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**Management of timber and non-timber forest products:
Evidence from a framed field experiment in Benin, West Africa**

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Abstract.

Across sub-Saharan Africa, rapid deforestation threatens the economic and environmental benefits forests provide to communities and individuals. These losses are especially salient when forest users benefit from multiple forest products and not just timber resources. Using a series of common-pool resource (CPR) games in rural Benin framed around a threatened species, *Azadirachta africana*, this paper tests how different Payments for Ecosystem Services (PES) programs may induce conservation behavior among individuals who harvest both timber and non-timber (i.e. leaves) forest resources. PES treatments vary along two dimensions: the level of the payment (High/Low) and how the payment is divided among group members. We find strong evidence that all implemented PES treatments reduce the harvest of timber; however, a high PES payment evenly divided among group members also significantly reduced the harvest of leaves. Our findings suggest that a single-product PES focused only on whole trees might not be effective for multipurpose species.

Keywords: forest management, common pool resource, experiment, sub-Saharan Africa, Benin

1. Introduction

In tropical Africa, the main drivers of deforestation are the natural human population growth on the forest margin, the slow expansion of subsistence agriculture, and the extraction of primary products such as wood for fuel, timber, non-timber products and charcoal for domestic use (Burgess et al., 2002; Palm et al., 2005; Twongyirwe et al., 2018; Pendrill et al., 2019). The loss of productive forest resources threatens numerous community benefits including economic benefits (regular cash income and safety nets in times of crisis), health services (medical usage), and ecological services (carbon sequestration, water regulation, and many others). To ensure continued forest benefits, communities are challenged to implement sustainable management programs to protect forests while simultaneously supporting development and household livelihoods through the production of timber and non-timber products (Brandt et al., 2016). Payments for Ecosystems Services (PES) programs, which provide monetary incentives to producers or resource users in exchange for specific conservation actions, have been implemented as a strategy for aligning forest use and conservation incentives (Andersson et al., 2018). PES programs vary in the conditions of payment (Wilebore et al., 2019), the level of payment (Handberg & Angelsen 2016), and the form of disbursement (Ngoma et al., 2020).

Most PES mechanisms have been studied in the context of a single forest product, specifically timber (e.g. Handberg & Angelsen 2016; Ngoma et al. 2020). We build on previous studies to investigate how a threshold-based PES program affects individual and group decision-making for two different harvests (timber and leaves) from a multipurpose species¹ among forest users in rural areas of Benin. Focusing on the effectiveness of PES mechanisms to change behavior, we use a lab-in-the-field experiment to test the effects of PES programs that vary across

¹ This paper uses the term multipurpose tree species to mean a tree species that provides more than one product/service such as timber, firewood, fodder, food, medicine, soil conservation, or shade.

two dimensions: 1) the level of the PES payment provided to eligible communities and 2) how the payment is shared among forest users. We find strong evidence to suggest that all four implemented PES schemes induce pro-social conservation behaviors regarding timber; however, a high PES payment evenly divided among group members also significantly reduced the harvest of leaves.

Payments for Ecosystem Services

Given their increasing popularity, there is a large literature on the effectiveness of PES programs for behavioral change in conservation. Some findings suggest that in settings where resources are managed locally and collectively, there could be a mismatch between economic incentives and intrinsic motivations leading to crowding out from prosocial behavior (Agrawal et al., 2015; D'Adda, 2011; Luck et al., 2012; Muradian et al., 2010; Vatn, 2009). Yet, in a number of cases, the crowding out effect can be explained by the non-existence of a market situation for the resource prior to the introduction of the monetary incentive (Andersson et al., 2018; Frey, 1994). In other circumstances, there is evidence that PES can reinforce people's intrinsic motivations for biodiversity conservation (Sommerville et al., 2010; Van Hecken & Bastiaensen, 2010).

Given this mixed evidence, Rode et al., (2015) conducted a systematic review of eighteen empirical studies and found that crowding out effects outweigh crowding in effects. The authors suggested that the lack of baseline information on intrinsic motivations as well as cultural and contextual heterogeneity across studies prevent evidence that is more conclusive. Moreover, the extent to which the monetary incentives affect (positively or negatively) motivations depends on whether it is administered to the beneficiaries at the individual or community level and the amount of the payment.

Looking at how PES are administered to the beneficiaries, Agrawal et al. (2015) suggest that individual benefits induce crowding out effects, whereas collective benefits lead to crowding in effects. This implies that payments for ecosystem services conditional on group performance have the potential to induce cooperative conservation behavior (Andersson et al., 2018; Moros et al., 2019). Meanwhile, Narloch et al. (2012) found that collective rewards could be ineffective and crowd out social norms while individual rewards may increase conservation levels through a crowding-in effect. Their findings are in line with others studies from Ngoma et al. (2020) who conclude that individual payments are better than group payments. Concerning the effect of the amount of PES administered, Handberg and Angelsen (2016) investigated how different levels of individual PES affect intrinsic and social motivations for forest conservation in Tanzania. They found that low levels of PES have little effects on forest harvest but higher PES levels reduce forest use.

This paper uses a forest-based framed field experiment (FFEs) to test different PES mechanisms. We contribute to the literature by first considering two products of choice for users: trees and leaves instead of just trees alone like in the other forest-related experiments (Cardenas et al., 2000; Handberg & Angelsen, 2015; Handberg & Angelsen, 2016; Ngoma et al., 2020). Second, this paper adds to the thin evidence of the impact of PES programs in West Africa by focusing on forest management in Benin. Third, this research combines two different PES mechanisms: the amount of PES (which level of payment induces the desired conservation outcome) and the PES sharing rule across community members (uniform payment across community members or payment based on individual actions), which are two important aspects relevant for PES implementation. Handberg and Angelsen (2016) investigate how the amount paid affects motivations for forest conservation. However, they only focus on the effect of payments induced

by individual actions. Our study expands that framework by looking at how the payment level might influence group behaviors. Finally, although this paper is contributing to the literature on policies for forest management in general, it focuses on an endangered species – *Afzelia africana* – on the brink of extinction and classified as vulnerable on the International Union for Conservation of Nature (IUCN) red list. Thus, it has an ecological importance for the preservation of the species and the protection of many African ecosystems.

The paper proceeds as follows. The next section provides background information on the study area and the species. The third section details the data collection methods, the experimental design and the hypothesis. The empirical results and discussions follow, and the last section presents conclusions and some policy recommendations.

2. Background information

2.1. Forestry sector in Benin

Benin's total forested land area in 2016 was 42,610 square kilometers (37.79% of the land area) split between modified natural forests, protected zones and planted forests (World Bank, 2020). The country has one of the highest annual deforestation rates in the world (FAO, 2006) and has recorded a loss of over 215,000 hectares (approximately 3%) of its forest cover from 2007 to 2016 (World Bank, 2019). According to the UN Food and Agriculture Organization (FAO), Benin does not have undisturbed primary forests and has lost 29% of its forest cover since 1990 (FAO, 2006). Despite dwindling acreage, in 2009, the forestry sector contributed 6% to Benin's Gross Domestic Product (Politique Forestiere Nationale, 2012). This figure includes the exploitation of timber, firewood, and non-timber products such as shea, honey, cashew, fiber, and medicinal plants. The forestry sector employs 15,000 to 20,000 persons in the country and constitutes an important

source of revenues for rural communities especially during the dry season (Koudenoukpo Biao, 2003).

The forestry regime in Benin is governed currently by Law No. 93-009 of 2 July 1993 and Decree No. 96-271 of 2 July 1996². These laws divide the forest domain into different zones while setting the conditions for the forests' classifications and the user rights (conditions of development and exploitation of forests). Article 26 in the decree states that "forests must be managed, exploited, protected and valued in a sustainable and balanced manner. As much as possible, they must be managed according to the participatory methods associating surrounding local populations..." (Page 3 of the "Décret d'application du régime forestier"). Although participatory approaches and co-management are explicitly mentioned, there is no legal text laying out the rights and responsibilities of each stakeholder in the process of decentralized forest management (Koudenoukpo Biao, 2003). In 1994, the country ratified the Convention on Biological Diversity that aims to achieve three objectives: (i) the conservation of biological diversity, (ii) the sustainable use of the components of biological diversity, and (iii) the fair and equitable sharing of the benefits arising from the utilization of genetic resources. However, lack of enforcement of these policies have allowed rapid and uncontrolled deforestation (Tchiwanou, 2000).

Climatic factors such as drought, reductions in rainfall, fragile ecosystems and human factors such as major population growth and inappropriate extensive production systems contribute to the challenge of managing the country's forest resources and wildlife populations (FAO, 2003). The forestry sector also faces impediments, such as seasonal movement of local and foreign herds, low interest in and low incentives for reforestation, lack of knowledge about silviculture for some valuable native species, and underdevelopment of existing non-timber forest product (NTFP) value

² The law must be conform to the constitution and the decree is the enforcement order of the law, which is issued and signed by the president.

chains (National Program for Sustainable Management of Natural Resources, 2008; World Bank, 2019).

