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The impacts of a simple one-day capacity building workshop in a randomized adaptation project

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[Introductory paragraph]

Encouraging adaptation to climate change is fundamentally about encouraging changes in human behavior. To promote these changes, governments, nonprofits, and multi-lateral institutions have invested in a range of adaptation projects. Yet there is little empirical evidence about which project components are effective in changing human behavior [1] [2]. This lack of evidence is concerning given that the failure of adaptation initiatives has been described as the global risk with the highest likelihood of occurring and with the largest negative impacts [3]. Here, we report on a scholar-practitioner collaboration in which a simple one-day workshop delivering two ubiquitous components of adaptation projects [4]—capacity building and the dissemination of climate science—was randomly assigned among the management councils of over 200 community water systems in an arid region of Central America. The workshop was based on more than three years of scientific research and local collaborations, and it aimed to convey downscaled climate modeling and locally-informed, expert-recommended adaptation practices. Two years later, we detect no differences in pricing and non-pricing management practices of participant versus non-participant councils. These results suggest weaknesses in the common practice of using simple workshops for delivering capacity building and climate science.

[Main text]

A lot of scholarly and practitioner attention has focused on developing science for adaptation—in other words, understanding the likely impacts of climate change [5] [6]. Yet the science of

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adaptation, which aims to understand adaptation decision-making, is equally essential. For example, a commonly identified barrier to adaptation is a lack of scientific information about climate change and its current and potential future impacts, in forms that decision-makers can assimilate and act on [7] [8] [9]. Accompanying that scientific information gap is a gap in management information—information about how decision-makers can best adjust management, investments, and policies to better adapt to a changing environment [2] [10].

Given widespread acknowledgement of these information gaps, the vast majority of adaptation projects include efforts to build local capacity [4]. In our own analysis of funded proposals to the Adaptation Fund, we found that components of capacity-building—equipping individuals, communities, and institutions with the knowledge and ability to adapt to climate change—are nearly universal (see Supplementary Note 1). Although the depth of these components varies widely, from simple one-day workshops to persistent interventions spanning years, capacity-building components typically include social, natural and physical science that aims to provide decision-makers with: simplified explanations of climate change, forecasts of future conditions based on downscaled climate modeling, and locally-informed expert opinions on best adaptation responses.

Whether such efforts induce behavioral change, however, is an empirical question. Designing programs that measurably affect behavior is notoriously difficult [11]. On one hand, these efforts could change the behaviors of decision-makers by: making scientific information more accessible or more credible; broadening the scope of actions that are considered feasible and effective; or focusing attention on adaptation to climate change and thereby raising its salience. On the other hand, even well-designed capacity building might fail to change the behavior of decision-makers who are: constrained by financial, labor, or cognitive resources; constrained by social norms; focused on short-term outcomes at the expense of long-term outcomes; or focused on private outcomes at the expense of public outcomes. Which of these countervailing forces tend to be strongest, on average, is unknown. Evaluations of capacity building in adaptation projects tend to focus more on documenting inputs than on documenting impacts [12] [13].

Here we focus on capacity building and climate science communication in the context of water scarcity. Driven by population growth and rising living standards, demand for freshwater has led to rapid depletion of aquifers [14]. The resulting water scarcity will likely be exacerbated by

climate change-driven increases in the volatility of precipitation, which will lead to more frequent droughts in many regions of the world [15] [16]. To adapt to increasing water scarcity, water supply systems must change how they operate [14].

One widely promoted behavioral response is to change how water is priced—specifically, charging higher, volumetric prices [9]. Such pricing serves two purposes. First, it raises revenue, with which water systems can improve management (e.g., via investments in storage or in repairing leaks) [17]. Second, it encourages water conservation, which reduces demands on the aquifer [18]. However, managers are often reticent to raise prices. Higher water prices raise concerns about equity and access [19], which can lead to conflict. A partial solution to the efficiency-equity tradeoff is to use an increasing block structure, in which low volumes for basic human needs are charged lower variable prices. Even without changes to prices, however, water systems can engage in other adaptive responses, including better management of existing finances, staffing, infrastructure and customers [20]. Inducing these changes in pricing and management practices is a principal aim of adaptation projects in the water scarcity context.

We use a randomized experimental design to test the effectiveness of a simple one-day workshop for inducing these changes in pricing and management practices. The workshop was targeted at 233 community-based water management organizations (CBWMOs) in Costa Rica operating in a drought-prone region, for which downscaled climate modeling predicts decreasing water availability in the near future [21]. CBWMOs, which are the most important water managers in rural communities of low and middle-income countries, are often regulated by the central government but typically do not receive financial support. CBWMOs are managed by volunteer councils and are involved in everything from billing to maintenance of infrastructure to protection of watersheds [22] [23] [24].

