Can community monitoring save the commons? Evidence on forest use and displacement

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Abstract

Rapid deforestation is a major driver of greenhouse gas emissions (IPCC, 2019). One proposed policy tool to halt deforestation is community forest management. Even though communities manage an increasing proportion of the world's forests, we lack good evidence of successful approaches to community forest management. Prior studies suggest successful approaches require a number of 'design conditions' to be met. However, causal evidence on the effectiveness of individual design conditions is scarce. This study isolates one design condition, community-led monitoring of the forest, and provides causal evidence on its potential to reduce forest use. The study employs a randomized controlled trial to investigate the impact of community monitoring on forest use in 110 villages in Uganda. We explore the impact of community monitoring in both monitored and unmonitored areas of the forest using exceptionally detailed data from on-the-ground measurements and satellite imagery. Estimates indicate that community monitoring does not affect our main outcome of interest, a forest use index. However, treatment villages see a relative increase in forest loss outside of monitored forest areas compared to control villages. This increase is seen both in non-monitored areas adjacent to treatment villages, and in non-monitored areas adjacent to neighboring villages not included in the study. We tentatively conclude that at least part of the increase in forest loss in non-monitored areas is due to displacement of forest use by members of treatment villages due to fear of sanctions. Interventions to reduce deforestation should take this potentially substantial effect into consideration.

Keywords: Common pool resources | Tragedy of the commons | Forest conservation | Deforestation | Community monitoring | Community forest management

1 Signficance statement

To halt deforestation, communities are increasingly being given the authority to manage their own forests. Although standard economic theory predicts that community management leads to over-exploitation, field studies have reported that communities can sustainably manage their forests if specific conditions are present.

One condition that is correlated with successful common pool forest management is community-led monitoring of the forest. However, whether such monitoring causes improvements in forest conditions is unclear. Using a randomized controlled trial, we provide causal evidence about the impact of community-led monitoring on forest use. Unlike prior studies, we estimate the effects of monitoring on both monitored and unmonitored forests. The results suggest that monitoring may simply displace forest loss to unmonitored forests, rather than reduce it.

2 Introduction

eforestation is associated with increased greenhouse gas emissions (IPCC, 2019) and species loss (Betts et al., 2017; Barlow et al., 2016). It also affects households in the developing world that rely on income generated from forests (Angelsen et al., 2014). One proposed policy tool to halt deforestation is community forest management (Agrawal and Angelsen, 2009; Gilmour, 2016; Oldekop et al., 2019), which involves the statutory recognition of local communities' rights to manage forests (Samii et al., 2015). In contrast to centralized forest management by an external party (e.g. a government agency), community forest management relies on input and investment from within the community. Given its promise for improving forest management, community forest management has become widespread, with 28% of forests across Africa, Asia and Latin America officially designated to be managed by local communities and Indigenous People (Rights and Resources Initiative, 2020).

However, the theoretical underpinning behind community forest management has historically been controversial. Early studies focused on community forest management in light of the 'tragedy of the commons', and argued that over-exploitation is an inevitable consequence. Subsequent influential work by Elinor Ostrom (Ostrom, 1990, 2009) changed this narrative, suggesting that sustainable community management is possible if a set of specific 'design conditions' are met. From Ostrom's case studies, those design conditions include community involvement in rule-making, community-led forest monitoring, graduated sanctions and low-cost dispute resolution.

Whether and when community forest management is effective in halting deforestation is uncertain. While a number of recent studies document that community forest management can reduce deforestation (Oldekop et al., 2019; Wright et al., 2016; Somanathan et al., 2009), few studies employ a rigorous methodology for causal identification (Samii et al., 2015). Additionally, we still lack a full understanding of what makes community forestry a success. In particular, rigorous evaluations of design conditions through randomized controlled trials are extremely rare (Samii et al., 2015). Case studies and lab experiments provide a growing evidence base on successful approaches to the management of common pool resources (Ostrom, 2006), but we need a better understanding of the scalability and external validity of insights from these studies.

This paper provides a large-N causal evaluation of a key design principle: community monitoring of common pool resources. Community monitoring is important to study, as it is arguably a precondition for graduated sanctioning and dispute resolution. Without community monitoring to collect information on overuse, sanctioning and dispute resolution would be less feasible.

