Teaching and Educational Methods

Managing a Multiuse Resource with Payments for Ecosystem Services: A Classroom Game

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Abstract
This article presents a classroom experiment that introduces students to the concept of payment for ecosystem services (PES) applied to a multipurpose renewable forest resource. Through a natural resource management game, students can analyze how PES programs may alter the individual and group harvest decisions and stocks of both components of the multipurpose resources. Participants can choose between harvesting whole trees for timber, harvesting leaves for fodder, or some combination of both. In each round, students choose the quantity of both resources to harvest for profit. Students complete the experiment with and without the PES program to enable comparison of decisions across management regimes. The outcome (usually complete forest removal) at the end of the game helps demonstrate the tragedy of the commons in the absence of conservation policies.

1 Introduction

Finding the right balance between biodiversity conservation and human well-being is crucial for the preservation of the earth in general and communities' sustainable development (Haines-Young and Potschin 2010; McShane et al. 2011). The complexity of this debate lies in the following question: how do we preserve forest richness while meeting the needs of local communities who depend on them for their livelihoods? With climate change and growing world population, this question is becoming more challenging. An obvious response could be a win-win approach that enhances humans' needs while reducing the impacts on the ecosystems. Payments for ecosystem services (PES) have the potential of providing such dual benefits (Food and Agriculture Organization 2012). Although there is no agreed-upon definition for PES, the definition proposed by Wunder (2005, p. 3) is widely cited and stipulates that PES is "(a) a voluntary transaction where (b) a well-defined environmental service (ES; or a land-use likely to secure that service), (c) is being 'bought' by a (minimum one) ES buyer, (d) from (minimum one) ES provider, (e) if and only if the ES provider secures ES provision (conditionality)." The Heredia Declaration on Ecosystem Services[1] provides a concise and short definition stating that PES are fund-services provided by nature (Farley and Costanza 2010).

The classroom game presented in this article introduces students to the PES concept and its impacts on individual and group decisions. The game expands from a single forest product to two forest products received from the same species of tree. Many tree species, both in tropical and temperate forests, can provide multiple harvestable products (Myers 1988; Alexander, McLain, and Blatner 2001). An example is *Gliricidia sepium*, which provides timber, fuelwood, fodder, and green manure for agricultural crops (Simons and Stewart 1994).

[1] "A consensus statement signed by international and local experts outlining the mechanisms for successfully implementing PES at the global, regional, and local level."

This game is also flexible enough to accommodate any classroom format and size, as well as a broad range of education levels. It was implemented in undergraduate and graduate microeconomics courses in an agricultural and resource economics department during 50- and 100-minute class periods. The number of students per class ranged from ten to thirty students.

The learning objectives for the classroom game are to (1) calculate individual and group profit-maximizing harvest decisions based on a profit function; (2) illustrate the tragedy of the commons (Hardin 1968) in the absence of conservation policies for multipurpose resources; and (3) analyze how PES alter harvest decisions and stocks of timber and nontimber resources. While there are several games depicting the tragedy of the commons available for instructors to choose from, the game presented in this manuscript adds payments for ecosystem services as one approach to slow down overharvesting in the commons. Moreover, the game looks at more than one harvestable product, which mimics the real use (i.e. multipurpose) of forests in various ecosystems. It also has the potential to capture the ecological dynamics between timber and nontimber products during a classroom game.

2 Some Common Pool Resources (CPR) Games

CPR games have become a key teaching tool in applied micro and environmental economics classes to demonstrate firsthand the tragedy of the commons to students. Sophisticated examples of the CPR game for the classroom (Murphy and Cárdenas 2004; Secchi and Banerjee 2019) and for field research (Handberg and Angelsen 2016; Ngoma et al. 2020) have been developed to test a variety of different important institutional changes to the classic CPR problem, including the number of resource users, communication methods, and regeneration rates. However, all of these games are limited by focusing on a single harvestable resource (e.g., timber). This limitation ignores that common-pool resources may provide multiple products. For example, trees in a forest may provide timber in addition to food, medicine, and fodder created from the same resource. We extend this game to allow for the harvest of multiple products from the CPR in the context of a forest where individuals can harvest trees and leaves. This game illustrates how the availability of additional products for harvest may change the dynamics of a classic CPR.

