Pre-Analysis Plan:

Monitoring and Managing Forest Resources in Liberia

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November 21, 2017

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1. EGAP Metaketa

This project is part of the "Metaketa III" research program organized by the Evidence in Governance and Politics (EGAP) network that focuses on the role of community-based monitoring as a bottom-up mechanism to improve natural resource governance in developing country contexts. This EGAP Metaketa (Basque for "accumulation") includes six field experiments of which our study is one.[1] This analysis plan was informed by two harmonization meetings, which included members from the six Metaketa research teams and a steering committee, as well as ongoing consultation among the Metaketa researchers and steering committee.

2. Relevance & Research Question

2.1 Increased Pressure on Forest Resources

Liberia has been a target for new investments in forestry and agribusiness. The aim of this experiment is to provide information and training that will allow communities to make decisions about forest use that maximize their conservation or development goals.

The intervention is motivated by increased pressure on the country's forest resources. First, external demand has increased, including from international investors. Between 2004 and 2009, Deininger and Byerlee (2011, xxxii) report that investors acquired or renegotiated concession agreements covering roughly 17 percent of Liberia's land area. A 2012 report offers a more startling assessment:

> "Inventory work at the national level indicates that the [Government of Liberia] has already allocated 50.95% of the total Liberian land mass as different long term land use rights (25 years and more) to various categories of land users, especially to commercial companies. Planned extensions of these areas take up another 25%, thus 75% of Liberian land is already committed, at least theoretically" (De Wit 2012, 1).

This burgeoning resource demand generates new opportunities for communities to monetize their land and forests. This includes through timber concessions, conversion to palm or other agricultural use, or conservation agreements, including those tied to carbon credits.

Second, local demand has simultaneously increased. Following the end of the Liberian civil war in 2003, resettlement and population growth have increased forest activities, ranging from harvesting timber for local construction (pit-sawing), producing charcoal, and hunting and gathering

[1] Details are available on the EGAP website.

forest animals and plants. Rivard (2016, iv) claims that 20 percent of Liberia's forested areas was lost between 2000 and 2014 due principally to "small-scale commercial and subsistence uses, particularly chainsaw milling of timber, charcoal production and shifting agriculture." Unfortunately, this loss is not expected to drop off; the same report alarmingly notes that, "the threat to forest of these land uses will increase dramatically as population and consumption increases."

2.2 Regulatory Failures

Both informal and formal approaches to regulating forest use appear to be failing. Given increased demand and demographic churn, older community-based mechanisms, designed to manage and monitor these activities struggle to deter unsustainable use (Alden-Wiley 2007). Moreover, the state does not effectively regulate the timber sector. A 2017 report from USAID offered a stark assessment: "currently, there is no regulation or monitoring of the domestic timber value chain in Liberia, and chainsaw milling activity is increasing at exponential rates" (USAID 2017, 11). "[I]f the sector remains outside the scope of long-term development plans and policy improvements," the report bleakly continues, "its probable unsustainable nature risks increasing the current rates of deforestation and forest degradation, and ultimately limits long-term growth opportunities for Liberia."

2.3 Prospects for Bottom-up Approaches

A body of work in development economics suggests that social accountability — involving end-users in monitoring and pressuring government or other entities — can substitute for top-down regulatory efforts. **?** refers to this as "client power" and experimental evidence from Bjorkman and Svensson (2009) (Uganda) and Bonargent et al. (2015) (Sierra Leone) suggest that these bottom-up approaches can improve health service delivery. By contrast, Olken (2007) finds that increased community participation in "accountability meetings" did not reduce corruption related to road projects in Indonesia.

A complementary literature due to Ostrom (1990) argues that communities can devise solutions to social dilemmas, including the exploitation of common-pool resources. Repeated interaction within relatively small groups enables individuals to monitor and punish the misuse of common-pool resources. Bueno de Mesquita (2016, 136) summarizes Ostrom's narratives about Spanish farmers' success in locally managing water resources: "they were a small and sufficiently tight-knit community that they could monitor one another and coordinate on punishing people who misbehaved. And in this way, they were able to avoid the tragedy of the commons."

Both schools of thought envision an important role for community monitoring and, as with the other projects incorporated in this EGAP Metaketa, motivate our first research question: does community monitoring of forest resources affect resource use or the benefits community members derive from that use?[2]

We also note that these bodies of work posit different problems and, thus, different theories of change. Social accountability is intended to solve an agency problem (moral hazard) by detecting and deterring shirking by front-line bureaucrats or local officials (e.g., those local officials responsible for granting concessions or rangers responsible for enforcing the protection of forest areas). Ostrom focuses instead on a collective action problem (i.e., externalities related to individuals' consumption decisions) and argues that repeated play allows for punishment and, thus, the development of norms that discourage overuse among those who have access to the forest resources.

3. Theoretical Framework

The first EGAP harmonization meeting argued that community monitoring can affect common-pool resources through two mechanisms:

1. Monitoring encourages the **enforcement** of rules around the use of these resources. Monitoring can supply authorities with information about users' compliance, enabling authorities to detect and deter misuse. Monitoring could also supply citizens with information about rent-seeking, enabling them to exert pressure for a more generous distribution of revenues derived from forest concessions.