2.2. Study Species

Afzelia africana is a multipurpose tree species, also known as African oak or African mahogany, from the Fabaceae family that can reach up to 40 meters high (Orwa et al., 2009). The species is a fast growing tree; its diameter increases by 1.5 centimeters every year during the first seventeen years of its life (Gérard & Louppe, 2011). In Benin, *Afzelia africana* is found in dry forests, savanna woodlands, and in some gallery forests; however, it is not currently used in silvicultural operations. Meanwhile, *Afzelia africana* is one of fifteen endangered plant species in the country and is classified as “vulnerable” on the International Union for Conservation of Nature (IUCN) Red List. In addition, it is a preferred species for the quality of charcoal production it offers (Akouehou, 2011; Heuze, 2019). These two reasons motivate the selection of the species for our study.

Afzelia africana produces an excellent timber (Brenco, 2019)³ which is termite-proof and used in carpentry for furniture making and house building (SCIFO, 2015)⁴. The species provides several services (Fern 2014). It is a leguminous tree used for soil improvement. It serves as shelter for several wild animals and therefore constitutes a favorite site for hunters. In rural areas, it is also used to mark property and land boundaries. Its foliage is good forage for cattle (Sinsin, 1993) and serves as human medicine (Akinpelu *et al.*, 2002; Arbonnier, 2002; Ouédraogo-Koné *et al.*, 2008). The flowers are used in sauces, and the seed has high protein (26%) and high oil (33%) contents, and the pods serve to make soap (Orwa et al., 2009). Culturally, the tree is said to be inhabited by spirits and is considered to be a sacred tree in many West African villages (Delvaux *et al.*, 2009).

³ <http://brenccollc.com/doussie/>

⁴ <http://scifocameroon.net/en/wood-species/doussie-2/>

2.3. Study Area

This study was conducted in the municipality of Djidja located in the Zou department of Benin, West Africa (Figure 1) where *Afzelia africana* is found and harvested. The species is highly valued in the region and under human pressure, so community management is important. Of the nine municipalities of the Zou department, Djidja is the largest, covering almost 42% of the area and the second most populated with 123,542 inhabitants in 2013 (RGPH4⁵, 2013). We purposely select the district of Djidja because it is one of the major suppliers of charcoal and firewood to the cities of Cotonou and Porto-Novo.

Djidja is located in the Sudano-Guinean region of Benin also called the transition zone, with a sub-humid climate characterized by two rainy seasons (March-July and September-October) and two dry seasons (November-February and July-September). The annual precipitation ranges from 1100 to 1200 mm (Azalou et al., 2017). The soils in Djidja are predominantly tropical ferruginous, hydromorphic and sandy-clay. The region supports dense dry forests, gallery forests, woodlands, and wooded savannas. Intense production of charcoal, grazing, and land clearance for farming have heavily deteriorated the natural vegetation in the area (Guidibi & Akomagni, 2006; N'Danikou et al., 2015).

⁵ RGPH4: Le quatrième Recensement Général de la Population et de l'Habitation, or Fourth National Census in English

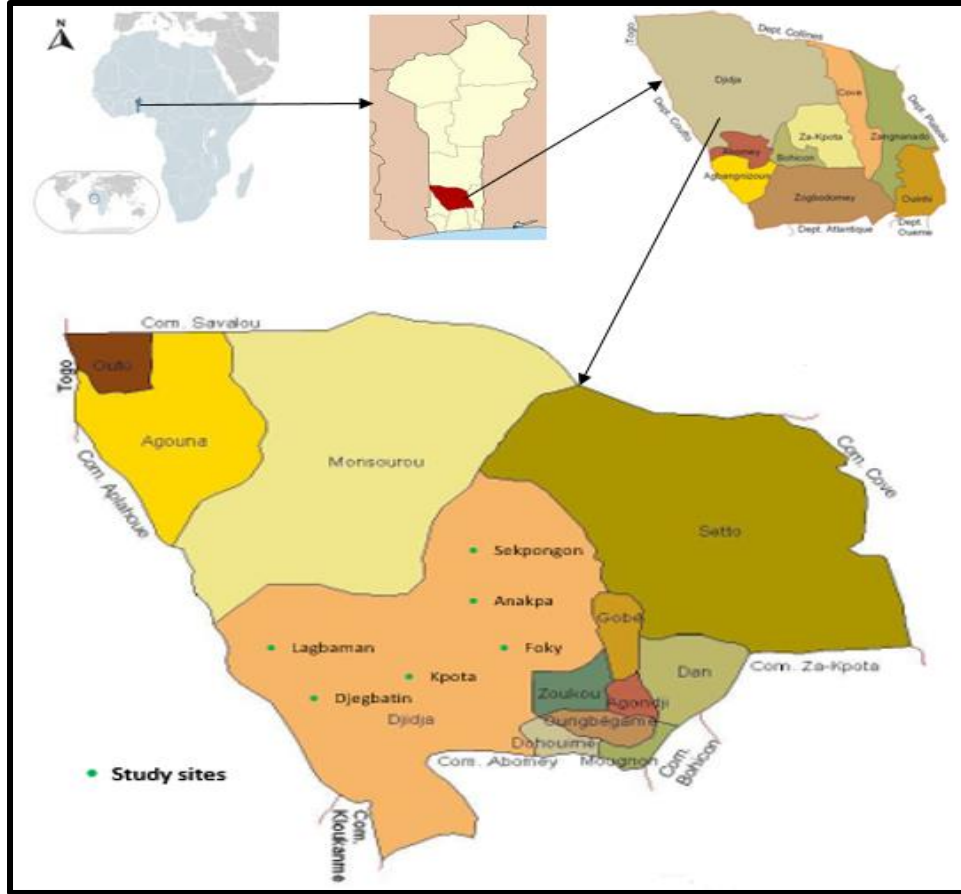


Figure 1: Map showing study sites in Djidja District, southern Benin.

3. Methods

3.1. Data Collection and sampling

Fieldwork was carried out during February-March 2020. To select villages, we conducted an exploratory phase in January 2020. In collaboration with local forest conservation agents,⁶ we retained six villages of the district of Djidja: Anakpa, Djegbatin, Foky, Kpota, Lagbaman, and Sekpongon. The criteria for selection included: presence of the study species, community-managed forests, a lack of current forest conservation projects, and accessibility.

⁶ Trained specialists included forest and environmental protection agents hired by the government and under the jurisdiction of the Ministry of Environment. They provide technical assistance to local communities in forest management and reforestation programs and monitor any illegal practices at the municipality level.

Participants to the field experiment were individuals at least 18 years of age who knew and have used *Afzelia africana* in the past. With the assistance of local forest conservation agents and/or chiefs of the villages, we selected participants from the listings of active forest users or village registers using a proportionally-stratified random sampling approach. From each list, reading bottom to top,⁷ we selected every fifth name by gender.⁸ In case of unavailability (death, current absence from the village, sickness), the following fifth name was the replacement. We alternated between male and female participants to have a gender-balanced sample. However, some participants – mostly female – preferred to delegate participation to another member of the household (male in general).⁹ Overall, 240 individuals (60% males and 40% females) participated in the experiments. Within each village, we randomly assigned each individual to a group. With five participants per group, there were 48 experimental games across the six villages. The experiments occurred at a public location (e.g. village meeting facility or school).

3.2. Experimental Design

Building on the framed-field experiments of Cardenas (2000) and Handberg and Angelsen (2015, 2016), we design a common-pool resource (CPR) game where subjects manage a forest resource and harvest two products: leaves and timber. We frame the management of *Afzelia africana* as a common-pool resource problem, which is characterized by rivalry and non-excludability (Gardner et al. 1990; Murphy and Cardenas 2001; Ostrom 2006). Without quantity restrictions on timber harvest, individuals may have incentives to overuse the resource, causing its destruction. If some

⁷The lists were not in alphabetical order so we opted for a selection from the bottom to the top to divert any preference/privilege given to some inhabitants.

⁸ Female names were marked with an asterisk symbol and the selection was done by gender i.e. every fifth male name followed by every fifth female name.

⁹Our fieldwork overlapped the cotton-picking season and the first rains of the rainy season. Women usually pick cotton and men prepare the fields after the first rains. Those were the main reasons from the selected who suggested a substitute. We made sure the substitutes know or have used *Afzelia africana* in the past. While most substitutes were male, there were also female ones especially in Anakpa.

individuals reduce their consumption levels, the benefits are shared with all other users regardless of their harvested quantities. Therefore, individuals face the dilemma of acting selfishly to maximize their benefits vs. thinking about social welfare and reducing their consumption.

The experiment makes use of a game board with 50 spots representing a common pool forest with 50 trees. Each spot has two magnets: one white and one green (Figure 2). The white magnets represent the trees and the green magnets represent the reachable leaves on the trees. The advantage of this game board is that it helps with framing and allows participants to interact directly with the resource system. They can also easily perceive the focus on two products (trees and leaves) introduced in our experiment.

