PRE-ANALYSIS PLAN

Competition for Ecosystem Services

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1. Introduction

Deforestation has become a critical issue, substantially driving climate change. Many of the world's forests, particularly those in developing countries, have been traditionally managed by local communities. To effectively address deforestation, there is a pressing need for innovative institutional frameworks that empower community-based forest management by enhancing incentives for forest conservation and restoration.

One potential strategy is "Payment for Ecosystem Services (PES)" system. PES recognizes the economic value of ecosystem services provided by forests—such as water and food provision, climate regulation, and disaster mitigation—and compensates local communities financially for their contribution for maintaining forests. By linking financial rewards to measurable outcomes, such as forest area preservation and increased carbon sequestration, PES is expected to enhance motivation for forest conservation and active management. In fact, many empirical studies have demonstrated PES's potential to improve both forest conservation and livelihoods (Alix-Garcia et al., 2018; Jack et al., 2008). However, challenges remain, including securing sustainable funding for payments and fully leveraging community management capacities (Alix-Garcia and Wolff, 2014; Hayes et al., 2022).

This research proposes a novel forest management framework, "Competition for Ecosystem Services" (CES), which introduces competitive dynamics into community-based

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forest management. Like PES, CES rewards communities for forest conservation and restoration achievements. However, CES differentiates itself by fostering competition among communities: communities that demonstrate greater restoration success compared to others receive higher financial rewards. This competition-based model is expected to drive stronger incentives for conservation and management efforts, potentially yielding greater restoration outcomes than PES alone.

The primary objective of this study is to examine whether introducing a CES system into existing community-based forest management increases forest carbon restoration by strengthening community members' incentives to contribute labor to management activities. In addition, if competitive incentives lead to greater conservation gains, we aim to identify the mechanisms underlying this effect. We focus on two potential pathways through which competition may increase the effectiveness of community-based forest management: (1) enhanced within-community cohesion and (2) parochial altruism.

The first mechanism is enhanced within-community cohesion. Competition with external groups may strengthen bonds among community members through increased cooperation and trust within the group. This enhanced cohesion can improve collective action capacity, leading to more effective forest management. Under this mechanism, we would expect to observe increases in within-group trust and prosocial behavior toward fellow community members, without necessarily decreasing generosity toward other communities.

The second mechanism is parochial altruism. Competition may trigger parochial altruism—a combination of in-group favoritism (altruism toward one's own group members) and reduced generosity toward out-groups. Prior research shows that inter-group competition can generate this pattern of parochial altruism by simultaneously enhancing prosocial behavior within groups and lowering generosity or cooperativeness toward rival groups (Bauer et al., 2016; Bowles, 2008; Choi and Bowles, 2007; Lehmann and Feldman, 2008). Under this mechanism, we would expect to observe increases in within-group trust and prosociality, accompanied by reduced generosity or more competitive behavior toward other communities.

These two mechanisms have distinct behavioral signatures. While both predict enhanced within-group cooperation, only the parochial altruism mechanism predicts lower generosity toward out-groups. By measuring both within-group prosociality and out-group generosity, we can empirically distinguish between these mechanisms and identify the psychological and social processes through which competition affects forest conservation outcomes.

To evaluate these hypotheses, we will implement a randomized controlled experiment in Bangladesh, measuring both forest conservation outcomes and the underlying social mechanisms using behavioral games.

2. Research Design

2.1. Study Area and Sampling

We selected the Chittagong Hill Tracts (CHT) in Bangladesh as our study site. The CHT is a mountainous region inhabited by numerous ethnic minority groups, where each community maintains a shared forest known as a Village Common Forest (VCF). Communities oversee their respective VCFs through forest management committees, which typically consist of around ten members responsible for day-to-day management and oversight.

For this study, we will select 60 VCFs—and their corresponding communities—within the CHT. As detailed later, we will measure forest carbon stocks using drone-based aerial imagery. Because certain areas of the CHT are subject to drone flight restrictions, communities located in or near these no-fly zones will be excluded. From the areas where drone operations are permitted, we will identify and select 60 communities to comprise our experimental sample.

2.2. Treatment and Randomization

After selecting the 60 communities for the experiment, we will randomly assign them to one of two treatment arms—CES or PES—or to a control group prior to the start of the experiment. Each group will consist of 20 communities. In the control group, we will conduct the baseline and endline surveys and measure forest carbon stocks using drone imagery, but we will not introduce any payment scheme. Instead, communities in the control group will continue their conventional community-based forest management practices.