The development of the workshop is an example of scholar-practitioner collaborations that have been called for in adaptation science [10]. A cross-disciplinary team comprising climate scientists, water supply specialists, social scientists, and extension and outreach specialists spent three years developing downscaled climate modeling of future water availability in the region [25] [21] [26], doing fieldwork with CBWMO management councils and households to identify management practices for assessing adaptive capacity that were characteristic of the highest performing CBWMOs in the region, and developing pedagogical material that reflected the

education and learning styles of the target audience (see Methods). By identifying implementable and measurable management practices tailored to the dynamic context of CBWMOs, the team was adhering to best practices for assessing adaptive capacity [27]. The team was coordinated by the Tropical Agricultural Research and Higher Education Center (CATIE), which obtained the approval of regional leaders for randomly assigning CBWMOs to an intervention (see Methods). CATIE is well known in the study region and broadly trusted for unbiased scientific information and its dedication to applied research for development and environmental management.

Approximately half of the CBWMOs in the targeted region were randomly assigned to receive a simple one-day capacity building and climate science workshop (see Methods), and half were assigned to a no-workshop control group. The workshop, which was run at various locations for subsets of CBWMOs, communicated climate science information—both past and future trajectories of rainfall and water availability—and six recommendations to improve water system management. The information was presented in oral, written and pictorial forms. Figure 1 shows three images used in the workshop to convey temperature change and rainfall change projections, and their implications for water scarcity. The most prominent recommendation was to adopt the variable, increasing-block price schedule set by the national regulator, which in most cases would require CBWMOs to raise prices. The recommendations also included five practices related to financial management, infrastructure maintenance, and organizational behavior that were characteristic of the highest performing CBWMOs in the region. The facilitators then coordinated group exercises focused on goal setting and pricing innovations, and distributed written and pictorial materials for the participants to bring back to their communities. The cost of the research input, workshop development, and workshop delivery was about €700,000. Such workshops are common in adaptation projects (see Supplementary Note 1). In the same way that a short visit to a doctor can change patient behavior when it is preceded by a battery of diagnostic tests and is supported by a patient's respect for years of medical training, the theory behind a simple one-day workshop is that it can change behavior when, like ours, it is the culmination of years of trust-building and diagnostic research by the facilitation team.

Assessing adaptive capacity is highly context-dependent [27] [28]. We therefore focus on two behavioral outcomes that are closely tied to the workshop design and the research that produced the management recommendations: a pricing outcome, which increases as a CBWMO moves

towards using the recommended maximum allowable, variable, increasing-block prices; and a ~~count~~ outcome of the five recommended non-pricing management practices, with higher values indicating more practices being used. These two outcome variables are quantitative measures of the workshop's management recommendations, which were tailored to the dynamic context of CBWMOs in this region of Costa Rica. These outcomes are measured two years after the workshop in order to give the CBWMOs sufficient time for behavioral change. The design has high statistical power (see Supplementary Note 2).

Figure 2 shows that the estimated effect of the workshop on water pricing is roughly zero: an increase of 12 Costa Rican colones (CRC) (approximately €0.01), 95% CI [-271, 295] (see Table 1, col. 1). To put this estimate into context, the average monthly variable charge—the amount owed by the average household excluding fixed monthly fees—rose from 3693 CRC in 2015 to 4085 CRC in 2017 (from approximately €5.91 to €6.54). Using alternative measures of pricing that include fixed monthly fees, reported in Table 1, we come to the same conclusion: the estimated difference in the pricing of participant and control CBWMOs is negligible.

Figure 2 also shows that the estimated impact on non-pricing management practices is small and negative. In other words, participant CBWMOs had slightly fewer of the five recommended non-price practices in place than control CBWMOs: 0.15 fewer practices, 95%CI [–0.37, 0.08] (see Table 2, col. 1). In the endline survey (see Supplementary Materials), the CBWMOs were also asked if they had expanded storage capacity in the past two years—an adaptation action that was not emphasized in the workshop because costly expansion was deemed to be infeasible for many CBWMOs. Participant CBWMOs were less likely to have expanded storage capacity: 5 percentage points less likely, 95% CI [–15, 6] (see Table 2, col. 2).

Our inability to detect even modest impacts highlights the importance of rigorously testing adaptation initiatives, including initiatives that, like ours, follow common practices. Such testing provides an opportunity to refine practices so that future initiatives will be more successful in changing behaviors. Learning what does not work is just as important for informing adaptation initiatives as learning what does work. Our results suggest that simple one-day workshops to disseminate climate science and build capacity do not have substantial impacts on actual behavioral outcomes. We believe more ambitious capacity-building components can be

successful in changing behavior, and rigorously testing those components is just as important as testing a simple one-day workshop.

