experiential learning intervention with 30 groups of players in 15 sites in SNNPR of Ethiopia. The goal of the study is to assess to what extent can the experiential learning intervention change individual mental models, stimulate conversations among community members, and lead to real actions to improve groundwater governance in communities. In particular, we focus on two levels of assessment: 1) the immediate learning effect of the game on participants through comparing before- with after-game individual mental models, and 2) the medium-term effects of the intervention (including game and community debriefing) on the communities. We also analyze how the group gender and within-game treatments (i.e., non-communication, communication, and group rule-setting) differ in affecting game decisions and outcomes. Understanding these differences is important for designing gender-responsive approaches to sustainable groundwater management.

METHODS

GAME-BASED EXPERIENTIAL LEARNING INTERVENTION

We adapted the groundwater game from Meinzen-Dick et al. (2018), which was developed for and piloted in India. The game simulates the connection between individual crop choices and groundwater levels which are shared by all community members, capturing the tradeoff between greater economic return from higher level of groundwater consumption in the short term and the depletion of the resource critical for not only productive use but also domestic needs in the long term.

Individual players choose to irrigate either Crop A, a local crop that requires low water input but also yields less income, or Crop B, a local water-intensive crop that yields higher income. These choices in turn lead to simulated changes in groundwater levels for the whole group. The game consists of multiple rounds, each representing a year, with the water table changing over the years depending on players' choices and factoring in groundwater recharge.[1] If all players choose Crop A in a given round, the water would replenish back to the original level at the beginning of the round, but if all players choose Crop B successively for 4 rounds, there will be no more water available for productive use, ending the game. The game ends either when the water level reaches a "red zone" at 0 units after crop choice decisions where water can no longer be extracted for irrigation, or after 7 rounds if players manage to keep the aquifer above this level. Throughout the game, players make their decisions individually in private. In the first 7 rounds, players are not allowed to communicate. Another set of (up to 7) rounds follows where players are allowed to communicate. Finally, in the third set of (up to 7) rounds, players can discuss and the group may decide whether to elect rules and which rules. Facilitators refrained from making suggestions and groups were encouraged to discuss and implement their own strategies. This design was motivated by evidence that experiential learning is expected to be more effective when participants decide on rule election on their own (as opposed to the facilitators suggesting particular rules) and try them out in a low-risk environment (Falk et al., 2023). In each pilot site, two concurrent game sessions were held, one for men and one for women.

The game was tweaked to fit to the overall biophysical context of the Butajira region, such as by adjusting crop choices and aquifer levels, rather than to the detailed conditions in each community. This ensured the game would remain relevant and scalable to adjacent communities yet simple to facilitate and understand to avoid losing participant focus, given the tradeoff between simplicity and relatability (Janssen et al. 2023). Further, the last set of rounds on rules-setting by groups was added as a new within-subject treatment of the current study aimed at enhancing the learning experience. The number of rounds to be played in each of the three within-subject treatments or sets was not disclosed to avoid the end-round effect, though we do not rule out the possibility of participants making "guesses" about the number of rounds once they have played the first set. If the limit of seven rounds is known, players could cooperate to allow each player to grow a water saving crop twice and a higher-income water-intensive crop five times; a win-win situation.

An important component of the intervention is the subsequent community debriefing held after the game. For this, all community members (including players and non-players) are invited to discuss lessons and insights from the game, how the game relates to their own experiences and challenges regarding groundwater, and what community actions are needed to ensure the sustainability of groundwater. A spillover of learning from game players to non-player community members is expected through this process of sharing and collective reflection on the game experience.

STUDY AREA, SAMPLING AND GAME ADAPTIONS

The study was conduced in the SNNP region near Butajira town south-east of Addis Ababa (Figure 1). A scoping study informed the design of the pilot intervention and construction of the sampling frame. First, the selection of the Butajira-Enseno area as the study focal region was based on a hydrological assessment[2] of the groundwater characteristics (including aquifer properties and groundwater recharge), to select areas where shallow groundwater aquifers are renewable (replenished by rainfall) and relatively localized such that actions taken by communities on groundwater governance would likely have an impact that can be felt by local users. This also helped adapt the game's narrative and simulated water tables to increase relevance to local communities.

Given the focal region, we then consulted with the Department of Agricultural and Natural Resource Development (DANRD) of the Gurage Zone to identify four suitable woredas (districts) in the south-east part of the Gurage Zone surrounding the Meki River catchment with greater groundwater irrigation potential: South Sodo, East Meskan, Meskan, and Mareko. In each selected woreda, we collected information on the distribution of groundwater irrigation users, main crop types, and other socioeconomic information to gain more understanding of the context through interviewing woreda agricultural experts, extension workers, groundwater users, and local community leaders. Further game adaptations were made to identify locally relevant water saving and water consumptive crops.

Finally, we identified kebeles[3] in each woreda where there is widespread and increasing use of groundwater, especially in the dry season. A Kebele is the lowest administrative structure in Ethiopia, typically a cluster of villages. Our sampling frame included 39 kebeles in 4 woredas, from which we drew a random proportional sample of kebeles from each woreda, resulting in 34 kebeles. We then randomly sorted the 34 kebeles to extract 15 treatment[4] kebeles and two reserve kebeles. We selected the village with the highest groundwater use for irrigation in each kebele, with assistance from a local coordinator. Game participants, 5 women and 5 men in each pilot village, were randomly selected from community members who were available on the day of the intervention, with priority given to those identified by village leaders as groundwater irrigators. Baseline focus group discussions (FGDs) were held in all 15 kebeles with other non-player participants. For the selection of endline FGD participants, priority was given to those who participated in the baseline FGDs.

