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Getting Ahead of the Game

Experiential Learning for Groundwater Governance in Ethiopia

Hagar ElDidi

Wei Zhang

Fekadu Gelaw

Caterina De Petris

Ivy Blackmore

Natnael Teka

Seid Yimam

Dawit Mekonnen

Claudia Ringler

Ruth Meinzen-Dick

Natural Resources and Resilience Unit

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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AUTHORS

Hagar ElDidi (h.eldidi@cgiar.org) is a Senior Research Analyst in the Natural Resources and Resilience Unit of the International Food Policy Research Institute (IFPRI), Washington, DC.

Wei Zhang (w.zhang@cgiar.org) is a Senior Research Fellow in IFPRI's Natural Resources and Resilience Unit, Washington, DC.

Fekadu Gelaw (fekadugelaw1@gmail.com) is an Assistant Professor of Agricultural Economics at the College of Agriculture and Environmental Sciences at Haramaya University, Addis Ababa, Ethiopia.

Caterina De Petris (depetris@b-tu.de) is a PhD student and academic staff at the Department of Environmental Economics, Brandenburg University of Technology Cottbus-Senftenberg, Germany

Ivy Blackmore (ivy.a.blackmore@gmail.com) is an independent consultant.

Natnael Teka (natnaelsosa@gmail.com) is an independent consultant.

Seid Yimam (s.yimam@ictd.ac) was a Research Officer in IFPRI's Environment and Production Division, Addis Ababa, Ethiopia, when he wrote this work. He is currently a Research Associate at the International Centre for Tax and Development, UK.

Dawit Mekonnen (dmekonnen@worldbank.org) was a Research Fellow in IFPRI's Natural Resources and Resilience Unit, Addis Ababa, Ethiopia, when he wrote this work. He is currently at the World Bank, Washington, DC.

Claudia Ringler (c.ringler@cgiar.org) is the Director of IFPRI's Natural Resources and Resilience Unit, Washington, DC.

Ruth Meinzen-Dick (r.meinzen-dick@cgiar.org) is a Senior Research Fellow in IFPRI's Natural Resources and Resilience Unit of the International Food Policy Research Institute, Washington, DC.

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ABSTRACT

The goal of this study is to assess the potential of game-based experiential learning in raising awareness and stimulating discussions about groundwater resource systems, the social dilemma in groundwater management, and the need for institutional arrangements (rules) governing this shared resource, as well as whether such awareness and community discussions lead to actual change in groundwater governance in Ethiopia. Groundwater management is highly complex, with many users sharing the same resource often without realizing 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. The Meki River catchment in rural Ethiopia is a unique context where small-scale irrigation is expanding, but overextraction and competition over groundwater have not yet reached alarming levels. The groundwater game, adapted from Meinzen-Dick et al. (2016 and 2018), was played in 15 villages, accompanied by community-wide debriefing discussions in each village after the game to reflect on the process and lessons learned, and to stimulate discussions around groundwater governance. We carried out participant surveys to capture individual mental models regarding groundwater use and management, as well as any immediate learning effects. Focus group discussions were held in each village prior to the intervention to establish a baseline and again six months after the intervention to assess 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 evolvement of group-level resource management across no-communication, communication, and rule-making rounds of the game. We discuss community-wide learning and institutions-building, and considerations for future intervention designs. We recommend embedding experiential learning, facilitated by local extension officers or other community engagement practitioners, in intervention packages that include both technical assistance on water-conserving technologies and management approaches and support in building communities' institutional capacity.

Keywords: governance, groundwater, games, Ethiopia, irrigation, common-pool resource, experiential learning

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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; Ostrom, 2000). Yet limited awareness of resource dynamics and lack of user cooperation, particularly when communities cannot perceive the interconnectedness of their actions and choices on the resource as a whole, contribute to resource overuse and degradation (Zhang et al., 2022). Understanding the biophysical and systems' characteristics of natural resources, the social dilemma in common-pool resources (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 source of freshwater for drinking, domestic and productive uses while serving important ecological functions (Closas and Molle, 2016). The resource is under pressure from climate change and increased demand from human activities (Nagaraj et al., 1999). Groundwater has high subtractability (i.e. one person's use reduces available groundwater for others) and low excludability (i.e. it is difficult to establish boundaries and prevent others from using the resource). These characteristics, combined with low visibility of aquifers' response to extraction (as aquifer boundaries and depth are often not directly visible), mean that groundwater resources are particularly prone to over-extraction and depletion. As water resource 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, 2014). But effective governance of groundwater to prevent over-extraction is further compounded by the difficulty of coordinating among a large number 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 CRP 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 framed around natural resource management (NRM) to facilitate the engagement with communities to improve socio-ecological systems' understanding and stimulate discussions about the need and options to improve governance (see Falk et al. [Forthcoming] for a review). 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.

In India, the piloting of an experiential learning game that simulated crop choices and impacts on aquifers has improved the understanding of groundwater conditions and need for coordination and adoption of rules for effective resource management by community members, thus aiding collective action and decision making (Meinzen-Dick et al., 2016 and 2018). Communities who participated in the game 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 (SSA) (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; Theis et al., 2018).

In Ethiopia, groundwater irrigation development is still at an early stage (Bryan et al., 2020) despite the 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.

This paper presents results from piloting an experiential learning intervention in SNNPR of Ethiopia in 2021. The rest of the paper is structured as the follows: We first present the intervention and research methods, followed by the results of both quantitative and qualitative analyses. We discuss findings of the experiential learnings and lessons learned before we conclude.

Objectives and research questions

The goal of this study is to assess the potential of game-based experiential learning in raising awareness and stimulating discussions about groundwater resource systems, the social dilemma in groundwater management, and the need for institutional arrangements (rules) governing this shared resource, as well as whether such awareness raising and community discussions lead to actual change in groundwater governance in the Ethiopia country context. 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. This study therefore focuses 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. Specifically, we examine whether there has been any change at the community level regarding groundwater governance 6 months later at endline. This includes whether there have been changes in rules governing groundwater or procedures for developing rules, and whether the community perceives a need for rules as a result of the intervention. We account for the counterfactuals by comparing results from control and treatment groups, controlling for exogenous factors that operate at a larger scale and could affect both control and treatment communities.

The study addresses two sets of research questions using the methodology described below.

1) To what extent can the experiential learning opportunity created by the intervention change individual mental models and stimulate conversations among community members, and lead to real actions to improve groundwater governance in the communities?

2) How do within-subject treatments (i.e., non-communication, communication, and group rule-setting) affect game decisions (crop choice) and outcome (groundwater consumption) ? What group characteristics help explain variations in crop choices and cooperative behavior in the game among groups? Are there differences between the male and female groups?

GAME-BASED EXPERIENTIAL LEARNING INTERVENTION

We adapted a groundwater game from Meinzen-Dick et al. (2016 and 2018), which was developed for and piloted in India, and fitted it to the local context in Ethiopia. The game simulated 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 (due to growing water demanding crops) 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 (referred to as "water saving crop" hereafter), a crop that requires low water input but also yields less income, or Crop B (referred to as "water demanding crop" hereafter), a water-intensive crop that yields higher income. These choices in turn lead to simulated changes in groundwater levels for the whole group. Crop A is set to use 1 *kind*[1] of water and yields 200 Birr in income, while Crop B is set to use 3 *kind* of water and yields 500 Birr in income. Through an earlier scoping study in the region, several relatively water saving and relatively water demanding crops commonly cultivated in the study area were identified and later used as choices in the game. That is, players decided Crop A to be either tomato or onion, and Crop B to be either cabbage or carrot.

In each pilot site or village, two concurrent game sessions were held, one for men and one for women. The game consists of multiple rounds, each representing a year, with the water table changing over the years depending on players' choices. The group starts with 40 *kind* of water available. Each of the 5 players in the group makes their decisions individually and receives income according to their crop choice. In addition, 2 *kind* of water is deducted each round to account for domestic water use. The facilitator then shows the collective effect of players' choices on the groundwater level on a chart, adds a set annual recharge of 7 *kind* from rainfall, and announces the new water level in the aquifer available for use in the next round. If all players chose Crop A in a given round, the water would replenish back to the level it was at the beginning of the round, but if all players chose 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 *kind* 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 is then played where players are allowed to communicate. Finally, in the third set of (up to 7) rounds, players are prompted to discuss and choose to set rules for the group and the group decides 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). While choosing locally relevant crops, adjusting the units of land to local context, and other changes were necessary "tweaks" to fit the original game in Meinzen-Dick et al. (2016 and 2018) to the local context, the last set of rounds on rules-setting by groups is 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 duration of the set once they have played the first set.