Data from an endline survey and in-depth interviews suggest three lessons for designing more ambitious capacity-building interventions in the future. First, interventions should be persistent. Communication strategies can fail if the information is not new, credible, transmitted, understood, and retained by the relevant decision-makers [29]. In our context, the workshop transmitted new information through a trusted messenger (see Methods). CBWMO baseline awareness of the relationship between climate change and drought was low, while trust in the CATIE workshop facilitators and in the national water regulator was high. In-depth interviews indicate that the new information was transmitted to the management council: nearly three-quarters of treated CBMWOs recalled the workshop information being shared with the entire council (see Supplementary Table 1). However, retention was a problem: in only one in five CBWMOs could council members who did not participate in the workshop remember the workshop content. Council member turnover was likely a factor in retention: one-third were replaced between baseline and endline, and in about one-quarter of CBWMOs, the council members who participated in the workshop no longer served on the council. Although workshop interventions aimed at information transfer and capacity building are common in adaptation projects, inducing behavioral change beyond business-as-usual may require more elaborate and persistent interventions. In the context of Costa Rican CBWMOs, a more elaborate intervention could include holding multiple workshops for each CBWMO and arranging one-on-one follow-up conversations with participants and other council members. Such interventions, however, are more costly, for both projects and participants.

Second, interventions should target actors with the greatest opportunity to improve behavior. The Costa Rican workshop targeted the highest-ranking members of the management councils. In most cases, these leaders attended; otherwise, alternates attended. Prior to the workshop intervention, the ability of these leaders to change prices was assumed based on the high variance of prices across CBWMOs. That conjecture was corroborated post-workshop: one-third of all CBWMOs actually did increase prices by some amount between baseline and endline. However, we have some evidence that inviting high-performing CBWMOs may have had negative impacts. At baseline, about one-quarter of CBMWOs were already using the recommended non-

pricing practices. Two years later, two-thirds of these high-performing CBMWOs in the control group were still using the practices. In the workshop treatment group, however, more than two-thirds of the high-performing councils had abandoned at least one of the practices (see Supplementary Table 2). We are hesitant to attribute that difference to the workshop, but the pattern is consistent with claims of "boomerang effects" from peer comparisons, whereby the best-performing actors infer that they might be better off behaving more like the other actors [30]. We thus think it is prudent to consider how capacity building might be more effective and cost-effective when targeted exclusively to under-performing actors.

Third, interventions should actively shape interactions with nonparticipant community members and other initiatives. Our interviews and surveys suggest that some management councils were deterred from implementing changes by fear of backlash from community members. Two-thirds of the CBWMOs that claimed in the endline survey that they could not afford to employ a half-time plumber actually had prices below the maximum allowable and could therefore raise revenues by raising prices. When asked why they did not raise prices, almost half reported that higher prices would impose financial hardship on their fellow community members or spark disapproval of the council's management. Furthermore, the endline surveys indicate that the adaptation workshop may have been just one of several projects that competed for the attention of CBWMOs and their constituents: about three-quarters of the CBWMOs reported having received other types of training activities, unrelated to adaptation, since baseline. By anticipating interactions with nonparticipant community members and other development initiatives, future adaptation initiatives can incorporate those interactions into their designs. In the context of Costa Rican CBWMOs, the workshop could have provided an exercise for participants to approach their constituents and build consensus for changes in prices. The facilitators could also have reached out to other groups to coordinate and perhaps reinforce information and capacity building from one training to the next, rather than compete for the attention of local leaders.

Our "large N" study that used a set of real behavioral outcomes and a mixed-methods, randomized experimental design suggests that rather than designate capacity building and the dissemination of scientific evidence as "non-scientific" project components, often done at the very end of adaptation projects, a more impactful approach is to apply a scientific lens to such activities—design at least some of these activities to be rigorously tested. With such tests, we can

begin to build a more credible evidence base for encouraging greater uptake of adaptation behaviors globally.

Methods

AC3 Project Background

From 2013 to 2015, the Tropical Agricultural Research and Higher Education Center (CATIE) ran a research and development project, "Water for Human Consumption, Communities and Climate Change: Expected Impacts and Adaptation in Central America" (AC3 project). The AC3 project was intended to improve the capabilities of community-based water management organizations (CBWMOs) in Central America to adapt to climate change. CATIE is a multilateral research institute based in Costa Rica, with a long history of working with communities and a reputation for producing high quality research on water-related issues in Latin America. Government authorities and members of the management councils were formally included in the project and had regular meetings with the field teams.