The intervention and baseline data collection took place in March 2021. First, we conducted the FGD to capture the baseline contextual information and perspectives regarding irrigation water sources, existing community institutions for governance of natural resources, specifically water-related institutions, and community-level mental models regarding groundwater resources. Game sessions were held concurrently with the FGD in each village. The field team took notes of the discussions that took place between players during the game, including any agreed upon rules, sanctions

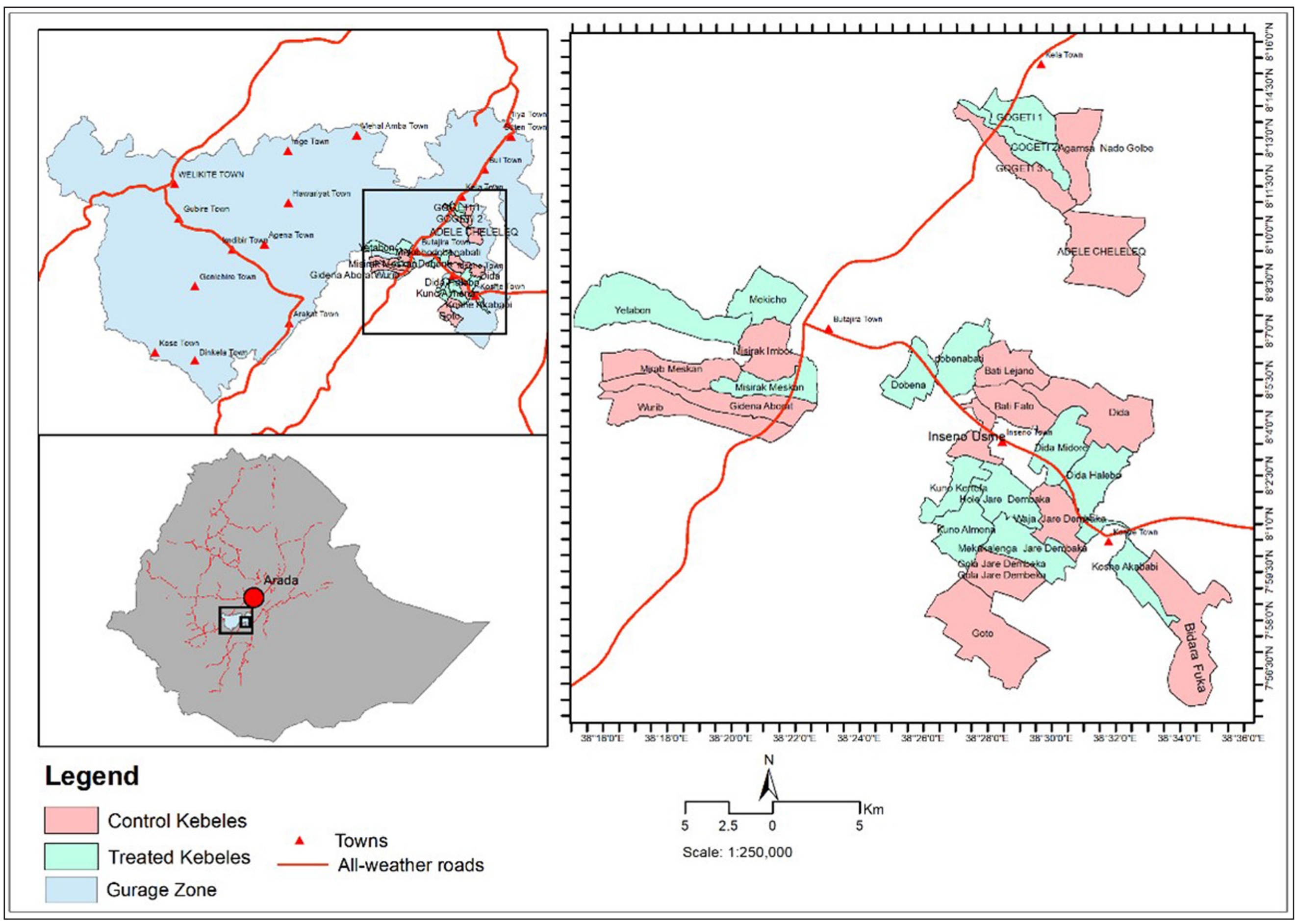


Figure 1 Map of the study area.
Source: Authors.

and violations during the game. A survey of individual participants immediately before and immediately after the game provided both qualitative and quantitative data on characteristics of the players, their households and farms including current irrigation practices, individual mental models regarding groundwater resources and their management, and perceptions about levels of trust and cooperation between community members. After the game, we collected qualitative information from the community-wide debriefing discussions of the game experience and its relevance to water governance. Endline FGDs were held in the treatment sites in September 2021.

ANALYSIS

We adopt a mixed methods approach comprised of quantitative analysis of game data and pre- and post-game player surveys, and qualitative analysis of FGDs, community debriefings, and notes from game discussions. This approach allows us to quantitively assess how pro-social behavior in the game (i.e., choosing water save crop) are affected by group characteristics, different within-subject treatments, and gender. Insights from the qualitative analysis allowed us to first assess the context and factors that shape the community mental models on groundwater and resource governance, take a deeper dive into game behavior, and finally curate the key lessons and new perceptions taken away by the whole community after the game experience.

Qualitative data from FGDs, games, and community debriefings were transcribed and then analyzed through inductive thematic analysis and coding, with the aim of identifying frequencies of words and themes in the participants' contributions. For quantitative data from the games and player surveys, we conducted regression analysis to explore the effects of within-subject treatments (i.e., non-communication, communication, and group rule-setting) and group characteristics on water extraction in the game at the group level in each round. Specifically, we focus on one (bounded) dependent variable 'share of group members making water saving crop choices in the round', for which we estimated a Generalized Linear Model (GLM), controlling for group and village-level fixed effects. To explore possible gender differences in responses, we ran the model for male and female groups separately. A Levene's test for homogeneity of variance indicated that there is not a statistically significant difference in the variance in between female and male groups in the dependent variable. Dichotomous variables for *kebele* were included to control for village-level fixed effects. A complete list of variables and summary statistics can be found in the annex. Standard errors were robust to misspecification and intra-group correlations.

RESULTS

Based on the baseline FGDs, we gathered several key demographic and groundwater use indicators for the 15 intervention villages.[5] On average the village population was 851, while average farm size was 1 hectare. The proportion of FGD participants who were irrigators ranged from 20% to 100%, averaging 61%. Similarly, access to wells varied from 40% to 100%, averaging 76%. In this region, farmers who are not irrigators and have no access to pumps often rent out their land in the dry season to investors who have the capability to irrigate the land. On average 11.7% of farmland is rented out to investors in the dry season.

Participants in FGDs reported wide variations in groundwater table and accessibility across and within communities. In some villages due to topography, elevation, and variable depth and volume of aquifers, groundwater was easily accessible while in others or other parts of the same village it was available but accessible only to those who owned motorized water pumps or had the financial capacity to dig deeper wells. Many irrigators used buckets for irrigation, less than half the farmers surveyed before playing the game mentioned having access to a motorized pump for irrigation. Reliance on surface water was also predominant in some cases. Most FGD participants reported observing seasonal variability in groundwater availability, and groundwater table declines in the last 10 years, which was mostly attributed to climate change and rainfall patterns rather than increase in the number of groundwater users or extraction rates.