2. Monitoring induces **self-regulation** by changing norms around resource use. Heightened awareness regarding the state and management of forest resources increases concerns about conservation.

Our goal here is to provide a simple model that rationalizes these claims about the consequences of community monitoring. Before jumping in, we note that these two mechanisms loosely relate to the two dilemmas noted above: management authorities may be uninformed or unmotivated or external pressures may render old norms ineffective at encouraging socially-optimal use.

Our model includes three actors living in the same community: a chief and two families. The idea is that the families face a "tragedy of the commons" scenario in which their individualistic use of forest resources threatens the possibility realizing potentially larger gains from deals with outside

[2]Our project also studies whether training community members to negotiate increases the royalties that they earn from outside users (e.g., foreign investors or pit-sawing crews). However, this early draft of the PAP focuses on elements of the study related to the common treatment arm: community monitoring.

investors. A chief retains authority to use a Pigouvian tax on forest use to moderate individualistic use by the families so as to preserve forest resources for potential outside investment opportunities. However the chief is constrained in its ability to play this role by the costs of imposing the taxes on forest use; importantly, we assume that these include costs associated with monitoring forest use. As such, we assume that the intervention will affect the costs of imposing the forest use taxes. Then, the key first-order comparative static is in terms of forest use outcomes with respect to these costs.[3]

3.1 Actors

- **Families**: Each of the two families i and j controls a tract of forest of measure $\overline{f}$. The first family earns payoffs according to the following function (which is symmetric for the second family):

$$u_i(f_i;\ t, f_j) = f_i(b - t) + \frac{pw}{2} V(f_i, f_j)$$

  where $f_i \in [0, \overline{f}]$ is the amount of forest logged by the first family; $b \in (1, \infty)$, the marginal benefit from logging; and $t \in [0, 1]$, the effort that the chief puts into monitoring and taxing logging.

  The second component of the utility function represents the family's payoff if the chief strikes a deal with an outside investor to make use of the community's remaining forest: $p \in (0, 1)$ is the probability that a deal is made; $w \in [0, 1]$ captures the extent of revenue-sharing between the chief and families, thereby capturing accountability relations in reduced form; and $V(f_i, f_j)$ captures the value of the deal given the families' logging decisions. We parameterize $V(f_i, f_j) = F - (f_i + f_j)^\alpha$ where $F \in [(2\overline{f})^\alpha, \infty)$ and $\alpha \in \mathbb{R}_+$. The α exponent dictates the extent to which one family's forest harvesting affects the other family's utility, and thereby determines the severity of the "tragedy of the commons."

- **Chief**: the chief's payoff is defined as follows

$$u_C(t) = t(f_i + f_j) - k\frac{t^2}{2} + (1 - w)p\ V(f_i, f_j)$$

[3] A comparative static of secondary interest is the cross-partial effect of changes in the parameter that dictates the severity of the "tragedy of the commons" on the way that family welfare is affected by reductions in the chief's cost of taxing. We do not include this analysis at this point as it does not relate to the main hypotheses for the Metaketa.

where $t \in [0,1]$ is the effort that the chief invests in monitoring and taxing logging done by the individual families. The cost to this effort is convex and scaled by $k \in \mathbb{R}_+$. The chief retains share $1-w$ of external investor opportunities, $V(f_i, f_j)$, which are realized with probability p.

3.2 Sequence

(1) Nature determines exogenous parameters, (b, p, w, F, α, k). These features and all other features of the game are common knowledge.

(2) The chief chooses an effort level $t \in [0,1]$.

(3) The families simultaneously make their logging decisions $f_i, f_j \in [0,1]$.

(4) Nature moves and an outside investor arrives and strikes a deal with probability $p \in (0,1)$.

(5) Payoffs are determined.

3.3 Equilibrium

We solve for the subgame perfect Nash equilibrium using backwards induction. For the current analysis, we assume $\alpha = 2$, which accords with common parameterizations of common pool problems (Gibbons 1992, 27-29).

We start with each family's problem:

$$\max_{f_i \in [0,\overline{f}]} \left\{ f_i(b-t) + \frac{pw}{2} V(f_i, f_j) \right\}$$
$$f_i^*(f_j) = \frac{b-t}{pw} - f_j$$

This expresses a "tragedy of the commons": family i wants to log more when j conserves.

Given the symmetry of the families' problems, we can solve:

$$f_i^* = f_j^* = \min \left\{ \frac{b-t}{2pw}, \ \overline{f} \right\}$$

Given the families' optimal logging decisions, the chief solves the following problem:

$$\max_{t\in[0,1]} \left\{ 2tf_i^* - k\frac{t^2}{2} + (1-w)p\, V(f_i^*, f_j^*) \right\}$$

$$t^* = \min \left\{ \frac{b(2-w)}{2+kpw^2},\ 1 \right\}$$

Note that the chief is choosing a tax rate that balances tax revenues from cutting against expected gains from inducing conservation and increasing potential returns from outside deals.

