Can reminders of rules induce compliance? Experimental evidence from a common pool resource setting*

Sabrina Eisenbarth†, Louis Graham‡, Anouk S. Rigterink§

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This paper presents results from an RCT exploring whether a behavioural intervention can improve the conservation of a common pool resource. The literature on common pool resource management suggests that the existence of rules and sanctions are important to resource conservation. However, behavioural science suggests that these rules and sanctions may not be 'top of mind' for users of common pool resources. This paper investigates the impact of an SMS message intervention designed to improve users' knowledge of and attentiveness to existing forest use rules. An RCT in Uganda explored the impact of these messages on forest use and compliance with the rules. This paper finds that SMS messages improve self-reported knowledge of forest use rules, and raise the perceived probability of sanctions for rule-breakers. SMS messages do not induce full compliance with forest use rules and only reduce forest use based on few metrics.

Keywords: common pool resources, forest, deforestation, SMS messages, use rules, sanctioning
JEL Codes: Q2, Q56, O13

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†University of Exeter Business School and Land, Environment, Economics and Policy Institute
‡Busara Center For Behavioral Economics
§Princeton University, Woodrow Wilson School of Public and International Affairs

1 Introduction

Deforestation leads to greenhouse emissions (IPCC, 2019), biodiversity loss (Betts et al., 2017; Barlow et al., 2016) and it affects the livelihoods of rural communities, especially in developing countries. Policy interventions to solve this problem need to be tailored to local circumstances (Seymour and Harris, 2019) and bear in mind that 28 precent of all forest across Africa, Asia and Latin America are managed by communities (Rights and Resources Initiative, 2020). In light of the push towards decentralized forest management (Oldekop et al., 2019; Wright et al., 2016; Somanathan et al., 2009) it is of particular policy relevance to investigate how existing community-based and decentralized forest management can be improved. Behavioural interventions offer one way to make changes to conservation practices. Existing research indicates that behavioural interventions can be low-cost, while having a large impact on behaviours affecting environmental outcomes (see e.g. Carlsson and Johansson-Stenman, 2012; Croson and Treich, 2014; Brent et al., 2017; Schubert, 2017, for reviews of related literature). In the context of community forestry - where a common pool resource is being managed - it is an open question whether behavioural interventions can improve forest conservation.

Early studies, (most prominently Hardin, 1968) posited that common pool resources such as forests are doomed to be over-exploited. However, work by Ostrom (1990, 2009) suggests that if specific 'design conditions' are present, communities can sustainably manage common pool resources. Rules regarding resource use and graduated sanctions for rule-breakers feature prominently among these. Behavioural science meanwhile, suggests that such rules may not be 'top-of-mind' for resource users since benefits to resource conservation are diffuse, materializing only in the long term. Moreover, sanctions are only meted out with some probability.

This study combines insights from behavioural science and the literature on common pool resource management. It designs an intervention to increase users' knowledge of use rules and to increase attentiveness to these rules – to make them 'top-of-mind'. The intervention consists of SMS reminders of forest use rules. We hypothesize that this intervention increases compliance with use rules, and decreases common pool resource use, through two potential channels. First, better knowledge of and attentiveness to use rules may increase users' scrutiny of others, and their willingness to sanction rule-breakers. A large body of literature has documented that sanctions can improve cooperation in common pool resource

settings (e.g. Markussen et al., 2014; Rustagi et al., 2010; Ostrom et al., 1992; Visser and Burns, 2015; Kosfeld and Rustagi, 2015), particularly if the sanctioning regime is chosen endogenously (e.g. Sutter et al., 2010; Tyran and Feld, 2006; Dal Bó et al., 2010). Alternatively, actual scrutiny and sanctioning may remain unchanged, but SMS recipients' *perceptions* of scrutiny and the likelihood of sanctioning may increase.

To investigate these hypotheses, we conduct a Randomized Controlled Trial (RCT) in 110 communities of common pool forest users in Uganda. Treatment households receive monthly SMS reminders of community-specific forest use rules. Data from household surveys allow us to assess the effect of the treatment on the knowledge of forest use rules and the probability of sanctions. High-resolution satellite images as well as detailed on-the ground assessments of the forest are used to measure the effect of the SMS reminders on forest use and compliance with use rules.

Results indicate that SMS messages indeed increase knowledge of forest use rules: forest users in communities subject to the SMS treatment have better self-reported - but not necessarily better actual - knowledge of forest use rules compared to other communities in the study. We furthermore find that SMS messages increase the *perceived* probability of scrutiny and sanctions for rule-breakers, but do not affect *actual* scrutiny and sanctioning. SMS messages do not induce full compliance with forest use rules and they do not systematically reduce forest use. Although the estimates generally point towards a reduction in forest use, they are not always statistically significant.

This paper contributes to three strands of literature. First, this paper contributes to the growing literature on behavioural 'nudges' in environmental economics (see Carlsson and Johansson-Stenman, 2012; Croson and Treich, 2014; Brent et al., 2017; Schubert, 2017, for reviews of this literature). The forest use SMS reminders studied in this paper are similar to nudges appealing to injunctive norms, (i.e. perceptions of behaviours that are typically approved of (Cialdini and Trost, 1998; Cialdini, 2003). Existing research mostly focuses on descriptive norms, informing individuals about their peers' behaviour, (Nolan et al., 2008; Goldstein et al., 2008; Ferraro and Miranda, 2013; Demarque et al., 2015) or a combination descriptive and injunctive norms (Schultz et al., 2007; Allcott, 2011). SMS reminders in this study also appeal to social identity, in the same way that advertising campaigns appealing to a sense of community have been shown to significantly reduce littering

in Texas (Grasmick et al., 1991). Since the effectiveness of nudges is often context-specific (Carlsson and Johansson-Stenman, 2012; Schubert, 2017; Carlsson et al., 2019), the present paper helps to understand how insights from existing studies on water and energy consumption in developed countries (Allcott, 2011; Allcott and Rogers, 2014; Goldstein et al., 2008) translate into a developing country context, and a different natural resource.

Second, this paper uses a field experiment to provide insights on common pool resource management, complementing existing observational studies (see Ostrom and Samii et al. (2014) and Bowler et al. (2010) for an overview) and lab-experiments. Observational studies suggest that endogenously emerging rules are one of the keys to success in community management of common pool resources. Whether outside initiatives can strengthen existing rules regimes is still an open research question. To answer this question, the present experiment exogenously varies knowledge of forest use rules and attentiveness to those rules.

Although the present experiment does not directly vary prevailing sanctions for rule-breaking (doing so would have serious ethical implications), it investigates whether SMS reminders affect scrutiny and sanctions within the community. This paper highlights a new mechanism through which sanctioning might induce co-operation: the *perceived* likelihood of scrutiny and sanctions. The effect of *actual* scrutiny and sanctions on contributions to the public good is well-documented, but behavioural science suggests that perceptions of scrutiny might also induce compliance with rules. Existing literature suggests that increasing a sense of being watched can increase compliance with rules, for example those regarding littering and contributions in a dictator game (Bateson et al., 2013; Nettle et al., 2013; Burnham and Hare, 2007), and also that providing information on sanctions and increasing their perceived probability can raise compliance, for example on taxes (Sanders et al., 2008; Iyer et al., 2010).

Finally, this paper complements the literature on the use of SMS messages to induce desired behaviour among recipients (e.g. Karlan et al., 2016; Schoar, 2011; Dale and Strauss, 2014). With the exception of Dale and Strauss (2014) this literature focuses on individually beneficial behaviour rather than contributions to public goods. Our paper presents the first application of SMS messaging to the management of common pool resources.

2 Setting: Community-managed forests in Uganda

This study is set in 110 villages in Central, West and South-West Uganda, all of which manage a common pool resource. Every village in the study has *de jure* management rights over a defined stretch of forest, which we will refer to as 'common pool forest'. Communities of forest users either have joint management rights with the government's National Forest Authority (NFA) over a section of a Central Forest Reserve, or sole management rights over a community forest.