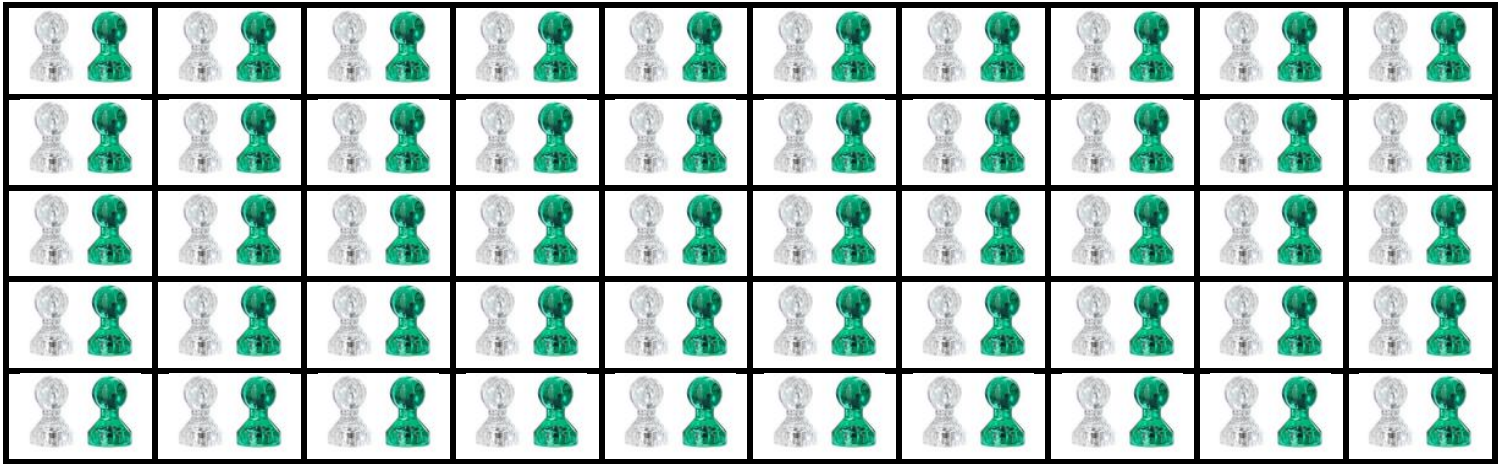


Figure 2: Game board with magnets representing the forest in the experiment.

During each round, participants select individually and privately the quantity of trees to harvest and/or the quantity of trees from which to harvest leaves from the game board. Choosing to harvest zero units of either trees or leaves was permitted. Each participant receives payoff tables showing the earnings in tokens based on the number of trees and the number of reachable leaves harvested. Payoff tables were designed to be accessible by our rural subjects who have, on average, a low level of education.¹⁰

¹⁰ On average, participants in our sample have a 1st grade level of education. We use images and colors to accommodate their comprehension and ensure they fully understood the earnings tables (see Appendix A)

In the experiment, a group of five subjects manage the forest resource. After the practice rounds,¹¹ each game is divided into two different stages. In Stage 1, all subjects make ten rounds of harvest decisions with no PES scheme imposed (Control). In Stage 2 all subjects play ten rounds of the game with one of four PES treatments imposed (Table 1).

We design the four PES treatments across two dimensions: the level of the PES received and the disbursement rule. Across all PES treatments, a threshold condition must be met to determine whether a payment is triggered in a given round. We set a concave payoff function that reaches its maximum at a tree harvest of four and leaf harvest of five per round so as not to explicitly impose harvest limits. In addition, we fix the resource level that triggers PES payments to 70% of the initial stock.

Table 1: Treatments design

Treatments		Payment level	
		Low	High
Payment form	Group rewards	Treatment 1 (T1) <i>Low-Group PES</i>	Treatment 3 (T3) <i>High-Group PES</i>
	Individual rewards	Treatment 2 (T2) <i>Low-Individual PES</i>	Treatment (T4) <i>High-Individual PES</i>

In the low payment level treatments (T1 & T2), the level of PES received is set based on 50% of the sale price of one tree in the experiment.¹² Therefore, at the end of each round, the group receives a payment of 1750 (350 x 5) tokens to be split among all players, based on payment form, if the threshold condition is met. In the high payment level treatments (T3 & T4), the level of PES received is set based on 70% of the sale price of a tree in the experiment. In these treatments, the amount to be split among players, based on payment form, at each round is 2500 (500 x 5) tokens when the threshold condition is met.

¹¹ After the instructions, the experiment begins with three practice rounds to make sure that the participants understand the harvesting method, the calculation of earnings, and the regrowth mechanism of the resource.

¹² In the experiment, for each tree harvested, participants earn 700 tokens.

Treatments also vary by payment form. In the group reward treatments (T1 & T3), all subjects receive an equal share of the PES payment as long as the threshold condition is met. In the individual reward treatments (T2 & T4), the reward is proportional to the individuals' effort to maintain the threshold. The higher the effort (i.e. the lower the individual's harvest), the bigger the reward. For instance, an individual who harvests two trees will get a higher reward than the one who harvests three trees.

Combining both dimensions, we call T1 “Low-Group PES” treatment, T2 “Low-Individual PES” treatment, T3 “High-Group PES” treatment, and T4 “High-Individual PES” treatment (see Table 1). The distribution of treatments is even across all villages but uneven between villages due to the sample sizes per village.

The game was structured to allow a sequential decision-making process to best reflect how community forest users may access the resource.¹³ At the beginning of each round, each player drew a number from a bag to determine the order in which players would extract resources during a given round. The subject drawing number 1 would make the first decision and the subject drawing number 5 would access the resource last. At the end of each round, players were told the aggregate number of trees and leaves harvested by the group.

We also allow for resource regeneration through forest re-growth between rounds of the experiment. We use a constant rate of re-growth where one tree is regenerated for every five trees left standing at the end of a round. Any leaves harvested from a tree that is still standing also regenerate at the end of every round. The experiment ends after ten rounds or when the stock of trees is depleted or when the regrowth process is not possible (i.e. less than five trees remain on

¹³ The choice of sequential decision-making approach in the game is justified by our attempt to represent the reality, to capture the harvesting pressure on the species, and to account for the growth rate of the species. This approach is different from those developed in Janssen et al. 2008 (stationary and simultaneous) and Handberg & Angelsen 2016 (withdrawal of trees with replacement during the same round).

the game board).¹⁴ A flow chart explaining the steps of the game within a round is presented in Figure 3. All instructions were translated in the local language (Fon) and presented to the participants at the beginning of each game. Those instructions are given in English in Appendix B.

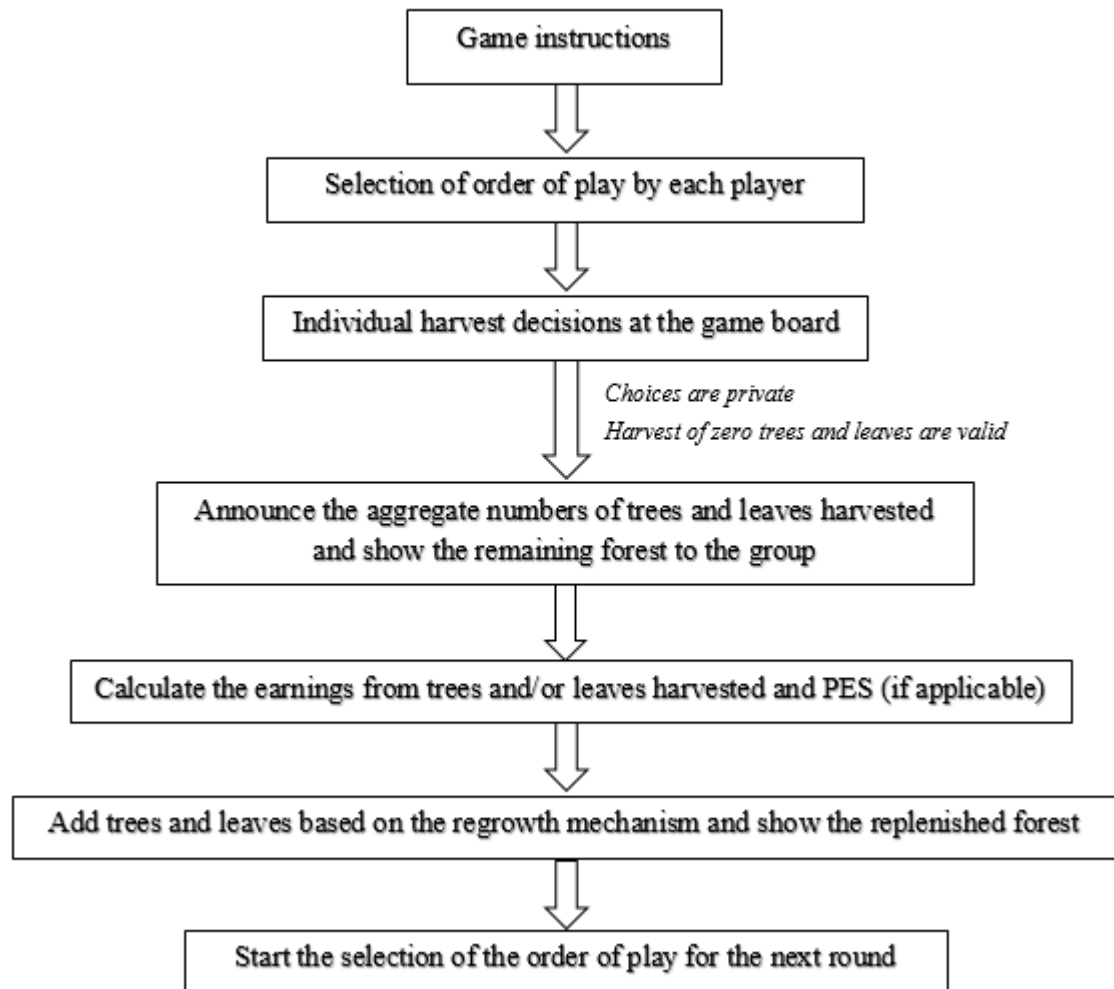


Figure 3: Order of steps within one round of the experiment

¹⁴ This last condition during the game is justified by Article 18 in the Decree No. 96-271 of 2 July 1996, which states that the use of forests cannot be allowed if there are less than 25 trees per hectare. We avoid encouraging a complete depletion of the forest if not preceded by a regrowth mechanism.