Table 1 presents six CPR experiments played by students, which are similar in design and/or procedures to the game presented in this manuscript. The table summarizes the key features of those experiment designs, their main contributions, and their applications to the real world. To avoid any complications from combination or sequence of treatments that could affect students' strategies and overall outcome of the exercise, in our game, we implement one control (an unregulated CPR as in Murphy and Cárdenas 2004) and one treatment (a threshold-based PES scheme).

PES contracts can be designed using a linear payment or a threshold-based payment (Climate Investment Funds 2019). A linear payment contract will pay individuals a given amount per unit of tree surviving at the end of a designated period. The threshold payment contract will pay individuals a predetermined amount if the number of trees living at the end of a designated period meets or exceeds the threshold. These two PES contract designs were used in August 2017 in Burkina Faso under the Gazetted Forests Participatory Management Project for REDD+ implemented by the African Development Bank. Under the linear payment, a group of five community members received US$0.62 per tree surviving at the end of a given period. The threshold-based contract paid US$238 for 400 or more trees, US$185 for 300 to 400 trees, or US$62 for less than 100 trees. The theoretical economic prediction of suing these contract types suggests that threshold payments have the potential to induce more cooperative efforts (Climate Investment Funds 2019). This is because of the fact that they are likely to prevent collective action failure and create a coordination game. The treatment design used in this game represents a threshold-based PES scenario.

We also focus on two harvestable products (trees and leaves) unlike experiments presented in the table where the decisions are made for one resource (trees, fishes, or water). The decision making in our game is about the units of products to harvest (similar to Bednarik et al. 2019 and Secchi and Banerjee

Table 1. Classroom CPR Games in the Literature

Resource (References)	Level of decisions	Key features of designs	Game procedures	Findings/contribution	Applied to real world
FORESTS **(Dissanayake and Jacobson 2019)**	Individual and/or group decisions	Ability to commit contract fraud, uncertainty in earnings, auction payment, and community-level decision making.	10 to 60 students Adjustable number of rounds 45-90 minutes	No specific finding because the game is designed to cover many topics such as PES programs; climate change; cost-effectiveness; etc.	No
FORESTS **(Bednarik et al. 2019)**	Individual decisions	Treatments with rainfall intensity, flood losses due to cut trees, and communication.	5 students 20 rounds Session of 70 minutes	Adding flood risk to the game does not change the overharvesting outcome.	No
FORESTS **(Murphy and Cárdenas 2004)**	Individual decisions	Three treatments: an unregulated CPR, an imperfectly enforced externally imposed regulation, and communication for self-governance. Finite repeated game with undisclosed number of rounds.	8 students Simultaneous decisions 15 to 20 rounds split between the three treatments in a 75-minute class	Regulation induces a more self-interested behavior. Communication enables perfect or near-perfect compliance by all group members.	Yes
FISHERIES **(Secchi and Banerjee 2019)**	Individual decisions	Full information feedback, nonbinding communication.	5-10 members Dynamic sequential setting Played for multiple rounds throughout the semester Allotted time of 5 to 10 minutes per class period	Peer punishment improves group performance and prevents self-interested behaviors.	No

Table 1 continued.

Resource (References)	Level of decisions	Key features of designs	Game procedures	Findings/contribution	Applied to real world
WATER **(Farolfi and Erdlenbruch 2020)**	Individual decisions	Factorial design (communication/no communication) × (high surface water availability/low surface water availability).	Group of 15 players Run in 1.5 and 2.5 hours 10 rounds	Communication between resource users is conducive to more cooperative resource use. Resource scarcity might not increase the likelihood of cooperation.	No
NATURAL RESOURCES (Kumakawa 2018)	Groups (paired) decisions	Four treatments based on matching setup and feedback information. Endowment of money to be split between market and savings.	Simultaneous decisions 20 rounds in each pair 2 hours to complete each treatment	Cooperation in CPR games is derived from participants' strategic behavior for future rewards not from a sense of intimacy with other community members.	No

2019) to mimic reality, unlike the decisions on the number of months to spend extracting the resource (Murphy and Cárdenas 2004).