3.4 Comparative Statics

- Reducing the **costs of monitoring** increases the chief's monitoring and taxation effort: $\partial t^*/\partial k > 0$. This, in turn, reduces how much the families log: $\partial f_i^*/\partial k < 0$.
- As the **likelihood of striking a deal** with an outside investor rises, the amount of cutting by families falls: $\partial f_i^*/\partial p < 0$. This is true even though the chief reduces his equilibrium tax rate: $\partial t^*/\partial p < 0$.
- Increased **revenue-sharing** has ambiguous effects on the families' logging decisions. On the one hand, it reduces the equilibrium tax rate. On the other hand, it increases the value of an outside investment, encouraging conservation. $\partial f_i^*/\partial w < 0 \iff \frac{(1-w)}{w^2} < \frac{kp}{2}$.

3.5 Hypotheses

The metaketa seeks to test the following hypotheses related to community monitoring (CM): CM decreases forest use, and CM increases community members' welfare. Based on our analytical framework we propose that community monitoring could decrease forest use in the form of logging by families, and this would be the result of mechanisms related to monitoring costs and expected value of outside deals:

(H1) CM reduces logging by families.

(H2) CM reduces monitoring costs.

(H3) CM increases citizens' expected value from outside deals and revenue sharing.

We can also use the model to determine how these changes affect **welfare**:

(H4) CM increases families welfare.

(H5) CM increases the chief's welfare.

Finally our analytical framework suggests that an interaction effect with factors that enhance the value of potential outside deals:

(H6) The negative effect of CM on logging by families is amplified by factors that increase the expected value from outside deals.

We state this hypothesis here in anticipation of a second treatment arm that will use negotiation training for community members to allow them to negotiation better deals with external investors. This second treatment arm will not be part of the common arm meta-study, however.

4. Community Monitoring Treatment

Our intervention protocol was developed in consultation with the other teams involved in the Metaketa, particularly those working on forest management. Below we outline initial thoughts on the phases of the intervention, which will be implemented by Parley, Liberia. Parley is a local organization that focuses on "assisting individuals, communities, companies and state authorities to assess, mitigate and manage challenges related to developing land and natural resources."

4.1 Introduction

Upon obtaining consent from local authorities to work in a community, Parley asks for the nomination of four community monitors and two community reporters. We follow the harmonized protocol for monitor recruitment, encouraging that nominees be literate/numerate and include a female. Parley collects phone numbers for nominees and the reporters to enable follow-up communication.

During this initial visit, Parley takes a GPS coordinate at the community, as well as at the boundary of the community's forest. The community forest is defined as a forested area where community members enjoy usufruct rights and where no individual has legally converted the forest into private property. Monitoring occurs along roads/paths within this community forest.

4.2 Monitor Training

Parley hosts monitors in Gbanga for a one-day training workshop. Per the harmonized training protocol, this presentation provides background on the goals and purpose of community monitoring; conceptual information on where monitoring should occur, how frequently, and of what activities; technical training on the use of both paper and mobile-based surveys to record forest activities; and guidance and practice on how to present the information to their community. The training ends with Parley providing a date for each community's first monitoring visit.

Monitors take both a pre- and post-test to confirm a basic understanding of the training materials.

4.3 Initial Monitoring Visit

Parley trainers escort monitors on their first visit to reinforce both the conceptual and technical training. All monitors are provided mobile devices for this first visit to enable them to practice using the digital form.

Monitors record the entry point of the forest and ongoing activities (e.g., clearing for farming, pit-sawing, charcoal production, hunting, clearing for concessions, gathering, mining) within the community forest. This information is collected both on paper forms and digitally; the paper forms are used as an aid for monitors when they report their results back to the community.

At the end of this visit, monitors are provided a date for their next monitoring visit, which occurs roughly three months later.

4.4 Second Monitoring Visit

Parley trainers send reminders to the monitors one week prior to their second monitoring visit. A representative from Parley will also stop by the community on the day of the visit to provide paper forms and a smartphone to the monitoring team for data collection. During this drop-off, the Parley representative will provide a quick reminder of the task and fix a time to collect the data from the monitoring visit.

Per the harmonized encouragement protocol, monitors are sent a personalized SMS after their visit thanking them for their service. Parley also provides a small monetary compensation to monitors ($\sim$2 USD/monitor) to purchase a meal after their visit.

4.5 Ongoing Quarterly Monitoring Visits

Parley will schedule third and fourth monitoring visits. However, interaction with the community will be limited to reminders, picking up the data after monitoring, and SMS encouragements.

4.6 Data Collection & Handover

Endline measurement will be undertaken in both the intervention and the control communities. This will consist both of measures of the forest resources as well as household surveys.

As a final step, the implementation partner should convene community meetings in the intervention communities to debrief and to transfer "ownership" of the process to communities. We hope to ensure that the intervention can be sustained beyond the period of active facilitation by the implementation partner, but note that could be unlikely in the absence of additional support and incentives.