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

[1] A local unit of water measurement used in the region, meaning an arm's length.

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.

METHODS

Study area and sampling

The study area is located in the SNNP region near Butajira town south-east of Addis Ababa (Figure 1) and is within the Feed the Future program's zone of influence[2]. A scoping study, including two consecutive field visits in February and December, 2020, was undertaken to inform the design of the pilot intervention. We first consulted with a hydrologist to identify groundwater characteristics (including aquifer properties and groundwater recharge) in the Butajira-Enseno area. We then consulted with the Department of Agricultural and Natural Resource Development (DANRD) of the Gurage Zone to identify four woredas (or districts) in the south-east part of the Gurage Zone surrounding the Meki River catchment with greater groundwater irrigation potential: South Sodo, North Sodo, East Meskan, Meskan, and Mareko. In each selected woreda, the scoping study further collected information on the distribution of groundwater irrigation users, main crop types, size of irrigated land, and other socioeconomic information to gain more understanding of the context through interviewing woreda agricultural experts, extension workers, groundwater users, and local community leaders. To inform the construction of the sampling frame, further in-depth assessment identified kebeles (the lowest administrative structure in Ethiopia and are typically clusters of villages) in each woreda where there is widespread and increasing use of groundwater, especially in the dry season, and where aquifer sizes are relatively small such that actions taken by communities on groundwater governance would likely have an impact that can be felt by local users. Since such information is not available at the village level, the sampling was done at the kebele level. North Sodo was dropped as groundwater use was found in only 2 kebeles.

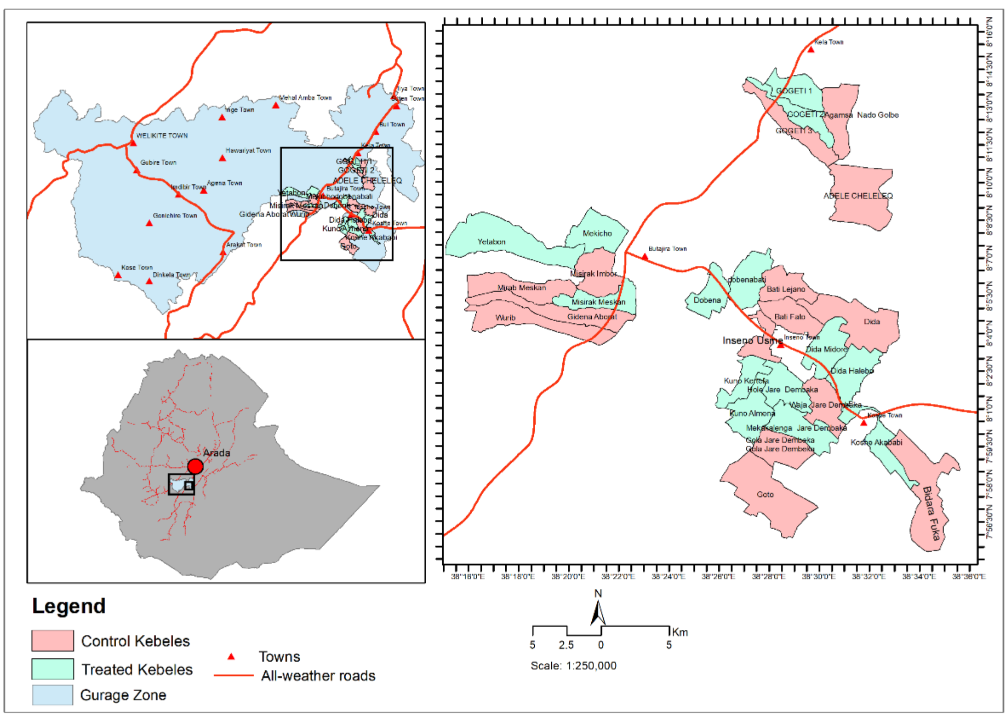


Figure 1. map of the study area

Source: Authors

[2] https://www.feedthefuture.gov/country/ethiopia/

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 into 17 treatment and 17 control kebeles. The last two kebeles in each group were reserved as replacements, and our main pilot sample consisted of 15 treatment and 15 control kebeles (Table 1). The final step was to select the pilot sites or villages from within the selected kebeles. We applied a practical criterion by selecting one village with the highest groundwater use for irrigation among all villages in a given kebele, with assistance from a local coordinator. Game participants, 5 women and 5 men in each pilot site or village, were randomly selected from community members who were available on the day of the intervention, and priority was given to those who had been identified by village leaders as groundwater irrigators.

Table 1 Sampled kebeles

Woredas	Treatment kebeles	Control kebeles
South Sodo	2	3
East Meskan	4	4
Meskan	3	4
Mareko	6	4
Total	15	15

Source: Authors

Baseline focus group discussions (FGDs) were held in all 30 kebeles. For the treatment group, FGDs were held concurrently with the game in each kebele[3]. With the assistance of extension workers and kebele administrators, we selected FGD participants with knowledge about the village from different segments of the kebele community including kebele administration, elders, youth, and women, making sure to include as many groundwater users as possible. For the selection of endline FGD participants, priority was given to those who participated in the baseline FGDs. Where baseline participants were unable to attend the endline FGDs, other members were selected using the same criteria as for selecting the baseline FGD participants.

Data collection instruments

The intervention and baseline data collection took place in March 2021 (Table 2). First, in each of the control and treatment villages, we conducted an 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. In the treatment villages, a game session was held concurrently with the FGD. The field team took thorough notes of the discussions that took place between players during the game, including any agreed upon rules, sanctions and violations and how they were handled by players during the game. A pre- and post-game survey of individual participants immediately before and immediately after the game was conducted to gather both qualitative and quantitative data on characteristics of the players, their households and farms including current irrigation practices, individual mental models

[3] While all game participants were from the villages selected as the pilot sites, FGDs and community debriefing discussions included some individuals from outside the villages in the corresponding kebeles to discuss administrative and governance issues that are relevant at the kebele level.

regarding groundwater resources and their management, and perceptions about levels of trust and cooperation between community members. After the game, we additionally collected qualitative information from the community-wide debriefing discussion which aimed to reflect on the game experience and its relevance to water governance. Endline FGDs were held in both control and treatment sites in September 2021, following the same qualitative data collection approach. The FGDs and community debriefing discussions were audio recorded after receiving informed consent from participants and transcribed verbatim to capture all the discussion details in preparation for analysis.

Table 2 Implementation activities and timeline

Timing	Activity	Treatment	Control	Type of data
Visit to control village	Baseline community FGD		Yes	Qualitative
Visit to treatment village to implement intervention – Day 1	Baseline community FGD	Yes		Qualitative
	Pre-game player survey	Yes		Qualitative and quantitative
	Game	Yes		Quantitative (+ qualitative in-game discussion notes)
	Post-game player survey	Yes		Qualitative and quantitative
Visit to treatment village to implement intervention – Day 2	Community debriefing meeting	Yes		Qualitative
Approx. 6 months after intervention implementation	Endline community FGD	Yes	Yes	Qualitative

Source: Authors

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 and village 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 through analyzing in-game discussions, agreements, and violations, and finally curate the key lessons and new perceptions taken away by the whole community after the game experience.

Analysis

Qualitative data from FGDs, games, and community debriefings were transcribed and then analyzed through inductive thematic analysis and coding in Nvivo, with the aim of identifying frequencies of words and themes in the participants' contributions. We generate frequency tables and present selected representative quotes.

We conducted associative regression analysis to explore the effects of within-subject treatments (i.e., non-communication, communication, and group rule-setting) and group characteristics (averaged from individual participant crop choices and household characteristics) on water extraction in the game at the group level in each round. Specifically, we focus on two dependent variables: i) share of group members making water saving crop choices in the round, and ii) total amount of water consumed by irrigation by all players in the group in the round. Both variables were found to be normally distributed. For the dependent variable of total amount of water consumed by irrigation by all players in the group in the round, which is bounded data, we estimated pooled Tobit model as well as Ordinary Least Squares (OLS) model for comparison and approximation, controlling for village-level fixed effects. For the dependent variable of share of group members making water saving crop choices in the round, we estimated Generalized linear model (GLM) as well as OLS. To explore possible gender differences, we ran the same models 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 either dependent variable. The explanatory variables used in the analysis include gender (in pooled models), age, education level, years lived in the village, household land ownership, indicators of trust and cooperation, household reliance on agriculture during the dry season, and household access to water pumps. 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 Table 4 in the Results section. Standard errors were robust to misspecification and intra-group correlations.