IMMEDIATE EFFECT: LESSONS LEARNED AND SHIFTS IN MENTAL MODELS

Both the pre- and post-game surveys and post-game debriefings indicate that the game had a direct effect on changing immediate mental models and beliefs regarding biophysical groundwater characteristics (such as its nature as a depletable CPR), users' roles in groundwater resource sustainability and governance, and the need for institutional arrangements for groundwater governance.

Pre-and post-game player mental models

Players were asked to agree or disagree with statements related to governance of water resources immediately before and immediately after the game (Figure 2). For most statements perceptions changed after the game, with more players agreeing that current groundwater use would affect resource sustainability, there is a need for surface and groundwater rules, and there is a need to act collectively to govern groundwater. Further, participants perceived potential declines in groundwater availability on own farms linked to other farmers extracting groundwater. Statements linked to collective actions to establish and maintain community water structures did not change after the game.

Players were asked before and after the game what they believed should be done to improve groundwater availability. Figure 3 shows the aggregate changes in men and women players' answers, highlighting gender differences. Digging deeper wells was the main solution identified to improve groundwater availability. Following the game, fewer people mentioned digging deeper wells as a solution to water shortages, although the number was still quite substantial, especially among women: 25 (compared to 40) for women and 11 (compared to 22) for men. A second change was the suggestion by participants to use crop rotation as well as collective action for improving groundwater availability. Before the game and in baseline FGDs, considering planting water saving crops was not mentioned. The main reasons driving crop choice were household consumption and market price, followed

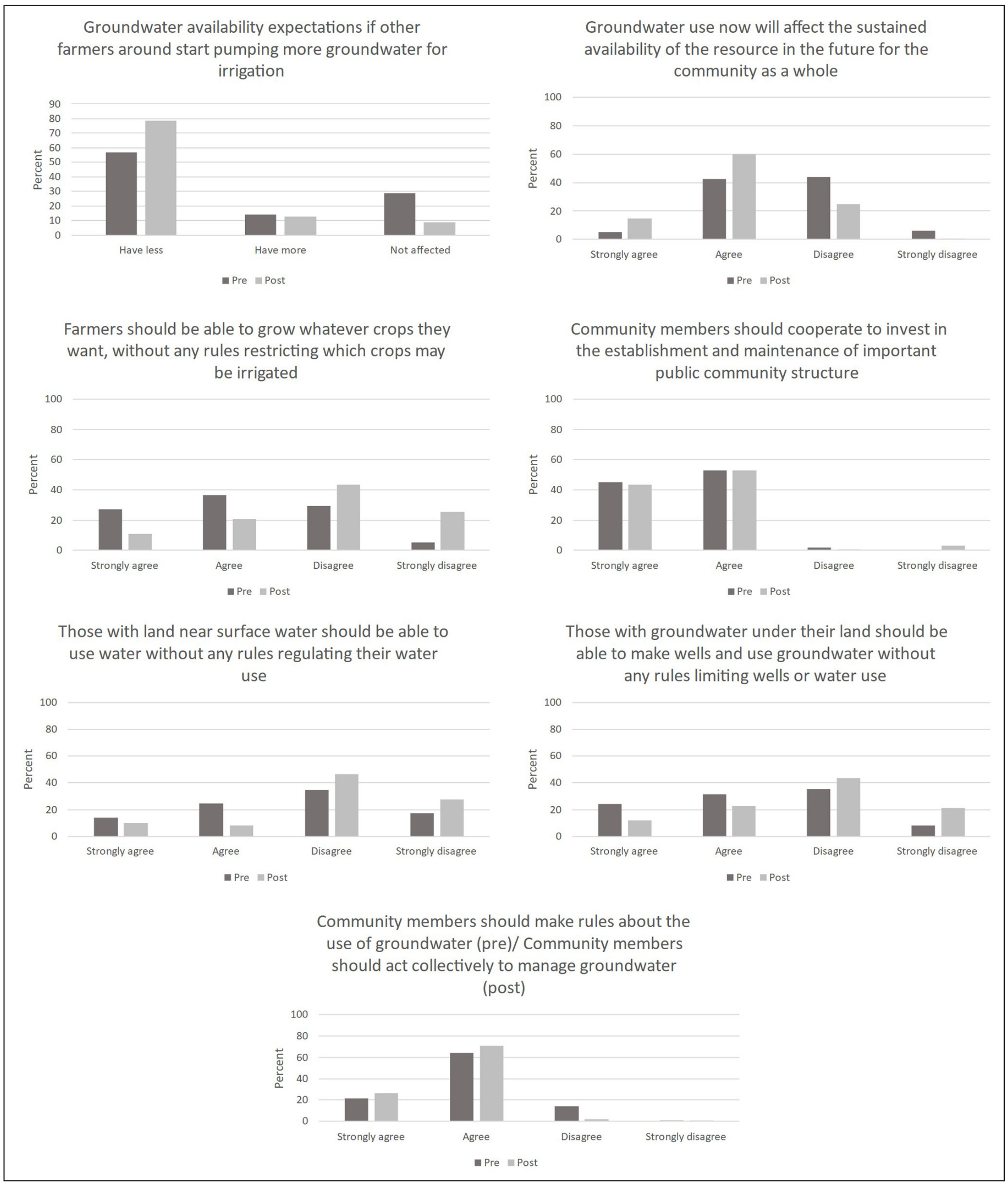


Figure 2 Before and after game mental models regarding water resources N = 150.