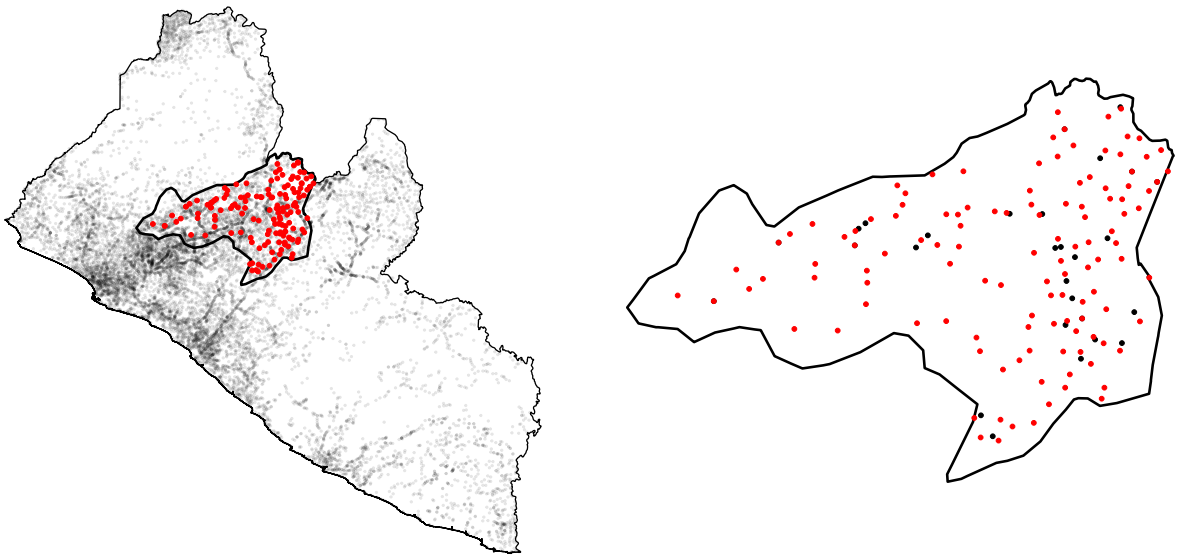
5. Evaluation Sample & Treatment Assignment

5.1 Evaluation Sample

In collaboration with Liberia Chainsaw and Timber Dealers Union and our implementing partner, we identified communities in Bong County hosting active pit-sawing (also referred to as chainsaw milling) crews. Given concerns about the unsustainable growth of unregulated chainsaw milling, our evaluation sample will be drawn (primarily) from these communities. The academically and policy relevant question is whether treatment changes forest use; where forest resources are not exploited our treatment is of limited relevance.

Communities that do not have a communal forest — a forested area where individuals from the community enjoy usufruct rights — are not eligible for community monitoring and, thus, excluded from the program. This includes communities where the community forest is only used for traditional purposes (e.g., secret society meetings) and, thus, can not be entered by outsiders.

Figure 1: Settlements and Pit-sawing Communities in Bong County, Liberia



(a) Liberia (b) Bong County

Points in red are geo-located pit-sawing locations in Bong County; lighter grey points represent settlements based on data from UNMIL (2011). County boundaries are included for Bong County, where we plan to work. The right panel zooms in on Bong County. Black points represent communities trimmed from the sample due to their proximity to other communities (see section 5.2).

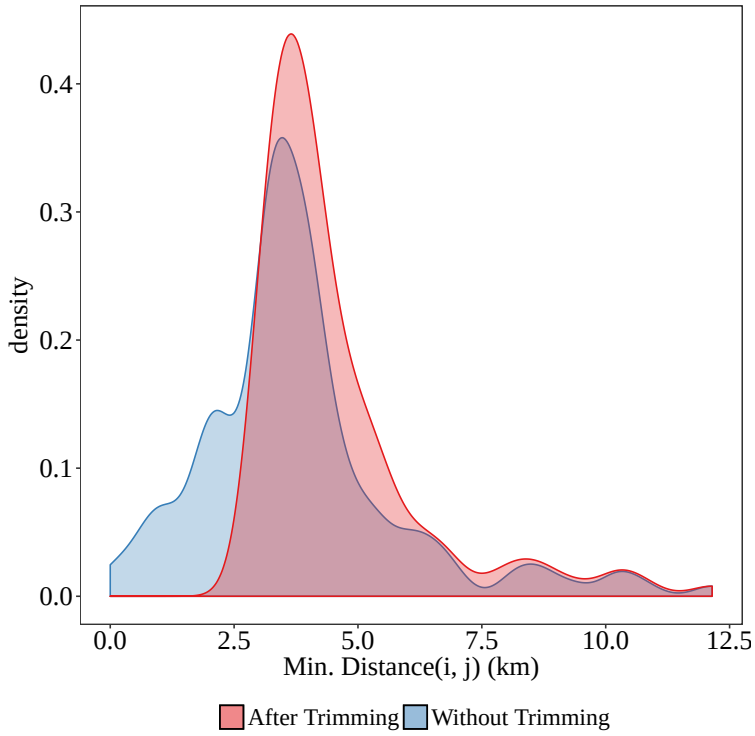
Table 1: Baseline Covariates for Sample Communities

Statistic	N	Mean	St. Dev.	Min	Max
Pop. Density (2012)	120	40.37	31.87	3.62	260.64
Nightlights (2012)	120	0.04	0.39	0.00	4.12
Nightlights (2013)	120	0.07	0.52	0.00	5.38
Elev.	120	256.57	48.71	146.93	407.31
Precip.	120	212.25	12.64	201.66	271.89
Temp.	120	25.37	0.48	24.63	26.70
Forest Loss	120	0.14	0.03	0.08	0.21
Dist. Monrovia	120	162.36	29.99	80.96	212.02
Dist. Primary Road	120	10.86	7.94	0.08	29.64

5.2 Minimizing Geographic Spillovers

Given that forest boundaries are not well demarcated, we worry about spillovers to adjacent communities. To minimize the risk of spatial spillovers, we deliberately trim our evaluation sample

Figure 2: Proximity of Units after Trimming Evaluation Sample



This figure shows how the algorithm described in section 5.2 affects the proximity between units included in the evaluation sample. If we do not trim based on distance, then we use the blocks with the lowest distance scores to determine which 120 communities are included.

prior to randomization.