RESULTS

Descriptive comparison of the treatment and control sites

Based on the baseline FGDs, control and treatment groups are similar in several key demographic and groundwater use indicators, including average farm size, role of rainfed farming, groundwater use, ethnic and religious heterogeneity score, and existing institutions for shared resources such as forest (Table 3, based on estimates provided by FGD participants). However, the two groups differ in average population, percentage of farmland rented out in dry season, and whether irrigated farming is the primary livelihood in the dry season. Additionally, compared to the control sites, treatment sites had, on average, higher percentages of irrigators and farmers who have access to groundwater. Yet there are large variations within control and treatment villages, with some villages having all farmers access groundwater and practice irrigation, and others with very few farmers having such access.

While we do not believe there was systematic bias in the sample selection process that could have resulted in the imbalance between the two groups, it is possible that the information we collected from the woreda offices during scoping visits on the prevalence of existing groundwater irrigation in each kebele for the construction of sampling frame is not entirely accurate[4]. This is, however, difficult to validate because of the lack of alternative information sources. The presence of imbalance hinders our ability to use the control group as valid counterfactuals, thus endline results reported for control vs treatment sites are treated as anecdotal evidence. However, we are confident in the overall qualitative assessment of learning effect for the treatment sites, thanks to the multiple qualitative datasets collected which allow a multi-pronged angle to provide a comprehensive picture of the game effect.

Table 3: Characteristics of control and treatment sites

	Control	Treatment
Average community population	709	851
Average farm size	1.00 ha	1.00 ha
Percentage of farmland rented out in dry season (Average)	6.5% (0-25%)	11.7% (3-25%)
Percentage irrigators (Average)	33% (0-100%)	61% (20-100%)
Percentage access to wells (Average)	49% (10-100%)	76% (40-100%)
Rainy season primary livelihood is rainfed farming	15 communities	15 communities
Dry season primary livelihood is irrigated farming	12 communities	15 communities
GW primary water source for community (Ranks 1)	6 communities (from the 15 communities, 68% on average being GW users[5])	5 communities (from the 15 communities, 81% on average being GW users)
GW second most important source (Ranks 2)	6 communities (from the 15 communities, 58% on average being GW users)	8 communities (from the 15 communities, 67% on average being GW users)
Ethnic and religious heterogeneity score (Average)	2.2	2.1
Existing institutions for shared resources such as forests?	Majority yes	Majority yes
Number of sites	15	15

Source: Authors; qualitative evidence based on FGD participants' estimations in each community

[4] In addition to the first scoping study, the information from woreda offices was used as a crude estimate for sample design due to lack of other sources. We found discrepancies between this information given and realities on the ground during fieldwork.

[5] Includes all uses such as domestic, livestock, and irrigation.

Baseline mental models of communities at both control and treatment sites

The FGDs[6] and pre-game player survey gathered information on groundwater availability, accessibility, use and governance in study communities, and give an initial (and baseline) picture of community mental models with regard to understanding of groundwater resource dynamics and groundwater governance.

Groundwater availability and change

Participants reported wide variations in groundwater availability and accessibility across communities. In some communities due to variable depth and volume of aquifers, groundwater was easily accessible while in others it was available but accessible only to those who owned motorized water pumps or had the financial capacity to dig deeper wells. Less than half the farmers surveyed mentioned having access to a motorized pump for irrigation. Some farmers in the community who do not have access to pumps and are not irrigators rent out their land during the dry season to outsider farmers who irrigate using their own motorized pumps.

At the same time, many irrigators in treatment and control communities did not have motorized pumps for intensive irrigation but instead used buckets for irrigation. FGD participants further reported that oftentimes the groundwater table varied within the same community depending on the topography, and in particular, on the elevation. Reliance on surface water was predominant in some cases.

When asked about any observed changes to the groundwater table in the last 10 years, most participants reported groundwater table declines and seasonal variability, attributing observed groundwater declines to seasonality and climate change. Significantly fewer participants attributed declines in water table to an increase in the number of users, or the arrival of outsiders/investors who developed larger irrigation systems. Yet it was widely acknowledged that wells *"need to be dug deeper year after year because the amount [of water] continues to decrease"*. On the other hand, some participants in a few communities reported an increase in groundwater over the preceding 10 years due to terracing and soil and water conservation practices or due to increased precipitation.

Most communities believed that digging deeper wells is the primary way to improve groundwater availability, suggesting that groundwater is seen as a question of accessibility rather than supply. Afforestation and soil conservation were among measures identified, mostly by men, that could improve groundwater availability, while some women mentioned cleaning wells from mud.

Existing rules and institutions for (ground)water resources

At baseline, most communities did not have any water related rules or arrangements, for either surface water or groundwater. Rules did not exist for groundwater because it was perceived as private property, in particular wells on private land, in contrast to surface water, which was perceived as a common pool resource. Further, most communities (especially treatment communities) did not believe that such rules and governance strategies were necessary or relevant for the sustainability of the resource.

Among those communities who mentioned existing rules regarding groundwater wells, most of the rules were not related to irrigation but to general safety and property rights, such as mandatory covering and fencing of wells to protect children and livestock from hazards and accidents, and the prevention of people digging wells outside of their own land. Community groundwater rules and regulations that are relevant to irrigation, water availability and management, and monitoring of individual wells were

[6] Baseline FGDs included 10 to13 participants each, while endline FGDs on average included 8 to 12 participants each (at endline there were typically 2-4 women).

limited, and only mentioned by 4 treatment and 2 control communities at baseline. Those rules mostly related to maintaining a distance between wells and only allowing each household to dig one well on their land. On two occasions, participants mentioned institutions that govern group-shared irrigation water wells, where a group of farmers share the cost of digging a well collectively and then devise arrangements for irrigation turns.

Groundwater institutions, regulations and committees were in place for communal water resources, such as shared springs and drinking water wells that are provided by the government for the community, but typically do not apply to privately dug wells on private land. Participants of one particular FDG commented that *"there are rules that govern how the community uses government-built facilities, such as [drinking] boreholes, since without them, people can get into arguments when drawing water from the well."* Similarly, in another community, FGD participants mentioned that they have rules regarding surface water, as well as the groundwater *"used by all the community collectively. But this rule excludes the individual wells that are developed in their farming area or in their land."*

Surface water rules and community arrangements/institutions, though not widespread, were more prevalent than groundwater rules at baseline. In most cases, these rules prohibit farmers from blocking, rediverting or impeding the flow of rivers, including building small dams on streams. This was mentioned in 8 treatment and 3 control communities. FGD participants in 4 communities also mentioned having a rule to irrigate in turns when using streams and rivers. One community had a rule that obliges farmers to participate in canal cleaning and maintenance.

Perceived importance of community water rules and norms

In contrast to the perceptions of groundwater rules, communities considered surface water rules to be important because these resources were shared. In Kuno Kertefa, before the game was played, a woman participating in the FGD stated that *"no one can stop the river's natural flow because the river does not belong to a single family like the ground well does."* More control communities seemed aware of the importance of rules to govern groundwater resources compared to treatment sites at baseline. Eight treatment and 5 control communities believed that having groundwater rules or restrictions on use of groundwater was not necessary, and in many of these cases opposed the idea of such rules. This was most often due to the belief that groundwater on one's land is private property and farmers thus have the right to this water, followed by a justification that groundwater is currently not yet scarce and thus there is no need for rules to govern groundwater use. Some also mentioned that they have not witnessed any conflicts around groundwater in the community, unlike for surface water, thus the latter should be governed by rules while the former need not be.