3.3. Payoff structure and hypotheses

The function that defines individual payoffs at each round t is:

$$\Pi_{it}(h_{it}, l_{it}, PES_{it}) = \Pi_{it,Tree}(h_{it}) + \Pi_{it,Leave}(l_{it}) + PES_{it} \left(\sum h_{jt}, \bar{X} \right) \quad (1)$$

where h_{it} is the quantity of trees extracted from the forest by individual i during a round t ; l_{it} is the quantity of leaves extracted from the forest by individual i during a round t ; $\sum h_{jt}$ represents the aggregate decision of trees harvested by all five members in a given group during a round t ; \bar{X} is the threshold for payment set at 70% of the original stock.

For the tree and leaf profit functions from equation 1, we assume a linear form for the benefit function and a quadratic form for the cost function. These assumptions allow the profit function to increase at a decreasing rate. After the fourth unit for the trees and the fifth unit for the leaves, the costs start to increase faster than the benefits.

$$\Pi_{it,Tree}(h_{it}) = ah_{it} - \frac{1}{2}bh_{it}^2, a, b > 0 \quad (2)$$

$$\Pi_{i,Leave}(l_i) = cl_i - \frac{1}{5}dl_{it}^2, c, d > 0 \quad (3)$$

The parameters a and b were set using online price data from websites selling logs of *Afzelia africana*. There is currently no formal market for the leaves of the species even though they are used by local households. So, we use the sales values of *Tectona grandis* leaves to approximate the parameters c and d .

In treatments 1 and 3, the PES is equally distributed among the participants:

$$PES_{it} \left(\sum h_{jt}, X_t; \bar{X} \right) = \begin{cases} \frac{P}{n} & \text{if } X_t \geq \bar{X} \\ 0 & \text{if } X_t < \bar{X} \end{cases} \quad (4)$$

where n is the number of participants; X_t is the stock of trees in time t ; and P is the total payment amount available for the group.

In treatments 2 and 4, the PES is proportional to individual harvest. The payment for an individual is:

$$PES_{it} \left(h_{it}, \sum h_{jt}, X_t; \bar{X} \right) = \begin{cases} P * \frac{(\sum h_{jt}) - h_{it}}{\sum((\sum h_{jt}) - h_{it})} & \text{if } X_t \geq \bar{X} \\ 0 & \text{if } X_t < \bar{X} \end{cases} \quad (5)$$

$\sum h_{jt}$ is the total harvest of trees by the group in a given round t and h_{it} is the quantity of trees harvested by an individual in a given round t .

Based on the standard economic model of rational choice, individuals have preferences and are self-interested, short-term maximizers (Ostrom, 1998). This theoretical prediction suggests that few will cooperate by engaging in collective action to manage common-pool resources. In addition, based on the game theoretical predictions presented by Handberg and Angelsen (2015, 2016), for low levels of individual PES, the Nash equilibrium is for each participant to maximize the number of products harvested. For higher levels of PES, the optimal strategy depends on each participant's beliefs about the decisions of the other participants in the same game. If the belief is that the others will be selfish (above threshold), the optimal decision is to maximize harvests of both products. If the belief is that the others will have prosocial behaviors (below threshold), there is an incentive to free ride by maximizing harvests. If the belief is that the others will cooperate (at the threshold), the optimal strategy is to harvest slightly below the Nash equilibrium. In the light of the previous theoretical predictions, we develop and test three hypotheses:

Hypothesis 1: Individual rewards are more effective than collective ones for conservation of common pool resources among local forest users in Benin.

Hypothesis 2: Higher levels of PES increase motivations for conservation.

Hypothesis 3: High PES payments conditional on individual performance induce a lesser harvest of trees and positively influence the magnitude of leaf extraction.

To test these hypotheses, we examine differences in means and variances between and within treatments by using t- and F-tests. We also use graphs to analyze the harvest trends of trees and leaves by pre-treatment and treatment rounds. Additionally, we conduct non-parametric tests – the Wilcoxon (MannWhitney) test – to check robustness against deviations from the normal distribution.

Our data analysis also includes regression analyses to test for the effects of the treatments along with participants' stated preferences on the outcomes while controlling for participant characteristics and village fixed effects. We used a five-point Likert scale to measure participants' stated preferences for risk, happiness, trust, impatience, awareness of the impact of their actions on others, and community discussions about forest usage. We cluster the standards errors at the group level since individual harvest choices are not independent from other participants' choices in the group.

4. Results and discussion

Overview of the sample and the environment of the game

We present an overview of participant characteristics in Table 2. On average, our subjects are 38 years old, with no formal education (61.25%). Subjects are primarily heads of their household (65%) with an average of six family members. Most subjects are employed in the agricultural sector, generating approximately \$2.50 per day. Thirty-five percent have a secondary employment activity, most commonly motorcycle drivers for males and retailers for females, which can provide up to \$4.30 daily depending on the seasons. On average, our sample uses the forests, i.e., extracts some forest products, more than three and seven times per week during the dry season and rainy seasons, respectively and forty-five percent sell forest products (charcoal, timber, firewood, leaves,

and bark). All participants know the species and forty-four percent of the respondents have used it during the last twelve months preceding the field experiment. A vast majority of them (98%) has noticed a reduction in numbers of the species and eighty-seven percent have used a substitute species during the last twelve months preceding the survey.

Concerning their stated preferences, the respondents in our sample varies in terms of being risk takers, being happy, being impatient, and trusting their neighbors to help in times of need. They also appear not to be fully aware of the impact their actions could have on others around them. They neither agree nor disagree that there is a community discussion about the use of forests at the village level.

The experiment/game was welcomed and appreciated by 99% of the sample and 95% stated that they felt like they were making decisions about an actual forest. While forty-two percent of the participants stated having at least one family member in their group during the game, only 10% of the sample declared being influenced in their decisions by such presence. The concept of getting a reward for a pro-conservation behavior (like not harvesting a tree) was new to more than half of the participants (61%). The novelty of the concept could explain the respondents' stated preferences for a reward payment. Seventy percent would prefer the reward paid to the community rather than to the individual.

Table 2: Summary Statistics (N=240)

Variables	Mean	S.D.	Min	Max
Respondents characteristics				
Age	38	15	18	90
Gender (Female=1)	0.40	0.49	0	1
Education (in percentage %)				
<i>None</i>	61.25			
<i>Middle school</i>	13.33			
<i>Second grade</i>	5.42			
<i>Vocational</i>	4.58			
Head of family (yes=1)	0.65	0.48	0	1
Household size	6.54	4.09	0	28
Agriculture as primary occupation (yes=1)	0.98	0.14	0	1

Off-farm employment (yes=1)	0.35	0.48	0	1
Daily labor rate for primary occupation (in FCFA) *	1277.16	2372.61	100	30000
Daily labor rate off-farm (in FCFA) *	2139.17	2387.15	80	12000
Weekly use of forests in dry season (in percentage %)				
0-3 times	48.33			
4-7 times	20.84			
>7 times	30.83			
Weekly use of forests in rainy season (in percentage %)				
0-3 times	27.50			
4-7 times	16.25			
>7 times	56.25			
Knowledge of the species				
Know Afzelia Africana (yes=1)	1	0	1	1
Use Afzelia Africana the last 12 months (yes=1)	0.44	0.50	0	1
Notice change in the habitat of the species in the last 12 months (yes=1)	0.98	0.13	0	1
Use a substitute species in the last 12 months (yes=1)	0.87	0.33	0	1
Sell forest products (yes=1)	0.45	0.50	0	1
Stated preferences* (1 = strongly disagree 5 = strongly agree)				
Risk preferences	1.63	0.96	1	5
Happiness	1.68	0.62	1	5
Trust in neighbors	2.00	0.82	1	5
Impatience	2.1	0.78	1	4
Awareness of impact of actions	1.98	0.81	1	5
Discussion of forest use in the community	2.58	1.57	1	5
Rewards payment (Pay me=0; Pay the community=1)	0.70	0.46	0	1
About the experiment				
Like the game (yes=1)	0.99	0.11	0	1
Felt like making a decision an actual forest (yes=1)	0.95	0.21	0	1
Presence of family members in one's group (yes=1)	0.42	0.49	0	1
Number of family members in one's group	1.04	0.22	1	2
Influence by members in one's group (yes=1)	0.10	0.30	0	1
Understand being rewarded for not harvesting a tree (yes=1)	0.39	0.48	0	1

Notes: *5 point Likert scale where 1 = strongly disagree and 5 = strongly agree. Labor rates are in local currency (FCFA) and \$1=500FCFA.