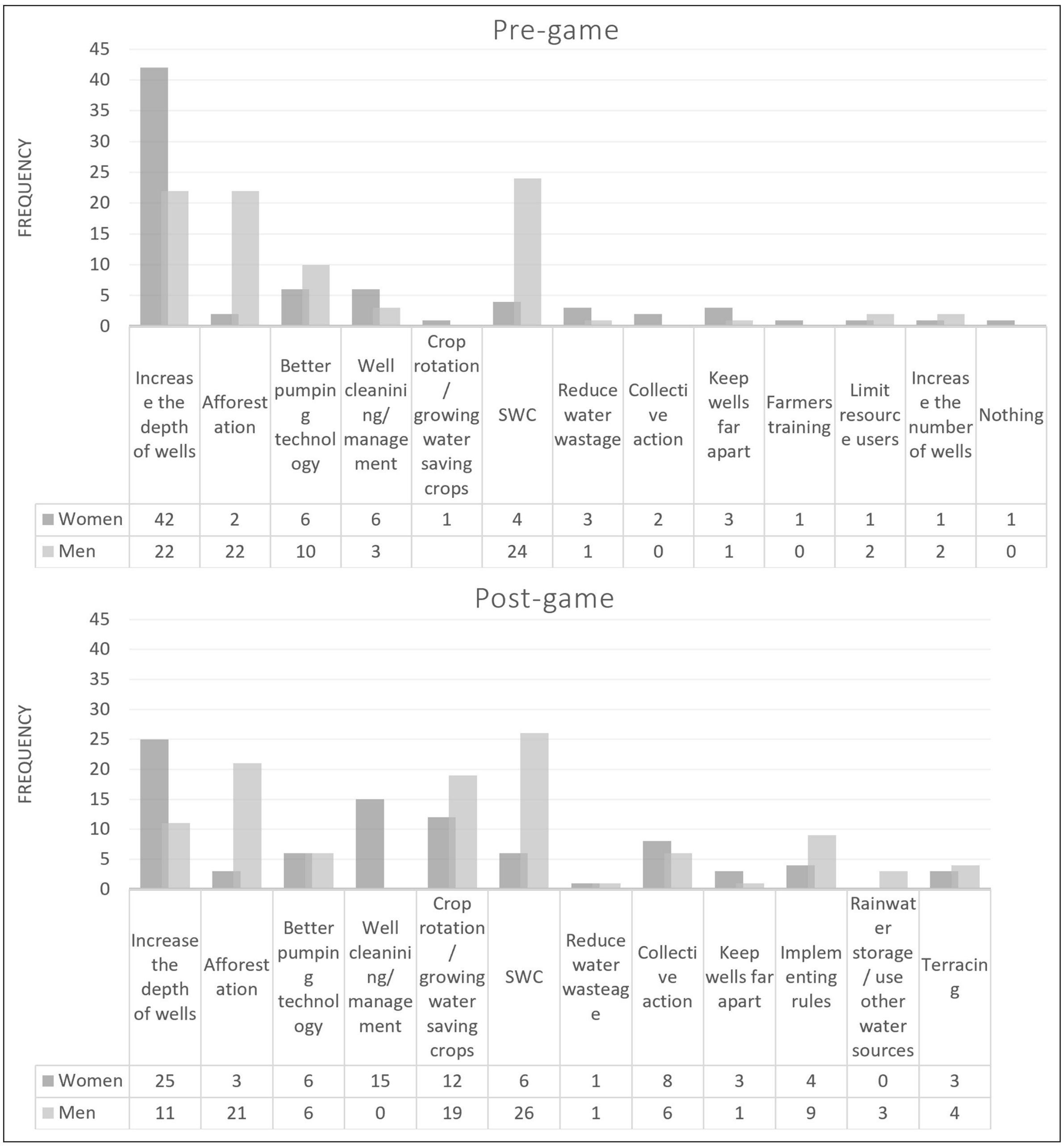
Source: Pre-game and post-game player survey.

by financial viability of crops; irrigation water availability was not a factor.

Additionally, in the post-game survey, many men (but few women) maintained the importance of afforestation and soil and water management techniques as ways to improve groundwater availability, possibly as men are more exposed to government-led soil and water conservation programs, making men more aware of these solutions than women. By contrast, several women maintained that proper well maintenance and cleaning increases groundwater availability.

Lessons learned and reflections

During the community-wide debriefing, players reflected on and discussed various learnings from the game. One of the most mentioned themes was realizing that groundwater is a **depletable resource**. This represents a stark and immediate shift in mental models. As a male player related *"we used to think that groundwater is something that will never dry, but now we know it can be depleted."* Another common response was learning that groundwater is a **shared resource**. Understanding the shared character of groundwater can be challenging due



	Increase the depth of wells	Afforestation	Better pumping technology	Well cleaning/management	Crop rotation / growing water saving crops	SWC	Reduce water wastage	Collective action	Keep wells far apart	Farmers training	Limit resource users	Increase the number of wells	Nothing
Women	42	2	6	6	1	4	3	2	3	1	1	1	1
Men	22	22	10	3		24	1	0	1	0	2	2	0

	Increase the depth of wells	Afforestation	Better pumping technology	Well cleaning/management	Crop rotation / growing water saving crops	SWC	Reduce water wasteage	Collective action	Keep wells far apart	Implementing rules	Rainwater storage / use other water sources	Terracing
Women	25	3	6	15	12	6	1	8	3	4	0	3
Men	11	21	6	0	19	26	1	6	1	9	3	4

Figure 3 Pre-game and post-game survey answers regarding how to improve groundwater availability, distinguished by gender N = 150. Source: Pre-game and post-game player survey.

to the invisibility of the resource. A female player said *"we learned that groundwater is a shared resource which we all can get from one aquifer. We used to think that we have our own independent groundwater source since we have independent wells."*

Realizing the common and depletable nature of groundwater, players and community members identified **collective action** and **crop rotation** as ways to manage the resource more sustainably. A player mentioned *"after playing this game, we realized that one farmer's water consumption pattern has an effect on the entire system, and that we must make a collective decision and work together."* Players also commonly mentioned learning from the game that **different crops have different water uses**, and about which crops save water and which crops are water consumptive.