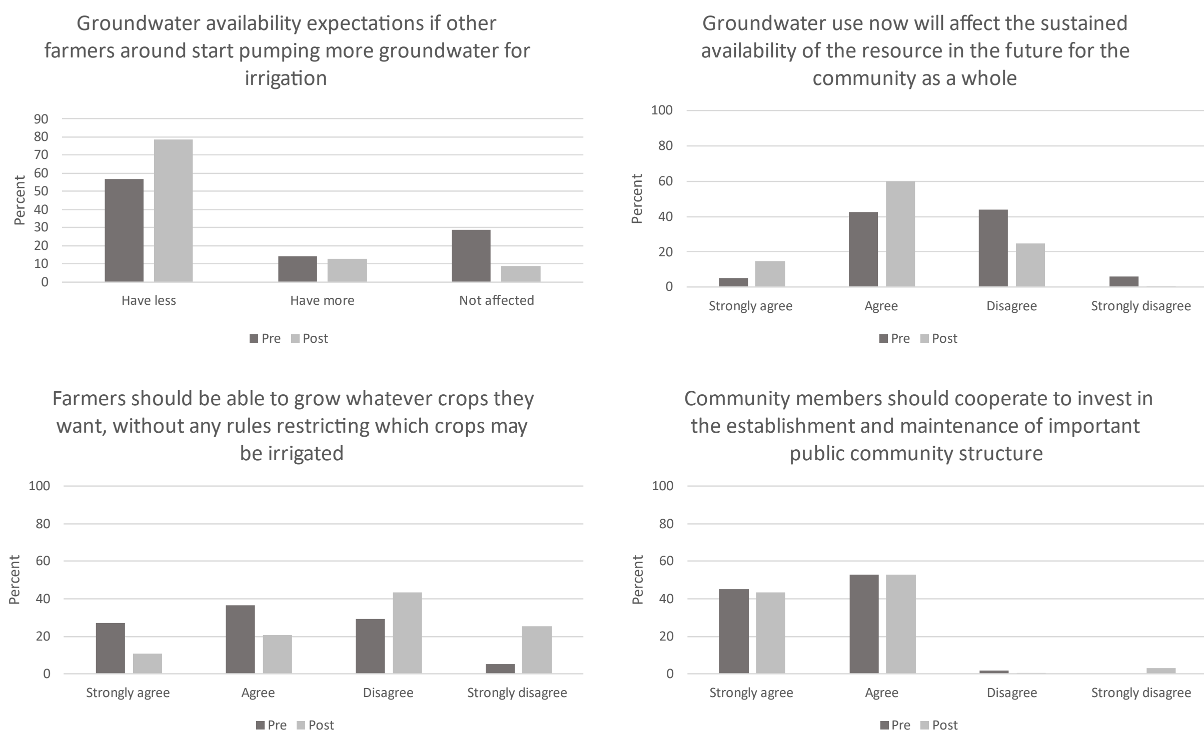
Participants who suggested that rules for groundwater use are needed gave equity as the reason. For instance, limiting groundwater depth, retaining distances between wells, and limiting large investors' access were suggested rules that would help ensure equitable access of groundwater among neighbors and community members. Some participants (especially in control communities) believed that rules to govern groundwater use may be needed to control investors who rent land in the dry season. In Gola Chumena, participants noted that *"from our experiences these investors are using our groundwater very intensively and this has been drying out our wells. Since such unfair distributions can affect many farmers, rules which set how much groundwater may be used are very necessary."*

Immediate effect: Lessons learned and shifts in mental models

Both the pre- and post-game surveys and the debriefing discussion after the game 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 common pool resource), 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. Following the game, more players agreed that current groundwater use would affect resource sustainability, there was a need for surface and groundwater rules, and there was 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 as a result of the game.



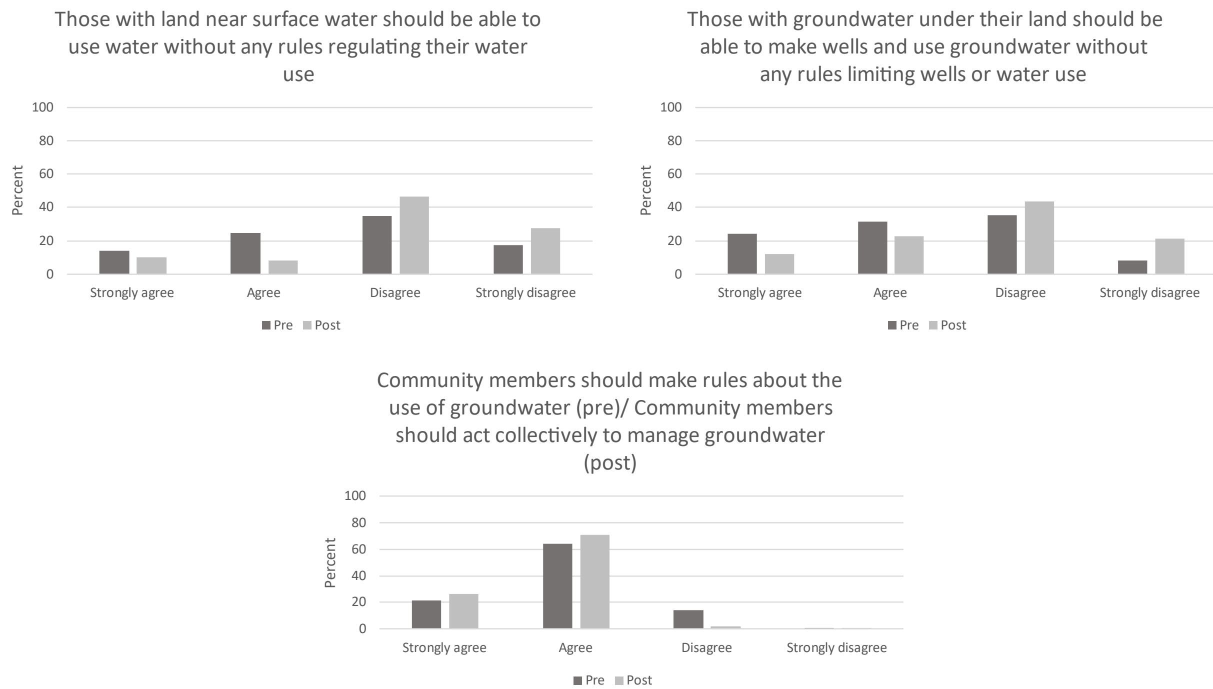


Figure 2. Before and after game mental models regarding water resources
N=150
Source: pre-game and post-game player survey

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 to this open-ended question, highlighting gender differences.

Following the game, fewer people mentioned that deeper wells should be dug as a solution to water shortages, although the number was still quite substantial, especially among women. Digging deeper wells was the main solution identified to improve groundwater availability. Following the intervention, this solution was proposed by fewer respondents, 25 (compared to 40) for women and 11 (compared to 22) for men.

A second change following the game was the suggestion by participants to use crop rotation as well as collective action for groundwater management. As a female player reflected, *"I know now crop choice can affect saving water."* Considering planting water saving crops was not mentioned and did not appear as relevant for improving groundwater availability pre-game and in baseline FGDs. The main reasons driving crop choice were household consumption and market price, followed by financial viability/farm capacity of crops; irrigation water availability was not a factor.

Additionally, in the post-game survey, many men maintained the importance of afforestation as a solution for improving groundwater availability, unlike woman who did not propose the same suggestion. A similar trend was observed for soil and water management techniques, 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, an aspect not mentioned by men.