Effect of the treatments on trees harvest

We find that the implemented PES treatments significantly ($p < 0.01$) decrease the average harvest rates of trees (Table 3). For example, relative to the average harvest rate in the pre-treatment stage, the low group PES treatment induces the harvest of 1.32 fewer trees per round on average while the high individual PES intervention leads to a harvest reduction of 0.93 trees per round on average. Although mean differences across treatments are insignificant (Table 4), the mean harvests under

both *group* treatments (1.48 for the low PES and 1.53 for the high PES) are higher in value than the means harvest under both *individual* treatments (1.43 for both low and high PES). In addition, a chi-square test for equality of the means in the four treatments reveals that the means of harvested trees are likely the same between the treatments ($p=0.3676$). The insignificance of the differences in means suggests that participants might be indifferent to the treatments administered given that payment for ecosystem services is relatively a “new” concept to them. Therefore, a small payment could go a long way in nudging prosocial conservation behavior for harvesting trees.

We also plot the average harvest rates by treatment over time in Figure 4. In the pre-treatment rounds, subjects begin the game harvesting about 3 trees per round on average which quickly depleted the resource. In the treatment rounds, the starting point is around 2.5 trees and decreases below 1.5 trees by the 10th round. To examine the change in harvests at the individual level, we graph the aggregated mean harvest by order of harvest for each round per treatment (Appendix C Figure 1). During the control rounds, the forest was depleted in the 8th round, on average. The forest did last until the 10th round under the control in one game (i.e. 2.08% of the games).

By the 10th round in the treatments rounds, the individual average harvest of trees declines and stabilizes below two units across all four treatments and regardless of the order of harvest. The individual average harvest rate seems uniform throughout the treatment rounds for the low group treatment, which could explain why this intervention records the highest decrease (47.14%) in harvested trees at the group level. Under the individual treatments (low and high) rounds, the average harvest rate reaches below one unit of tree per round per participant by the last round. About 89.58% of the treatment games (i.e. 43 out of 48) lasted until the 10th round.

Table 3: Mean harvest of trees by treatment

	Control		Treatment		Mean difference (T-stat)	Variance difference (F-stat)
	N	Mean (s.d)	N	Mean (s.d)		
Low Group PES	290	2.80 (1.49)	595	1.48 (1.01)	-1.32*** (13.64)	-0.48*** (2.18)
Low Individual PES	300	2.70 (1.53)	600	1.43 (1.06)	-1.27*** (12.91)	-0.47*** (2.08)
High Group PES	285	2.79 (1.65)	555	1.53 (1.19)	-1.26*** (11.45)	-0.46*** (1.92)
High Individual PES	345	2.36 (1.60)	595	1.43 (1.05)	-0.93*** (9.66)	-0.55*** (2.32)

Notes: N is the sample size per category. Differences are Treatment-Control. T-test for the statistical difference between means and F-test for the statistical difference between variances. ***1% significance level, **5% significance level, *10% significance level with two-tailed tests.

Table 4: Mean difference between treatments for trees

	Low Group PES	Low Individual PES	High Group PES	High Individual PES
Low Group PES		-0.05 (-0.83)	0.05 (0.77)	-0.05 (-0.84)
Low Individual PES	0.05 (0.83)		0.10 (1.50)	0 (0.00)
High Group PES	-0.05 (-0.77)	-0.10 (-1.50)		-0.10 (-1.51)
High Individual PES	0.05 (0.84)	0 (0.00)	0.10 (1.51)	

Notes: Differences are Column-Row. T-test for the statistical difference between means across paired treatment are in parentheses.

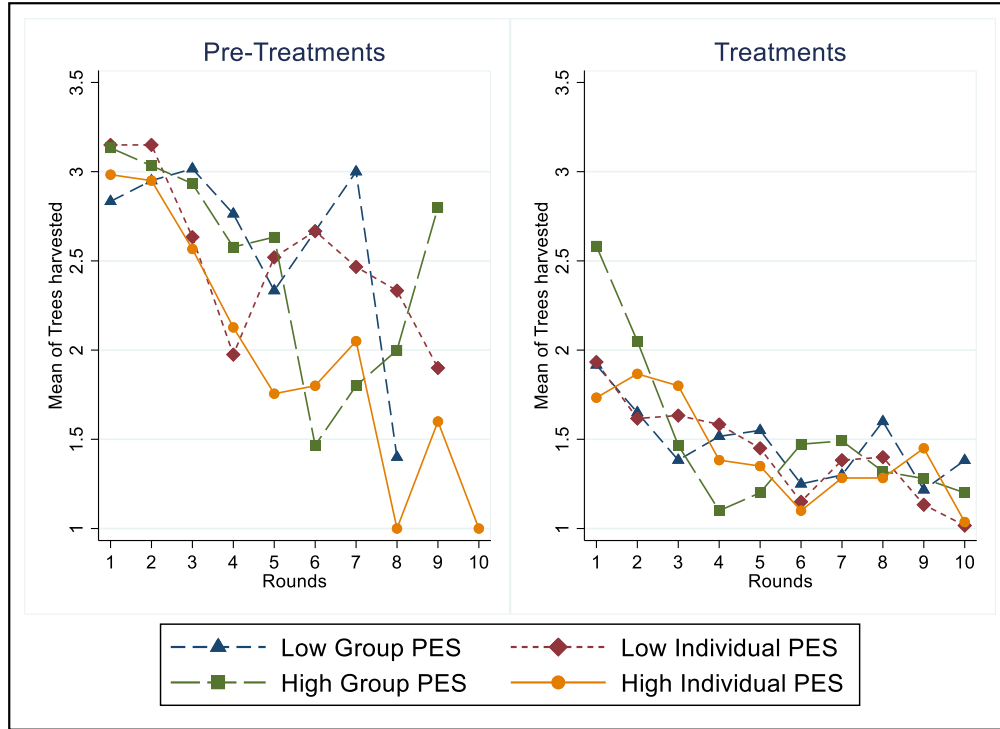


Figure 4: Harvest trends of trees by pre-treatments and treatments rounds

Effect of the treatments on leaf harvest

The high group PES treatment induces an average decrease of 0.55 in leaves harvested when comparing the pretreatment and the treatment rounds (Table 5). In addition, it is the only treatment statistically different from the three others (Table 6). Under the low individual PES treatment, the respondents harvested leaves on 0.61 fewer tree per round on average compared to the control rounds. However, the low individual PES treatment is not statistically different than the high individual PES and low group PES treatments (Table 6). Figure 5 supports the result of Table 6. The test for equality across all treatments ($p < 0.01$) reveals that the means of harvested leaves are not likely to be the same across the four treatments. Therefore, it appears that the most effective conservation intervention for the leaves was the high group PES treatment. Individual harvest trends follow the same pattern as the group behavior (Appendix C Figure 2). The lowest

average in the treatment rounds is recorded in the high group PES treatment (below 2 units of leaves harvested per round per individual).

Table 5: Mean harvest of leaves by treatment

	Control		Treatment		Mean difference (T-stat)	Variance difference (F-stat)
	N	Mean (s.d)	N	Mean (s.d)		
Low Group PES	290	3.30 (2.09)	595	3.04 (2.19)	-0.26* (1.71)	0.10 (0.91)
Low Individual PES	300	3.82 (2.19)	600	3.21 (2.22)	-0.61*** (3.92)	0.03 (0.97)
High Group PES	285	3.23 (2.10)	555	2.68 (2.05)	-0.55*** (3.62)	-0.05 (1.05)
High Individual PES	345	3.23 (2.13)	595	3.13 (2.04)	-0.10 (0.70)	-0.09 (1.09)

Notes: N is the sample size per category. Differences are Treatment-Control. T-test for the statistical difference between means and F-test for the statistical difference between variances. ***1% significance level, **5% significance level, *10% significance level with two-tailed tests.

Table 6: Mean difference between treatments for leaves

	Low Group PES	Low Individual PES	High Group PES	High Individual PES
Low Group PES		0.17 (1.33)	-0.36*** (-2.88)	0.09 (0.73)
Low Individual PES	-0.17 (-1.33)		-0.53*** (-4.22)	-0.08 (-0.65)
High Group PES	0.36*** (2.88)	0.53*** (4.22)		0.45*** (3.73)
High Individual PES	-0.09 (-0.73)	0.08 (0.65)	-0.45*** (-3.73)	

Notes: Differences are Column-Row. T-test for the statistical difference between means across paired treatment are in parentheses. ***1% significance level, **5% significance level, *10% significance level with two-tailed tests.