The present study is the first to document displacement resulting from an intervention aiming to improve community forest management. A growing literature studies local displacement from forest conservation programs (Pfaff and Robalino, 2017) and highlights substantial heterogeneity in the existence, magnitude and even the direction of local displacement. Several studies find displacement only when they look at heterogeneous effects (Robalino et al., 2017; Alix-Garcia et al., 2012). To date, these studies have focused on protected areas or national parks (Robalino et al., 2017), payments for ecosystem services (Alix-Garcia et al., 2012; Jayachandran et al., 2017) and zero-deforestation certification schemes (Alix-Garcia and Gibbs, 2017; Moffette and Gibbs, 2021). In contrast to most empirical research on displacement, we conduct a Randomized Controlled Trial (RCT) that follows a pre-registered study design to provide causal estimates of this displacement.

3 Study design

Under a community monitoring treatment, six community members in each village were incentivized to measure forest use and threats to the forest on a monthly basis over the period of a year. These monitors then communicated this new information on collective forest use to the wider community through village meetings, thus providing an opportunity for discussions. The monitors also displayed their findings on a poster in a public place in the village. Our main hypothesis is that community monitoring decreases forest use.

The community monitoring treatment consisted of three essential components: the creation of new information on forest use, discussion at the community level, and direct patrolling with the potential to catch rule breakers in the act.

We hypothesize three main causal channels that may drive changes in forest use by the treatment villages: an increase in sanctioning, a change in unwritten norms related to resource use and a change in official forest use rules. The first channel may affect forest use through users' fear of being caught, the second and third through users' coordinated self-restraint in harvesting. These channels are similar to those developed by Ostrom and later literature (Ostrom, 1990; Cox et al., 2010), in which the role of enforcement (underlying the first channel), and information sharing (underlying the second and third channels) are stressed.

Sanctioning and local enforcement (the first channel) have been shown to be important drivers for the success of community forest management (Chhatre and Agrawal, 2008; Gibson et al., 2005). In the context of community monitoring, the most direct (though rare) route for sanctioning and enforcement is through patrolling, in which monitors catch rule breakers in the act. Additionally, community discussion of aggregate forest use could lead to rule-breakers being outed by others in the community, and sanctioned.

Unwritten norms (the second channel) may be changed by improved information provision and discussion. Results from lab experiments suggest that giving participants information about collective harvesting rates, as well as the opportunity to discuss these, decreases over-harvesting (Cardenas, 2004; Handberg and Angelsen, 2015; Ostrom, 2006; Ostrom and Nagendra, 2006). In some lab studies, when communication is introduced, harvesting declines as much as (Cardenas, 2004; Handberg and Angelsen, 2015) or more than (Ostrom, 2006) in conditions that include imperfectly enforced external regulation. The gains from communication are higher if harvesters have full information about the resource and others' harvesting (Janssen, 2013; Marrocoli et al., 2018). However, it is worth noting that these studies focus on contexts in which all use resource is monitored, and hence do not speak to displacement of use to unmonitored areas.

Information provision and discussion could also shift official forest rules (the third channel). For example, in the face of new information stating that deforestation and forest degradation is occurring more quickly than was believed, a community may collectively decide to restrict use more than previously. Various studies document that groups are able to agree on norms and rules through discussion, and that this is related to decreased resource use (Ostrom, 2006; Gallier et al., 2017).

If reductions in forest use are driven by a fear of being caught rather than self-restraint, community members could merely displace forest use outside of the monitored areas and accelerate deforestation in adjacent areas.

The study is located in 110 villages in Central, West and South-West Uganda with *de jure* management rights over a common pool forest. Households at baseline used the forest to harvest fuelwood, poles for construction, medicinal plants and a range of other forest products, mostly for domestic use. Although forest use rules forbade the cutting of whole trees in all villages, this did take place. At baseline, the rate of forest loss in areas of the forest adjacent to the village exceeded the national average, and large-scale clearing of stretches of forest was recorded in more than one-third of the villages.

Most of the Ostrom's design principles for successful management of common pool resources were satisfied fully or partly in the study villages at baseline (SI Appendix S1D for more details). Common pool forest boundaries and user groups were clearly defined. Forest use rules were set through negotiation between organizations of forest users within the community and an external agency, the National Forest Authority. Graduated sanctioning mechanisms for violations of forest use rules and clearly defined conflict resolution mechanisms were in place. Sanctioning could be informal, for example households scolding each other for violations of forest use rules. Households also reported violations to the local village head, the forest management organization and, less frequently, to the National Forest Authority. Formal sanctions were mostly imposed externally by the National Forest Authority and usually included the confiscation of forest products, fines, and imprisonment.