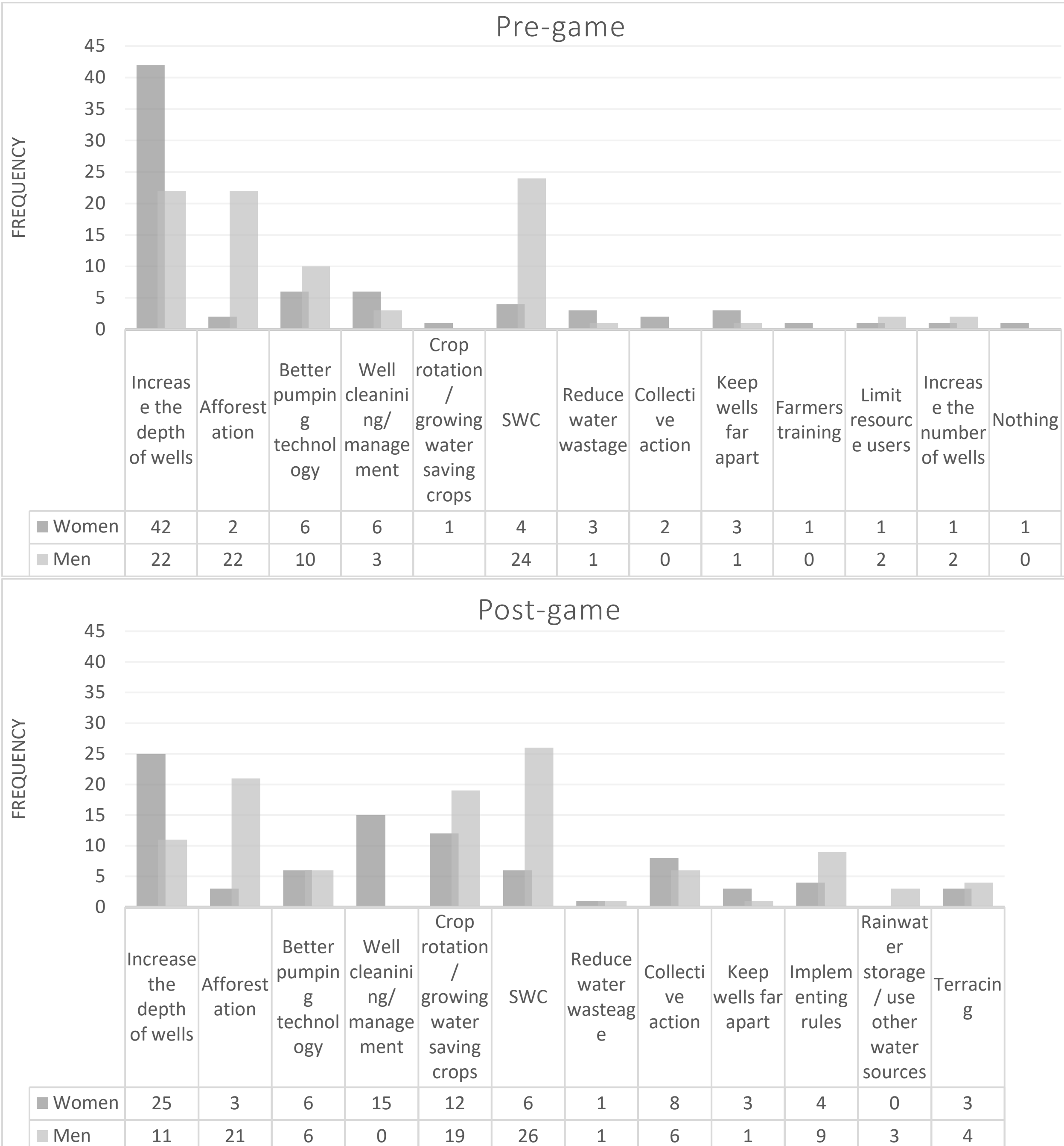


Figure 3: Pre-game and post-game survey answers regarding how to improve groundwater availability, distinguished by gender

N=150

Source: pre-game and post-game player survey

Lessons learned and reflections

During the community-wide debriefing sessions, players reflected on and discussed the 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."* This had some implications on the way community members see investors who rent their lands for the dry season. A man from another village points out: *"previously I didn't know the groundwater will fall, I thought the water level as it is. When the investor came for irrigation I thought they open the opportunity of employment for the community but now I understood their impact on our groundwater."*

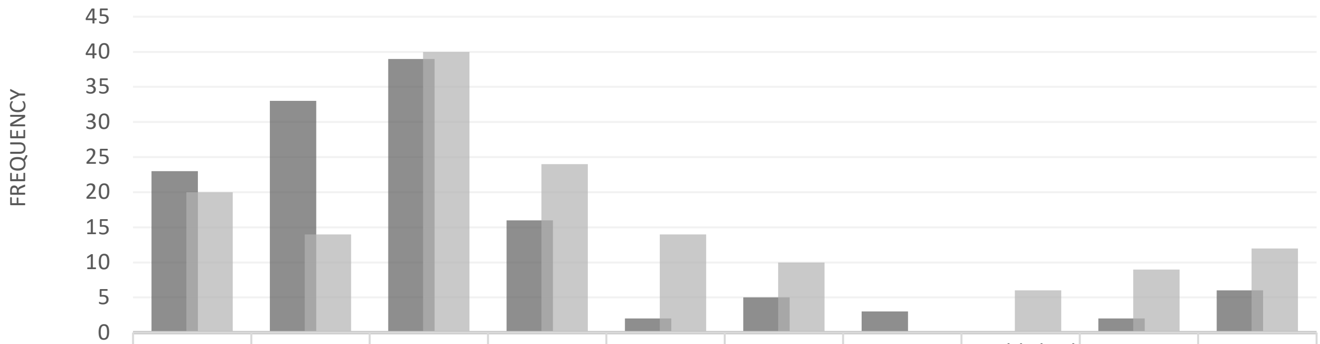
To a lesser extent but also a common response was learning that groundwater is a **shared resource**. Understanding the shared character of groundwater can be challenging due to the invisibility of the resource. A female player said *"we learned that groundwater is a shared resource which we all can get from one aquifer. We used to think that we have our own independent groundwater source since we have independent wells."* Similarly, a man from another village learned that *"groundwater is a shared resource, not personal or privately owned."*

Realizing the common and depletable nature of groundwater, players and community members identified **crop rotation** and **collective action** 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."* The importance of collective action for groundwater governance was another lesson learned that was mentioned by most players in most of the treatment villages.

Crop rotation between water saving and water consuming crops was seen as an important practice for balancing water consumption and economic returns for farmers. During the community-wide debriefing discussion in Geoogeti2, a male player said: *"The game taught us how to sustain the availability of groundwater by making a wise crop selection for cultivation individually as well as collectively. Searching for a higher return we may cultivate crops intensively which leads to the extraction of more groundwater resulting in exhaustion."*

In most community debriefings, the groups mentioned learning from the game that **different crops have different water uses**, and about which crops save water and which crops are water consumptive. It is worth noting that some groups took the crop water requirements and crop income returns literally, rather than as an illustration, which provides some lessons learned for future implementation of the game. For example, a player said: *"We learned that onion takes too much water (threefold of cabbage) and the financial return of producing onion is higher. However, from the game we got important lesson that cultivating cabbage would enable us to conserve water and sustain environments."* Others understood the illustrative nature of the game, taking home a broader lesson: *"when we cultivate crops we must identify which crop use water intensively and which crops save water,"* said a woman player from another village.

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…when we were not communicating, 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 without reaching the yellow level."* A man from another village summed up the game takeaways: *"Irrigating in rotation with an open discussion and effective monitoring of rules helps to use the groundwater for more years."*



	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

The post-game survey identified 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 levels, particularly that crop choices have an impact on 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. A few participants, mostly men, mentioned gaining an understanding that water must be protected particularly for future generations. *"I have also learned our current consumption of water can affect future generations,"* said a male player.

Brainstorming village-level groundwater management

During the debriefing discussion, each community brainstormed ideas on how they could improve groundwater use and management in their community based on learnings from the game. The three suggestions mentioned the most by communities were to maintain a 'reasonable' distance between wells, set community rules, and share wells and groundwater rather than dig new individual wells. Yet communities admit they do not know what the appropriate distance between wells should be, suggesting the need for external input.

Community members suggested sharing a well and its water would be a solution to depleting water, rather than digging more wells. One participant believed that *"As a community, we need to have a group and* *better to have fewer groundwater wells that serve all the community, rather than we all individually dig our own."* Further, introducing shifts for groundwater irrigation, and practicing soil and water conservation activities were also commonly mentioned. In another village, a man asserted that *"Groundwater can be depleted due to an increase in arid climatic condition, so we need to plant indigenous plants to prevent aridity in our area."* Other less frequently mentioned ideas for improving groundwater availability included community level discussions, practicing crop rotation, saving rainwater, standardizing well depths, and raising awareness around sustainability of groundwater resources.

At the same time, a few communities highlighted the issue of equity in access to groundwater particularly when mechanized well-drilling and pumps are used compared to hand-digging, manual lifting and buckets. A participant noted: *"I suggest there must be some kind of group or association in the community. It won't be fair and right if one digs using machines while the other digs manually…big and deep wells should be built at kebele level from which all the community members can have fair and equal access to groundwater."* Some communities also stressed that the government (or community elder) as the higher authority should set the rules *"based on research",* and that government interventions also assist farmers with expanding groundwater irrigation (to improve access to groundwater for those who cannot afford it), through subsidized pumps and solar power to reduce irrigation fuel costs.

Medium-term effects on mental models and retention of lessons learned

Mental models on groundwater characteristics

The endline FGDs which took place 6 months after the intervention showed some of the sustained medium-term effects on mental models related to groundwater resource characteristics, effects of users' choices on groundwater dynamics and availability, as well as the importance of institutions and collective action. The results show that following the game, communities realized the importance of communication and groundwater rules, a learning that was sustained 6 months later at the community level.

While at baseline, 8 treatment and 5 control communities believed that having groundwater rules or restrictions on use of groundwater was not necessary nor desirable, at endline, only 3 treatment communities retained this view, while there was no change in control communities. At endline a participant commented that *"previously we had no rules but now I think we should make rules."* In another village, at endline, a participant said *"Rules are required for the community because, even if we are not now facing a groundwater shortage, 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 treatment communities, some respondents' answers seem to be inspired by the game intervention. In one village, community members stated during the discussion at the 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.