The AC3 project included three research components:

- **Downscaled climate modeling.** CATIE used sophisticated modelling tools (e.g. downscaled global circulation models coupled with topography and vegetation maps) to analyze, identify and produce downscaled maps of the impact of climate change on water resources available to rural communities in Central America.
- **Identification of adaptive management practices.** CATIE convened a team of engineers and social scientists to conduct extensive field work in 81 CBWMOs, including detailed interviews with each of the 81 management councils and with 3413 households. The interviews helped to characterize high-performing CBWMOs from a manager and client perspective and to identify factors present in CBWMOs that performed well during intense droughts. The premise underlying this component is that characteristics of CBWMOs that performed well in past droughts can be adopted by the low-performing CBWMOs to improve their resilience as droughts become more frequent and severe due to climate change.
- **Identification of nonfinancial barriers to adaptive behavior.** A team of economists analyzed the incentives and constraints, both financial and nonfinancial, that affected the decisions of communities and households to invest in adaptation to climate change. This analysis included designing recommendations for CBWMO management practices and conducting two randomized controlled trials (RCTs) geared towards behavioral change and more adaptive organizations. One RCT explored household adoption of water-conserving technologies in nine communities. The other RCT tested the effect of simple one-day workshops on pricing and management practices of CBWMOs and is reported in this article.

Recommended Management Practices for Adaptation

The first two AC3 project components were synthesized and distilled into six recommendations:

- **National block price schedule.** CBWMOs should charge the national block pricing schedule. The national water regulator, ARESEP, sets a schedule of block prices, which depends on the number of users served by the CBWMO. CBWMOs that deviated from the national schedule typically set prices lower than the national prices. CBWMOs that used the national schedule therefore tended to be in a better financial situation, and they were better able to respond flexibly

to infrastructure needs during a drought or other crisis. Higher block pricing was also believed to encourage water conservation, reducing demands on the system and aquifer.

- **Water meters.** CBWMOs should install water meters in each household. Water meters are a pre-requisite for block pricing because households can only be charged based on their water use if there is a meter monitoring their water use.
- **Monthly meetings.** CBWMOs should hold public meetings at least once per month. CBWMOs with monthly meetings were more accountable to their constituents and performed better during droughts.
- **Dedicated bank account.** CBWMOs should transact business through a dedicated bank account formally in the name of the CBWMO, rather than through the personal accounts of CBWMO council members. CBWMOs with bank accounts had better bookkeeping.
- **Prohibit late payments.** CBWMOs should have rigid rules discouraging late payments and an information program to create a moral code of conduct that favors timely payments. These rules and programs reduce both the incidence and duration of payment delinquencies. CBWMOs with low delinquency rates had better cash flows.
- **Half-time plumber.** CBWMOs should employ a plumber, at least half-time. CBWMOs that employed a plumber at least half-time had higher performing systems (e.g., better maintained infrastructure) and were more prepared for responding to infrastructure needs, for example by promptly detecting and repairing leaks.

Other adaptation responses. Portfolio diversification and infrastructure consolidation are worthwhile adaptation responses. However, the goal of the AC3 project was to promote adaptation behavior on the level of the CBWMO, and both of those responses are beyond the scope of CBWMO behavior. Development of alternative water supplies—recycled wastewater, urban stormwater, or desalinated seawater—would be prohibitively costly for a CBWMO in this region of Costa Rica. As a national project, alternative supplies are certainly worthwhile to consider, but a project of this scale could not take place in the small communities served by the CBWMOs. Similarly, infrastructure consolidation in this region would typically involve the dissolution of the CBWMO and a full take-over by the national authority after long negotiations with the CBWMO and potential legal challenges.

Workshop Preparation, Structure, and Content

Climate science and adaptive management practices were disseminated to CBWMOs through a simple one-day workshop at or near the communities they serve.

Stakeholder buy-in. Obtaining buy-in from stakeholders was facilitated by the research center CATIE, which worked with the communities for several years prior to the intervention. The major institutional and stakeholder buy-in for random assignment was obtained from the national regulator and from regional leaders in Guanacaste province. The CBWMOs that were randomly assigned to the control group were not informed of the existence of the workshop.

Communication and pilot testing. The workshop was carefully prepared as part of the dissemination and communication effort of the AC3 project. The technical staff worked with a team of communication experts at CATIE in preparing the material for the workshop, translating technical terms and customizing information with visualization tools that were suitable and effective for the understanding of the target audience. The workshop material included a visual presentation to be delivered during the workshop and written materials for participants to take with them back to their communities: a printed poster summarizing the six recommendations described above, a printed version of the presentation, and a colorful summary of the concept of climate change (see Supplementary Materials). To ensure consistency

as the workshop was delivered in multiple locations, the workshop was designed and executed with a detailed protocol that included every aspect of the event, from participant registration to sample responses to questions from the audience. All visual materials and protocols were tested in focus groups and pilot workshops. The team in charge of the workshop was highly skilled and rigorously trained, remaining in place for the duration of the whole experiment.