Ostrom's community monitoring design condition was not met in the study villages at baseline (Ostrom, 1990). Monitoring of the forest did occur, but the monitors were not part of or accountable to the community. According to case study data, such community involvement and accountability is the essential aspect of Ostrom's community monitoring design condition (Cox et al., 2010). At baseline, monitoring took place at least once a week in 3 out of every 4 study villages. However, this monitoring was conducted primarily by external actors. At baseline, only 8% of villages reported that village inhabitants volunteered to monitor. Hence, baseline monitoring was a component of centralized forest management rather than community forest management.

In turn, centralized monitoring at baseline did not lead to information flows and opportunities for communication: 46% of surveyed village members at baseline agreed that it was difficult for them to assess the size of the forest, a fairly basic indicator of its state. This was likely driven by two factors: forest governance meetings were held at the centralized level with limited community involvement, and community meetings did not need to discuss forest-related information (see SI Appendix S1B for details).

110 villages were selected from eligible Ugandan villages with *de jure* forest management rights (573 in total). We ensured that villages included in the study were not contiguous to avoid contamination from the treatment to the control group (SI Appendix S1C). The 110 study villages were randomized in 50 control villages, 50 community monitoring treatment villages, and 10 villages who received a combination of the community monitoring treatment, and another treatment, which is covered in (Eisenbarth et al., 2020). See SI Appendix S1E for details.

This study designed a two-part community monitoring treatment. First, in each selected treatment village, six community members underwent a training in which they learned to measure forest use along forest transects (existing paths into the forest). Community monitors were recruited with the help of the village leadership and were selected for their literacy, numeracy, availability to execute community monitoring, residency and possession of a mobile phone. The community monitors were paid to independently measure forest use along transects into the forest on a monthly basis for one year. This monitoring was designed to detect a number of forest use activities, including the cutting of whole trees, cut branches, domestic animal grazing, and charcoal production. The second part of the community monitoring treatment focused on communication. Monitors were required to present the results of their monitoring at a community meeting each month, aided by a poster designed to communicate findings to a population with low literacy rates. Once the monitors had presented the poster, they facilitated a discussion around forest use, clear-cutting activities and the sustainability of forest use in the community.

In comparison to the pre-treatment institutional setups in study villages (see SI Appendix S1B for details), the treatment ensured that members of the community monitored the forest, that additional information on forest use became available and that this information on forest use was discussed with the wider village in regular meetings.

The main outcome of interest is forest use, which was measured using exceptionally detailed data from on-the-ground assessments, satellite imagery and a household survey. On-the-ground assessments measured forest use on two transects (paths) into the forest, starting at a point on the forest edge close to the village center. Satellite imagery captured the disappearance of tree cover in a pixel of the image, which we will refer to as forest loss. Forest loss is a consequence of geographically concentrated forest use without replanting, so the two concepts are related but not the same. Finally, household surveys at baseline and endline captured self-reported forest use, intermediate outcomes and household exposure to the treatment.

Our main outcome indicators are two standardized indices of forest use: an index of on-the-ground and satellite measures at the village level, and an index of survey and satellite measures at the household level (see SI Appendix S2B). Unless otherwise indicated, these analyses were specified prior to the execution of this study in a Pre-Analysis Plan (PAP). SI Appendix S6 details all deviations from the PAP.

Exploiting the spatial dimension of our data, we pre-specified analyses to investigate whether community monitoring shifted forest use from monitored to unmonitored areas. We define the 'monitored area' as the area surrounding the transects subject to on-the-ground assessment (see Figure 2). In treatment villages, community monitors were instructed to monitor these transects each month. In control villages, no monitoring took place, but on-the-ground assessments defined a commensurate area. We hypothesize that community monitoring might increase forest use in several less monitored areas (see Figure 2). First, in areas of the forest adjacent to the village ('wider' area[1]). There may have been some monitoring in these areas, as community monitors were instructed to also monitor two transects adjacent to the village at their discretion. Those transects may be either in the 'monitored' area or in the 'wider' area. Second, forest use may increase in areas of the forest adjacent to neighboring villages ('neighbor' area). Those neighboring villages were not part of the study sample (SI Appendix S1C) and they may or may not have had *de jure* management rights for the forest (SI Appendix S5H). Third, community monitoring may increase forest use on private land in the village ('around HHs' area).