Unexpectedly, increasing well depth was reported more frequently in the endline FGDs than in the baseline FGDs as a measure to increase groundwater availability, which may have to do with the change in focus group composition and/or the seasonality of the baseline vs. endline. Moreover, some gendered differences were evident. Increasing the depth of wells was mentioned much more often by women, while afforestation and soil conservation measures were mentioned more frequently by men in the endline. Additionally, well maintenance, mainly intended as removing mud from wells, was mentioned frequently by women. Nevertheless, the intervention led to a learning effect, which was clearly visible in the endline FGDs, where respondents mentioned that planting less water-intensive crops as well as to alternate them with more water-intensive crops as a measure to improve groundwater availability. This measure had not been identified in the baseline FGDs.

As to the main drivers of crop choice, we found only minor changes between the baseline and the endline FGDs. Household consumption and market price were the main reasons for crop choice, followed by financial viability and favorable soil conditions for crops. However, "crop rotation" was also listed as a driver for crop choice during the endline FGDs, reflecting the learning that water-intensive crops can increase the pressure on groundwater resources.

Adoption of groundwater governance institutions

While respondents in treatment communities noted the importance of rules to 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 development is expanding. As such, collective action would only concern a small number of farmers. Most farmers are primarily interested in improving access to groundwater irrigation at this point. Third, the timing of the endline FGD, September, did not coincide with the dry season, which might have further reduced farmers' perception of water scarcity. Finally, participants mentioned in the endline FGD that they needed additional help to establish groundwater institutions, from government and 'experts'.

At baseline, only one treatment and one control 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 game and debriefing intervention. East Meskan was the only treatment community practicing turns in groundwater irrigation before the intervention. In Koshe Akababe and Dobena Bati treatment communities this seemed to have emerged following the intervention. There was no change in control groups.

There is evidence that the game intervention had a sustained effect on communication on groundwater among community members, planting "seeds" of collective action for groundwater governance. In 8 treatment communities, participants mentioned during the 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 started taking 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 related that *"the majority of us discussed the game at various social settings, and others learned from us, implying that we should consider the water level when deciding which crops to produce…we used to focus solely on the market price before we began training, but now we recognize the importance of conserving water as well."*

The endline FGDs also show evidence of small-scale collective action, including small group agreements, taking shifts with the neighbors, and improved communication at the community level. Several participants expressed that they had learnt the importance of communication and rules through the game. In 2 communities, participants reported community collective action beyond groundwater, including appointing a guard for village forest protection, and collective investments in roads to improve access to the market.

Game behavior and group outcomes

Group water consumption choices and group characteristics associated with group outcomes

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.

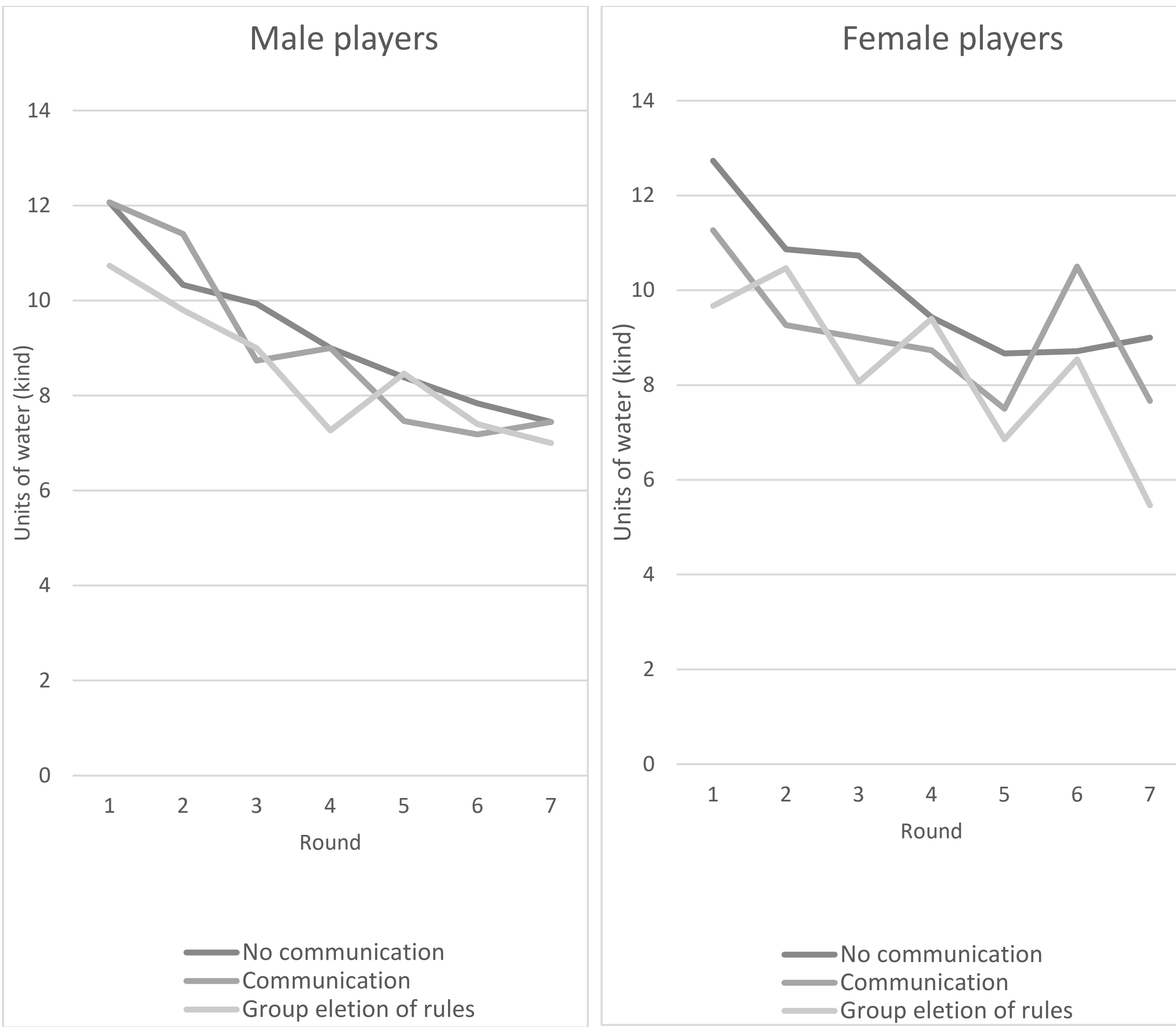


Figure 5. Total amount of water consumed for irrigation in each round by game treatment (non-communication, communication, and group election of rules) by male and female players
Source: Game data

Summary statistics for the variables used in the regression analysis are shown in Table 4.

Table 4 Summary statistics for group-level dependent and explanatory variables

Variable	Mean	SD
Share of the group that chose a water saving crop in the round	0.57	0.31
Total amount of water consumed for irrigation by all players in the round *(kind)*	9.21	3.05
Water level at the start of the round (*kind*)	25.57	10.32
Total amount of water consumed for irrigation by all players in the previous round (*kind*)	9.21	3.04
Share of group that found the game relatable (proportion)	0.97	0.07
Gender (female)	0.50	0.50
Average respondent age across group (years)	37.45	4.90
Average education level across group (years)	5.00	2.23
Average hectares of land owned across group (hectare)	0.98	0.79
Average years lived in village across group (years)	32.11	7.23
Share of group who is a member of a water association (proportion)	0.19	0.27
Share of group who agree groundwater use now will affect future availability (proportion)	0.48	0.22
Share of group that trusts almost everyone with something important (proportion)	0.19	0.13
Average number of players respondent gets along with in the group	3.62	0.40
Average number of neighbors respondent believes would help with community activity across group	7.18	0.94
Share of group whose primary livelihood in the dry season is farming	0.85	0.20
Share of group who own a water pump	0.41	0.32
Share of group that only use rainfed irrigation	0.58	0.16

Source: pre-game player survey and game choices

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 5). Specifically, players chose more (fewer) water-saving (water-intensive) crops in the rounds when communication was allowed, resulting in overall reduction of water used for irrigation. These results align with the findings from the community discussions where participants noted the importance of communication and rules for sustainable groundwater use. 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.