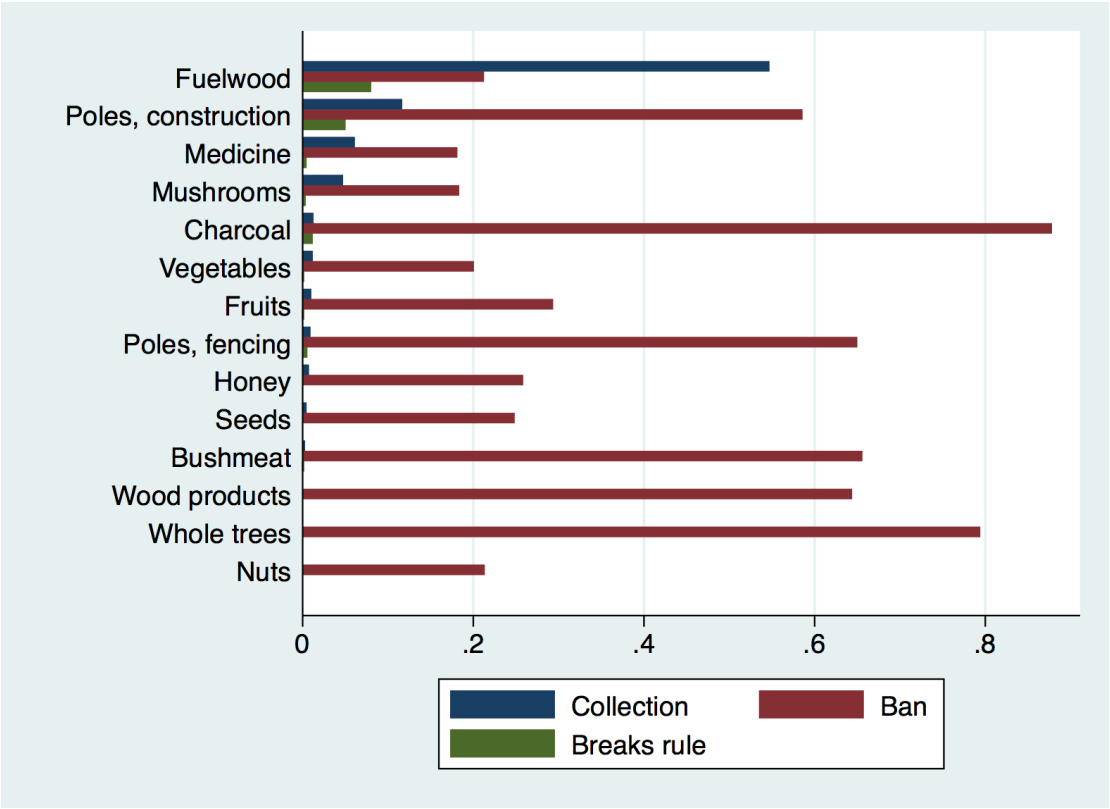
Households in the study communities collect a range of products from the common pool forest, mostly for domestic use. The blue bars in Figure 1 show the percentage of households collecting the respective forest products from the common pool forest at baseline. Fuelwood is the most important forest product: 54 percent of all households collect fuelwood from the common pool forest. Next, poles for construction are extracted by about 12 percent of all households. A smaller number of households fetch water (12%), collect medicinal plants (6%) and collect mushrooms (5%). Only 1% of the households report that they produce charcoal, and no household reports taking whole trees from the forest.

The prevailing forest management regime is chosen by (at least some subsection of) those living in the study villages. Participating in joint forest management with the NFA or registering a community forest requires that the community actively form a community-based organization to manage the forest, which either negotiates with the NFA or takes legal steps to register a particular stretch of forest as a community forest. The default management regime for a Central Forest Reserve is sole NFA management, while that for a community forest is private forest ownership.

Communities also have a say in the rules that govern the use of the common pool forest. In the case of community forests, these rules are set by a community-based organization managing the forest. In the case of Central Forest Reserves, rules are jointly set by a community-based organization and the NFA through a process of negotiation. The rules may vary from community to community, but there are similarities across communities. In most communities, the production of charcoal and timber cutting are completely banned.[1] Poles for fencing or construction can usually only be harvested with the permission of the community-level forest governance body, village elders or the NFA. The collection of fuelwood (and

[1]Figure 1 shows the percentage of households subject to harvesting bans for specific products.

Figure 1: Harvesting (bans) for forest products



Note: Collection: Percentage of survey respondents collecting a forest product at baseline. Ban: Percentage of survey respondents living in a community where harvesting the respective forest product is completely banned in the community forest. Breaks rules: Percentage of survey respondents harvesting a forest product despite a harvesting ban.

sometimes other forest products such as fruits or mushrooms) is often only allowed on two days of the week, and entry to the forest is usually banned on days which are not designated for the collection of forest products.

Formal sanctions upon breaking forest use rules exist in almost all villages in the study. These sanctions are enforced mostly by the NFA, but also by village-level authorities. Penalties range from fines and confiscation of forest products, to physical violence or imprisonment. The penalties are imposed by the NFA in the majority of the villages. In some communities, penalties are imposed by village authorities, community forest management bodies or the local government.

In addition to formal sanctions, informal sanctions – sanctions imposed by or triggered by fellow forest users – also exist. Such informal sanctions could range from scolding a fellow resource user for breaking the rules (more than 20% of surveyed village inhabitants reports to have done so in the last year), to reporting a fellow user to the formal authorities (13% of respondents reports to have done so).

At baseline, there was a high perceived likelihood that sanctions would be implemented among inhabitants of the village. Most surveyed village members (87%) stated that it was likely or very likely that someone breaking forest use rules would receive a penalty and 6% reported having received some penalty in the last year.

Despite existence of sanctions, forest use rules are frequently violated in study villages. Even though deforestation is forbidden, we found evidence of clear-cutting in more than one third of the villages. Average forest cover loss around households adjacent to the forest was estimated to be 1.2%, which is roughly as high as the national average[2]. This is despite the fact that the forests in study villages are protected as Central Forest Reserves or community forests, and deforestation in these locations is forbidden. In 13% of villages, we found evidence of charcoal production, an activity similarly forbidden in virtually all villages. In the household survey, 15% of households report harvesting of forest projects from the common pool forest in a way that would break at least one forest rule. The green bars in figure 1 show the percentage of survey respondents reporting to harvest a forest product despite a harvesting ban.

[2]According to Global Forest Watch

3 Study rationale and hypotheses

We hypothesize that SMS messages containing reminders of forest use rules may increase compliance with forest use rules, and decrease forest use, by increasing knowledge of and attentiveness to rules and therefore (the perceived likelihood of) scrutiny and sanctions for rule-breakers.

There is abundant evidence from several fields that SMS reminders can encourage desired behaviour among recipients. SMS reminders have been shown to encourage recipients to self-manage health conditions (Hall et al., 2015; Krishna and Boren, 2008), save (Karlan et al., 2016), repay loans (Schoar, 2011), register for benefits (Blanco and Vargas, 2014), adopt productive agricultural practices (Larochelle et al., 2019) and vote (Dale and Strauss, 2014).

SMS reminders may achieve this by increasing recipients' *knowledge* of what the desired behaviour is, or by *reminding* recipients with limited attention spans to engage in desired behaviour. The latter explanation has garnered more support in existing literature than the former. Karlan et al. (2016) and Larochelle et al. (2019) propose that individuals fail to engage in behaviour that is beneficial to them - meeting their savings goals and adopting better agricultural practices respectively - because the benefits of these actions are opaque and are not 'top-of-mind'. Both sets of authors show that the recipients of SMS reminders are more likely to engage in beneficial behaviours. SMS interventions that mainly rely on providing information, such as information on eligibility for benefits to welfare recipients or market and weather information to farmers, have had small (Blanco and Vargas, 2014) and no effects (Fafchamps and Minten, 2012) respectively.