Finally, we pre-specified analyses investigating displacement of forest use to less visible parts of the monitored area. Specifically, we hypothesize that community monitoring might decrease forest use along the forest border, which is easily visible from the village, but increase forest use in the less visible interior of the forest.

[1] The distinction between the 'wider' and 'monitored' areas was not pre-specified, but dictated by practical challenges during treatment implementation. See SI Appendix S6 for details.

4 Results

The community monitoring treatment increased forest monitoring, the dissemination of information and opportunities for discussion. Nevertheless, we find no evidence that it decreased overall forest use. However, forest loss in unmonitored areas increased in treatment villages compared to control villages, suggesting that community monitoring shifted forest use.

The treatment successfully affected monitoring, information flows and discussion relating to the forest (see SI Table 10). Monitors report results to the research team an average of 9 times over a 12 month study period, and 46 percentage points more household respondents in treatment villages report that somebody measured the forest in their village than in control villages (74% vs 28%). There is also a significant but imperfect correlation between cut trees reported by monitors, and endline transect and satellite measurements. Most (68%) of all household respondents in treatment villages report receiving information about forest use either through a meeting, the poster or another channel. The majority of households agree that the monitors provided information that would not have been available to them otherwise. Attendance at forest-related meetings is 12 percentage points higher in treatment villages (49% vs 37%), providing additional opportunities for discussions.

Nevertheless, the treatment did not demonstrably reduce forest use, as measured by the forest use indices. The main effect[2] of the community monitoring treatment on standardized indices of forest use is not statistically significantly different from zero (Figure 1). Estimated effects are small: less than one tenth of a standard deviation. The effect of the treatment does not vary with baseline levels of forest monitoring (SI Appendix S5L), or with the ease with which households can decrease forest use, as measured by shocks to household income, the availability of alternatives to forest products, and access to credit and savings (SI Appendix S5C). Furthermore, we find no evidence that community monitoring had a statistically significant effect on any of the individual components of the forest use indices (SI Appendix S5E). The single exception is the number of trees cut on transects, which is higher in treatment villages than in control villages, contrary to what was hypothesized. This puzzling result is explored in SI Appendix S5H. However, this result is not robust to adjusting the standard error for multiple comparisons.

The estimated effect of the community monitoring treatment on the forest use indices might obscure differential effects in monitored and unmonitored areas of the forest. Particularly, the village level forest use index lumps together measurements taken in the monitored and wider area adjacent to the study villages, and does not include measurements for areas adjacent to neighboring non-study villages.

We find tentative evidence suggesting that forest loss decreased in the monitored area in treatment villages (Figure 2). The probability that a satellite pixel in the monitored area had been deforested at endline was half as large in treatment villages as in control villages (0.2% versus 0.4%, $p = 0.06$ in a one-tailed test). This amounts to a modest $450m^2$ of forest conserved per treatment village. However, this result is sensitive to correcting standard errors for spatial autocorrelation (see SI Appendix S5J). We find no evidence for displacement of forest loss to any private forested areas within the village.

Compared to control villages, forest loss in treatment villages is significantly higher in the less frequently monitored wider area adjacent to the village, and in the unmonitored area adjacent to neighboring villages (the neighbor area) not included in the study. The probability that a pixel is deforested is approximately 1.82% higher in the neighbor area and 0.68% higher in the wider area. This means forest loss in these areas is an estimated 1.5 times higher in the wider area and 3 times higher in the neighboring area if we compare

[2] All effects are conditional on control variables, the baseline level of the dependent variable, and randomization-cluster fixed effects.