PES Treatment: In the PES treatment arm, the 20 assigned communities will receive monetary rewards based on the amount of forest carbon conserved within their VCFs. Payments will be calculated relative to the baseline carbon stock measured in December 2025 and benchmarked against changes observed in the control group. Thus, even if the carbon stock in a PES community's VCF remains constant over the intervention period, the community will still receive a payment if carbon stocks in the control VCFs decline, as the reward is determined by the relative improvement in conservation outcomes. To ensure meaningful incentives for participation and effort, we will calibrate the payment scheme such that the average total payment per community over the two-year intervention period is approximately USD 2,000. Payments will be made to the forest management committee rather than to individuals, reflecting the collective nature of VCF management.

CES Treatment: In the CES treatment arm, payments will also be based on the amount of carbon conserved relative to the control group. The key difference from the PES scheme is that the CES design introduces performance-based differentiation: communities that achieve greater conservation outcomes receive higher payments. As in the PES arm, the payment schedule will be calibrated such that the average total payment per community over the two-year intervention period is approximately USD 2,000. However, among the 20 CES communities, the top ten communities in terms of carbon conservation will receive payments calculated at a rate 25 percent higher than the baseline PES payment rate, while the bottom ten communities will receive payments calculated at a rate 25 percent lower.

For both PES and CES communities, we will provide an interim report in December 2026, one year after the start of the intervention, summarizing each community's carbon conservation relative to the baseline. In the CES group, communities will additionally be informed whether they are currently performing in the upper half or lower half of the distribution, although specific rankings will not be disclosed.

2.3. Ethical Considerations

Although one of the potential mechanisms examined in this study is parochial altruism—which includes both in-group favoritism and reduced generosity toward out-groups—we take several measures to ensure that the intervention does not induce or exacerbate inter-community tension. The CES scheme provides performance-based financial rewards, but all information provided to communities is limited to whether their conservation performance falls within the upper or lower half of the distribution. No information about the identity, ranking, or performance of other communities will be disclosed. This design prevents direct comparison with specific out-groups and minimizes the risk of encouraging unfavorable attitudes toward other communities.

We will monitor any signs of inter-community tension throughout the study. Should any adverse effects emerge, we will immediately adjust or suspend the relevant components of the intervention to safeguard community well-being. In addition, we will continue monitoring inter-community relations for at least six months after the final payments (through mid-2028). If concerns persist or if additional support is deemed necessary, we will organize facilitated dialogue sessions bringing together community leaders.

We commit to transparent reporting of all findings, including any adverse effects on inter-community relations. If the study finds that CES enhances conservation but does so by increasing inter-group hostility, we will clearly report this finding and recommend against scaling such interventions without substantial modifications to address the social costs.

2.4. Planned Timeline

The baseline measurement of forest carbon stocks within each VCF will be conducted in December 2025 using drone-based imagery. The actual intervention, involving the introduction of either a CES or a PES scheme, will be implemented between February and March 2026 and will remain in place for approximately two years. Payments will be determined based on the amount of carbon conserved between the baseline (December 2025) and the endline measurement in December 2027. Disbursement procedures will be completed between January and February 2028.

3. Data

3.1. Forest Carbon Stock Measurement

The primary outcome variable is the amount of forest carbon conserved within each VCF. Carbon conservation is central both to the payment calculations under the PES and CES interventions and to evaluating the causal impacts of introducing competitive mechanisms into community-based forest management.

We will estimate forest carbon stocks using a DJI Mavic 3 Multispectral drone, which captures standard RGB imagery as well as Green, Red, Red Edge, and Near Infrared (NIR) spectral bands. Carbon stock data will be collected at three points in time: the pre-intervention baseline in December 2025 and the follow-up measurements in December 2026 and December 2027, corresponding to one and two years after the intervention, respectively.

The multispectral bands enable the construction of vegetation indices such as the Normalized Difference Vegetation Index (NDVI), which provides information on vegetation vigor. However, NDVI exhibits saturation in dense canopy conditions and therefore offers only an indirect proxy for biomass. To complement these indices, we will generate canopy height estimates using Structure-from-Motion (SfM) photogrammetry from Unmanned Aerial Vehicle (UAV) derived point clouds. The combination of spectral information and canopy structure provides a more robust basis for estimating above-ground biomass.

To calibrate these remote-sensing measures, we will establish approximately one to two ground plots in each VCF (roughly 60–120 plots in total). Plot-level biomass will be measured through standard forestry inventory methods, including tree diameter measurements, height assessments, and application of allometric equations. These ground-based estimates will be used to develop predictive equations linking above-ground biomass density to UAV-derived vegetation indices and canopy height.