Our algorithm for trimming is straightforward. Suppose that N units are eligible for inclusion in the evaluation sample, but we can only afford to include $M < N$. For each community $i \in N$, we compute the minimum (great-circle) distance between i and all other units $-i$. We determine the pair of units that are most proximate and eliminate one unit in this pair, leaving us with $N-1$ eligible units. We repeat this process until M units remain.

5.3 Randomization

We assign treatments using a restricted blocked randomization. The blocking is done in two stages. First, we created district-blocks that consisted of groupings of geographically close districts. These district blocks group districts as follows:

1. Salala and Suakoko,

2. Fuamah and Sanayea,

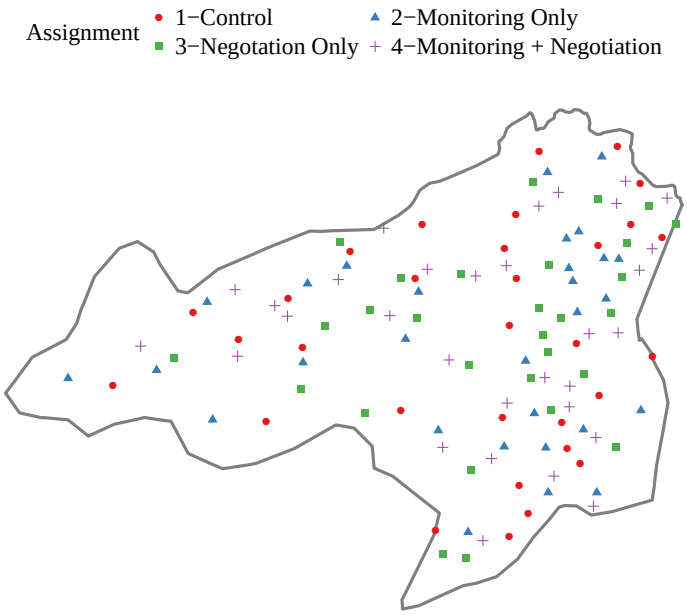
3. Zota and Panta-Kpa,

4. Jorquelleh, and

5. Kokoya and Saclepea.

Then, within each of these district blocks, we applied a second level of blocking based on minimum-Mahalanobis distance clustering on the covariates listed in table 1. This created blocks of four communities each. Randomization took place within these blocks of four. Finally, the restriction on the randomization applies what Bruhn and McKenzie (2009) refer to as the "big stick," which limits the set of possible assignments to those that satisfy a covariate balance criterion. We produced 50,000 candidate randomizations and then accepted as candidate randomizations the 6,003 for which the minimum naive p-value of the F-test from a regression of each of these blocking covariates on the treatment indicators was above 0.30. We then randomly selected one of the 6,003 randomizations as our actual random assignment. This is displayed in figure 3. We use the set of 6,003 candidate randomizations to obtain the first- and second-order assignment probabilities for unbiased inference as per (Morgan and Rubin 2012).

Figure 3: Treatment Assignment



Community locations and eligibility were difficult to assess ex-ante due to incomplete or inaccurate administrative data. Moreover, we could not verify that every community in our sample had a communal forest. As such, we use the 18 communities that we trimmed to maximize the distance between units as replacement sites. These replacement sites were then ordered on the basis of their Mahalanobis distance from the covariate values of other sites within their respective district-clusters. These replacement sites were to be drawn upon in this ordering in case any of the assigned sites was inaccessible, ineligible, or otherwise unavailable for use in the experiment.

6. Variables and data to be collected

The set of outcome, moderator, and covariate variables as well as their operationalization follows the harmonization guidelines as set out in the Metaketa Meta-Preanalysis Plan (Meta-PAP). Here we present our proposed operationalizations and indicators in the format solicited by the Metaketa Steering Committee team for the Meta-PAP.

6.1 Outcomes

Before listing the operationalizations and indicators, we should note that we do not have funding for baseline data collection. As such, we may not be able to calculate the "percent reduction in forest stocks," which is the primary outcome measure noted in the original version of the Meta-PAP (version 4/3/2017). Remotely sensed measures of forest loss are only available with a lag, and we are not yet certain that annual extraction by a pit-sawing crew is observable given the resolution of LandSat imagery.

Overuse requires a measure of efficient or sustainable use; we do not currently know of a widely-accepted target for forest flows in Liberia. As an alternative, we could posit that community monitoring reduces forest use and that these effects should be larger in communities with higher (i.e., less sustainable levels of) baseline use.

We now turn to our outcome measurement parameters:

6.1.1 Outcome I: Value of forest resources within community forest area

1. Value for external investment (timber extraction, carbon credits, etc.), we are consulting formulas used for such assessments.