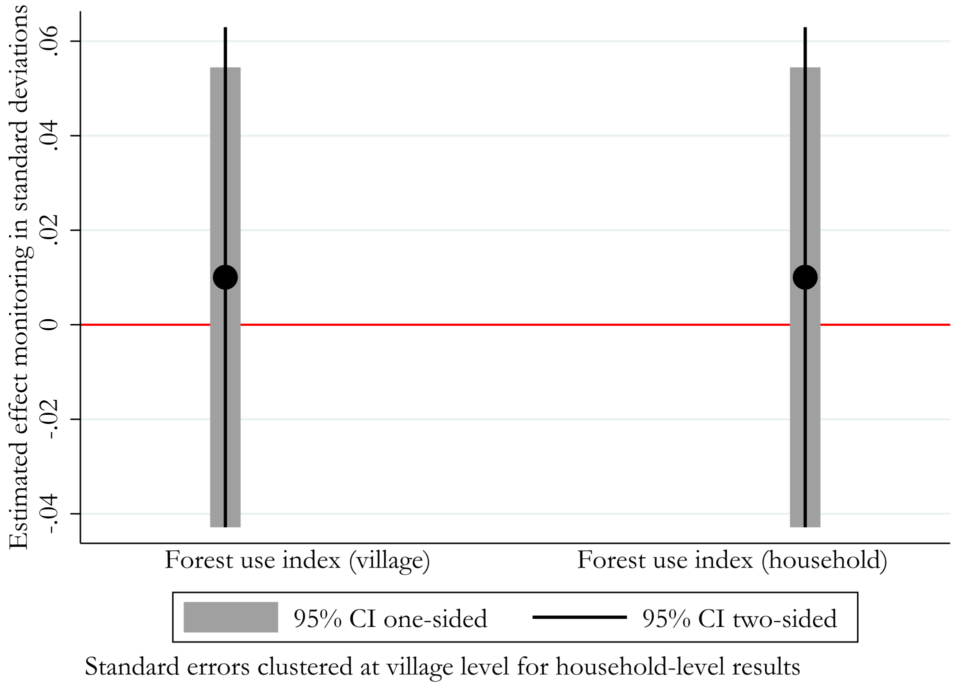

Figure 1: Effect of community monitoring on forest use, in standard deviations. Dependent variable is an index capturing forest use at the village and household level respectively.

villages subject to the monitoring treatment to the control villages (see SI Table 26 for control means). Forest loss in the wider and neighbor area represent an estimated additional 12,600m^2 of forest lost per village.

As the increase in forest loss in unmonitored areas outweighs the decrease in monitored areas, the estimated net effect of the treatment is an increase in forest loss. This is surprising: if displacing forest use comes at a cost (e.g. of carrying harvested products farther), we would expect users to harvest less after displacement. We conduct exploratory analysis, which was not pre-specified, to offer two possible explanations. First, the observed overall effect can partially be an artifact of outliers, as neighbors to two treatment villages experienced extremely high levels of forest loss. The estimated overall effect (in the monitored, wider and neighbor areas combined) of the community monitoring treatment when excluding these villages is substantially lower, though still positive and statistically significant at the 10% level (Figure 2)[3]. Second, inhabitants of the neighboring villages might themselves increase forest use in response to treatment, compounding any increase in forest loss due to inhabitants of study villages relocating their forest use. SI Appendix S5H shows that the effect of the treatment in neighboring villages is higher in the absence of forest management institutions in those neighboring villages.

Pre-specified analyses did not find evidence that community monitoring displaced forest use away from the forest edge to less visible areas in the interior of the forest. However, exploratory analysis of satellite and on-the-ground data for the monitored area provides tentative evidence for such displacement (see SI Appendix S5I). Displacement to less visible areas suggests that users fear detection by other village inhabitants who can easily observe the forest edge more than they fear detection by monitors who patrol the transects in the

[3] Considering the around HHs area as part of the overall area results in an estimated effect of community monitoring on forest loss in the overall area that is near zero and tightly estimated.