Carbon conservation will be calculated as the change in estimated above-ground carbon stock between the baseline and each follow-up period. Because these carbon estimates will be used as the basis for PES and CES payments, we will construct a VCF-level measure expressed as tons of carbon per hectare (tC/ha) to account for differences in VCF size.

For the main empirical analysis, each VCF will be divided into a regular grid of 30 m × 30 m cells, and carbon stock will be estimated at the cell level using the calibrated prediction equation derived from UAV-based and ground-plot data. This gridded structure allows for spatially explicit estimation and more precise identification of treatment effects across heterogeneous forest areas. The cell-level analysis leverages within-VCF variation while accounting for clustering of observations within communities through appropriate standard error adjustments.

3.2. Survey Data Collection

We will conduct questionnaire surveys in all 60 communities before and after the intervention (referred to as the baseline and endline surveys, respectively). The surveys will target two groups: all members of the forest management committee and a randomly selected sample of ten non-committee community members from each community. Because committee members serve fixed terms of approximately three years and are periodically replaced, the surveys will generate cross-sectional—not panel—data at both baseline and endline.

Across respondents, we will collect information on socioeconomic and demographic characteristics, including income, assets, education, and household composition. For committee members, we will additionally gather detailed data on labor contributions to forest management, including time spent on patrolling, tree planting, and other conservation activities.

3.3. Behavioral Game Experiments

To investigate the mechanisms through which competition affects forest conservation, we will integrate three incentivized behavioral game experiments at both baseline and endline surveys. The monetary incentives associated with each game follow parameter values established in prior experimental research (Higashida et al., 2025; Higashida et al., 2024).

First, we will conduct the **trust game** to measure within-community trust and reciprocity. Each participant will be endowed with 150 Bangladeshi Taka (BDT). The participant (Player A) can choose to send any amount (0 to 150 BDT) to an anonymous community member (Player B). The amount sent will be tripled, and Player B can then choose to send back any amount to Player A. The amount sent by Player A measures trust in fellow community members, while the amount returned by Player B measures reciprocity.

This game will be conducted using the strategy method: each participant will make decisions both as Player A (how much to send) and as Player B (how much to return for different amounts received). One decision from each participant will be randomly selected for payment. Participants will be informed that they are matched with someone from their own community but will not know the identity of their partner.

Second, the **dictator game** will be used to measure in-group prosociality or altruism toward fellow community members. Each participant will be endowed with 150 BDT and asked to decide how much (0 to 150 BDT) to allocate to an anonymous community member. The recipient has no decision to make and simply receives the allocated amount. The amount given measures the participant's willingness to sacrifice their own payoff for the benefit of an in-group member. As with the trust game, participants will be informed that the recipient is from their own community but will not know the recipient's identity.

Third, we will conduct the inter-group conflict game, adapted from Abbink et al. (2012), which measures out-group hostility and competitive behavior toward other communities.

Third, we will conduct the **donation choice game**, adapted from Bursztyn et al. (2020).

In this task, participants are asked whether they authorize a 150 BDT donation to be made on their behalf to a randomly selected community within the CHT. The donation is financed entirely by the research team; participants do not incur any personal financial cost. The identity of the recipient community is anonymized, and participants are informed that the donation will be actually implemented after the study. This decision therefore provides an incentive-compatible behavioral measure of participants' generosity toward another community within the CHT, as refusing to authorize a costless donation indicates a behavioral preference to avoid benefiting the out-group community.

4. Analysis

4.1. Regression Specification

In this study, following recent PES literature that conducts spatially disaggregated analysis (Alix-Garcia et al., 2015; Charoud et al., 2023; Cisneros et al., 2022), we will conduct the estimation at the cell level rather than the VCF level. Each VCF will be divided into a grid of 30 m × 30 m cells, and forest carbon stock will be estimated for each cell using the calibrated prediction equation described earlier. These cell-level observations will serve as the primary unit of analysis. As a robustness check, we will also estimate the same regression model at the VCF level.

Because we will construct a panel dataset of cell-level forest carbon stocks, our main empirical specification will use an analysis of covariance (ANCOVA) model, following McKenzie (2012). Specifically, we will estimate the following linear regression:

$$Y_{ij} = b_1 CES_j + b_2 PES_j + Y_{ij,0} + e_{ij}$$

where Y_i is the follow-up carbon stock for cell i in VCF j. CES_j and PES_j are the dummy variables equal to one if VCF j is assigned to the CES or PES treatment arm, respectively. $Y_{ij,0}$ represents the baseline value of the outcome in the same cell. Because the intervention is assigned at the VCF level, all standard errors will be clustered at the VCF level.