Recruitment and compensation. CATIE staff recruited CBWMO council members to participate in the workshop. CATIE staff had been in touch with CBWMO council members since 2010 for various projects, and since 2013 as part of the data collection efforts of the AC3 project specifically. In mid-2015, CATIE staff called two council members from each of the CBWMOs randomly assigned to the treatment group to invite them to participate in the workshop. CBWMOs typically have around six members who hold various titled offices, e.g. president, vice president, treasurer, secretary. We invited the members who held the highest titled ranks. In most cases, the invited members attended the workshop. In cases when they could not attend, lower-ranking members attended because the workshop coordinators prioritized having all CBWMOs participate over the participants' ranks on their respective committees. Each council member received a confirmation call one week after the initial invitation and a final reminder call one day before the workshop. 90% of the invited CBWMOs had at least one council member participate in the workshop. Council members are volunteers and typically earn a living in some other occupation. Hence, each participant was compensated in two ways: a "show up" fee of 15,000 colones (around 30 Euros) and a flat transportation stipend of 10,000 colones (around 20 euros). To minimize travel for participants, the workshop was run at 12 geographically disparate locations for different sets of participants. Each workshop provided food and beverages. The cost of each workshop was roughly 600 euros, 88% of which represented the monetary compensation to participants.

Workshop structure. Each workshop followed the same sequential steps: registration, greeting, presentation, coffee break, pricing exercise, goal-setting exercise, and baseline survey. The presentation began with an icebreaker in which participants were asked about perceived climatic changes in their communities. The presentation continued by transmitting information, using maps, about the expected impacts of climate change on temperature, precipitation, and water availability. The workshop framed participants as community leaders and agents of change in fostering adaptation to climate change. Workshop facilitators carefully explained the six recommendations (see Methods section "Recommended Management Practices for Adaptation"), then ran two exercises. In a pricing exercise, participants compared the status quo price in their CBWMO to the price set by the national regulator. Participants discussed the obstacles for using officially approved tariffs and strategies for raising tariffs towards the recommended price structure. Workshop facilitators presented a visual explanation of how block tariffs work and their purpose. In a commitment (goal-setting) exercise, each participant was encouraged to identify two actions that they had learned during the workshop and that they were willing to implement in their CBWMO. At the end of the workshop each participant completed a baseline survey, then received the workshop materials described above and the participation and transportation payment.

Climate science information. The climate science information communicated to workshop participants was new to them. Decision makers in Latin America are hungry for climate science information [31]. The climate science transmitted in the workshop was also specifically tailored to the region using original research and downscaled climate modeling. CBWMOs could not have obtained the information elsewhere. CATIE is a trusted source in the region, and the seminar facilitators were highly trained and credible messengers.

Experimental Design

Random assignment. The target population was CBWMOs in the Guanacaste and Puntarenas provinces of Costa Rica that use groundwater and serve fewer than 1100 customers. Using data provided by the Public Services Regulatory Authority (known by the Spanish acronym ARESEP), we identified 233 CBWMOs that met these criteria. Using randomization blocks defined by (1) the number of users, (2) the canton-level administrative district, and (3) whether the CBWMO had participated in a previous CATIE survey in 2013, 116 CBWMOs were randomly assigned to the workshop treatment group and 117 to the no-workshop control group (see Supplementary Table 3). Prior to the workshop, some of the CBWMOs were determined to be ineligible because they were subsumed by another CBWMO, were directly controlled by ARESEP, were controlled by the only family served by the aqueduct, or failed to respond to repeated communication, leaving 104 CBWMOs in the treatment group and 107 in the control group. The treatment and control groups were similar to each other as measured by the random assignment blocking criteria and the pre-treatment outcomes (see Supplementary Table 4).

Treatment. Treatment group CBWMOs were recruited to participate in a one-day capacity building and climate science workshop (see Methods section "Workshop Preparation, Structure, and Content"). Of the 104 CBWMOs in the treatment group, 6 did not participate for various reasons (see Supplementary Note 3). The workshop was run by CATIE staff at 12 schools in the region in May and June 2015. The workshop was run 12 times with on average 16 participants.

Data collection. Baseline data, including pre-treatment price and management practices, were collected May–June 2015, in person during the workshop for treated CBWMOs and via phone for control CBWMOs. To collect the endline data, a CATIE-administered phone survey was used for all treatment and control CBWMOs that could be contacted by phone (139), and in-person surveys were done for the others (72). The endline surveys were conducted almost entirely in June and July 2017, with the exception of one in August and one in September. The order of the calls and visits were randomized. Baseline and endline survey scripts can be found in Supplementary Materials.