In the present study, individuals are reminded by monthly SMS messages of rules regarding forest use. In our setting, individuals' baseline knowledge of forest use rules is imperfect: on average, household survey respondents at baseline score their own knowledge of forest rules at less than 4 on a 5-point scale. Furthermore, as in the case of adopting better agricultural practices and saving, the benefits of forest conservation are opaque and would only materialize relatively far into the future. Therefore, we hypothesize that SMS reminders may increase knowledge of forest use rules, or attentiveness to forest use rules:

Hypothesis 1 (H1)**.** *SMS reminders of forest use rules: (a) increase knowledge of forest use rules; (b) increase attentiveness to forest use rules.*

Increased knowledge of or attentiveness to rules within the community of users may change *actual* scrutiny of forest users and enforcement of forest use rules. H1 implies that recipients of SMS reminders know the rules better and/or are more attentive to rule violations by others. This could induce them to increase their level of scrutiny and informal sanctioning of others. A variety of studies suggest that individuals are indeed willing to incur costs to monitor and sanction rule-breakers at no direct individual benefit to themselves (Rustagi et al., 2010; Fehr and Gachter, 2000; Fehr and Gächter, 2002). Such behaviour may be restricted to individuals that Rustagi et al. (2010) classify as "conditional cooperators" (those who will contribute to a public good provided others also do so), and may be motivated by a sense of indignation or reciprocity (Carpenter and Matthews, 2012).

Hypothesis 2 (H2)**.** *SMS reminders increase actual scrutiny and the willingness to sanction other forest users.*

SMS reminders can also raise *perceived* scrutiny by others, and the *perceived* probability of formal and/or informal sanctions for rule-breakers, through three potential channels: (1) an increase in actual scrutiny; (2) higher attentiveness to sanctions; and (3) through a sense of being watched. It is worth noting that we can empirically distinguish between the first and latter two channels, but cannot distinguish among the latter two. The first channel follows logically from hypothesis H2. An increase in actual scrutiny would likely also raise perceived scrutiny. The second channel operates if recipients' greater attentiveness to forest use rules translates into greater attentiveness to instances of scrutiny or sanctions imposed on rule-breakers. According to the availability heuristic (Tversky and Kahneman, 1973) - which posits that individuals judge the probability of an event by the ease with which a relevant instance comes to mind - this may result in a higher perceived probability of scrutiny or sanctions. Alternatively, the third channel suggests that receiving SMS reminders may instill a sense of being watched, raising the perceived probability of scrutiny or sanctions. In experimental settings, such a sense of being watched has been induced in absence of actual human interaction, for example by images of eyes (Bateson et al., 2013; Nettle et al., 2013; Burnham and Hare, 2007). Note that for either the second or third channel to operate, *actual* scrutiny and the *actual* probability of sanctions need not change.

This leads us to the following hypotheses:

Hypothesis 3 (H3)**.** *SMS reminders increase the perceived scrutiny and the perceived probability of sanctions by others upon breaking forest use rules;*

Hypotheses 2 and 3 imply that the (perceived) costs of breaking forest use rules increase with SMS reminders, giving the following hypothesis:

Hypothesis 4 (H4)**.** *SMS reminders: (a) increase compliance with forest use rules; (b) decrease forest use.*

Whether a household actually receives a sanction is a function of the actual probability of receiving a sanction upon breaking forest use rules, and the household's compliance with forest use rules. Hence, if both hypothesis 2 and 4 hold, the effect on actual sanctions received is indeterminate.

Hypothesis 5 (H5)**.** *The effect of SMS reminders on actual sanctions received is indeterminate ex ante.*

Some of the hypotheses above could also follow from a neo-classical model where SMS messages merely provide information, whereas other hypotheses rely on departures from this. In such a neo-classical model, individuals choose their level of forest use while being uncertain about the forest use rules (and whether their behaviour breaks them), the size of the penalty for breaking forest use rules, and the probability of enforcement. A rational individual might choose to remain ignorant of forest use rules if acquiring information about rules is costly and the marginal costs of doing so outweigh the marginal benefits. SMS messages plausibly provide information about forest use rules at a low marginal cost, and therefore may improve knowledge of these rules, as per hypothesis H1(a). However, the impact on compliance with rules and forest use is indeterminate in a neo-classical model – contrary to hypothesis H4 – and depends on an individual's prior about forest use rules. SMS reminders may make some individuals realize they have unwittingly been breaking forest use rules, decreasing their forest use, whereas others may realize that they have been mistaken in believing that they were breaking forest use rules, increasing their forest use.[3] These predictions resemble results obtained in experimental studies of the effect of information on willingness to pay for environmental conservation (see for example Munro and Hanley, 2001; Needham et al., 2018).

[3]Furthermore, SMS messages might increase individual's level of certainty about forest use rules. If individuals are risk-averse, they may increase forest use as a result.

Other remaining hypotheses also do not obviously follow from a neo-classical model. Such models do not predict that individuals would be willing to incur costs to punish others at no direct benefit to themselves (H2). Furthermore, receiving information about forest use rules would not obviously cause individuals to update their beliefs about the probability that sanctions are enforced (H3). However H3 could follow from a neo-classical model if individuals take the SMS message with information about forest use rules as a signal regarding the probability of enforcement. If individuals think that SMS reminders are sent by a third-party enforcing forest use rules, this could be plausible.

4 Experimental design

This study randomly assigns households in 110 villages in Uganda with *de jure* management rights over a forest to receive SMS reminders of forest use rules and a second treatment. Out of the 110 villages, 10 were assigned to receive SMS reminders. All of these 10 villages also received a second treatment, which encouraged community monitoring of the common pool forest.

4.1 The treatment: SMS reminders of forest use rules

The SMS reminders aim to raise awareness and knowledge of forest use rules.[4] To that end, households receive monthly SMS reminders which clarify one of the community's forest use rules. Each month, a different rule is selected until all rules have been clarified, at which point rules are repeated. The text of the SMS message differs by village depending on the community's forest use rules. However, all households within a village that consented to receive SMS reminders received the same message, barring the recipient's name. An example of an SMS reminder of forest use rules is displayed below.

> Dear [name], please remember that *community members can only collect firewood on Wednesdays and Saturdays.* Thank you for obeying your community's rules.

[4]The treatment and treatment randomization as well as the empirical strategy follow a Pre-Analysis Plan (PAP), which was deposited in a repository prior to data collection and is available on https://egap.org/registration/2892.

The italics were added by the authors to highlight the component of the SMS message that varies across villages depending on the community's specific forest use rules.

SMS reminders were sent to households in 10 treatment villages. Within these villages, SMS reminders were sent to all households that agreed to participate in the treatment. A total of 70 households across the 10 villages consented to receive SMS messages, with a varying number of SMS recipients across villages. Out of these, 40 households were covered by the household survey.

4.2 Community forest monitoring as second treatment

These SMS reminders of forest use rules were part of a wider study investigating effective ways of reducing deforestation in common pool forests. All the villages receiving the SMS reminders treatment also received a second treatment, which will be referred to as the community monitoring treatment.

Under the community monitoring treatment, six community members systematically measure forest use and threats to the forest on a monthly basis. The monitors report information about collective forest use in village meetings and display their findings on a poster in a public place in the village. The community monitoring treatment is analysed in detail in a separate paper.[5] For the purpose of this paper, the community monitoring treatment ensures that second-party monitoring is present in all villages receiving SMS reminders.

Throughout the paper, our main statistic of interest is the effect of the SMS reminders, where the comparison group is formed by villages who received the community monitoring treatment only. We will also report the joint effect of the SMS reminder and community monitoring treatment.

4.3 Study population and sample

The study population consists of 110 villages in Central, West, and South-West Uganda. To qualify for inclusion in the study, villages had to border a forest, and have *de jure* management rights over this forest. From the pool of potential villages, study villages were selected so as to avoid including neighbouring villages

[5]Self-identifying citation is omitted for the review process.

in the study. Hence, no two study villages with management rights over the same forest border each other.

Within each study village, 10 households were surveyed at baseline and endline. In communities receiving the SMS reminder treatment, all SMS recipients were sought for surveying at endline (some were not surveyed at baseline), though 30 of the 70 total could not be reached. If this led to fewer than 20 households being selected at endline in a SMS reminder community, additional households were surveyed until 20 endline surveys were reached. The sample for the household survey consisted of stratified randomly selected households, oversampling households bordering the common pool forest. Wherever possible, the same households were surveyed at baseline and endline. Where this was not possible, a replacement household was selected from the original sampling list.