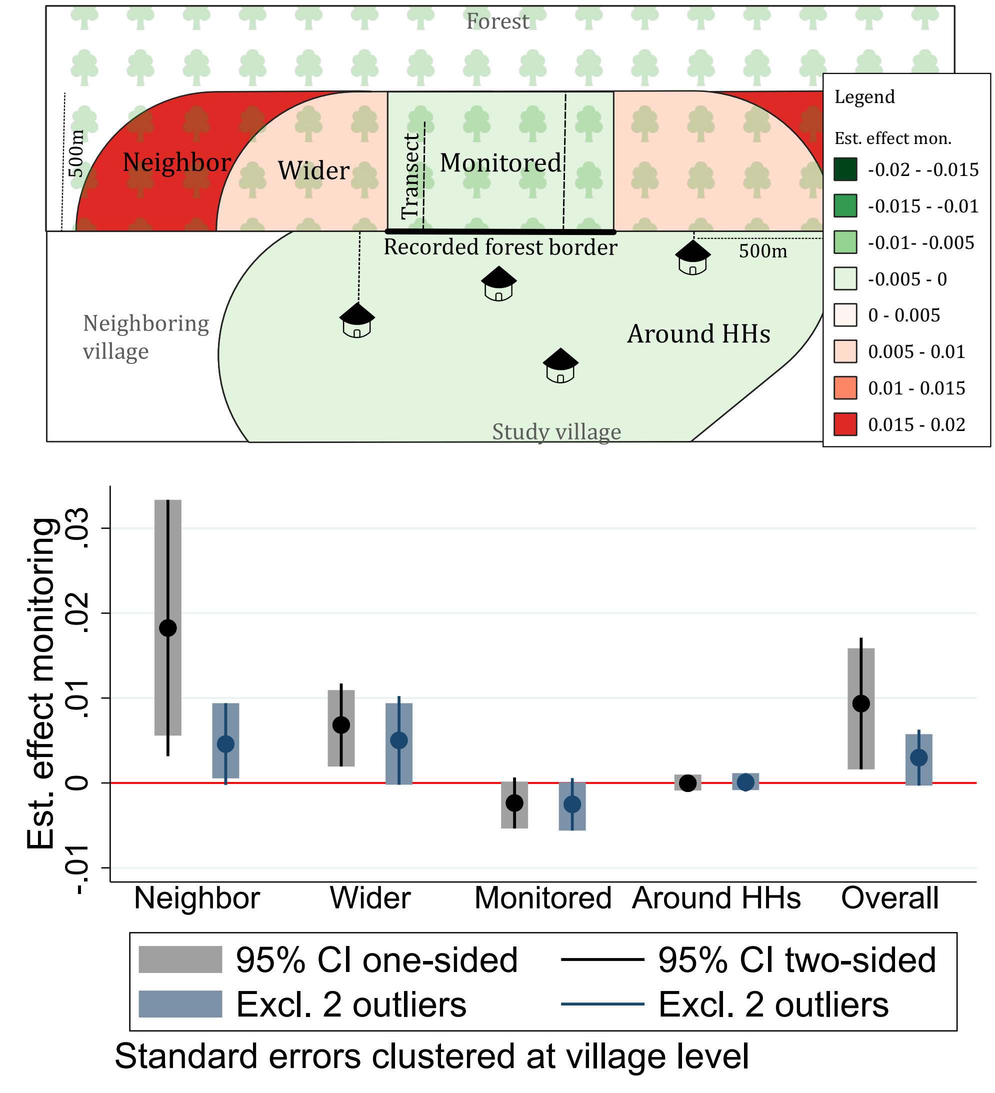

Figure 2: Effect of community monitoring (in percentage points) on the probability of forest loss at the pixel level. The top panel shows the estimated effect of community monitoring on the probability that a pixel is deforested, for four different areas. The bottom panel shows the same effect and its confidence interval for these four areas, and the overall effect across the monitored, wider and neighbor areas combined. The bottom panel also shows results obtained when excluding two villages that are outliers in terms of the rate of forest loss in the villages neighboring them.

forest interior once a month.

5 Mechanisms

We hypothesize that community monitoring leads to a reduction in forest use among households in treatment communities through three non-exclusive channels: an increase in sanctioning, changes in unwritten norms related to forest use, and changes in official use rules. In this section we explore how these channels could drive a shift in forest use from monitored to less monitored areas. The results suggest that a fear of sanctions may drive part of the displacement of forest use by members of the treatment villages. There are also indications that the treatment may have inadvertently increased forest use by members of neighboring villages not in the study.

There is scant evidence that community monitoring changed norms or rules related to forest use. Households in treatment villages are only 2 percentage points ($p = 0.7$ in a one-sided test) less likely to think that it is acceptable to break forest use rules than control households (SI Table 34). Hence, these results point to a small change in norms. Similarly, control households are just as likely as treatment households to think that community members should reduce forest use for the sake of future generations (SI Table 35). The effect of the community monitoring treatment on norms does not vary across households in treatment villages that did and did not attend forest-related meetings (see Figure 3 and SI Tables 34 and 35). Official rules for forest conservation did not change in the villages studied.

To investigate the importance of sanctioning, we estimate the impact of the community monitoring treatment on the sanctioning outcomes shown in Figure 3.[4] We hypothesize that any change in sanctioning is more likely to result from community meetings than from monthly forest monitoring, which is unlikely to catch many rule-breakers in the act. Meetings plausibly raise the (perceived) probability of detection since they help village inhabitants collectively infer who violated forest use rules. Therefore, in addition to analyzing the effect for all households, we conduct a mediator analysis comparing households in treatment villages who attended at least one forest-related meeting during the study period to households in treatment villages who did not attend any such meeting (SI Appendix S5K). Results shown in Figure 3 highlight the effect of meetings above and beyond forest patrols. Since households self-selected into attending meetings, the results in Figure 3 are exploratory and not strictly causal.