Supplemental interviews. To supplement the survey data and help shed light on the mechanisms underlying the treatment effects, a randomly selected subsample of 44 CBWMOs was interviewed in August and September 2017, after the primary outcomes were measured. The interview questionnaire can be found in Supplementary Materials. Half of the interviewed CBWMOs were from the workshop treatment group, and half were from the no-workshop control group.

[subheading] Outcome Measures, Results, and Attrition

To reduce the potential for finding false positive effects, we restricted our attention to only two behavioral outcome measures, which we chose prior to examining the outcome data: a pricing measure and an index of other management practices.

Pricing outcome. To measure impacts on CBWMO water pricing, we sought an outcome measure that (1) increases when water systems move from fixed to marginal pricing, (2) increases when water systems raise marginal prices at any point in their block tariff schedule, (3) weights marginal prices in lower volume ranges more heavily than marginal prices in the tail of the volume distribution, and (4) expresses the incentive to conserve resources as conveyed through marginal prices. Our measure is therefore a weighted average variable charge. Most CBWMOs charge both a fixed price per month and a variable price, which depends on volume. Using each CBWMO's actual pricing schedule, we multiply the variable price at a particular volume of consumption by the fraction of households that consumed that volume, according to a pre-treatment survey. The fraction of households at each volume is the weight that we apply to the variable price. See Supplementary Note 4 for an example calculation. The estimated treatment effect on pricing is the estimated coefficient on the treatment indicator in a regression of the

weighted average price in 2017 on the treatment indicator, the weighted average baseline price, and dummy variables for the blocks used in random assignment (see Supplementary Note 4). The estimated treatment effect is 12 colones and the standard deviation is 1535 colones. The 95% confidence intervals in Figure 2 are constructed such that a two-sided test of the null hypothesis of no effect is rejected at the 5% level if the confidence interval excludes zero. The F-statistic with 190 degrees of freedom of no impact on CBWMO water pricing is 0.01, which corresponds to a p-value of 0.93. As a robustness check, Table 1 reports estimated treatment effects for alternative pricing measures: (1) total price, which includes the fixed price per month and (2) "cash left on the table", which subtracts total price from the weighted average price calculated from the price schedule set by the national regulator. Additional robustness checks are reported in Supplementary Note 4 for weighted average price (Supplementary Table 5), total price (Supplementary Table 6), and cash left on the table (Supplementary Table 7).

Count of management practices. To measure impacts on the other five recommended management practices, we use the count of the number of practices used by the CBWMO (0-5). The estimated treatment effect on the other practices is the estimated coefficient on the treatment indicator in a regression of the count of practices in 2017 on the treatment indicator, the count of baseline practices, and dummy variables for the blocks used in random assignment (see Supplementary Note 4). The estimated treatment effect is -0.15 practices and the population standard deviation is 0.99 practices. The F-statistic with 191 degrees of freedom of no impact on nonprice management practices is 1.62, which corresponds to a p-value of 0.20. As a robustness check, Table 2 reports the estimated treatment effect on the purchase of a new water storage tank, which would have been a prudent response to the information presented but was not emphasized in the workshop. Additional robustness checks are reported in Supplementary Note 4 for management practices (Supplementary Table 8) and expanded storage capacity (Supplementary Table 9).

Baseline and endline comparison. The baseline sample, comprising eligible and responsive CBWMOs, was 211 CBWMOs: 104 in the treatment group and 107 in the control group. Five CBWMOs in the baseline sample failed to respond to repeated communication at endline. The endline sample size was therefore 206 CBWMOs: 102 in the treatment group and 104 in the control group. Among the 206 CBWMOs in the baseline sample that responded to endline surveys, 2 CBWMOs declined to provide a price schedule and 1 CBWMO declined to answer questions about other management practices. Among CBWMOs with data at both baseline and endline, the baseline and endline standard deviations of the main pricing variable were 1602 CRC and 1551 CRC respectively. The baseline and endline standard deviations of the count of management practices were 1.3 practices and 1.0 practices respectively.

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Ethics statement

The RCT described in this article did not collect identifiable private data about human participants and does not qualify as human subjects research. The subjects in the experiment are CBWMOs, and all data collected were about the CBWMOs. Prior to random assignment of CBWMOs, staff from the Georgia State University Institutional Review Board (IRB) confirmed that the RCT does not qualify as human subjects research. Prior to endline data collection, staff from the Johns Hopkins University IRB confirmed that the RCT does not qualify as human subjects research.

Data Availability

Survey data that support the findings of this study and Stata code that produces Figure 2, Table 1, Table 2, as well as tables in the SI, are available from the Open Science Framework at https://osf.io/vcu9d/.