Attrition from the baseline sample was 10.7%. Attrition is strongly balanced ($p = 0.55$) across treatment conditions.

4.4 Treatment assignment and randomization

Out of the 110 study communities, 50 communities were assigned to a pure control group (T0), 50 communities were assigned the community monitoring treatment only (T1), and 10 were assigned the community monitoring treatment and the SMS reminder treatment (T2).

We block-randomized communities by creating 40 pairs and 10 triplets, based on the Mahalanobis distance between communities. The Mahalanobis distance is a measure of how dissimilar two observations are in a multivariate space. This distance was calculated based on the baseline forest cover loss rate, baseline forest cover, and a forest identifier. The latter identifies the ten individual Central Forest Reserves included in the study, and considers all community forests as a single category.

5 Empirical strategy

This paper estimates the effect of SMS reminders on knowledge of forest use rules, attentiveness to forest use rules, actual and perceived scrutiny and sanctions, compliance with forest use rules and forest use. This section describes how we measure these outcomes based on detailed data from household surveys and high-

resolution satellite images. Moreover, it describes the estimating equations used to test the paper's hypotheses.

5.1 Outcome variables

This paper combines data from household surveys, satellite data and on-the ground measurements of forest use to measure the effect of the SMS reminders on the outcomes specified in hypotheses H1- H5.

5.1.1 Measuring knowledge and attentiveness through household surveys (H1)

Household survey data are used to test hypothesis H1 through investigating the effect of the SMS reminder treatment on knowledge of forest use rules and attentiveness to forest use rules at the household level.

Household survey responses are used to measure *self-reported knowledge of forest use rules*. We asked respondents how well informed they are about the rules regarding usage of the common pool forest. The response was measured on a 5-point Likert scale, with higher values indicating that respondents judge themselves to be better informed. The outcome variable was normalized by subtracting the control group mean and dividing by the control group standard deviation.

Objective knowledge of forest use rules is measured as an index based on four variables. We create three dummy variables if households correctly identify that there are rules limiting fuelwood collection, harvesting of poles for construction, and the production of charcoal, and an additional dummy variable if they know whether there are any rules limiting entry into the forest.

When several survey questions or outcome variables can be used to test a single hypothesis, we test the effect of the treatment on a standardized summary index to avoid multiple comparisons. Following Kling et al. (2007), these summary indices are simple averages across standardized z-scores. Z-scores are calculated subtracting the control group mean and dividing by the control group standard deviation. The index is then constructed as a simple average over the z-scores across all relevant survey questions measuring one hypothesis.

We use the normalized frequency of discussions about forest use rules as a proxy for *attentiveness* to forest use rules. This measure is motivated by the idea that topics which are top of mind are discussed more frequently. Attentiveness

is difficult to measure and most papers analysing the effect of SMS reminders on behaviour assume that these achieve an effect through increasing attentiveness without measuring changes in this intermediate outcome.

5.1.2 Measuring scrutiny and sanctions (H2, H3, H5)

Measures of scrutiny and sanctions are derived from the household survey. We distinguish between *actual scrutiny of other forest users* and *willingness to sanction others* (H2), and *perceived scrutiny by others* and the *perceived probability of sanctions by others* (H3). To test hypothesis 5 on *actual sanctions*, we asked survey respondents whether they received sanctions and whether they sanctioned other forest users in the village. For all outcomes, higher values indicate more scrutiny or sanctioning. All outcomes are measured through individual household survey questions or indices to avoid multiple comparisons. The survey questions and components of the respective indices are detailed in Table 1. All indices were constructed using simple averages of z-scores. Outcome variables that were measured on a 5-point Likert scale were normalized using control group means. With the exception of the measure of hypothetical sanctions by others, all survey questions were only collected at endline.

5.1.3 Measuring compliance and forest use (H4)

Compliance with forest use rules (H4(a)). We define households as non-compliant with forest use rules if they report collecting a forest product even though collection of the product is completely banned. A non-compliance index captures non-compliance with harvesting bans for fruits, vegetables, mushrooms, nuts, honey, seeds, medicinal plants, bushmeat, fuelwood, poles for construction, poles for fencing, thatch for roof, wood processed into furniture or other wood products, whole trees, charcoal and water. For each of these products, we create a dummy variable that takes a value of 1 if the product is collected by a household in the common pool forest even though collection of this product in the common pool forest is banned. The dummy variables are aggregated into a non-compliance index which is the average over the z-scores for each of the variables. Note that this index does not capture compliance with harvesting limits or rules limiting the time at which a product can be harvested. However, an increase in compliance along those dimensions could be reflected by lower forest use.

Table 1: Components of scrutiny and sanctions indices

Outcome variable	**Component household survey questions**
Actual scrutiny of others	In the past 12 months, have you or members of your household voluntarily patrolled the common pool forest? [Yes=1][a]
Willingness to sanction others	Imagine your neighbour broke a rule relating to forest use. How likely is it you would scold your neighbour? (Likert scale, very likely=5)
	Imagine your neighbour broke a rule relating to forest use. How likely is it you would report your neighbour to (i) the local government (ii) a community-based organisation responsible for common pool forest (iii) the NFA? (Likert scale, very likely=5)
Perceived scrutiny	Imagine you broke a rule relating to forest use. How likely is it that your neighbour would notice that you did this? (Likert scale, very likely=5)
Perceived sanctioning	If a household in this village breaks a rule about forest use, how likely is it that they will receive a penalty? (Likert scale, very likely=5)
Actual sanctioning of others	At times, people in this village may break the rules relating to forest use. In the past year, have you personally scolded someone in the villages for breaking the rules? [Yes=1]
	At times, people in this village may break the rules relating to forest use. In the past year, have you personally reported someone in the village to the LC1, the CFM or CLA or the NFA, for breaking the rules? [Yes=1]
Actual sanctioning by others	In the past 12 months, has the [authority] exacted any penalties on you or members of your households for violating the rules regarding the use of the forest? [Yes=1]
	In the past 12 months, have you or members of your household been scolded/told off for violating the rules regarding the use of the forest? [Yes=1]

[a]The pre-analysis plan specifies the question "Imagine your neighbour broke a rule relating to forest use. How likely is it that you would notice that your neighbour did this?" as a measure of scrutiny of others. However, this is a hypothetical question. Since we are interested in actual scrutiny of others, this question is not used in the analysis.

Therefore, we measure changes in forest use at the household level (hypothesis H4(b)) through a *forest use index*. The index summarizes information on self-reported collection of all the above-mentioned forest products. Collection of the different forest products is measured through count variables, which are often skewed towards zero with long right tails. Therefore, we transform these variables using the function $ln(1+x)$ prior to the construction of the z-scores. The index represents the average over the z-scores.

The forest use index is a continuous measure that can proxy for compliance with forest use rules, and capture increased compliance that falls short of full compliance. It reflects whether individuals harvest less of potentially banned products and move closer to compliance. Moreover, reduced forest use could reflect stronger compliance with upper limits for the harvest of forest products.

There is a risk that both the compliance index and the forest use index suffer from social desirability bias if individuals under-report forest use. Therefore, we complement our analysis using satellite data.

We calculate the *household level forest cover loss rate* using satellite data with a 10x10 meter pixel resolution from the Sentinel-2 satellite. Presence or absence of tree cover in each pixel in the buffer was determined using a Classification and Regression Tree (CART) classifier (Vaglio Laurin et al., 2016). For each forest-bordering household in either wave of the household survey, we construct a 200 meter buffer around the closest point on the forest edge to the household. For each of these buffers, the rate of deforestation - the number of pixels forested at baseline but not at endline over the number of pixels forested at baseline - was calculated. As the amount of time elapsed between baseline and endline satellite pictures differed between households, the deforestation rate was weighted to correct for this.

Finally, we use data on forest use from on-the-ground measurements and the village-level forest cover loss rate as dependent variables in the robustness checks presented in section 7. More detail on the variables used is given in section 7.