   Unit : Ultimately, a gross measure at community level on a standardized scale.

   Instrument : Calculations based on other measures below.

2. Gross forest cover degradation, measured by remote sensing at the 30mx30m grid cell level.

   Unit : Change score by grid cell, clustered by community.

   Instrument : Satellite data.

3. Patterns of forest degradation, again, we are consulting formulas used for such assessments.

   Unit Index measure(s) at community level.

   Instrument Based on the same satellite data.

4. Forest use events, measured in specified period (e.g., 30 days or 3 months) and then measured through both (1) self-reports, allowing for attribution to different actors (community members, leaders, and specific forest users like pitsawers) and (2) observation of enumeration teams.

   Unit Event counts at the community level. Events include amount of timber (in whole trees), poles (number), charcoal (sacks), firewood (standard bunch) harvested over the past year, and potentially others (e.g., as defined in the FAO forest livelihoods instrument).

   Instrument (i) Self reported forest use module in household survey and (ii) forest use events assessment instrument for enumeration team.

6.1.2 Outcome II: Household welfare

1. Consumption/income/wealth indicators based on FAO forest livelihoods module.
   (a) Forest-related income/consumption/wealth.

   Unit FAO and LSMS rosters, aggregated in terms of current dollar value.

   Instrument Endline survey.

   (b) Non-forest related income/consumption/wealth.

   Unit FAO and LSMS rosters, aggregated in terms of current dollar value.

   Instrument Endline survey.

2. Perceived value of community forest resources.
   (a) Expectations regarding external investment opportunities.

   Unit Likert scale indicating confidence investment opportunities.

   Unit Elicited expected community benefit in current dollars.

   Unit Elicited expected household benefit in current dollars.

   Instrument Endline survey.

   (b) Reservation value assigned to piecemeal forest degradation.

   Unit Elicited reservation value in current dollars.

   Instrument Endline survey.

3. Satisfaction with natural resource management.
   (a) Satisfaction with access to forest resources in recent time period.

   Unit Likert scale.

   Instrument Endline survey.

   (b) Satisfaction with community leaders' management of forest resources in specified time period.

   Unit Likert scale.

Instrument Endline survey.

(c) Existence of conflict or conflicting points of view in other community members use of forest resources.

Unit Likert scale.

Instrument Endline survey.

4. Satisfaction with community leadership.

(a) Satisfaction with community leaders' management of forest resources for the future benefit of household.

Unit Likert scale.

Instrument Endline survey.

(b) Satisfaction with community leaders' management of forest resources for the future benefit of community.

Unit Likert scale.

Instrument Endline survey.

6.1.3 Outcome III: Knowledge/perceptions about forest resources and resource management institutions for leaders and households

1. Participation in forest maintenance activities (precise activities to be determined, but could involve planting new saplings, brush clearing, etc.).

Unit Participation rate.

Instrument By direct observation.

2. Knowledge of current size, health, and potential value of the forest resources.

(a) Elicited size estimate.

Unit Elicited hectares.

Instrument Endline survey.

(b) Elicited forest health estimate.

Unit Elicited percent forest cover and incidence of degradation-related events.

Instrument Endline survey.

(c) Elicited value estimate

Unit As described in the welfare section above.

Instrument Endline survey.

3. Knowledge of recent changes in size, health, and potential value the forest resource.

   Unit Elicited percent change.

   Instrument Endline survey.

4. Expected future changes in size, health, and potential value the forest resource.

   Unit Elicited percent change.

   Instrument Endline survey.

5. Perception of strength and legitimacy of forest management institutions.

   Unit Index from likert scales.

   Instrument Endline survey.

6.2 Covariates

Note that because we are not running a baseline survey, we are limited in the types of pretreatment covariates we can measure. That is, for covariates that need to be measured using surveys, we can only measure time- or treatment-invariant characteristics. We do have at our disposal covariates from administrative and remote-sensed data, however.

1. Natural resource outcome covariates, timing of measurement.
   (a) Historic forest use (measured via satellite for time period specified prior to treatment)
   (b) Historic forest management (time period specified prior to treatment)
   (c) Geographic fixed effects.
2. Wellbeing outcomes, timing of measurement.
   - No welfare measures are available, although we can measure related things like household land holdings in the endline survey.
3. Knowledge outcomes, timing of measuerment.
   - We will not be able to obtain such pre-treatment measures as covariates.

6.3 Moderators

In this section we indicate our operationalizations of the moderator variables as proposed in the meta-PAP. Because we are not collecting baseline survey data, we will not be able to measure all of the moderators proposed in the meta-PAP.

1. Population (unstandardized)

   Measure used Survey question to community chief asking about number of households living in the village.

   Response categories and likely range (min/max) Number of households (40-300).

   Collection timing Post-treatment.

   Collection instrument Endline survey.

2. Pre-existing severity of resource threat to community

   Measure used Local forest degradation rate in recent years.

   Response categories and likely range (min/max) (i) Share of local HA degraded in past five years (0-100) and (ii) forest degradation incidents over past 2 years (TBD).

   Collection timing Pre-treatment (using remote sensed data).

   Collection instrument (i) Remote sensed data and (ii) endline survey.