3 Game Setup

We present a classroom extraction game (e.g., Gardner, Ostrom, and Walker 1990; Murphy and Cárdenas 2004; Ostrom and Nagendra 2006; Holt et al. 2012) where students make individual decisions over harvesting two different products from a common pool resource: trees and leaves. Played in groups of five, individuals will participate in two stages of the game each lasting 10 rounds. Stage 1 is conducted with no PES program, and Stage 2 is conducted with a PES program. During each round, students decide the quantity of trees and/or leaves to harvest from the forest, which initially has fifty trees.[2]

To implement this game, we construct a game board where students can see the entire resource stock from which they may harvest. In Figure 1, we present a representation of our board where green magnets represent the fifty trees available for harvest, and clear magnets represent the reachable leaves of fifty trees available for harvest.[3] Students are provided with background information on the use of forests in tropical ecosystems with the associated consequences on multipurpose species populations and the concept of payments for ecosystem services (see Appendix A: Game Instructions/Student

[2] For instructors using a different group size, we recommend setting the starting stock of trees equal to ten times the number of players in each group.

[3] For an alternative approach that does not require a magnetic whiteboard or additional supplies, we also include an Excel representation in the Supplementary Materials.

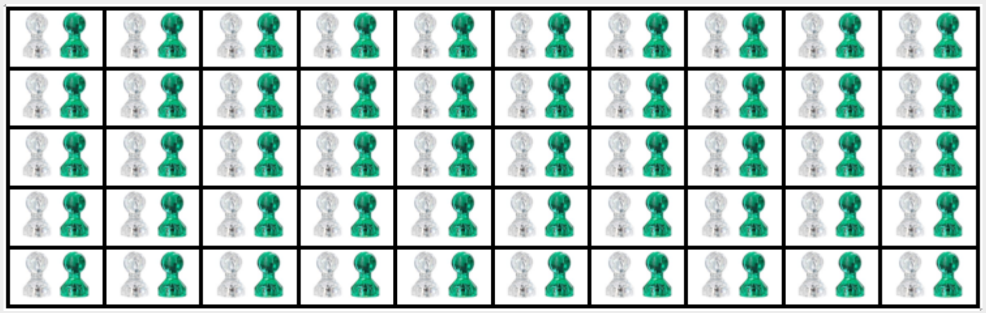

Figure 1. Game Board with Magnets Representing the Forest for a Group of Five Students

Handout). In addition, depending on the course level (i.e. for graduate students), a reading assignment of articles on PES programs may be assigned.[4]

All players are provided payoff tables showing the profit in tokens that can be earned based on the quantities of trees and leaves harvested and a decision sheet to record their payoffs (see Table 1 in Appendix A: Game Instructions/Student Handout).

During the game, students make their decisions simultaneously. When the stock size is low, if the players in the group submit harvest decisions that are greater than the remaining number of trees or leaves, the moderator/instructor will evenly divide the available resource among the five players, and any remainder will be discarded.

The game consists of two parts: (i) ten rounds of the control where players are given no additional information besides the context of the experiment and the general information about how to play the game, and (ii) ten rounds of the treatment where the stock of trees is reset to the same starting stock as part (i). At the end of each round in part (ii), all students receive a bonus payment for ecosystem services if 70 percent of the initial (prior to round 1) stock remains. The bonus is set at 500 tokens per student and is independent of any earnings from the individual student's actions during that round. Students are aware of the number of rounds they will be playing in the control and the treatment. The instructor could withhold information on number of rounds to be played to mimic an infinitely repeated version of the game and avoid end-game effects.

The trees and leaves regenerate throughout the game. At the end of each round, for every five trees standing, one tree is added to the forest. All leaves harvested during a round regrow for the next round. The game continues for ten rounds or until there are no more trees remaining. The total time for the game when playing with five students per group is approximately 45 minutes. Larger groups may require more time to work through each round. The earnings in the game are denoted in tokens. If desired, the instructor could convert the total earnings into bonus points at a pre-announced rate or award them based on the student's profit in a randomly chosen round.[5]

4 Instructor and Student Tasks

When conducted in person, the instructor will need the following resources to carry out the game:

1. Game Instructions (See Appendix A: Game Instructions/Student Handout)
2. Game board, options include:

[4] See Appendix D: Suggested Reading List.