Table 5. Pooled regressions: 1) 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 2) total amount of water consumed for irrigation by all players in the round estimated from Tobit (left censored) and OLS regressions

	Share of group making water saving crop choices		Water consumed for irrigation	
VARIABLES	GLM	OLS	Tobit	OLS
Game round	0.134***	0.0256***	-0.275***	-0.270***
	(0.0504)	(0.00923)	(0.0881)	(0.0901)
Communication game	0.379**	0.0854**	-0.901***	-0.895**
	(0.148)	(0.0343)	(0.326)	(0.336)
Communication game w/rules	0.743***	0.166***	-1.654***	-1.657***
	(0.162)	(0.0368)	(0.355)	(0.366)
Water level at the start of the round	-0.0270**	-0.00697***	0.0678***	0.0686***
	(0.0116)	(0.00228)	(0.0217)	(0.0224)
Total amount of water consumed for irrigation in the previous round	0.0550**	0.0113*	-0.112*	-0.111*
	(0.0266)	(0.00598)	(0.0571)	(0.0588)
Share of group who found the game relatable	0.118	0.0279	0.488	0.394
	(0.815)	(0.189)	(1.864)	(1.924)
Gender (female)	-0.537***	-0.115***	1.211***	1.208***
	(0.141)	(0.0322)	(0.315)	(0.326)
Group mean respondent age	0.253***	0.0580***	-0.574***	-0.576***
	(0.0415)	(0.00932)	(0.0907)	(0.0937)
Group mean education level	0.319***	0.0717***	-0.691***	-0.695***
	(0.0719)	(0.0163)	(0.157)	(0.163)
Group mean ha of land owned	-0.461***	-0.104***	0.936***	0.943***
	(0.143)	(0.0328)	(0.318)	(0.329)
Group mean years lived in village	-0.194***	-0.0430***	0.433***	0.433***
	(0.0227)	(0.00509)	(0.0499)	(0.0514)
Share of group with membership in water association	-3.402***	-0.740***	7.366***	7.365***
	(0.341)	(0.0730)	(0.706)	(0.728)
Share of group who agree groundwater use now will affect future availability	-1.060***	-0.206**	2.286***	2.254**
	(0.361)	(0.0821)	(0.798)	(0.827)
Share of group who trust almost everyone	-2.832***	-0.539***	6.177***	6.088***
	(0.704)	(0.162)	(1.577)	(1.632)
Group mean number of players respondent gets along with	2.545***	0.533***	-5.525***	-5.489***
	(0.220)	(0.0450)	(0.444)	(0.457)
Group mean number of neighbors would help with community activity	-0.861***	-0.180***	1.801***	1.795***
	(0.0765)	(0.0164)	(0.159)	(0.165)
Share of group whose primary livelihood in the dry season is farming	-0.343	-0.0364	0.124	0.146
	(0.374)	(0.0861)	(0.848)	(0.877)
Share of group with water pump	-3.421***	-0.708***	7.257***	7.230***

	Share of group making water saving crop choices		Water consumed for irrigation	
VARIABLES	**GLM**	**OLS**	**Tobit**	**OLS**
	(0.259)	(0.0533)	(0.528)	(0.543)
Share of group who only irrigated in the rainy season	-0.415	-0.145**	1.113*	1.176*
	(0.272)	(0.0615)	(0.595)	(0.618)
Constant	-0.413	0.313*	11.54***	11.60***
	(0.714)	(0.160)	(1.558)	(1.613)
Observations	611	611	611	611
R-squared	0.302	0.300		0.307
Pseudo R-squared			0.0731	

Robust standard errors in parentheses. Results for *kebele* dummy variables are not reported here.
*** p<0.01, ** p<0.05, * p<0.1

Additional variables included in the models to better understand behavior dynamics within the game include the water level at the start of the round, a water consumption lag variable and game relatability. The amount of total groundwater use in the previous round is positively correlated with the selection of water saving crops and negatively correlated with water consumption in the current round, suggesting players are adapting more water conserving behaviors in response to higher water use in the previous round.

The effects of sociodemographic characteristics of the group on the selection of water saving crops and the amount of water consumed for irrigation are mixed. Groups with older participants and with a higher mean education level chose more water saving crops and used less water for irrigation. Groups that on average owned more land, had lived in the village longer, and had a higher share of participants that belonged to water association chose fewer water saving crops and used more water.

It appears that the strength of relationships among group members is positively correlated with pro-environmental behaviour. Groups that had a higher share of participants that got along with others in the group (an indicator of potential cooperation) choosing more water saving crops and used less water for irrigation. This is consistent with our expectation that groups whose members enjoy a better/closer relationship are more cooperative, resulting in reduced water extraction. Interestingly, groups with a greater share of participants that trusted almost everyone and felt that they could rely on neighbors for help with community activities chose fewer water saving crops and had increased levels of water consumption for irrigation. Another explanatory variable that had a significant but unexpected directionality is participants agreement that groundwater use now will affect future availability. Groups with a greater share of participants that agreed had decreased water conserving behaviors over the course of the game. This indicates a potential disassociation between current water use and the impact on future groundwater availability, perhaps owing to the fact that the water scarcity situation is not yet drastic.

The gendered differences in resource consumption noted in the FGDs can also be seen in the quantitative results. Examining the dependent variables by gender (Table 6), we found that additional rounds of the game and communication had a significant effect only on female groups. The addition of group election of rules resulted in both female and male groups choosing more water saving crops and decreasing water consumed for irrigation. A higher water level at the start of the round significantly decreased the selection of water saving crops and increased water consumption among male groups while female groups adapted more water conserving behaviors in response to higher water consumption in the previous round. The relatability of the game decreased selection of water saving crops for male groups and was associated with increased water consumption for both groups.

Table 6. Share of the group making water saving crops choices estimated from GLM regressions <u>by gender</u>; total amount of water consumed for irrigation by all players in the round estimated from Tobit regressions <u>by gender</u>

	Share of group making water saving crop choices		Water consumed for irrigation	
VARIABLES	**Female**	**Male**	**Female**	**Male**
Game round	0.162*	0.0310	-0.491**	-0.0969
	(0.0918)	(0.0630)	(0.195)	(0.132)
Communication game	0.660***	0.0835	-1.684***	-0.277
	(0.256)	(0.189)	(0.593)	(0.398)
Communication game w/rule	1.037***	0.515**	-3.038***	-1.109**
	(0.281)	(0.208)	(0.706)	(0.451)
Water level at the start of the round	-0.0124	-0.059***	0.0196	0.131***
	(0.0177)	(0.0192)	(0.0372)	(0.0390)
Total amount of water consumed in the previous round	0.0929***	0.0187	-0.237***	-0.0319
	(0.0315)	(0.0420)	(0.0785)	(0.0874)
Share of the group that found the game relatable	-0.0830	-11.36***	0.361***	24.84***
	(0.0763)	(0.787)	(0.133)	(1.680)
Constant	-1.716**	12.43***	14.72***	-17.18***
	(0.817)	(1.387)	(1.877)	(2.908)
Observations	304	307	304	307
R-squared	0.309	0.345		
Pseudo R-squared			0.0816	0.0876

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 and amount of sanctioning or punishment that would be appropriate for breaking the rules. All groups chose to monitor players' choices in this round.

Out of the 30 groups, 10 men groups and 10 women groups chose to introduce a monetary fine as part of their agreed upon sanctions for violators. The fines ranged from as little as 10 Ethiopian Birr (equivalent to US$2.83 on Dec 31/2021) to as high as 1500 Birr, but 300-500 Birr were most common, which is within the range of a farmer's income from the harvest in the game (300 Birr for water saving crop, and 500 Birr for water consumptive crop). Some players commented that sanctions of less than 100 Birr were too small to affect a change. A female player reflected that *"there should be a big penalty for a rule violation. In our group we fixed the penalty to be 100 Birr, in my opinion, this did not hurt the rule violator."* However, a few others thought that it was still significant no matter the amount*: "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 from another village.

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 progressive 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. In those discussions, some players were against fines that involved irrigation bans, which were seen as unfair as farming is vital to the livelihoods and survival of community members.

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. In the debriefing discussion, a male community member stated "*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."* In another community, the women's group also forgave players the first time, but eventually required paying a penalty after repeat violations. This is an explicit example of Ostrom's (1990) design principle of graduated sanctions.

Interestingly, a few groups applied a sanction even if violators deviated from the agreement by saving more water. For example, if it was decided that everyone plants the water consumptive crop for a year, and one person decided to plant the water saving crop, they would still be considered in violation, and some of those players were fined. The rationale behind such sanctioning related to the disruption of agreed upon processes, and potential impacts of actions on market prices of crops and therefore the income of the group.