3. Transparency and visibility of baseline severity to affected communities

   - N/A: no baseline survey will be done, and such perceptions require measurement at baseline.

4. Propensity for compliance with treatement, given pre-existing community norms and regulations

   - N/A: no baseline survey will be done, and such perceptions require measurement at baseline.

5. Composition of enforcement body (gender, tenure, age)

   Measure used Gender, tenure, and age of chief.

Response categories and likely range (min/max) Female/Male (0/1), years (0-50), age (18-80).

Collection timing Post-treatment.

Collection instrument Community chief survey.

6. Inherent difficulty of compliance with treatment (e.g. community versus socially optimal)

   Measure used Accessibility of community forest.

   Response categories and likely range (min/max) :

   - Forest size (HA, TBD).
   - Distance from community (km, 0-100).
   - Forest density (scale TBD).
   - Terrain ruggedness (elevation SD, scale TBD).

   Collection timing Pre-treatment.

   Collection instrument Satellite data.

7. Extent of local knowledge of scale of problem

   - N/A: no baseline survey will be done, and such perceptions require measurement at baseline.

8. Other possible moderators

   Measure used :

   - Factors affecting whether there are externalities such that resource use by one quarter had implications for another, thereby producing the "tragedy of the commons"
   - Proximity to external markets for forest resources.
   - Value of forest resources for external markets.

   Response categories and likely range (min/max) :

   - Distance in km (0-200).
   - USD (0-100,000).

   Collection timing Pre-treatment.

   Collection instrument Based on satellite data.

7. Data Analysis

We will estimate effects using regression-adjusted difference-in-means estimates with two-sided tests, given that current theories allow for the possibility of effects in either direction. The basic empirical analysis will estimate regressions of the form:

$$Y_{ibc} = \alpha + D'_{bc}\beta + \gamma_b + \varepsilon_{ibc}$$

where Y_{ibc} corresponds to the outcome for individual i in district block b and community c. For community-level data, we simply drop the i subscript. The vector D_{bc} represents our treatment specification. We will use the following treatment specifications:

Analysis	Specification	Interpretation
Common arm	$D'_{bc}\beta = \beta_1 \text{I(CM)}_{bc} + \beta_2 \text{I(Negotiation)}_{bc}$	β_1 CM effect for meta-analysis, β_2 nuisance.
Negotiation only	$D'_{bc}\beta = \beta_1 \text{I(CM)}_{bc} + \beta_2 \text{I(Negotiation)}_{bc}$	β_1 nuisance, β_2 negotiation effect.
Full experiment	$D'_{bc}\beta = \beta_1 \text{I(CM)}_{bc} + \beta_2 \text{I(Negotiation)}_{bc}$ $+\beta_3 \text{I(CM)}_{bc} \times \text{I(Negotiation)}_{bc}$	β_1 CM effect, β_2 negotiation effect, β_3 interaction effect.

Then, γ_b is a district block fixed effect. By design our analysis is balanced within blocks, which obviates the need to include treatment-block effect interactions. Also, we note that we do not incorporate fixed effects to account for the within-district covariate blocking. Again, given balance within these blocks (they were all size 4), omitting these fixed effects does not bias the analysis, and moreover, yields conservative inference. (The exact randomization variance is unidentified in this case in the same way that it is unidentified in the matched pairs design, cf. Imai 2008). We weight the analysis by the inverse of the assignment probabilities, which we can compute exactly from the set of 6,003 candidate randomizations accepted under our balance criterion. Standard errors will be clustered on the communities indexed by c. For moderator hypotheses, we will include an interaction with the moderator variable of interest, M_{ibc}, which we will operationalize as a binary variable:

$$Y_{ibc} = \alpha^M + D'_{bc}\beta^M + \kappa^M M_{ibc} + (D_{bc}M_{ibc})'\phi^M + \gamma_b^M + \varepsilon_{ibc}^M.$$

Table 2 shows how we relate the hypothesis from out theoretical framework to our data analysis.

Table 2: Linking hypotheses to data analysis

Hypothesis	Observable Implication	Outcomes	Unit of analysis
H1	CM decreases logging by families	Forest degradation and exploitation	Forest area
		Forest use by families	Households and family leaders
		Willingness to contribute to forest rehabilitation	Households and family leaders
H2	CM reduces monitoring costs	Frequency of monitoring activities	Community
		Chief awareness of forest conditions	Chief
H3	CM increases citizens' expected value from outside deals and revenue sharing	Assessments of potential for outside deals	Households and family leaders
		Assessments of potential for benefitting from an outside deal should it be struck	Households and family leaders
H4	CM increases household members' welfare	Consumption	Households
		Expectations of material security	Households
		Savings	Households
H5	CM increases chief's welfare	Consumption	Chief
		Expectations of material security	Chief
		Savings	Chief
H6	CM's effects on logging is amplified by factors that increase expected value of outside offers (such as negotiation training)	Forest degradation and exploitation	Forest area
		Forest use by families	Households and family leaders
		Willingness to contribute to forest rehabilitation	Households and family leaders

Notes: This table links the hypothesis drawn from our theoretical analysis above to our data analysis plans, as described in this section. Even though we have directional hypotheses, we propose two-way tests in recognition that there are theoretical arguments for effects that go in the opposite directions.