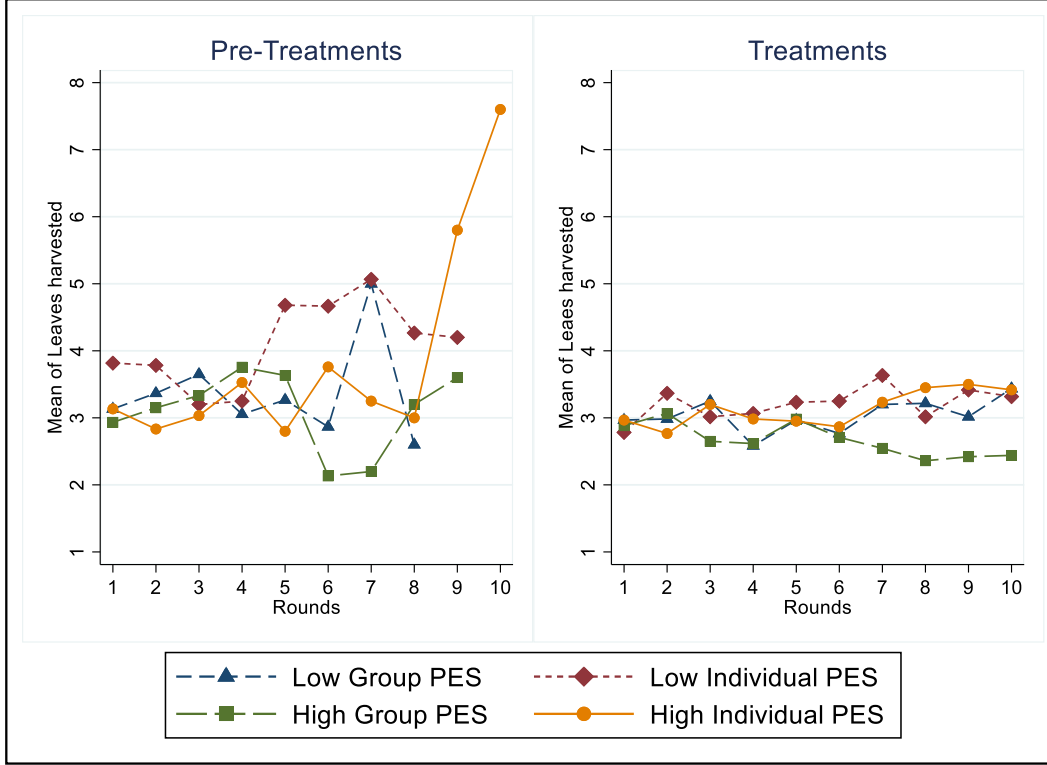


Figure 5: Harvest trends of leaves by pre-treatments and treatments rounds

Regression analysis of harvest rates

We next turn to regression analysis to better estimate the impact of our PES treatments on individual and group behavior. First, we regress harvest rates of trees and leaves on the five different treatment conditions (control plus four PES treatments). In our regression models, we control for individual demographics and preferences and time (rounds). We present the results in Table 7 and cluster errors at the group level.

The number of trees and leaves harvested per round are the dependent variable in models (1) and (2) respectively. Relative to the control treatment, all PES treatments significantly reduced harvest rates for trees. These reduced harvest rates are illustrated in Figure 6, showing that on average, participants are more likely to harvest below (or at) the threshold level during the treatment rounds for all PES schemes

Concerning the leaves, only the high group PES significantly affects the harvesting rate by reducing it by an average of 0.71 per round per individual. Figure 7 supports this finding by showing that the mean of leaves remaining is at its highest under the high group PES treatment. This regression result reinforces the comparison of mean leaf harvest rates in Tables 6 and 7. Overall, the use of a single-product PES for multipurpose species does not necessarily reduce the pressure on all harvested products. These patterns described for trees and leaves are robust to the inclusion of additional demographic, stated preference, and time controls presented in Table 7.

Models (3) and (4) present the effects of demographics on harvest rates of trees and leaves. Being one year older and selling forest products are associated with an average of 0.008 and 0.10 more trees harvested per individual per round. This suggests that older participants harvest more than younger ones. This finding is consistent with those of Ngoma et al. (2020) and Handberg and Angelsen (2015). In the context of this study, older people rely more on the species for the quality of its timber and many traditional purposes¹⁵. In addition, the Beninese government classified the species as endangered in 1996 under the Decree No. 96-271. This classification implies a restriction of the species' exploitation. Moreover, subjects with a higher education level are associated with reduced tree harvests and increased leaf harvests. Educated people may understand that leaf harvest does not impact the probability of obtaining the timber-based PES. Yet, if aggregated at the community level, the harvest of an average additional 0.07 trees' worth of leaves per individual per round may induce some ecological effects on the species population over time.

We investigate how stated preferences might be associated with pro-conservation behavior. Models (5) and (6) present the effects of preferences on harvest rates. We measured the preferences

¹⁵ The roots are valued for some mystical drinks in the practice of Vodoun. In addition, the timber is specifically required for wood carving and wood crafting for ceremonies of local religions. In the "Fon" ethnic, after the death of twins (both or one), they must be represented in a manly looking wood carving – called "atinkpavi" – to continue "living among the humans". The species serves this purpose and the task is left to older people.

using a five point Likert scale and mean-centered all responses. Our findings suggest that impatient respondents harvest more than patient ones. Average harvesting was increased by 0.11 tree by round by individuals per unit of impatience index. These results are similar to those of Ngoma et al. (2020). In addition, being aware that one's actions could affect others is associated with lower tree harvest rates. All the preferences' coefficients are insignificant for the leaves harvest (Model 6).

All the coefficients for the time (rounds) are negative and significant relative to round one for tree harvest – except for round two (Model 7). On the contrary, all the coefficients are positive and largely insignificant in Model 8; suggesting no clear pattern across time for the harvest of leaves.

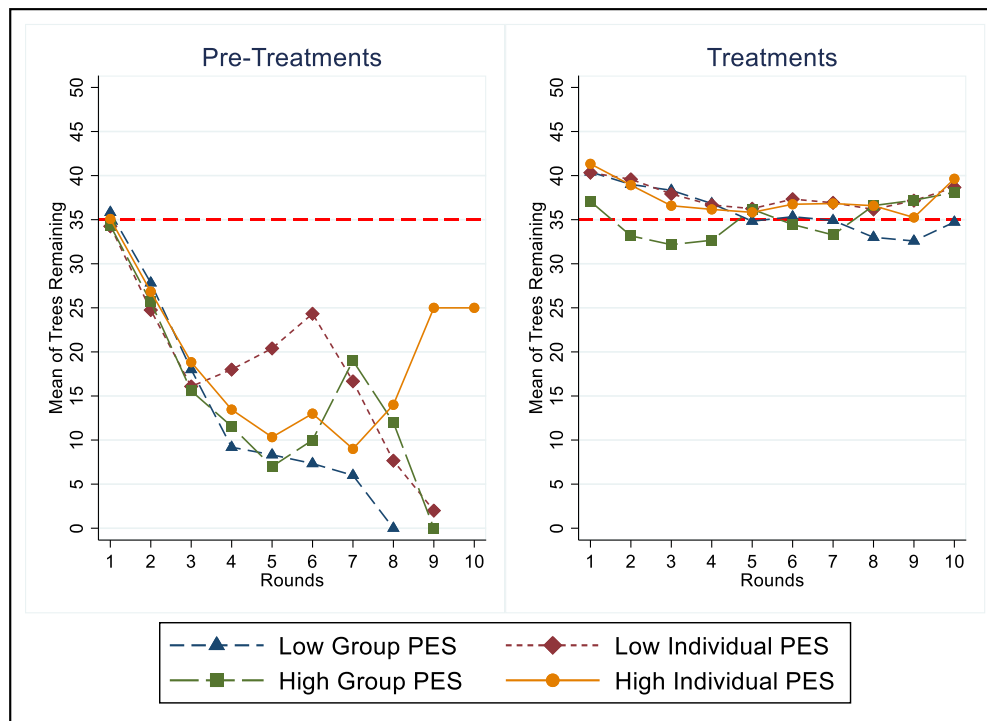


Figure 6: Stock size after each round relative to the threshold.

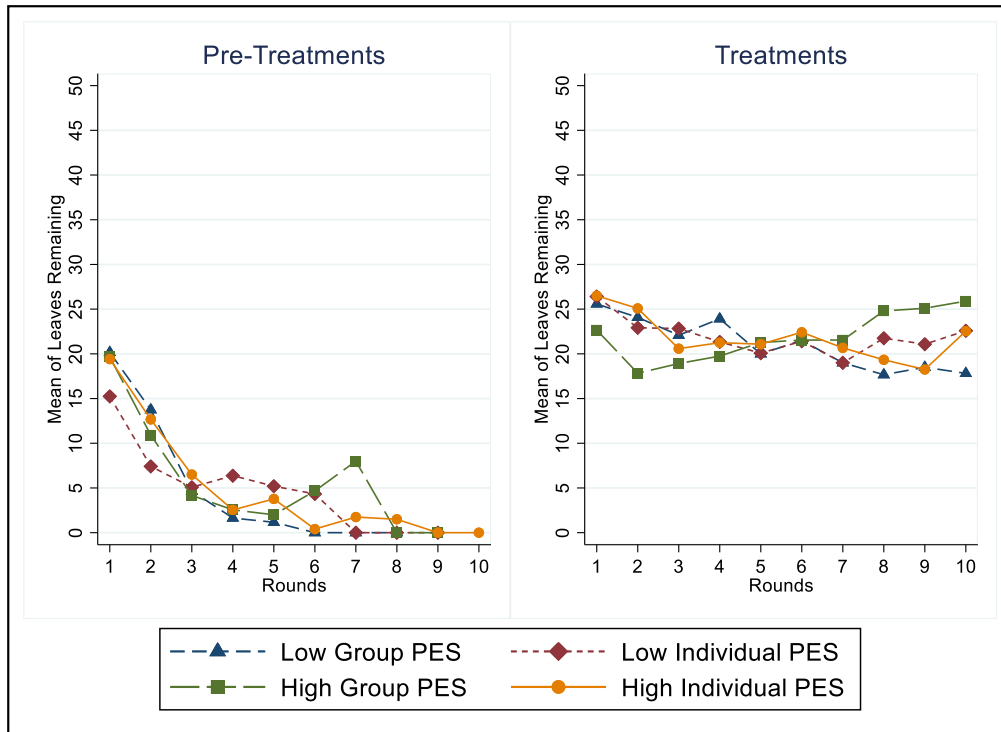


Figure 7: Mean of leaves remaining during pre-treatments and treatments rounds.