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Author contributions

P.J.F. contributed to all aspects of the paper, including study design, statistical analysis, writing, and revisions. F.A. and M.B.D.C contributed to the design of the study, writing, and revisions. B.S.M. contributed to the statistical analysis, writing, and revisions.

Additional information

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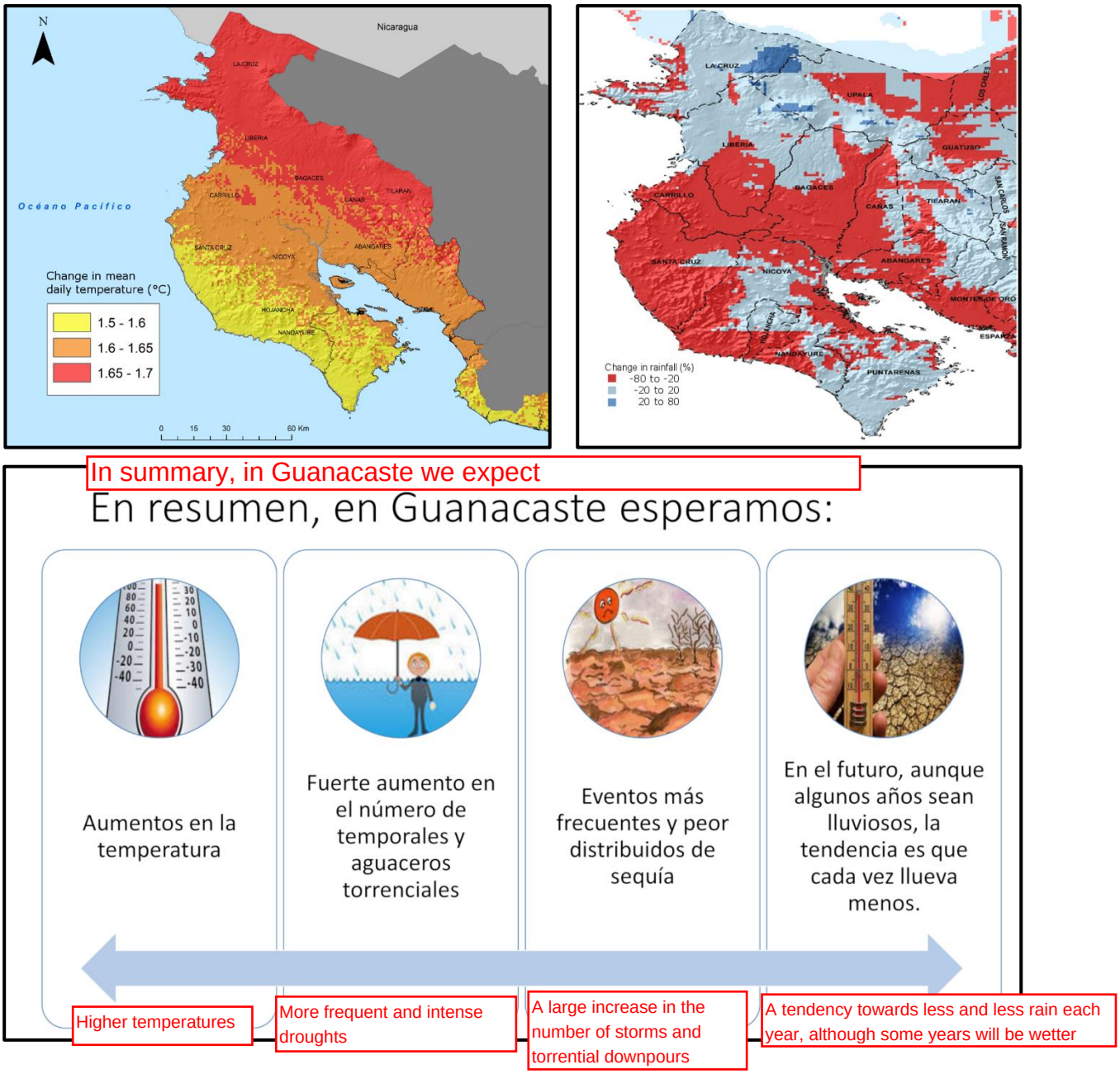

Figure 1. Downscaled climate modeling predictions in adaptation workshop. Materials used by facilitators to explain climate change, including predictions of higher temperatures and lower rainfall for the region and the consequences for community water supplies. Bottom panel translation: "In summary, in Guanacaste we expect: Higher temperatures, A large increase in the number of storms and torrential downpours, More frequent and intense droughts. Although some years in the future will be wetter, the tendency will be towards less and less rain each year."