Communication, cooperation and competition

During communication rounds, players discussed a range of things, including what to grow based on the available water, wise groundwater use, how to save water effectively, and the importance of crop rotation and group work. In Hobe JD, the men's group's discussion was *"mainly about balancing cultivation of water intensive crops with less water consuming crops."*

Communication rounds also improved group dynamics, and understanding between members. 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."* Similarly, in another group, a male player reflected that *"the second game with discussion has brought a change in our decision; we started to trust each other and work cooperatively..."* Communication further helped create awareness about groundwater depletion. In another village, a participant reflected on how *"communication was very important...it enabled us to see and share ideas about how the groundwater was decreasing."* In games 2 and 3, patterns in player behavior included both cheating and complying with rules. Players observed that in many instances, group members cheated, which showed the importance of rules and sanctioning to prevent violation. A man said: *"rules are very important to manage differences and conflicting interests. The punishment was a must to control those who cultivate against the rule. It was needed because some may only want to maximize their own income by using the water intensively."*

During the community debriefing, players reflected on the effects of communication on behavior and outcomes during the game, noting that communication played a key role in water saving, improving cooperative behavior and understanding among players, creating awareness, and balancing income inequities. Through communication and making collective decisions, groups were able to use the groundwater for more time periods and to reduce water waste. Yet players also stressed that communication went hand in hand with rules, including rules for punishment of 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 we were able to force all the members to save water"*.

Players, mostly women players, also mentioned that they found rules and sanctions to be important 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."* Another woman in another village stated *"when we played with cooperation and communication as a team., cheaters got much money, but after we introduced rules, things changed and improved so that we got almost equal incomes and conserved much water.*"

Players shared during 6 community debriefings that there was no violation, and all game players followed the rules. A man mentioned that *"as all members strictly followed the rules, it was not necessary to introduce sanctioning."* Social networks and trust between community members (i.e. the fact that they knew each other) appears to affect this cooperation. A woman reports *"we did everything in agreement because we all know each other."* Nevertheless, players agreed that sanctions are important to have, even where there was no violation in the game. A man thought that although "*sanctions were introduced they were not applicable, since we all played with mutual communication and understood each other. In general sanctions are important for the future.*"

Relevance to real life

Most community debriefing participants saw that there were similarities in the game with real-life situations and behavior. One player related that *"when the groundwater dries up, we could not farm in our real-life too."* It also seemed that players played the game in a life-like manner, considering water levels but also other factors, such as market prices, when making their individual and collective choices. In another village, a woman provided insights into her group's decisions: *"We said if we all cultivate cabbage or tomato the market price will be low. And we also have discussed to practice crop rotations; if two players cultivate cabbage and the other three players grow onions, the market price will be higher. But that may deplete the available groundwater."*

In the debriefing, some community members mentioned that many players acted out of self-interest, mimicking what usually happens in reality. Indeed, the game reflects game theory principals of maximizing self-interest, even at the expense of the group. This was particularly the case in the non-communication game, where the players *"were not talking and thus, we all were interested in our self-interest; getting more money*.". In another village, a player reflected on how "*some group members were advising others to grow the water-conserving crop while they themselves were growing the lucrative crop which was water intensive."*

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 learning, normative learning and relational learning. Cognitive learnings in this context refer to the understanding of the linkage between individual choices (i.e., crop type choices) and payoff and joint outcomes for the group including both monetary and resource outcomes, and how these play out on a temporal scale (i.e., the tradeoff between higher earnings in the short term and resource depletion, and thus loss of income source, in the long term). Normative learnings included the recognition of the need for rules, while relational learning encompasses the 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, and viewed as private property, unlike surface water.

Interest in the game is also key to the success of the intervention. Participants overwhelmingly reported that the game was fun, relatable, and educational. Most players agreed that the last game that allowed communication and the establishment of rules was the most interesting. This has a positive effect on learning, as the information is better retained when the experience is interesting and engaging for players (Falk et al. 2023). 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 games intervention, especially the debriefing, is designed for social learning to affect community-level action.

Community debriefing and spillover effects

The game intervention changed people's perceptions of groundwater management, stirring formal and informal community discussions related to collective action for groundwater conservation. Community-wide debriefing discussions were a vital part of this experiential learning process (Meinzen-Dick et al. 2018; Falk et al. 2023). It provided 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.

However, from the analysis of these debriefing discussions in Ethiopia, we observed a notable difference in players' and non-players' mental models and lessons learned from the process. Facilitators noted that participants from the FGDs (who did not play the game) were mostly silent during the debriefing discussion. Though in some cases non-players seemed to be actively following the discussion, in other cases they 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 to experience playing the game first-hand in each treatment village. 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[7], but may necessitate having more facilitators to manage any outside influence that can affect player choices in the game. 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 selection of players is the continued reinforcement of underrepresentation of

[7] See https://gamesforsustainability.org/

traditionally marginalized groups, who may be seen as less influential community members and thus are less likely to be selected.

Considerations for implementation

Many game participants reflected on the particular crops used in the game and their different water requirements, yields and incomes—even six months after the intervention—instead of considering them as illustrative of the link between individual management practices that have implications for water use and groundwater tables. As an example, farmers reported learning that tomatoes consume more water than cabbage, and they thus planned to plant cabbage in the following season to save water. 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 and correct advice that is most useful for their context and needs. Facilitators need to stress the illustrative nature of the game, crops, and relative water requirements and associated incomes. Further, embedding the games in a larger intervention package that includes technical assistance and follow up with local extension officers who can provide communities with up-to-date, accurate crop water requirements and other management options that have implications for water consumption can help communities to take evidence-based action for managing groundwater. 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, and a Crop Water Budgeting tool (Android app) that computes the water consumption of different crop combinations, based on local conditions (FES, 2021).

Recognizing the importance of having groundwater rules is not sufficient on its own for bringing about the establishment of rules. 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. Embedding the games in a larger extension package can be beneficial in supporting community capacity to build institutions around groundwater governance that are more relevant to their local context. As an example, the national program that promotes engaging rural villages in soil and water conservation activities enhanced the understanding of farmers 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). Most communities referred to soil and water conservation activities such as afforestation and planting certain types of trees as a way to improve groundwater availability before the game intervention. However, evidence on afforestation improving groundwater availability in the dry season is, at best, 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, evidence-based with solid scientific backstopping. Otherwise, we risk losing communities' trust if the promised benefit is 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 transparent and clearly communicated to the communities.

Wouters et al. (2013) find that multiple training sessions improved the outcome of participatory games. Some participants of endline FGDs 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. A refresher might be helpful for maximizing benefits from the experiential learning particularly for medium- and long-term retention of messages. Endline FGD participants across treatment communities suggested that the game/intervention should be repeated, otherwise the lessons learned would be forgotten.

CONCLUSIONS

This study contributes to the growing body of evidence that games offer a potentially valuable tool to improve governance of common pool resources (Falk et al. 2023). This is particularly important for groundwater, which is largely an invisible and fugitive resource (United Nations, 2022). The groundwater game experience had a clear effect on shifting mental models regarding the characteristics and use of groundwater resources. Before the game the majority of communities did not perceive groundwater as a shared or depletable resource, but rather as private property that was not affected by crop choices, and intensity of use. Following the game, farmers realized that groundwater is indeed a CPR and that their individual choices have an impact on availability for the whole village. Additionally, the participants recognized the value of communication and collective action in resource management, as well as the necessity of groundwater rules for better groundwater management. In most communities, most players expressed that sanctions, going hand-in-hand with set rules, were important to achieve desired outcomes.

Exploring the factors that affected players' choices in the games, we see clear gender differences, with women more likely to choose the water-consumptive crops, although the optional rule selection helped to moderate women's resource use. We also see clear gender differences in the 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 may help to expand the number of options that women can identify.

The relatability of the games enhanced their value for experiential learning; 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, particularly for the experiential learning of those who played the game to influence the larger community. We also see some decay in memory of the lessons from the game over time. Having additional rounds of the games so that individuals can play them more than once, and more people can play the games, might help address this. Developing toolkits and simple facilitation tools to enable communities to do this themselves, rather than relying on outside facilitators, can help address this. The fact that those who experienced the games found them to be enjoyable is a promising sign that there could be receptivity to such an approach. Further research on the relative effects of the breadth (number of people exposed) and depth (repeated exposure) of the intervention would be valuable.

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 the 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 walking a fine line between preventing overexploitation (and elite capture) without limiting the possibilities for using groundwater to increase agricultural production and incomes in Africa south of the Sahara.

While the games are a promising tool, they are not a panacea. In particular, while there is a significant positive shift in mental models following the game, there were few instances of rule changes, and no solid community institutions have been established to govern groundwater. There was, however, evidence that the game intervention sparked community discussions as a first step toward collective action. It may also be that there has been no significant change in rules and institutions yet as groundwater scarcity is not yet a big issue in most of the sites.

We also note that building community capacity takes time. While the games offer a promising first step, they need to be coupled with other interventions to provide communities with the information and technical skills to manage their groundwater resources effectively. We therefore recommend further studies of the effect of these combinations of interventions under different conditions, particularly different degrees of (ground)water scarcity.

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