[5] The instructor could use a rate of 0.0005 where 2,000 tokens earned in the game will correspond to 1 bonus point. The Excel workbook has a built-in tool for randomly choosing a round to award students. See the "Round chosen for payment" sheet in the "Payoffs Calculation" Excel file (available upon request to the editor).

- o Magnetic white boards: The necessary size depends on the number of players in a group, which determines the size of the initial stock. We use a 26- × 34-inch board for an initial stock of fifty trees.
  - Whiteboard tape is useful to separate the board into slots that will contain the trees and leaves.
  - Two different colors of magnets should be used to represent the resources. Each slot on the whiteboard must fit two of the magnets.
- o Chalkboard or dry erase board: The easiest way to use an existing classroom board would be to use two different color Post-it notes to represent the two resources. Alternatively, the instructor could use two different colored pieces of chalk or dry erase markers and mark/erase each slot as required for regeneration and harvest.
- o Excel file: In both in-person and online classrooms, the instructor can use the provided Excel file[6] projected in the classroom or shared in the course's learning management system.

3. A computer with the payoff calculations Excel file to record students' earnings
4. Payoffs tables (Table 1 in Appendix A: Game Instructions/Student Handout) for students
5. Decision recording sheets for students (Tables 2 and 3 in Appendix B: Student Decision Recording Sheet)
6. Snacks or any other incentives if playing the game for prizes other than bonus points (optional)

The instructor's tasks are to:

1. Present the game instructions
2. Assign students to groups
3. Collect decisions each round and record them into the Excel spreadsheet
4. Determine if the conservation threshold is met for PES and communicate this to students
5. Using the spreadsheet, determine regrowth of trees and communicate new stock to students

At each round, the students must (i) decide the quantity of timber and/or leaves to harvest; (ii) submit their decisions to the instructor (without sharing with other students) and record on their own decision recording sheet; and (iii) calculate their profit (including PES if applicable). The game is designed to accommodate different course levels (introductory, intermediate, and higher) with some variation in students' tasks. With an introductory level course, the instructor can provide the students with the decision recording spreadsheet containing all formulas. Students will merely enter their harvest choices at each round and automatically see their earnings (no calculations required). In an intermediate level course, the instructor can provide students with the price and cost functions. The students will have to determine their profit function and earnings. For a higher-level course, the students can create their own PES schemes to implement in treatment rounds.[7]

[6] The editor will share them upon request.

[7] PES schemes can be designed around one or multiple dimensions, such as the amount provided (high vs. low), the payment mechanisms (lump sum vs. recurrent payments; individual vs. group payments), the payment forms (vouchers exchanged for goods vs. direct cash transfers), and so on. In a graduate level course, students can be asked to explore those dimensions to come up with a variant of the treatment phase presented in this paper.

5 Game Outcomes

Across all courses in which the game was played, thirty-five students played the game. On average, the forest was depleted after the fourth round during the control rounds. The main strategy used by students was that of a profit maximizer. As in a finitely repeated game, they start by harvesting on average four units of trees, which quickly lead to the extinction of the resources. In the treatment rounds, the game extended on average to the eighth round (Figure 2). The trend is the same for the leaves (Figure 3) since their harvest is contingent on standing trees. By the third round in the treatment, the quantity of trees harvested decreased from an average of 3.5 units to 1.5 units (Figure 2). Meanwhile, the quantity of leaves harvested increased from an average of 2 units to 3.5 units and stayed around an average of 2.5 units for the remaining rounds (Figure 3). This change of focus in the game results helped to point out that for multipurpose species, the use of PES could shift the pressure from one product to another. Therefore, to be effective, PES ought to include all harvestable products in their design.