5.2 Estimating equation

The following pre-registered estimating equation is used to measure the effect of SMS reminders. Consider outcome variable Y, for household i in village j which is assigned to randomization block m, at time t (measured in years). Time $t = 1$

indicates the post-treatment period. We estimate the following model using an ANCOVA specification:[6]

$$Y_{ijmt=1} = \alpha_m + \beta_1 \text{Monitoring}_j + \beta_2 \text{Monitoring}_j * \text{Rules}_j + \beta_3 Y_{ijmt=0} + \delta X_{ijt=0} + \epsilon_{ijmt} \quad (1)$$

where $Monitoring_j$ is an indicator equalling one if the village is assigned to the community monitoring treatment and $Rules_j$ is an indicator equalling one if the village is assigned to the SMS reminder treatment. Since the communities assigned to the SMS reminder treatment are also assigned to the community monitoring treatment, β_2 measures the effect of the SMS reminders in villages assigned this treatment compared to villages receiving only the community monitoring treatment. The joint effect of the community monitoring treatment and the SMS reminder treatment is measured by the linear combination of $\beta_1 + \beta_2$. We report the linear combination of $\beta_1 + \beta_2$ and the corresponding p-values at the bottom of each results table.

The regressors in Equation 1 include a vector of randomization-block-fixed effects α_m, a set of control variables $X_{ijt=0}$ and the baseline level of the outcome variable $Y_{ijmt=0}$. Several village and household level survey questions were only asked at endline or had a poor response rate at baseline. In that case, $Y_{ijmt=0}$ is not included as a covariate.

The vector of control variables, $X_{ijt=0}$ includes the gender, age and education of the respondent, the percentage of people among survey respondents that are of the respondent's tribe, whether the respondent is native to the village, the number of adult females in the household, whether the household borders the forest, whether the household is a member of the community-based organization managing the common pool forest, the age of this organization, whether the household own a business, whether the household owns a panga (a tool used to cut branches from trees), whether the household owns a chainsaw, whether the household built a new building in the last year, the amount of land managed by the household, the size of the village, the travel time to the nearest financial institution, the travel time to nearest market for fuelwood, charcoal, poles and whole trees and the distance

[6] We use ANCOVA specifications as they are weakly higher powered than difference in difference specifications, with this difference increasing as autocorrelation of the outcome variables decreases (McKenzie, 2012).

to Kampala. The covariates were chosen either based on their high predictive power in Lasso regressions of potential baseline covariates on baseline outcomes, or because the covariate was unbalanced between treatment and control group at the 10% level.[7]

Specification 1 is akin to an intent to treat estimator. We expect all of the hypothesised effects to be stronger for households that consented to receive SMS reminders. To test this, we also estimate a second model which adds $\beta_4 \text{Monitoring}_j * \text{Rules}_j * \text{SMS recipient}_{ij}$ to Equation 1.[8] $\text{SMS recipient}_{ij}$ is a dummy variable equaling one if a household consented to receive SMS reminders. Note that SMS recipients were not varied experimentally within treatment villages: households could chose whether to opt in or out of the treatment. Therefore, the results from this regression cannot be interpreted as causal evidence.

5.3 Summary statistics and balance test

Table 2 displays summary statistics for all outcome variables. It also investigates whether outcome variables at baseline are balanced between those villages receiving the community monitoring treatment only, and villages receiving the community monitoring and SMS reminder treatments. When no summary statistics are given for the baseline, variables are only available at endline.

At baseline, self-reported knowledge of forest use rules is imperfect, with respondents scoring themselves less than a 4 on a 5-point Likert scale on average. Summary statistics at baseline also imply that there is substantial rule-breaking: the average forest cover loss rate at the household level is 1.2%, even though deforesting is forbidden.

Outcome variables are balanced between both treatment conditions, with the exception of the forest loss measure at household and pixel level. In both cases, forest loss is higher in villages receiving the SMS reminder treatment. Hence, this should bias our analysis *against* finding the hypothesized effects.

By a simple comparison of means, we observe some differences between villages receiving the SMS reminder treatment and other villages at endline. Self-reported forest use, household level forest loss and pixel level forest loss are significantly

[7] Household cash income was also unbalanced between treatment conditions at baseline, but this variable has too many missing observations to be included as a control variable.

[8] This specification was not pre-specified but was included due to the low take-up of SMS reminders in treatment communities.

Table 2: Summary statistics and balance tests

Variable	(1) Mon, t=0	(2) Rules, t=0	(3) Mon, t=1	(4) Rules, t=1	(5) Diff. t=0	(6) Diff. t=1
Hypothesis 1						
Self-reported knowledge	-0.160	-0.009	0.090	0.003	0.151	-0.087
	(1.045)	(1.042)	(0.932)	(0.963)	(0.144)	(0.079)
Objective knowledge			0.038	0.037		-0.001
			(1.042)	(0.824)		(0.094)
Attentiveness			0.036	-0.008		-0.044
			(0.998)	(0.984)		(0.083)
Hypothesis 2						
Scrutiny of others	0.195	0.154	0.319	0.301	-0.041	-0.019
	(0.397)	(0.364)	(0.467)	(0.460)	(0.059)	(0.042)
Willingness to sanction others			-0.014	-0.050		-0.036
			(0.854)	(0.827)		(0.071)
Hypothesis 3						
Perceived scrutiny			0.076	0.034		-0.042
			(0.985)	(0.973)		(0.083)
Perceived sanctioning	-0.121	0.008	-0.044	-0.017	0.129	0.027
	(1.143)	(0.940)	(1.022)	(1.005)	(0.123)	(0.086)
Hypothesis 4						
Non-Compliance	0.009	-0.005	0.033	0.048	-0.014	0.015
	(0.283)	(0.189)	(0.321)	(0.273)	(0.030)	(0.026)
Forest use index	0.018	0.010	0.033	2.655	-0.008	2.622
	(0.559)	(0.667)	(0.613)	(37.998)	(0.063)	(1.698)
Household forest loss	0.009	0.016	0.036	0.009	0.007*	-0.027**
	(0.039)	(0.038)	(0.125)	(0.026)	(0.005)	(0.012)
Hypothesis 5						
Actual sanctioning of others			-0.000	-0.034		-0.033
			(0.882)	(0.805)		(0.072)
Actual sanctioning by others	0.110	0.061	-0.021	-0.055	0.055	-0.034
	(1.204)	(1.124)	(0.749)	(0.728)	(1.107)	(0.062)
Robustness						
Trees cut	5.549	4.211	2.805	1.566	-1.338	-1.239
	(4.139)	(4.064)	(3.636)	(1.799)	(1.011)	(0.837)
Clear-cut	0.375	0.300	0.283	0.100	-0.075	-0.183
	(0.489)	(0.483)	(0.455)	(0.316)	(0.170)	(0.152)
Forest loss (pixel)	0.007	0.009	0.013	0.007	0.003***	-0.006***
	(0.081)	(0.096)	(0.112)	(0.083)	(0.000)	(0.001)

The table reports average outcomes for households receiving only the monitoring treatment (mon) and villages receiving both the community monitorinig and rules SMS reminder treatment (rules) at baseline (t=0) and at endline (t=1). Standard deviations are reported in parentheses. * p<0.1, ** p<0.05, *** p<0.01

lower in villages receiving the SMS reminder treatment. In contradiction with the effect proposed by hypothesis H2, scrutiny of others is lower in villages receiving SMS reminders at endline.

6 Results

Results indicate that SMS reminders of forest use rules increase self-reported knowledge of, but not necessarily attentiveness to, these rules. We do not find strong evidence that the treatment increases actual scrutiny or willingness to sanction other forest uses when they break forest use rules. However, the treatment is associated with a higher perceived likelihood of sanctions upon rule-breaking. The treatment does not raise compliance with forest use rules and does not systematically reduce household forest use.

6.1 Effects on knowledge of and attentiveness to forest use rules

The results in this paper provide support for H1a. The SMS reminders improve knowledge of forest use rules. However, our results do not indicate that the reminders raise attentiveness to forest use rules.