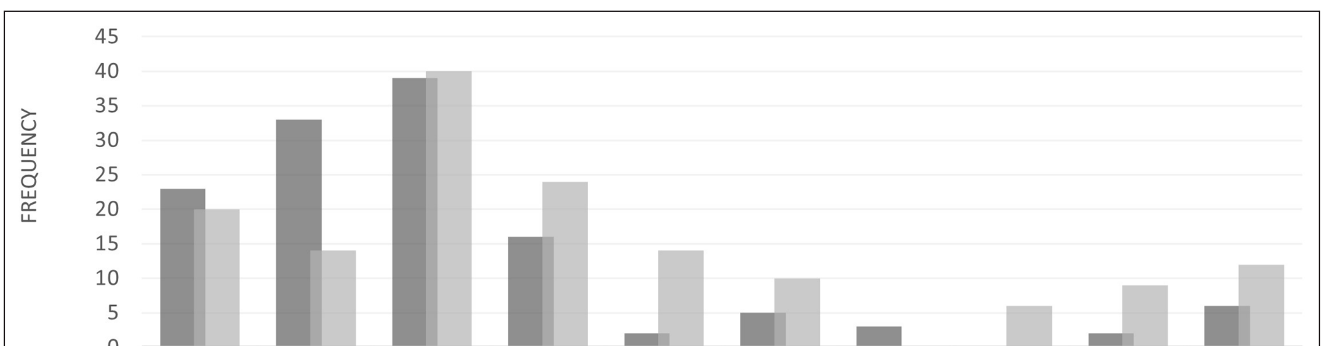
In most communities, discussants talked about coming to realize the importance of **communication and rules** for groundwater governance, reflecting that the progression between game treatments (with and without communication and rules) successfully gets the message across and contributes to changing the mental models of groundwater irrigators. For example, a player said *"I learned the importance of communication; without communication, we were hurting each other…we finished the groundwater so quickly since most of us were growing the water-intensive crop…[In game 2 and 3,] we managed to use our groundwater for more years."*

The post-game survey complemented the qualitative findings, highlighting gendered trends in lessons learned from the game. Many players, particularly men, reported realizing the importance of collective action and communication, as well as the need for rules (Figure 4). Further, more men than women reported learning that groundwater is a shared resource. Both women and men reported learning how to manage the groundwater resource sustainably, which crops are water-intensive and which require less water, and the link between crop choice and groundwater availability. The latter was mentioned more often by women. Additionally, some players, more frequently men, mentioned the existing trade-off between crop returns and groundwater availability, as the crops that have higher monetary returns are also the ones requiring more water.

MEDIUM-TERM EFFECTS ON MENTAL MODELS AND RETENTION OF LESSONS LEARNED

Mental models on groundwater characteristics

The endline FGDs six months after the intervention showed some sustained effects on community-level mental models related to groundwater resource characteristics, effects of users' choices on groundwater dynamics and availability, and importance of institutions and collective action.



	Established link between crop choice and groundwater level	Which crops are water intentsive/ water saving	Now knows how to sustainably manage groundwater	The importance of communication and collective action	Rules are necessary	Groundwater is depleatable, thus must be preserved	Established link between rainfall and groundwater level	Established link between water withdrawal / number of wells and groundwater level	Water is a common resource	Trade-off between money returns and intesity of crop water requirements
Women	23	33	39	16	2	5	3	0	2	6
Men	20	14	40	24	14	10	0	6	9	12

Figure 4 Post-game survey lessons learned from the game, distinguished by gender.

Source: Pre-game and post-game player survey.

While at baseline, eight communities believed that having groundwater rules or restrictions on use of groundwater was not necessary nor desirable, at endline, only three communities retained this view. At endline a participant commented *"rules are required for the community because, even if we are not facing a groundwater shortage now, it will appear in the future unless we begin to use it appropriately by establishing a community rule that controls and guides groundwater use."* In some communities, some respondents' answers seem to be inspired by the game intervention. In one village, community members stated during the discussion at endline that there should be rules, specifically referring to the baseline and game intervention as having triggered change of thought. In another village, FGD participants said there should be community rules related to crop rotation balancing the planting of water intensive with water saving crops, to ensure equitable access to groundwater. Respondents also frequently mentioned planting less water-intensive crops as well as alternating crops as measures to improve groundwater availability, which had only been mentioned once in baseline FGDs. Unexpectedly, increasing well depth to improve groundwater availability was reported more frequently at endline compared to baseline FGDs.

Adoption of groundwater governance institutions

While respondents at endline noted the importance of rules for groundwater management, this did not translate into rule adoption in most communities. This could be due to several reasons. First, the communities do not yet experience acute water scarcity, reducing the need for collective action. Second, the number of farmers using groundwater is still limited, though expanding. As such, collective action would only concern a small number of farmers and most farmers are primarily interested in improving access to groundwater irrigation at this point. Third, the timing of the endline FGDs, September, did not coincide with the dry season, which might have further reduced farmers' perception of water scarcity.

At baseline, only one community mentioned having groundwater rules related to taking turns to irrigate for private wells. At endline, three communities mentioned having such a rule, indicating a slight increase in basic rules related to groundwater irrigation after the intervention.

There is evidence that the intervention had a sustained effect on communication among community members, planting seeds of collective action for groundwater governance. In eight communities, participants mentioned during endline FGDs that the game intervention had sparked community discussions on knowledge exchange from the game on irrigation, crop rotation, and other groundwater management topics. In one village, discussions about proper use of water took place with *"neighbors at coffee places or even our workplaces. We've also spoken about our experiences or what we've learned here with regard to planting a variety of vegetables."* In another village, an FGD participant reported that *"the majority of us discussed the game at various social settings, and others learned from us [...] we should consider the water level when deciding which crops to produce...we used to focus solely on the market price [...] now we recognize the importance of conserving water as well."*

GAME BEHAVIOR AND GROUP OUTCOMES

Analyzing in-game player choices, we find that the total amount of water consumed for irrigation declined as the rounds advanced in all three sets of the game (Figure 5). Female participants generally used slightly more water than their male counterparts, while the game treatment of group election of rules led to slightly less overall water consumption, particularly in female groups.[6]

Consistent with our expectation, there is significant learning with each round of the game that is played and allowing discussions among players (communication game) helped improve cooperation toward pro-environmental behaviour (i.e. increasing the selection of water saving crops and reducing water consumption), as compared to the non-communication game (Table 1). Specifically, players chose more water-saving crops in the rounds when communication was allowed, resulting in overall reduction of water used for irrigation. Compared to the non-communication game, players on average also chose more water saving crops and thus consumed less irrigation water in the rounds when groups were prompted to elect rules.[7]

Strength of relationships among group members is positively correlated with pro-environmental behaviour (see annex for extended table). Groups with more participants that got along with others in the group (an indicator of potential cooperation) choose more water saving crops, consistent with expectations that groups whose members enjoy a better/closer relationship are more cooperative, resulting in reduced water extraction.

Examining the dependent variables by gender, we found that rounds with communication had a significant effect only on female groups, whereas group election of rules resulted in both female and male groups choosing more water saving crops. A higher water level at the start of the round significantly decreased the selection of water saving crops among male groups while female groups adapted more water conserving behaviors in response to higher water consumption in the previous round.