In contrast, secondary outcomes, such as labor contributions to forest management and social preference measures, cannot be analyzed using the ANCOVA specification. This is because membership in the forest management committee rotates approximately every three years, meaning that some VCFs will experience changes in committee composition during the intervention period. As a result, these outcomes are observed in repeated cross-sections rather than in a panel structure.

Therefore, we will estimate treatment effects on secondary outcomes using a standard ordinary least squares (OLS) specification, dropping the baseline value $Y_{ij,0}$ from the earlier ANCOVA model and conducting the analysis at the individual level. In these regressions, we will include a set of control variables reflecting respondents' demographic characteristics, such as gender and years of education, as well as behavioral traits including competitiveness and risk preferences.

4.2. Specific Hypothesis and Power Calculation

Our aim is to test the following hypotheses.

Hypothesis 1: Providing monetary incentives for ecosystem service conservation and forest management leads to higher conservation outcomes ($b_1 > 0$ and $b_2 > 0$).

Hypothesis 2: Introducing a competitive mechanism into the payment scheme further enhances conservation outcomes ($b_1 > b_2$).

Hypothesis 3a (Enhanced Cohesion): Competition increases within-group cooperation (trust and prosociality) while leaving out-group generosity unchanged.

Hypothesis 3b (Parochial Altruism): Competition increases within-group cooperation but reduces generosity toward out-groups.

Because treatment is assigned at the VCF level, statistical power is primarily determined by the number of VCFs rather than the number of cell-level observations. Although our main analysis uses cell-level outcomes, the effective sample size is constrained by within-VCF correlation in carbon stocks. We therefore compute minimum detectable effects (MDEs) under alternative assumptions about the intra-cluster correlation coefficient (ICC).

To parameterize the ICC, we constructed a baseline measure of vegetation conditions using Landsat satellite imagery. Specifically, we calculated the NDVI, which is the same remote-sensing indicator used in this study to derive cell-level estimates of forest carbon stocks. We overlaid these NDVI values onto the 30 m × 30 m grid cells that will serve as the primary unit of analysis and computed within- and between-VCF variation in baseline NDVI. Across all VCFs in our study area, the average number of grid cells per VCF was 505.3. Using this spatial structure, we estimated the intra-cluster correlation coefficient, which reflects the degree of similarity in NDVI values among cells within the same VCF. The resulting ICC estimate was 0.18.

Following these empirical estimates of cluster size and intra-cluster correlation, we parameterize the power calculations using assumptions aligned with the structure of our experimental design. Although the average number of grid cells per VCF is approximately 505, we conservatively set the cluster size to m=400 grid cells when computing detectable effects. We assume 20 VCFs per arm (CES, PES, and Control) and employ an ANCOVA specification with an assumed R^2=0.5, reflecting variance reduction from conditioning on baseline cell-level carbon stocks. For two-arm comparisons (e.g., CES vs. PES or each treatment arm vs. Control), we calculate standardized MDEs under a range of ICC values from 0.1 to 0.6, while using ρ=0.2 as the primary value for interpretation. The resulting detectable effect sizes are summarized in Table 1.

Table 1. Minimum detectable effect by assumed ICC (20 VCFs per arm, $m = 200$)

ICC (ρ)	MDE (SD units)
0.1	0.20
0.2	0.28
0.3	0.34
0.4	0.40
0.5	0.44
0.6	0.49

As Table 1 shows, for plausible ICC values in the range 0.1–0.6, the MDE for a comparison between two groups with 20 VCFs each lies between approximately 0.20 and 0.49

standard deviations in cell-level carbon stocks. Using our preferred ICC value of 0.2, which is consistent with the empirical estimate derived from baseline NDVI, the corresponding MDE is 0.28 standard deviations.

Figure 1 plots the MDE as a function of the ICC, holding the number of VCFs and the number of cells per VCF fixed, highlighting that statistical power is mainly driven by the degree of within-VCF correlation. To illustrate the limited role of additional within-cluster observations once m is large, Figure 2 plots the MDE against the number of cells per VCF for a fixed ICC of 0.2. The curve declines initially but quickly flattens, indicating that beyond a moderate number of cells per VCF, further increases in cell-level observations contribute little to power relative to the number of clusters and the ICC.