SMS reminders improve knowledge of forest use rules both compared to households receiving the community monitoring treatment and compared to the control group. The coefficient estimate for the SMS reminder indicator in Column 1 of Table 3 shows that self-reported knowledge of forest use rules increases by 0.27 standard deviations. This is a statistically significant, but relatively small effect. The linear combination of β_1 and β_2 and the associated p-value at the bottom of Table 3 reveals a statistically significant increase in the knowledge of forest use rules compared to the control group. Self-reported knowledge compared to the control group increased by 0.4 standard deviations.

SMS recipients are significantly more likely to correctly identify existing forest use rules. Column 4 of Table 3 shows a statistically significant increase in objective knowledge of forest use rules among SMS recipients by 0.5 standard deviations. Column 3 of Table 3 shows an increase in average objective knowledge of forest use rules by 0.225 standard deviations in the SMS reminder treatment villages, but the coefficient estimate is not statistically significant.

Even though the literature suggests that SMS reminders should increase attentiveness to forest use rules, there is limited evidence of this effect in the context of our study. We use the frequency of discussions as a measure of attention to forest use rules and find the SMS reminder treatment did not raise discussions

Table 3: H1a: Knowledge of forest use rules

	(1) Self-reported	(2) Self-reported	(3) Objective	(4) Objective
Monitoring	0.142**	0.143**	0.138	0.140
	(0.065)	(0.065)	(0.090)	(0.090)
Monitoring × Rules	0.267*	0.263*	0.225	0.198
	(0.144)	(0.142)	(0.192)	(0.197)
SMS recipient		0.043		0.524*
		(0.627)		(0.267)
$\beta_1 + \beta_2$	0.409		0.363	
$\beta_1 + \beta_2$ p-value	0.007		0.070	
$\beta_1 + \beta_2 + \beta_3$		0.449		0.862
$\beta_1 + \beta_2 + \beta_3$ p-value		0.472		0.000
Control mean	.101	.101	-.009	-.009
Lag dep. var.	Yes	Yes	No	Yes
Controls	Yes	Yes	Yes	Yes
Observations	570.000	570.000	915.000	915.000

Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 4: H1b: Attentiveness to forest use rules

	(1) Discussions	(2) Discussions
Monitoring	0.143**	0.144**
	(0.067)	(0.067)
Monitoring × Rules	-0.124	-0.134
	(0.152)	(0.153)
SMS recipient		0.199
		(0.416)
$\beta_1 + \beta_2$	0.019	
$\beta_1 + \beta_2$ p-value	0.897	
$\beta_1 + \beta_2 + \beta_3$		0.209
$\beta_1 + \beta_2 + \beta_3$ p-value		0.633
Control mean	-.019	-.019
Lag dep. var.	No	Yes
Controls	Yes	Yes
Observations	916.000	916.000

Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

about forest use rules (see Column 1 of Table 4). However, we cannot rule out an increase in attention to forest use rules since the frequency of discussions is only

an incomplete proxy of attentiveness. Higher attentiveness to forest use rules may be manifested through other channels than discussions.

Furthermore, it is worth recalling that all villages receiving the SMS reminder treatment also received a community monitoring treatment. As part of the latter treatment, meetings were organized for village inhabitants to discuss forest use. Although the protocol for these meetings did not include a discussion of forest use rules, results in column 1 of Table 4 suggest that the community monitoring treatment was associated with an increase in such discussions. As such, the community monitoring treatment may already have pushed treatment villages toward some upper bound of discussions about forest use rules, which may explain why the rules treatment did not have an additional impact on discussions.

6.2 Effects on actual scrutiny and willingness to sanction others

SMS reminders do not raise actual scrutiny of others or the willingness to sanction others. However, self-selected SMS recipients were significantly more willing than non-recipients to sanction other forest users who violate forest use rules.

Column 1 of Table 5 shows that scrutiny of other forest users declines in SMS reminder villages as a result of the treatment. This effect does not differ significantly between those households who opted to receive SMS reminders and those who did not (see Column 2 of Table 5).

Moreover, the SMS reminders of forest use rules did not have a significant effect on the willingness to tell a neighbour off for breaking forest use rules, or report them to the authorities for hypothetical violations of forest use rules, as demonstrated in Column 3 of Table 5.[9] However, SMS recipients are more willing than non-recipients to sanction a neighbour for a hypothetical breach of rules. This is shown by the coefficient estimate for the SMS recipient variable in Column 4 of Table 5. It is important to note that this effect is not causal, since households chose to opt into the treatment rather than being allocated to the treatment experimentally.

[9] A more broadly defined salience index yields similar results. This pre-specified index makes us of an additional survey "Would you agree with the following statement: It is important that people stick to the communal forest use rules even if they suffer a shock?".

Table 5: H2: **Actual** scrutiny and willingness to sanction others

	(1) Scrutiny	(2) Scrutiny	(3) Sanction	(4) Sanction
Monitoring	0.016	0.016	0.016	0.021
	(0.028)	(0.028)	(0.049)	(0.049)
Monitoring × Rules	-0.101*	-0.096	-0.054	-0.107
	(0.058)	(0.060)	(0.116)	(0.111)
SMS recipient		-0.091		1.005***
		(0.112)		(0.232)
$\beta_1 + \beta_2$	-0.085		-0.038	
$\beta_1 + \beta_2$ p-value	0.152		0.731	
$\beta_1 + \beta_2 + \beta_3$		-0.171		0.919
$\beta_1 + \beta_2 + \beta_3$ p-value		0.104		0.000
Control mean	.327	.327	-.022	-.022
Lag dep. var.	No	Yes	No	Yes
Controls	Yes	Yes	Yes	Yes
Observations	730.000	730.000	915.000	915.000

Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

6.3 Perceived scrutiny and sanctions by others increase

In line with hypothesis H3, the perceived probability of receiving a sanction upon rules violations is significantly higher in households in villages receiving the SMS reminder treatment relative to comparison villages. Perceived scrutiny by others is not statistically different in SMS reminder communities, although perceptions of scrutiny are higher among recipients of SMS reminders than among non-recipients.

The recipients of the SMS reminders report a higher level of perceived scrutiny by other forest users. Column 2 of Table 6 shows that the perceived probability of scrutiny is 1.1 standard deviations higher among SMS recipients. The coefficient estimate for $Monitoring \times Rules$ in Columns 1 and 2 of Table 6 is not statistically significant, indicating that perceived scrutiny did not change for the average household in treatment communities.

The SMS reminders raise the perceived probability of sanctions for rules violations by 0.4 standard deviations (see Column 3 of Table 6). SMS recipients feel that the likelihood of sanctions is significantly higher compared to other households in treatment communities. From the point of view of SMS recipients, the probability

Table 6: H3: **Perceived** scrutiny and sanctioning by others

	(1) Scrutiny	(2) Scrutiny	(3) Sanction	(4) Sanction
Monitoring	0.112	0.117*	-0.075	-0.072
	(0.069)	(0.069)	(0.058)	(0.057)
Monitoring × Rules	-0.159	-0.216	0.385***	0.333***
	(0.151)	(0.148)	(0.129)	(0.122)
SMS recipient		1.067***		0.972**
		(0.241)		(0.416)
$\beta_1 + \beta_2$	-0.048		0.310	
$\beta_1 + \beta_2$ p-value	0.732		0.022	
$\beta_1 + \beta_2 + \beta_3$		0.968		1.234
$\beta_1 + \beta_2 + \beta_3$ p-value		0.000		0.002
Control mean	-.002	-.002	.013	.013
Lag dep. var.	No	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	907.000	907.000	876.000	876.000

Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

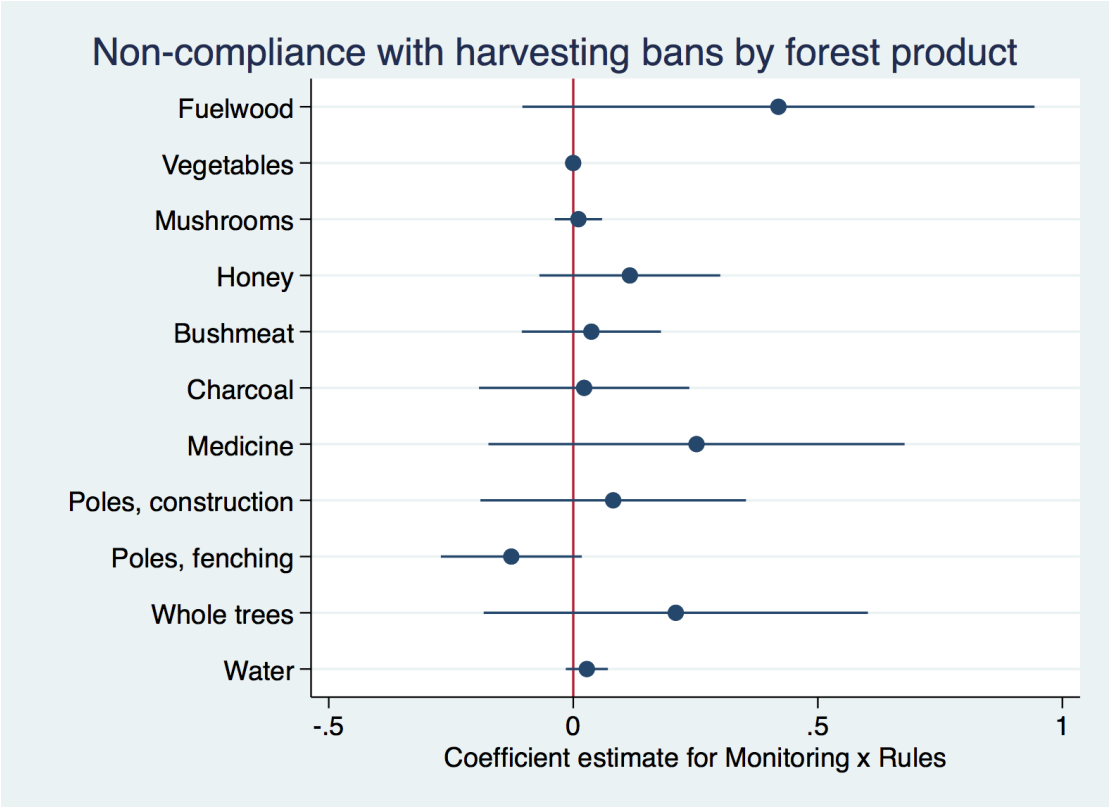
of penalties increase by an additional standard deviation (see Column 4 of Table 6).

6.4 Effects on compliance and forest use

The SMS reminders did not raise compliance with forest use rules. If anything, the incidence of rule-breaking in villages receiving the SMS reminder treatment is higher than in the comparison group (Column 1 of Table 7). Recipients of SMS reminders appear to break forest use rules marginally less than their fellow village inhabitants, but this result is not statistically significant (Column 2 of Table 7).

To understand this puzzling result, we investigate which forest use rules are more likely to be violated as a result of the treatment. To be precise, we estimate Equation 1 separately for each of the individual components of the non-compliance index. Figure 2 displays the estimated effect of the SMS reminders ($Monitoring \times Rules$) on non-compliance with harvesting bans for the respective forest products. None of the coefficient estimates is statistically significant, indicating that the treatment did not raise non-compliance with forest use rules for any individual forest product. The estimated increase in non-compliance in Table 7 seems to be an artefact of index construction.

Figure 2: Effect of rules reminders on non-compliance with harvesting bans for different products



Note: This figure shows the effect of the SMS reminder treatment on compliance with harvesting bans for specific forest products. For each of those forest products, we estimate Equation 1 and display the coefficient estimate for the treatment indicator "Monitoring × Rules". The dependent variable is a normalized dummy equalling 1 if a household collects the forest product in the community forest even though the collection of this product is completely banned.

Compliance with forest use rules is conceptually distinct from forest use. If households still break forest use rules, but do so on a smaller scale, forest use might decrease in absence of full compliance with forest use rules.

Table 7: H4: Compliance and forest use

	(1) Broke rules	(2) Broke rules	(3) Forest use	(4) Forest use	(5) Forest loss	(6) Forest loss
Monitoring	0.015	0.015	0.013	0.013	0.009	0.009
	(0.020)	(0.020)	(0.015)	(0.015)	(0.013)	(0.013)
Monitoring × Rules	0.074*	0.075*	-0.048	-0.041	-0.009	-0.009
	(0.040)	(0.042)	(0.034)	(0.036)	(0.025)	(0.026)
SMS recipient		-0.018		-0.115**		-0.010
		(0.044)		(0.048)		(0.028)
$\beta_1 + \beta_2$	0.089		-0.035		-0.000	
$\beta_1 + \beta_2$ p-value	0.027		0.314		0.992	
$\beta_1 + \beta_2 + \beta_3$		0.072		-0.144		-0.009
$\beta_1 + \beta_2 + \beta_3$ p-value		0.042		0.000		0.613
Control mean	.001	.001	.252	.252	.021	.021
Lag dep. var.	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	910.000	910.000	910.000	910.000	483.000	483.000

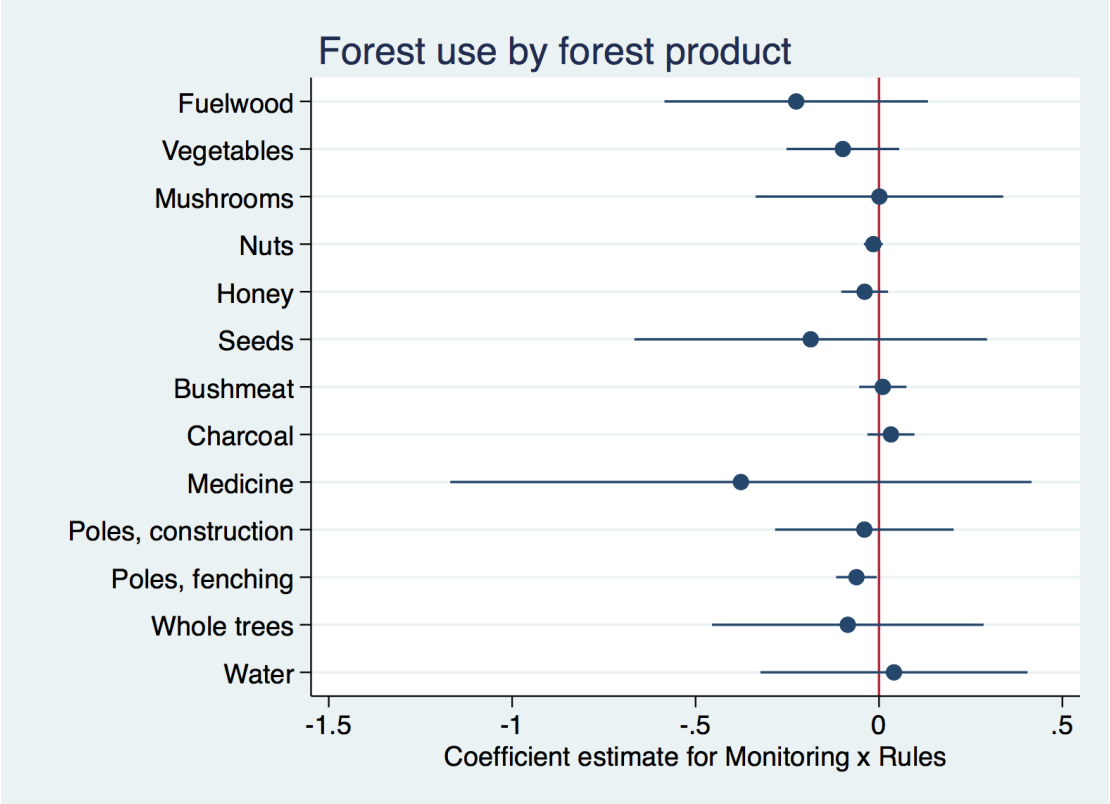
Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Results do not provide strong support for a reduction in forest use. Columns 3 and 4 of table 7 show the treatment's effect on self-reported forest use. The coefficients estimates are negative, but they are not statistically significant. Recipients of the SMS reminders report significantly lower levels of forest use. However, this effect is not causal and it has to be considered an upper bound if SMS recipients under-report forest use.