While the treatment did not affect sanctioning outcomes for households in the treatment villages overall, the results suggest that community monitoring raised the (perceived) probability of sanctions among households who attended forest-related meetings. Conditional on breaking forest use rules, the probability of sanctioning is a function of the visibility of rule-breaking and the community's willingness to sanction rule breakers. We find evidence that all these outcomes were affected by the community monitoring treatment among households who attended forest-related meetings. Within treatment villages, households who attended meetings think that their neighbors are significantly more likely to notice infringements on forest use rules. Moreover, those households are more likely to scold or report others for breaking forest use rules and they consider penalties for rule-breaking more likely (Figure 3 and SI Tables 36 - 38). There are two possible explanations for these results. Meetings may provide a forum to detect over-users, mete out informal sanctions to them and raise the likelihood of penalties. Alternatively, these results could be due to self-selection, if individuals who are willing to sanction others or rate penalties as likely are also more likely

[4] All outcomes were pre-specified. However, "Willingness to sanction others" and "Visibility" were pre-specified as outcome variables for the evaluation of the second treatment arm.

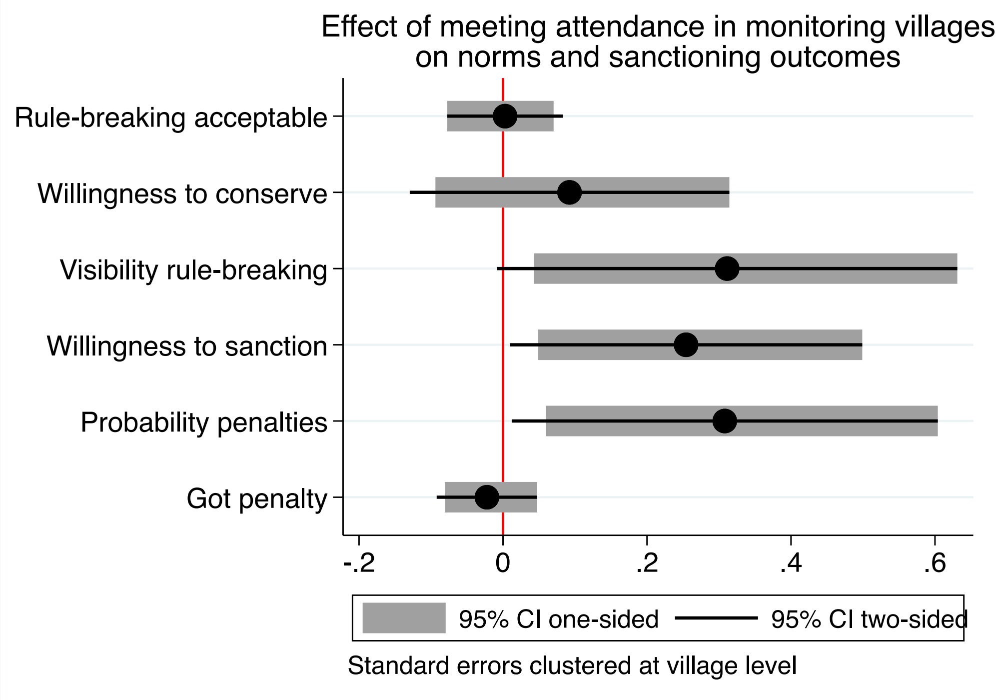

Figure 3: Estimated effect of meeting attendance in monitoring villages on outcomes related to sanctioning, listed on the left-hand side. Coefficients show a comparison between households in treatment villages who attended at least one forest-related meeting during the study period and households in treatment villages who did not attend any such meeting.

to attend meetings. This perception of a higher probability of sanctions is not matched by an actual increase in the number of penalties (Figure 3). Penalties are rare in the communities we study and we would not necessarily expect penalties to increase if violations of forest use rules do not increase or are displaced to less visible areas.

We tentatively conclude that members of treatment villages displace their forest use to unmonitored areas due to an increase in the probability of sanctions without an accompanying change in norms or official rules. Without the self-restraint implied by the latter two channels, treatment households could simply shift their activities outside the areas in which monitoring has been implemented. Other mechanisms could also drive this shift in forest use. Inhabitants of the neighboring villages might themselves increase forest use in response to the treatment, compounding any increase due to inhabitants of study villages relocating their forest use (and even driving an increase in overall forest use).