As an additional sensitivity check, we will complement the analytical MDE calculations with a non-parametric bootstrap using the baseline cell-level carbon data. Specifically, we will repeatedly resample VCFs with replacement, preserve the cluster structure of the data, and compute the sampling distribution of treatment–control differences under varying ICC assumptions.

Figure 1: Minimum Detectable Effect as a Function of the Intra-Cluster Correlation (ICC)

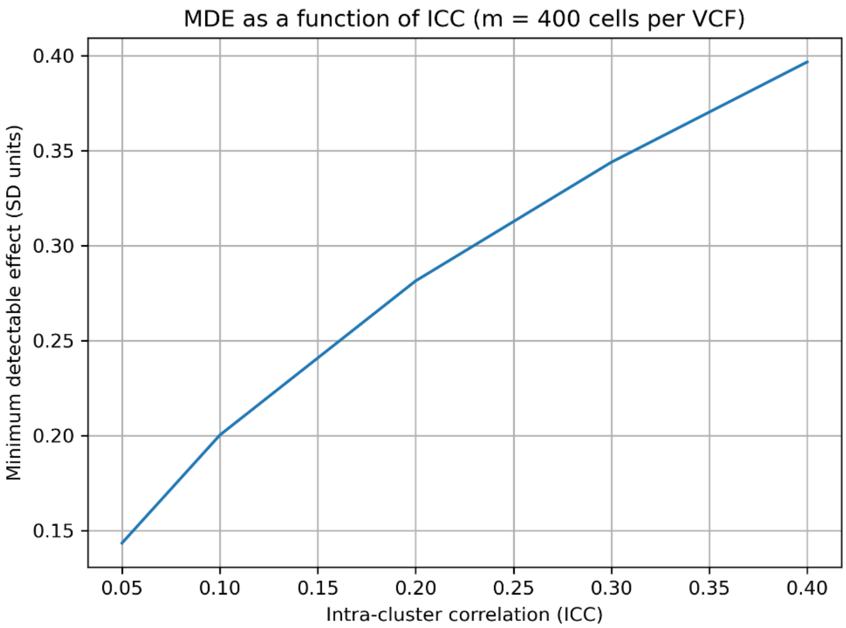
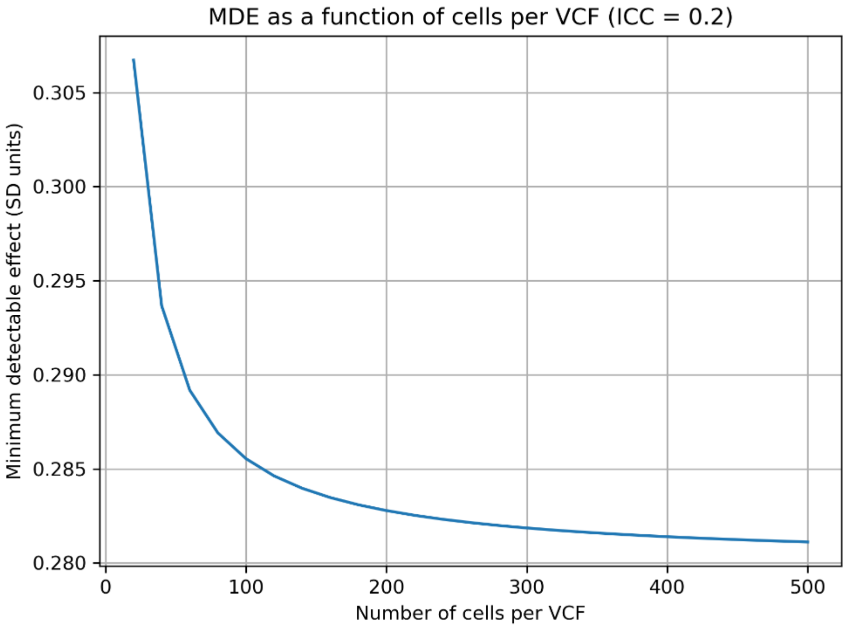


Figure 2: Minimum Detectable Effect as a Function of the Number of Cells per VCF


MDE as a function of cells per VCF (ICC = 0.2)
Minimum detectable effect (SD units)
0.305
0.300
0.295
0.290
0.285
0.280
0
100
200
300
400
500
Number of cells per VCF

4.3. Heterogeneity

We will examine treatment effect heterogeneity based on characteristics of the VCF management committees and the broader community. In particular, we will explore whether the impacts differ by (i) levels of intra-community trust, (ii) average income within the community, and (iii) preference for competition.

4.4. Attrition

We will present a balance of our covariates as well as two treatment dummies by the attrition in the endline survey.

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