7.1 Standardized Effects

As per the meta-PAP, we will generate the following standardized effects for hypotheses $H1$ and $H4$. If the estimated effect is $\hat{\beta}$, then we have:

- Standardized ATE with respect to resource use outcome, measured as community-level ATE over a year as a share of control group outcome standard deviation (denoted by $\hat{\sigma}_0$):

$$\text{Standardized ATE} = \frac{\hat{\beta}}{\hat{\sigma}_0};$$

- Cost effectiveness, measured as the standardized ATE (above) per \$1000 in community-level spending:

$$\text{Cost effectiveness} = \frac{\hat{\beta}}{\hat{\sigma}_0} \frac{\$1000}{\$ \text{ amount spent per community}};$$

- Return on investment, measured as community-level ATE multiplied by the per-unit value of the resource, divided per-community expense:

$$\text{Return on investment} = \hat{\beta} \frac{\text{Per unit \$ value of resource}}{\$ \text{ amount spent per community}}.$$

8. Power Calculations

Power calculations are displayed in Table 3. We plan for a balanced, full-factorial design that crosses the common arm with our alternative arm. This implies, for the common arm, a comparison of 60 treated and 60 control communities for the uninteracted specification. With no covariate control, 80 percent power, and 95 percent confidence for a two-sided test, our sample size of implies a minimum detectable effect size (MDES) of 0.5 for aggregate analyses at the level of treated and control communities. This also serves as a conservative approximation for the MDES for the outcomes using the household surveys, for which we will have multiple observations per community. By incorporating blocking and pre-treatment covariate controls that can account for 50 percent of outcome variance, the MDES would fall to 0.36. To obtain more power, we propose to use omnibus tests based on mean effects for multiple measures. The power boost from such an omnibus test depends on the correlation between outcomes. Even a 20 percent boost in power would imply an MDES (for the mean effect) of about 0.29. For household-level outcomes, assuming 10 households per community an an interclass correlation of 0.3, this would imply an MDES of 0.16. For remote-sensed, forest grid-level outcomes, we expect a much higher level of intra-class correlation.

Table 3: Power calculations

Level of analysis	N[a]	Outcome variance explained[b]	Omnibus test power gain	Intra-community correlation	Power	Confidence	MDES[c]
Community	120	0.5	20%	NA	80%	95%	0.29
Household	1200	0.5	20%	0.3	80%	95%	0.16
Forest grid cell	3000	0.5	0	0.8	80%	95%	0.32

[a]Including both treated and control, with half assigned to treatment and half to control.

[b]Using OLS based on the specification above.

[c]MDES="minimum detectable effect size," expressed in terms of control group standard deviation units, assuming equal variance in treatment and control.

Assuming 25 grid cells per community, an intra-class correlation of 0.8, and no omnibus testing (but maintaining the assumption of explaining 50% of outcome variance), we would have an MDES of about 0.32.

Now, the moderator analysis, as proposed, amounts to testing difference-in-difference hypotheses—that is, testing for the difference in treatment effects over values of the moderator. Under a balanced distribution over the moderator ad otherwise making conservative assumptions, this would amount to ca. a doubling of the MDESs for the interaction term, ϕ.

9. Timeline

Following the EGAP harmonization meeting in April 2017, the project team will move ahead with implementation. The following timeline is subject to change, but provides a guideline for the sequence of the next steps.

- **Phase 1: Unit identification and intervention protocol finalization.** The local partner, with the support of the PIs, will work to identify all the possible communities that manage their own forest use and conservation (i.e. they are not part of a larger community unit) in the counties selected for inclusion in the study (counties with a high prevalence of pit-sawing). The protocol for reducing spillovers outlined above will determine the final list of eligible communities. The PIs will conduct the randomization. The local partner will propose a logistical plan given the list of treatment communities. PIs and local partner will finalize the content and sequence for the intervention. PIs and local partner will finalize ethics and permission for carrying out the intervention and the study.
- **Phase 2: Implementation.** The local partner will implement the intervention in the treatment communities.PIs will update the PAP to include information on measurement.

- **Phase 3: Data collection.** The local partner will collect endline data in both treatment and control communities.
- **Phase 4: Data analysis and dissemination.** PIs will analyze the data and work with the local partner to disseminate the results.

10. Ethics & Permissions

Prior to implementation, the PIs and Parley will work together to obtain relevant approval for carrying out the project, including both the intervention and the study. This includes: obtaining IRB approval from the PIs universities; documenting the absence of any functioning ethics approval granting body in Liberia; documentation of collaboration with relevant local actors; and any necessary revisions or reporting of adverse events.

The PIs plan to file a request for IRB approval at NYU, UCL, and UCLA as soon as the intervention protocol is harmonized. Given the nature of the planned intervention and the data collection, including voluntary participation, the plan to collect no identifying information from survey respondents, and the absence of sensitive information, we expect to receive expedited approval.

As part of the IRB approval process, the project team will provide documentation from Parley of the fact there is no ethics approval granting body in Liberia. Parley will also seek documentation of the collaboration with the Liberian Chainsaw and Timber Dealers Union and any other authorities they advise Parley to contact as part of the project implementation.

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