Table 7: Effects of factors influencing harvest rates

	Treatments (T) only		(T) and Demographics		(T) and Preferences		(T) and rounds	
	(1) Trees	(2) Leaves	(3) Trees	(4) Leaves	(5) Trees	(6) Leaves	(7) Trees	(8) Leaves
Low Group PES	-1.172*** (0.110)	-0.357 (0.447)	-1.185*** (0.104)	-0.455 (0.436)	-1.149*** (0.113)	-0.348 (0.436)	-0.983*** (0.094)	-0.441 (0.455)
Low Individual PES	-1.219*** (0.104)	-0.183 (0.345)	-1.236*** (0.104)	-0.147 (0.343)	-1.237*** (0.106)	-0.184 (0.338)	-1.027*** (0.085)	-0.268 (0.344)
High Group PES	-1.116*** (0.106)	-0.713* (0.364)	-1.068*** (0.099)	-0.743** (0.367)	-1.115*** (0.108)	-0.726* (0.362)	-0.940*** (0.091)	-0.791** (0.378)
High Individual PES	-1.217*** (0.100)	-0.262 (0.352)	-1.177*** (0.098)	-0.276 (0.343)	-1.214*** (0.097)	-0.247 (0.342)	-1.028*** (0.079)	-0.345 (0.345)
Age			0.008** (0.004)	-0.006 (0.007)				
Gender			-0.024 (0.102)	0.109 (0.246)				
Education			-0.034* (0.019)	0.065* (0.036)				
Household Size			-0.012 (0.011)	0.007 (0.024)				
Sell forests products			0.099* (0.054)	-0.194 (0.282)				
Risks (I like taking risks)					0.005 (0.038)	0.043 (0.096)		
Happiness (I am a happy person)					-0.038 (0.074)	0.068 (0.180)		
Trust (I trust my neighbors to help me in times of need)					-0.058 (0.047)	-0.136 (0.135)		
Impatience (I am impatient and cannot wait when I want something)					0.109** (0.041)	-0.066 (0.119)		
Awareness (I know my actions could impact others around me)					-0.081* (0.048)	0.106 (0.128)		

Community (My community discusses the usage of forest resources in the village)					0.028 (0.030)	0.041 (0.062)		
Round 2							-0.125 (0.085)	0.088 (0.102)
Round 3							-0.354** (0.135)	0.090 (0.122)
Round 4							-0.645*** (0.150)	0.018 (0.157)
Round 5							-0.696*** (0.139)	0.171 (0.164)
Round 6							-0.827*** (0.139)	0.062 (0.162)
Round 7							-0.688*** (0.125)	0.363** (0.168)
Round 8							-0.713*** (0.124)	0.182 (0.179)
Round 9							-0.781*** (0.122)	0.327 (0.210)
Round 10							-0.905*** (0.127)	0.403 (0.245)
Constant	2.649*** (0.089)	3.393*** (0.184)	2.473*** (0.176)	3.461*** (0.373)	2.650*** (0.090)	3.393*** (0.177)	3.031*** (0.122)	3.308*** (0.162)
N	3565	3565	3440	3440	3565	3565	3565	3565
R ²	0.163	0.011	0.174	0.025	0.166	0.015	0.205	0.012

Robust standard errors in parentheses are clustered at the group level; ***, **, and * indicate significance at the 1, 5, and 10 percent critical level. The number of observations reduces to 3440 for the demographics models due to missing values for two participants.

5. Conclusion















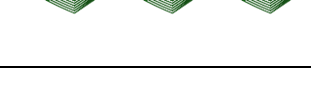


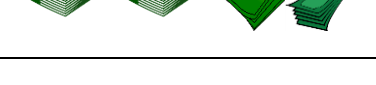


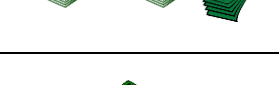








PES programs are important tools used to incentivize pro-conservation behaviors. When implemented in the forestry realm, they mainly focus on payments for conserving trees. However, in many tropical countries, forests serve multiple purposes. We use a forest-based field experiment to measure the impact of PES on conservation outcomes when forests produce two different products: timber and leaves. We focus on four policy instruments designed around the level of the PES payment provided (High/Low) and how the payment is shared among forest users (Individual/Group).

Our results suggest that all four treatments reduce harvest rates of trees and induce some conservation behavior in local Beninese forest users. However, only when forest users receive a high PES payment evenly divided among group members was leaf conservation significantly increased. These findings indicate that a single-product PES focused only on whole trees might not be effective for multipurpose species. We also found that impatient users, older users, and users who sell forest products have higher harvest rates for trees. Meanwhile, those who are self-conscious of the impact of their actions on others tend to harvest fewer trees. Educated respondents harvest fewer trees but more leaves.

From our results, we conclude that a forestry policy that offers a high incentive paid to the community rather than the individuals would have a chance to decrease harvest rates of both leaves and trees on *Afzelia africana* among Beninese local forest users. Further experimental work could include an ecological dynamic mechanism between leaves and trees into the design to assess to which extent overharvesting the leaves impact the trees populations.

























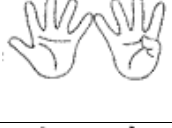





Appendix A: Payoff Tables used in the field

NUMBER OF TREES HARVESTED



NUMBER OF LEAVES HARVESTED



Appendix B: Experimental Instructions

Thank you all for being here today and for giving your consent to participate in our research. You will be participating in a game about the use of *Kpakpatin* in your community. The game will be played in groups of five people.

Please pay great attention to the instructions. Please remain seated unless it is your turn and do not communicate with other participants unless you are asked to do so. Your earnings from this game depend on the decisions that you make and on the decisions that your group members make.

[in all treatments]

This game board represents 50 trees in the forest [point to the game board]. This game board has 50 spots. Each spot has 2 magnets: one white and one green. The white magnets represent the trees and the green magnets represent the reachable leaves on the trees.

During each round of the game, you will individually and privately select the quantity of trees (white magnets) to harvest and the quantity of trees from which to harvest leaves (green magnets) by removing the magnets from the game board. If you harvest a tree, you automatically harvest the leaves. However, it is possible to only harvest the leaves without harvesting the tree.

[Demonstrate how trees and leaves are harvested].

For example, you could decide to harvest 2 trees (by removing 2 white magnets and the associated green magnets from two spots on the board) and harvest reachable leaves from 3 trees (by removing 3 green magnets from 3 spots). You will be observed by an enumerator who will record your choices.

Each of you have been provided with a payoff table showing you your earnings in tokens based on the number of trees and the number of reachable leaves you choose to harvest.

[Show the game profit tables].

Without talking to your group, you will decide the number of trees you would like to harvest and the number of leaves to harvest. You are free to make any harvest decision you would like. Harvesting additional units of trees and leaves will earn different profit according to the tables. After the fourth unit in Table 1 and the fifth unit in Table 2, the returns start to decrease because the costs are increasing faster than the benefits.

[Show the game profit tables again].

Profit from harvesting the tree is the equivalent to the value of firewood or charcoal or timber; and the earning from the foliage is the equivalent to the value of livestock feed. As mentioned earlier, by harvesting a tree, you are also harvesting all its leaves and that is accounted for in the earning from harvested tree.

To continue with the example above, if you decide to harvest 2 trees you will earn 1100 tokens and by get leaves from 3 trees, you will earn an additional 110.

You can think of a round as equivalent to a year or harvesting season. At the beginning of a round, each player will draw a number from a bag with numbers one through five. The number drawn will determine the order of the decisions. For example, the person who draws the number 1 will go first.

At the end of each round, the enumerator will show you the forest and announce: (i) the total number of trees harvested, and (ii) the number of trees from which leaves are harvested by the group.

Finally, the forest will grow at the end of each round. For every 5 trees standing, 1 tree will be replenished and added back to the game board. Any leaves harvested grow back during the next round.

[Show how trees and leaves regrowth mechanism on the board game].

The regrowth process will continue until the game is completed. If there are less than five trees standing, no additional trees will grow.

Do you have any questions? [Answer all the questions and provide examples for clarifications].

First, we will play three practice rounds to make sure you understand the harvest decisions and procedure. Tokens earned during the practice game will not count towards your earnings today.

[Begin practice rounds, starting with the random draw of subject order. Complete all three rounds and show subjects their total earnings.]

Do you have any questions? [Answer all the questions].

Now that you understand the procedures, we will begin the game. Please remember that all of your decisions are your own. All decisions you make in the next game will affect your earnings today. Please remember to not discuss decisions with one another from this point forward.

[if in treatment 1 (Low Group)]

In addition to earnings from your individual harvest, if there are **at least 35 trees** still standing at the end of a round, the group will receive a payment of **1750 tokens** to be split equally among all players. Each player in the group will receive an equal share of this amount which amounts to an individual payment of **350 tokens**. If there are less than 35 trees still standing at the end of a round there will be no additional payment.