The SMS reminders do not lead to a significant reduction of most dimensions of self-reported forest use. Figure 3 shows the effect of the treatment on standardized forest use across a range of forest products. We estimate Equation 1 and display the coefficient estimate for the treatment indicator $Monitoring \times Rules$ in Figure 3. Only the harvesting of poles for fencing declined as a result of the SMS reminders. Most of the other coefficient estimates point towards an insignificant reduction in forest use.

Satellite data, which are not subject to misreporting, confirm these insights. The dependent variable in columns 5 and 6 of Table 7 is the household level forest cover loss rate derived from satellite data. Although coefficients on the indicator for the

Figure 3: Forest use by product



Note: This figure shows the effect of the SMS reminder treatment on standardized forest use for specific forest products. For each of those forest products, we estimate Equation 1 and display the coefficient estimate for the treatment indicator "Monitoring × Rules".

SMS reminder treatment are substantial in size, slightly less than half the size of the control mean, results are not statistically significant. The forest cover loss rate for recipients of SMS reminders appears even lower than for others in the village, although results again lack statistical significance.

In sum, the results suggest that SMS reminders did not significantly reduce forest use and violations of forest use rules.

6.5 Actual sanctions are unchanged

The SMS reminders of forest use rules did not lead to a significant increase in actual sanctions. The coefficient estimates for the SMS reminder treatment indicator in Table 8 vary in sign and are not statistically significant.

SMS recipients are significantly more likely to have sanctioned other forest users in the past year. Since households self-selected into the treatment, this effect is not causal, but it is large. Column 2 of Table 8 shows that the probability of sanctions for others is roughly one and a half a standard deviation higher for households who consented to receive the treatment.

Table 8: H5: Actual sanctions

	(1)	(2)	(3)	(4)
		Actual sanctioning		
	of others	of other	by others	by others
Monitoring	0.046	0.053	0.042	0.045
	(0.048)	(0.048)	(0.048)	(0.048)
Monitoring × Rules	0.043	-0.037	0.033	-0.002
	(0.110)	(0.108)	(0.076)	(0.068)
SMS recipient		1.519***		0.673
		(0.207)		(0.467)
$\beta_1 + \beta_2$	0.089		0.075	
$\beta_1 + \beta_2$ p-value	0.429		0.374	
$\beta_1 + \beta_2 + \beta_3$		1.535		0.716
$\beta_1 + \beta_2 + \beta_3$ p-value		0.000		0.142
Control mean	-.005	-.005	-.02	-.02
Lag dep. var.	No	Yes	No	Yes
Controls	Yes	Yes	Yes	Yes
Observations	916.000	916.000	916.000	916.000

Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

7 Sensitivity analysis

Our analysis focuses on household-level measures of compliance with forest use rules and forest use. This section tests the robustness of our results using detailed data from on-the-ground assessments of the forest and satellite data at the pixel level. The results provide no consistent evidence that the SMS reminder treatment decreased forest use, although forest use is lower in treatment communities relative to comparison communities by some metrics.

Data from on-the-ground assessments are only available at a more aggregate level, but they are not subject to reporting bias. On the ground, the research team measured the number of *cut trees* along two transects, or paths into the forest at baseline and endline.[10] Moreover, the research team recorded *clear-cutting* events with more than 15 cut trees in the common pool forest at the village level. Due to the small number of villages in the SMS reminder group, results from on the ground-assessments should be taken with some caution.

Pixel-level satellite data also allow us to asses *forest cover loss*. Pixels within a 500 meter buffer around the forest border between the two outermost surveyed households in a village are assigned to the village.[11] Forest cover loss is an indicator equaling one if a pixel was forested at baseline, but not at endline.

Analysis of these outcomes variables is based on estimating equation 1, but the subscript i now represents either the transect or pixel. For outcomes at the village level, subscript i is irrelevant. At the transect, village and pixel level, the vector of control variables $X_{ijt=0}$ includes village size, age of the community-based organization managing the common pool forest, an ethic fractionalization index, the share of respondents born in the village, travel time to nearest market for fuelwood, charcoal, poles and whole trees, an average village asset index, and the percentage of the respondents in the village who own a business.

Table 9 shows the effect of the SMS reminder treatment on these three alternative measures of forest use. Forest use only declines in treatment communities if measured as the number of cut trees along transects.

Results from on-the-ground forest measurements on transects show a significant reduction in forest use in SMS reminder villages compared to monitoring villages.

[10] Those transects were also monitored every month by the community monitors as part of the community monitoring treatment

[11] Unlike the pre-specified plan in the PAP, the forest border was imputed using satellite data, as it proved prohibitively time-consuming to record this through on-the-ground measurement.

Table 9: Alternative forest use measures

	(1) Cut trees	(2) Clear-cut	(3) Forest loss (village)
Monitoring	1.161***	0.128	0.006**
	(0.371)	(0.079)	(0.003)
Monitoring*Rules	-1.975**	-0.184	0.005
	(0.780)	(0.147)	(0.004)
Control mean	1.701	.152	.004
$\beta_1 + \beta_2$	-0.814	-0.056	0.011
$\beta_1 + \beta_2$ p-value	0.271	0.705	0.015
Lagged dependent variable	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	204	100	713426

Standard errors (clustered at the village level) in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 9 column 1 shows that treatment villages cut 2 fewer trees on the average 100 meter of transect compared to villages that only received the monitoring treatment.

Clear-cutting at the village level is lower in villages receiving the SMS reminder treatment, compared to villages only receiving the monitoring treatment, but this effect is not statistically significant (column 2). Although statistically insignificant, the implied effect size is substantial, showing a 18% lower probability that clear-cutting took place in SMS reminder villages.

Results from satellite images at the village level do not show a decrease in forest use in SMS reminder villages. If anything, forest cover loss is higher in SMS reminder villages by this metric, although the effect is not statistically significant (Table 9, column 3).

8 Discussion and conclusion

This paper investigates the effect of a behavioural intervention designed to improve compliance with rules among users of a common pool resource in Uganda. The intervention employed SMS reminders to improve users' knowledge of the rules, and make these rules more 'top-of-mind'.

We find that SMS reminders of forest use rules increased self-reported knowledge of rules, but we find no evidence that actual knowledge of rules or attentiveness to forest use rules – as measured by the frequency with which individuals discuss these – are affected. SMS reminders also increased the *perceived* likelihood of

receiving a penalty upon breaking the rules, but there is no convincing evidence that forest users scrutinize or sanction each other more in actuality. SMS reminders furthermore do not induce full compliance with forest use rules, and we find no definitive evidence that this treatment decreases forest use, although forest use does decrease in the treatment communities relative to the comparison communities by some metrics.

This paper has several implications for the literature on the management of common pool resources. First, it suggests that behavioural interventions are a promising avenue for further research in common pool resource management. Although the intervention presented in this paper did not unambiguously decrease forest use, we do find reductions in forest use by some metrics. Therefore, future research might usefully explore how a behavioural intervention akin to the one in the present study might be strengthened.

Second, this paper highlights the importance of *perceived*, as opposed to actual, rule enforcement. The SMS reminder treatment most strongly affected the *perceived* likelihood of sanctioning. Future research might investigate this mechanism further, by investigating other interventions to increase perceived scrutiny and sanctions. Signage with a picture of eyes, which has been used successfully in other contexts such as littering (Bateson et al., 2013), is an example of this.

The behavioural intervention employed by this paper was inspired by behavioural interventions in other arenas. It has parallels with other studies employing SMS reminders to successfully increase desired behaviour in the areas of health, loan repayment or agricultural practices. SMS interventions have not been as successful in changing behaviour in the Ugandan case of common pool resource management as they have proven in other contexts. Behavioural 'nudges' have also proven to be more uniformly effective in other areas of environmental economics, for example in promoting reduced energy use (Brent et al., 2017). The results obtained are more reminiscent of the highly context-dependent and mixed results of behavioural interventions obtained in the literature on tax compliance (Anderson, 2017; Fonseca and Grimshaw, 2017; John and Blume, 2018; Sanders et al., 2008; Iyer et al., 2010). Unique dynamics around public goods or common pool resources could plausibly reduce the effectiveness of behavioural interventions. More research on how behavioural interventions interact with the context of public goods in general, and common pool resources in particular, seems warranted.

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