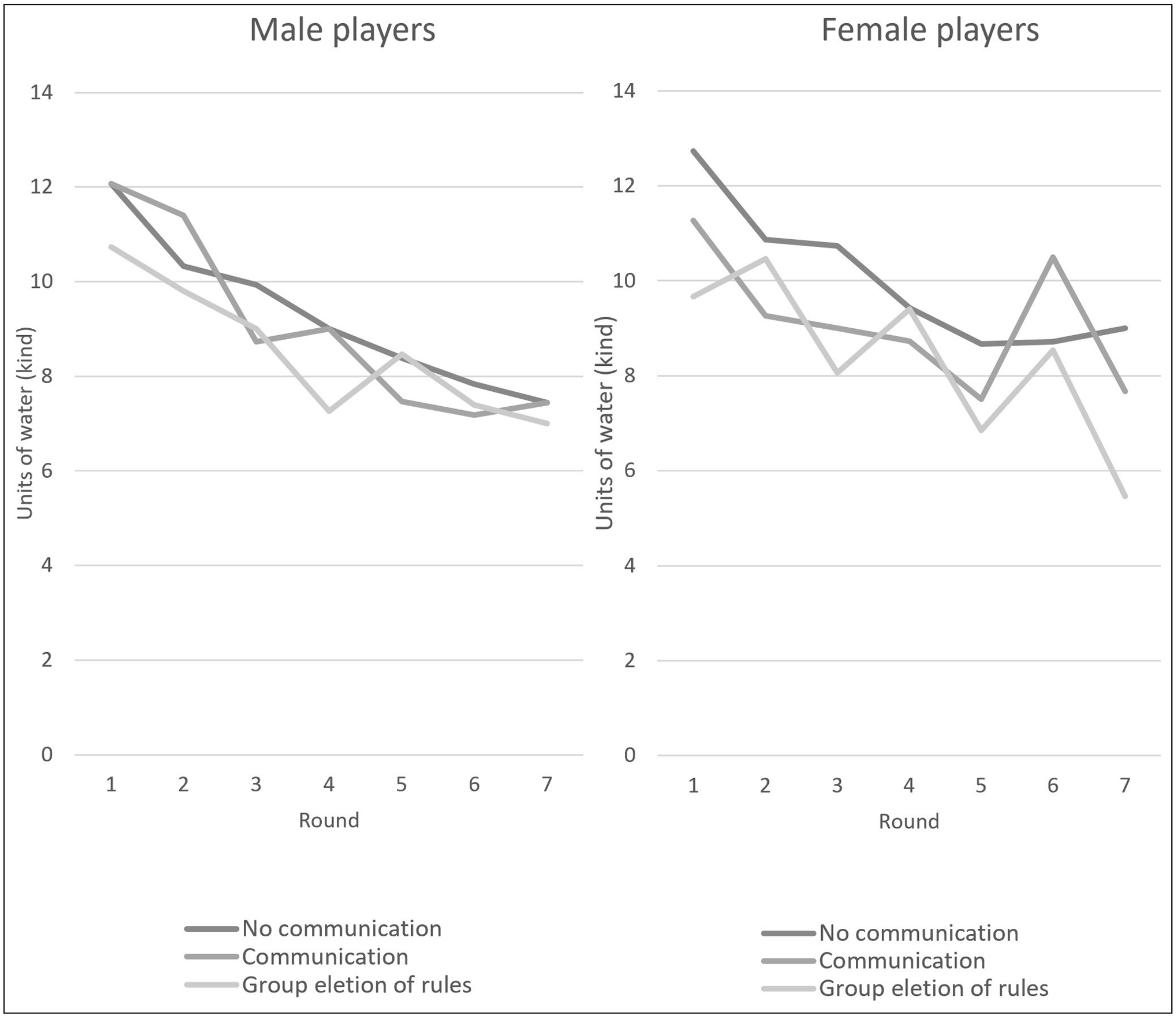


Figure 5 Total amount of water consumed for irrigation in each round by game treatment (non-communication, communication, and group election of rules) by male and female players.

Source: Game data.

	SHARE OF GROUP MAKING WATER SAVING CROP CHOICES		
VARIABLES	POOLED	FEMALE	MALE
Game round	0.134***	0.162*	0.0310
	(0.0504)	(0.0918)	(0.0630)
Communication game	0.379**	0.660***	0.0835
	(0.148)	(0.256)	(0.189)
Communication game w/rules	0.743***	1.037***	0.515**
	(0.162)	(0.281)	(0.208)
Water level at the start of the round	–0.0270**	–0.0124	–0.059***
	(0.0116)	(0.0177)	(0.0192)
Total amount of water consumed for irrigation in the previous round	0.0550**	0.0929***	0.0187
	(0.0266)	(0.0315)	(0.0420)

(Contd.)

VARIABLES	SHARE OF GROUP MAKING WATER SAVING CROP CHOICES		
	POOLED	FEMALE	MALE
Share of group who found the game relatable	0.118	–0.0830	–11.36***
	(0.815)		
Gender (female)	–0.537***		
	(0.272)	(0.0763)	(0.787)
Constant	–0.413	–1.716**	12.43***
	(0.714)	(0.817)	(1.387)
Observations	611	304	307
R-squared	0.302	0.309	0.345

Table 1 Share of the group making water saving crops choices in the round estimated from Generalized Linear Model (GLM) regression. Robust standard errors in parentheses. Results for *kebele* dummy variables are not reported here.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Rules for monitoring and sanctioning

During the third game treatment that prompted players to discuss and elect rules, they discussed monitoring and the type of sanctioning that would be appropriate for breaking the rules. Notes from game discussions show that all groups chose to monitor players' choices in this round.

Out of the 30 groups, 20 groups (10 men and 10 women groups) introduced a monetary fine as part of their agreed upon sanctions for violators. The fines varied widely, but 300–500 Birr were most common. Some players commented that sanctions of less than 100 Birr were too small to affect a change whereas a few others believed it was still significant: *"Although the penalty was very small, symbolically it's very important in our community, being caught violating the commonly agreed rule by itself means a lot in our community"* said a game participant.

Five groups introduced non-monetary sanctions for rule violators, including bans on cultivation or on water use, where the violator was not allowed to irrigate during the next round, social isolation, and on one occasion labor duty, such as doing well maintenance. A few groups introduced graduated sanctioning, starting with giving advice or warning to the violator, followed by a monetary or social sanction for second-time violators, or monetary sanctions that increase with the number of violations. This is consistent with Ostrom's (1990) design principles and local custom, as explained by one man in the debriefing; "*in our culture, we do not immediately punish our members, first, we often give a warning and then if he/she does not change behavior we impose a penalty.*"

Forgiving violators and opting for advice rather than sanctioning was a theme that emerged among players in some communities. In one community, for instance, both the men and women groups forgave violators who apologized for breaking the rule.