6 Conclusion

This paper tests an intervention to reduce forest use in common pool forests. The intervention successfully facilitated regular community-led forest monitoring and the dissemination and discussion of information on forest use. Estimates suggest that the intervention did not reduce forest use, beyond a possible small decrease in forest loss in monitored areas. However, the treatment led to an increase in forest loss in unmonitored forest areas, both adjacent to the treatment villages and adjacent to the non-study villages neighboring them.

To the best of our knowledge, this is the first study to document and quantify displacement from an intervention based on Ostrom's design principles. We suspect that the increase in forest loss in unmonitored areas is, at least to some extent, driven by displacement of forest use by members of treatment villages due to fear of sanctions. In addition, inhabitants of neighboring villages might contribute to the increase in forest use in areas adjacent to their villages. However, we cannot rule out that other mechanisms are at work. Further research is needed to shed light on mechanisms driving the results and to see how this study's findings translate to different contexts. This would help to improve the design of conservation programs based on monitoring.

If displacement is driven by a fear of sanctions, the design of a monitoring intervention might be improved if monitoring was more widespread or if community members could not predict which parts of the forest were unmonitored. This would raise the probability of detection and sanctions in larger stretches of forest and reduce displacement.

Furthermore, monitoring and information sharing might be more successful if changes in forest use were driven by community self-restraint. This could be facilitated through changes in informal norms and official rules around forest use. The monitoring intervention did not achieve norm shifts, possibly due to the short duration of the study of only one year. Future research from the field should investigate how to facilitate such norm shifts among forest users. This is particularly important in the context of ongoing efforts to decentralize forest management. When communities are put in charge of forest management, they cannot necessarily draw on long-established norms or institutions around forest use.

7 Materials and methods

7.1 Community monitoring treatment

The study received ethical approval from the Ugandan National Councili for Science and Technology (SS4331). Appendix SI S7A includes the protocol for the recruitment and training of community monitors.

7.2 Indices for forest stock and forest loss.

SI Appendix S2B lists the variables used to construct the forest loss indices in Figure 1 and details the method of index construction.

7.3 On-the-ground measurements.

Four components of the village-level forest use index were gathered through on-the-ground assessments of two transects, or paths into the forest. These components are: the number of cut trees, animals grazing, charcoal kilns and cut branches per 100 meter of transect. We recorded the location of the border between the village and the common pool forest for 2 kilometers on either site of a central point in the village, using a GPS device. Two existing paths into the forest starting at this border were selected as transects.

7.4 Household survey.

The sample for the household survey consisted of 10 stratified randomly selected households per village, selected from a list provided by local government, and oversampling forest-bordering households. Consent statements for survey respondents can be found in SI Appendix S7A. Attrition between baseline and endline was 10.7%. Attrition is balanced across treatment conditions ($p = 0.55$). SI Appendix S1C provides more details.

7.5 Satellite data.

Satellite imagery stems from the Sentinel-2 satellite. We used a CART classifier (**?**) to establish the presence or absence of tree cover for each pixel. Areas in Figure 2 are defined as follows. The monitored area is the minimum bounding box around the recorded forest border and transects, that overlaps with the common pool forest. The wider area is defined as a 500 meter forest-overlapping buffer around the forest border between the two farthest outlying surveyed households in the village, minus the monitored area. The neighbor area is defined similarly as the wider area, but adding 500 meter of forest border on either side of the farthest outlying households and subtracting the wider area. The area around households is a 500 meter buffer around the convex hull around surveyed households that does not overlap with the common pool forest.

7.6 Estimation.

Figures 1 and 2 display β_1 obtained from estimating following specification using ANCOVA:

$$Y_{ijmt=1} = \alpha_m + \beta_1 \text{Monitoring}_j + \beta_2 \text{Monitoring}_j * \text{T2}_j + \beta_3 Y_{ijmt=0} + \delta X_{ijt=0} + \epsilon_{ijm} \tag{1}$$

Y_{ijmt} represents the outcome for unit i (household, plot, transect) in village j in randomization block m at time t. For village-level regressions, subscript j is redundant. α_m is a set of randomization-block fixed effects. Monitoring_j and T2_j equal one if a village is assigned to the community monitoring and second treatment respectively. $X_{ijt=0}$ is a vector of control variables, selected because they have high power to predict $Y_{ijmt=0}$ or because treatment was unbalanced across this variable at baseline (see SI Appendix S2G for details). Standard errors are clustered at the village level, except for village-level regressions for which HC2 robust standard errors were calculated.

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