[if in treatment 2 (Low Individual)]

In addition to earnings from your individual harvest, if there are **at least 35 trees** still standing at the end of a round, the group will receive a payment of **1750 tokens** to be split among all players. The payment will be split based on the number of trees each player harvested. The larger the number of trees you harvest compared to other players, the smaller your individual payment. The proportion of the payment you receive will depend on your individual harvest and the total of harvest of the group. If there are less than **35 trees** still standing at the end of a round there will be no additional payment.

[if in treatment 3 (High Group)]

In addition to earnings from your individual harvest, if there are **at least 35 trees** still standing at the end of a round, the group will receive a payment of **2500 tokens** to be split equally among all players. Each player in the group will receive an equal share of this amount which amounts to an individual payment of **500 tokens**. If there are less than 35 trees still standing at the end of a round there will be no additional payment.

[if in treatment 4 (High Individual)]

In addition to earnings from your individual harvest, if there are **at least 35 trees** still standing at the end of a round, the group will receive a payment of **2500 tokens** to be split among all players. The payment will be split based on the number of trees each player harvested. The larger the number of trees you harvest compared to other players, the smaller your individual payment. The proportion of the payment you receive will depend on your individual harvest and the total of harvest of the group. If there are less than **35 trees** still standing at the end of a round there will be no additional payment.

[in all treatments]

You will be compensated for your time. You will receive 1250 FCFA (\$2.5) for taking part in this study and can earn up to an additional 1250 FCFA (\$2.5) from the profits you made during the game. Tokens will be converted to FCFA at a rate of 100 tokens equals 5FCFA. We will pay you individually in cash after you complete a short survey.

Do you have any questions about the instructions or procedures? [Answer all the questions].

[Begin and complete the 10 rounds].

Appendix C

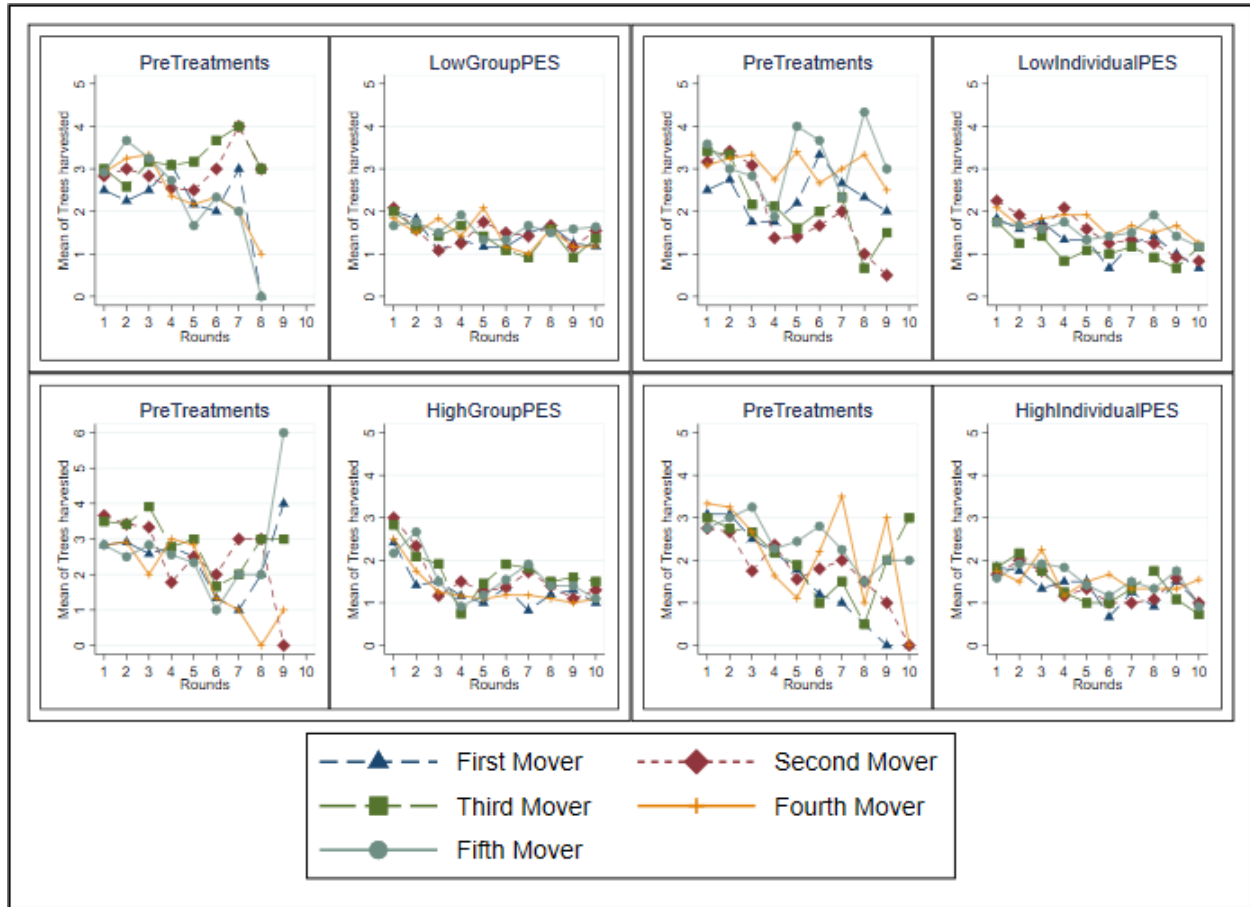


Figure 1: Individual trees harvest trends by experiment round, pre- treatment and during each treatment.

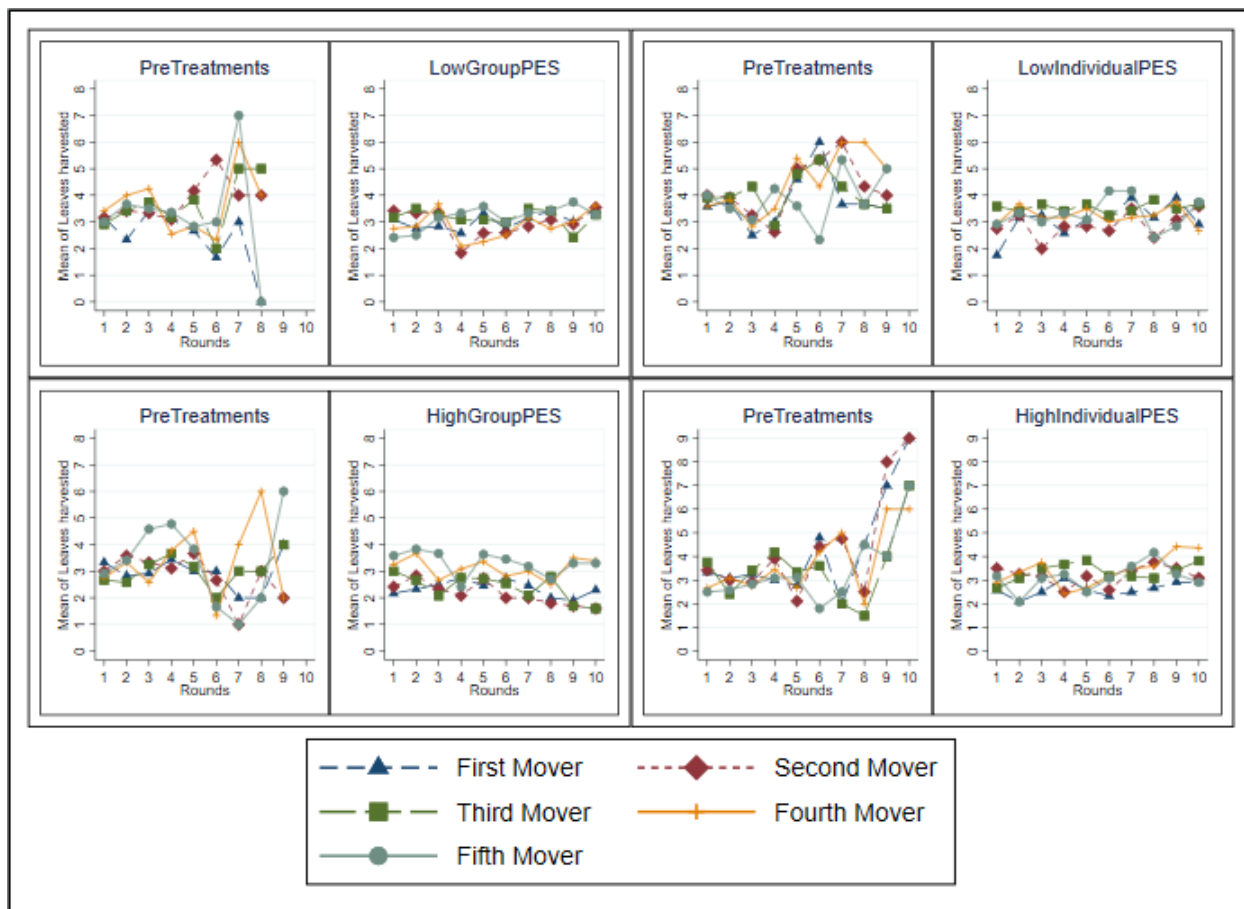


Figure 2: Individual leaves harvest trends by experiment round, pre- treatment and during each treatment.

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