Communication and cooperation

Communication rounds improved group dynamics, trust and understanding between members, as reflected by players during the community debriefing. One women's group recalled that *"in the first game there was disagreement among us, but when we started communicating, we were able to resolve our disagreements."* Players reflected that communication played a key role in water saving, improving cooperative behavior and understanding among players, aligning with quantitative findings.

Yet many players also stressed that communication went hand in hand with rules, including rules for punishment for not following agreed strategies, and the latter is the real reason that enabled water saving. As a participant mentioned *"it is only through the penalty that we were able to force all members to save water."* Players, especially women players, found rules and sanctions to be important particularly for equity reasons, in terms of water use and income gains. A woman player noted *"we agreed that we needed to have rules to ensure everyone got a fair share in the use of groundwater."* In another village, another woman stated that with cooperation and communication, *"things improved so that we got almost equal incomes and conserved much water."*

Community debriefings also confirmed the finding that social networks and trust between community members (i.e. the fact that they knew each other) affects cooperation.

In six community debriefings, there were no violations, and all game players followed the rules. In one village, a man mentioned that *"as all members strictly followed the rules, it was not necessary to introduce sanctioning."* A woman reported *"we did everything in agreement because we all know each other."* Nevertheless, in these communities players agreed that sanctions are important to have, even where there was no violation.

DISCUSSION

EXPERIENTIAL LEARNING

Congruent with the findings of den Haan and van der Voort (2018), we found that the games resulted in different kinds of experiential learnings, including cognitive, normative, and relational learning. Cognitive learnings in this context refer to understanding of linkages between individual choices (i.e., crop choices) and payoff, and joint outcomes for the group, including monetary and resource outcomes, and how these play out on a temporal scale (i.e., tradeoffs between higher earnings in the short term and resource depletion, and thus loss of the income source, in the long term). Normative learnings include the recognition of the need for rules, while relational learning encompasses recognition of the value of communication and the importance of collective action. As van Vugt et al. (2014) argue, people may not understand the impact of their actions unless they are clearly visible, heard or sensed.

The sensory experience of the game is particularly beneficial in the case of groundwater resources that are typically 'invisible' to resource users. The perceived importance of rules after the game and at endline was evident. Many communities shifted from believing that groundwater rules or restrictions on groundwater use were not necessary, and in many cases opposing the idea of rules due to the belief that groundwater on one's land is private property. While most communities did not have water related rules or arrangements, surface water institutions were more prevalent and accepted, including prohibiting blocking, rediverting or impeding the flow of rivers, since it was perceived as a CPR. Mental models also shifted away from solely considering the accessibility of groundwater (e.g. digging deeper wells), to also considering the overall supply of the resource.

SOCIAL LEARNING OPPORTUNITIES AT THE COMMUNITY DEBRIEFING

While individual experiential learning can be observed and can be useful for changing mental models, it is less likely to change norms or rules (Shelton et al., 2018). The community-wide debriefings are thus designed for social learning to affect community-level action, and were found to be a vital part of this experiential learning process (Meinzen-Dick et al. 2018; Falk et al. 2023). They provide a chance for spillover learning effects to community members who did not experience the game first-hand, as well as brainstorming possible approaches for resource governance from within the community. Indeed, in intervention villages the process changed perceptions and stirred formal and informal community discussions on locally relevant solutions to groundwater governance problems, including promoting more equitable access.

The three suggestions mentioned most by communities were to maintain a 'reasonable' distance between wells, set community rules, and share wells and groundwater rather than digging new individual wells. Further, introducing shifts for groundwater irrigation, and practicing soil and water conservation activities were also commonly mentioned. Other ideas for improving groundwater availability included practicing crop rotation, saving rainwater and standardizing well depths. While building on such homegrown ideas is key for intrinsic motivations (Janssen et al. 2023), equipping communities with scientific information on their effectiveness to ensure that when applied such institutions would lead to the desired sustainability outcomes is also important.

After-game reflections can also bring local concerns to the forefront, which are important considerations for creating an enabling environment to improve groundwater governance. For example, a few communities highlighted the issue of equity in groundwater access particularly when mechanized well-drilling and pumps are used compared to hand-digging and manual water-lifting. A participant noted: *"It won't be fair and right if one digs using machines while the other digs manually…deep wells should be built at kebele level from which all the community members can have fair and equal access to groundwater."* Some participants believed rules should be extended to limiting the intensive water withdrawals by investors who rent land in the dry season to end the "*unfair distribution*" of groundwater use.

CONSIDERATIONS FOR FUTURE EXPERIENTIAL LEARNING INTERVENTIONS

While debriefing discussions are instrumental for spillover effects, we observed notable differences in players' and non-players' engagement. Participants from FGDs who did not play the game were mostly silent during the debriefing and in some cases did not seem to be following well. This is a crucial part of the dynamic to achieve learning on a larger community scale, as resources are often limited, allowing only a handful of people per village to experience playing the game. Encouraging available community members to silently observe the games in real-time can provide an opportunity for wider social learning effects. This has been attempted in India,[8] but may necessitate having more facilitators to manage any outside influence that can affect player choices. Purposeful rather than random selection of players (e.g. choosing more influential community member/elders who are more likely to spread the word) may be another option to enhance spillover effects, though such selection process may be seen as unfair especially if some forms of compensation of participants is used and thus disenfranchising other community members from active participation in the subsequent debriefing discussion. Another potential pitfall of purposeful player selection is the continued reinforcement of underrepresentation of traditionally marginalized groups.

Wouters et al. (2013) find that multiple training sessions improved the outcome of participatory games. Indeed, some endline FGD participants seemed oblivious or did not recall the outcomes and purpose of the game six months later, particularly those who were present in the debriefing but did not play the game. Many participants suggested that the game/intervention should be repeated, otherwise the lessons learned would be forgotten. A refresher can be helpful for maximizing benefits from experiential learning, particularly for medium- and long-term retention of messages.