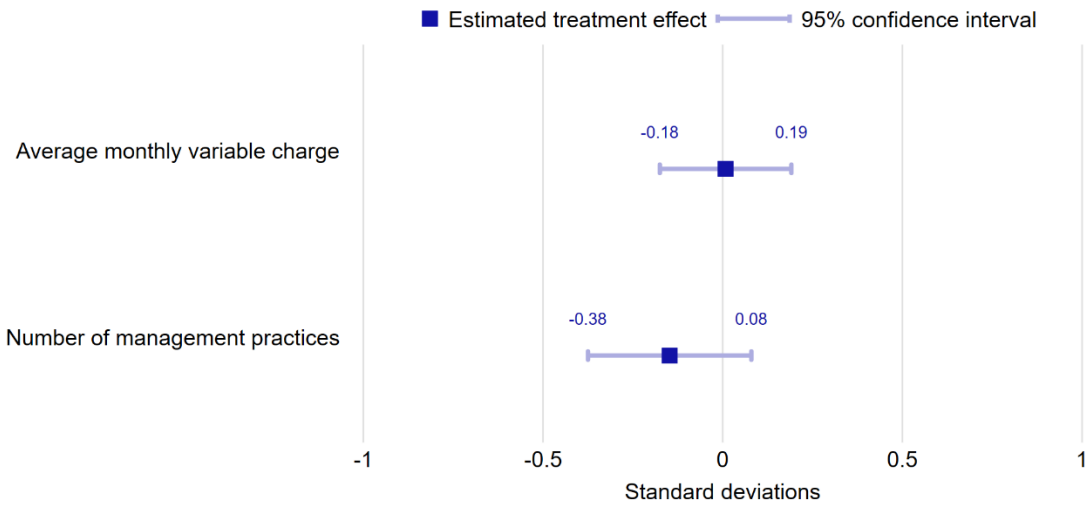

Figure 2. Standardized impact of simple one-day workshop to disseminate climate science and build capacity. The estimated treatment effect of a simple one-day workshop on two adaptation outcomes, measured two years after the workshop: the average price charged by the water system and an index of management practices. The estimated mean effect is reported in standardized units: fractions of a standard deviation of the outcome variable for the entire sample. The endline standard deviation of average monthly variable charge was 1551 Costa Rican colones, and the endline standard deviation of number of management practices was 1.0 practices.

	(1) Variable price	(2) Total price	(3) Cash left on the table
Estimated treatment effect	12.0	149.7	-187.2
Standard error	143.3	143.0	142.9
95% confidence interval	[-271, 295]	[-132, 432]	[-469, 95]
Observations	204	204	204
Degrees of freedom	190	190	190
Mean of dependent variable	4085	7384	596
Standard deviation of dependent variable	1551	1427	1493
F-statistic for null hypothesis of no effect	0.01	1.10	1.72
p-value of F-statistic	0.93	0.30	0.19

Table 1. Impact on water pricing. Estimated average treatment effect of a simple one-day workshop on three water pricing variables. Each estimate is derived from a regression of an endline pricing measure in 2017 on a binary indicator of the treatment condition and on covariate controls, which are indicator variables for the blocks used for random assignment and the baseline pricing measure in 2015. The variable price measure in column 1, which is our preferred measure and the basis for Figure 2, is a weighted average of increasing block marginal prices per cubic meter. The total price measure in column 2 adds the fixed monthly fee to the variable price. The "cash left on the table" measure in column 3 is the difference between: (1) the total price under the price schedule set by the national regulator and (2) the total price under the price schedule chosen by the CBWMO.

The estimated treatment effect and the standard error are both "CRC per month" for all three columns -- variable price, total price, and cash left on the table

	(1) ~~Count~~ of management practices	(2) New water storage tank
Estimated treatment effect	-0.147	-0.046
Standard error	0.115	0.052
95% confidence interval	[-0.37, 0.08]	[-0.15, 0.06]
Observations	205	194
Degrees of freedom	191	183
Mean of dependent variable	3.83	0.15
Standard deviation of dependent variable	1.00	0.36
F-statistic for null hypothesis of no effect	1.62	0.80
p-value of F-statistic	0.20	0.37

Table 2. Impact on other management practices. Estimated average treatment effect of a simple one-day workshop on two non-price management variables. Each estimate is derived from a regression of an endline management practice measure in 2017 on a binary indicator of the treatment condition and on covariate controls, which are indicator variables for the blocks used for random assignment. Regression (1) also uses the baseline count of management practices in 2015 as a covariate control. The ~~count~~ of management practices in column 1, which is our preferred measure and the basis for Figure 2, includes the five non-price management practices recommended in the workshop. The outcome in column 2 is an indicator variable for whether the CBWMO purchased a new water storage tank between 2015 and 2017.