Many game participants took away learnings related to the particular crops used in the game and their water requirements, yields and incomes, instead of considering them as illustrative of the link between individual practices and implications for groundwater tables. Such literal learning lessons have important implications for researchers and practitioners to consider in future implementations of game interventions, to ensure that the communities receive practical advice that is useful for their context and needs, while stressing the illustrative nature of the game.

SUPPLEMENTARY TOOLS FOR EXPERIENTIAL LEARNING

Recognizing the importance of having groundwater rules is insufficient on its own for bringing about the establishment of rules for both appropriation and provision of groundwater, which stresses the importance of long-term and technical engagement with communities to support capacity strengthening for collective action. Indeed, endline FGD results suggest that one of the reasons communities did not develop groundwater-related rules is that they require assistance from 'experts' on what rules would be suitable to sustain their groundwater.

Our pilot intervention offered an initial rapid and scalable experiential learning opportunity about the collective action challenges of groundwater and to raise awareness as a key first step to prime mindsets. A complimentary next step of deeper, longer-term and targeted engagement with communities is necessary, where more targeted games are embedded in larger intervention packages that include technical assistance, partnering with local extension officers. This is key to provide communities with up-to-date, accurate hydrological assessments, crop water requirements and other management options that have implications for both augmenting water supply and reducing consumption. In India, for instance, the games are implemented as part of a package of tools, including local aquifer mapping to improve understanding of water availability, a Crop Water Budgeting tool that computes the water consumption of different crop combinations, based on local conditions, and tools for siting water harvesting structures to increase recharge (FES, 2021).

The national program that promotes engaging rural villages in soil and water conservation activities enhanced the understanding of farmers in Ethiopia about the adverse effects of natural resource degradation on groundwater and surface water availability and the potential contributions of integrated watershed management (Haregeweyn et al., 2015). Thus, most communities referred to soil and water conservation activities such as afforestation and planting certain types of trees to improve groundwater availability even before the game intervention. However, evidence on afforestation improving groundwater availability in the dry season is mixed, with the majority of studies finding a decline in overall water yield (Acreman et al., 2021). While this is beyond the scope of the current study, we stress two points. First, technical advice regarding natural resource management given to communities must be transparent and evidence-based. Otherwise, we risk losing communities' trust if the promised benefit is not realized. Second, linking already existing pro-environment or pro-social initiatives with game interventions can help expedite and expand on community capacity for groundwater self-governance, provided that the rational and science behind these initiatives are clearly communicated to communities.

CONCLUSIONS

This study contributes to the growing body of evidence that games offer a potentially valuable tool to improve governance of CPRs (Falk et al. 2023). This is particularly important for groundwater, a largely invisible and fugitive resource. The groundwater game experience had a clear effect on shifting mental models regarding the characteristics and use of groundwater resources, particularly the shared and depletable nature of groundwater and that in addition to rainfall patterns, supply is affected by crop choices and intensity of use. Additionally, during the rulemaking round, a key innovation and contribution of this study, participants recognized the value of collective action and rules for effective groundwater resources management.

Exploring the factors that affected players' choices in the games, we see gender differences, with women more likely to choose water-consumptive crops, although communication and optional rule selection helped moderate women's resource use. We also see clear gender differences in response options that men and women identify, with men more likely to suggest soil and water conservation practices, because of their greater exposure to such programs. Ensuring women's access to extension services and soil and water conservation programs can help expand their access to groundwater governance information.

The collective nature of the games, particularly the rounds with communication and elective rules, created opportunities for social learning. This is consistent with the conceptual framework in Falk et al. (2023). While we do see a few examples of rules governing groundwater being implemented within six months in communities that played the game, the evidence also shows that the social learning aspect is more challenging. We also see some decay in memory of lessons from the intervention over time. Having additional rounds of the games so that individuals can play them more than once, and more people can play, might help address this.

Abstract games are a valuable tool for improving users' knowledge of resources like groundwater, especially in the context of communities without extensive experience and long histories of groundwater extraction for irrigation. While prior work in India has been done in contexts of overexploitation and clearly falling water tables, this study was conducted in areas where groundwater use is relatively new, without major over-exploitation. The question is whether it is possible to plant seeds of understanding of the limited and shared nature of groundwater at an inflection point, before resource depletion becomes critical. This requires engaging with tensions around preventing overexploitation (and elite capture) without limiting the possibilities for using groundwater to improve agricultural production and incomes in sub-Saharan Africa. Our research shows that collective action may also promote more equitable access to and productive use of groundwater.

While the games are a promising tool, they are not a panacea and need to be coupled with other interventions to provide communities with the information and technical skills to manage their groundwater resources effectively. In particular, while there was significant positive shifts in mental models and evidence that the intervention sparked community discussions as a first step toward collective action, there were few instances of new institutions created for groundwater governance. This may partially be attributed to the groundwater scarcity situation not being severe yet, and that building community capacity takes time and continuous engagement.

Finally, while the long-term sustainability of the resource is the ultimate outcome that matters, it is challenging to attribute changes in groundwater levels to any particular intervention because of the complex hydrology of groundwater systems and the many environmental and human factors that affect it. We therefore recommend further studies of the effect of these combinations of interventions under different conditions, particularly different degrees of (ground)water scarcity. Deeper follow-up engagement interventions that provide communities with technical crop water requirement information and simple hydrological mapping of their localized groundwater can better equip communities to create effective groundwater governance institutions.

NOTES

1 The recharge rate is constant for simplicity.

2 Prospective shallow groundwater sites for irrigation have been identified through analysis of Digital Elevation Model (DEM), topographic maps, and available geological maps of the area.

3 A Kebele is the lowest administrative structure in Ethiopia, typically clusters of villages.

4 In the larger study, 15 control kebeles were also included in the sample where baseline and endline FGDs were conducted for comparison. We do not report results of control kebeles as we found some imbalances in the sample results between control and treatment. Instead, we focus on before and after intervention effects. Results available from the authors.

5 See the annex for a full table.

6 Summary statistics for variables used in the regression analysis can be found in the annex.

7 More details can be found in the annex, including the share of the group making water saving crops choices in the round estimated from Ordinary Least Squares (OLS) and Generalized Linear Models (GLM) regressions; and total amount of water consumed for irrigation by all players in the round estimated from Tobit (left censored) and OLS regressions, all by gender.

8 See https://gamesforsustainability.org/.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Annex/Supplementary material.** Tables 1–4. DOI: https://doi.org/10.5334/ijc.1316.s1

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COMPETING INTERESTS

The authors have no competing interests to declare.

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