In the best-case scenario, we would expect the resource to remain by the tenth round under the PES treatment. However, this was not the case for various reasons. Several reasons include:

- Students were aware of the number of rounds of play at the beginning of the game. While they sustained low harvests in the early rounds, the impending end of the game disincentivized cooperation in later rounds.[8]
- While some players reduced their harvesting rate, others were free riding on their conservation actions. As a result, the "altruistic" players retaliated by readjusting their strategy.
- Several unexpected strategies occurred during the game, as well. For instance, one player was overharvesting trees based on their own profit, receiving negative profit, with the hope of forcing the rest of the group to harvest less for a continued bonus gain throughout the treatment rounds in the game. This attempt never succeeded.

To keep the activity simple, we did not account for the ecological dynamic between the two products in the regrowth mechanism of the game. This could be an interesting addition to use in higher level courses, where tree regeneration would depend on the stock of leaves.

Given that the activity is around natural resources, a common curveball observed was that some students behaved altruistically in the control rounds, which reduced the observed effect of the PES treatment. The strategies used generally generate a lively debate about altruistic behavior versus self-interest. In theory, to earn more during the treatment rounds, players must cooperate, and each player must harvest below the Nash equilibrium and trust the other players will have the same strategies. A larger magnitude of the reward at the end of the game would hinder such altruistic behavior if the instructor preferred to illustrate a truly noncooperative game.

[8] To better understand interaction in an ongoing resource management scenario, the instructor may want to focus analysis on rounds from the middle of the game before any end-of-game effects take hold.

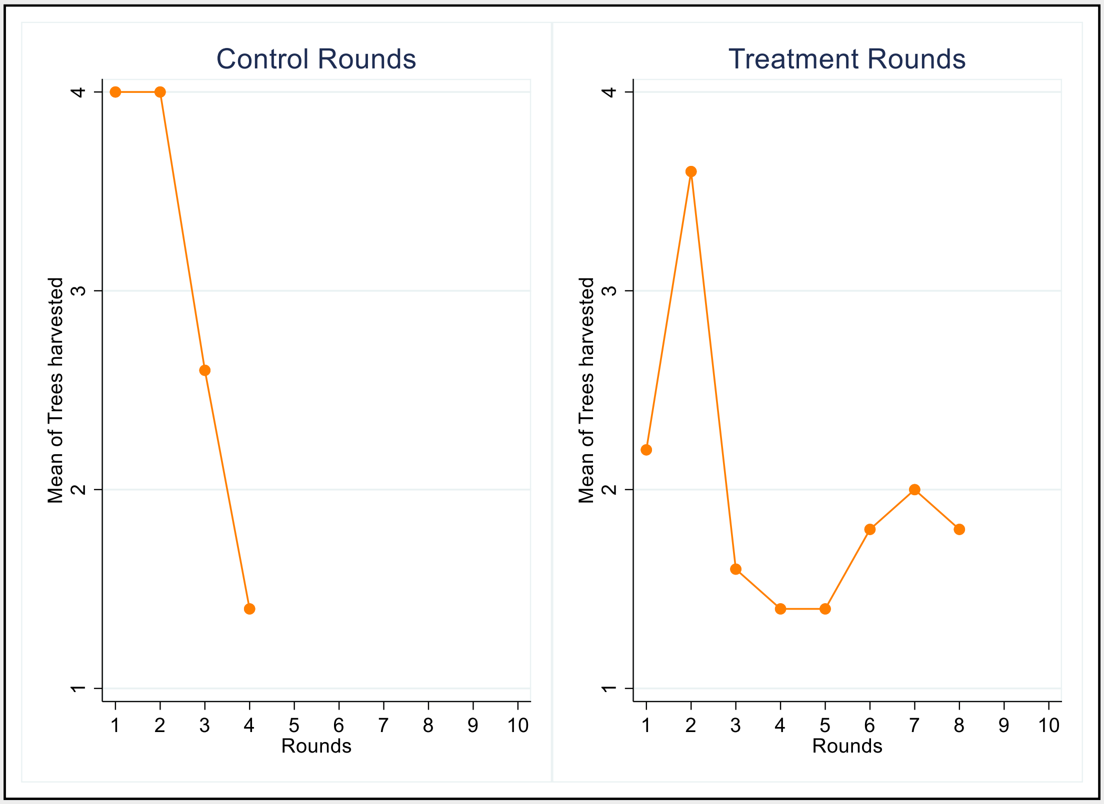

Figure 2. Average Harvest Trends of Trees

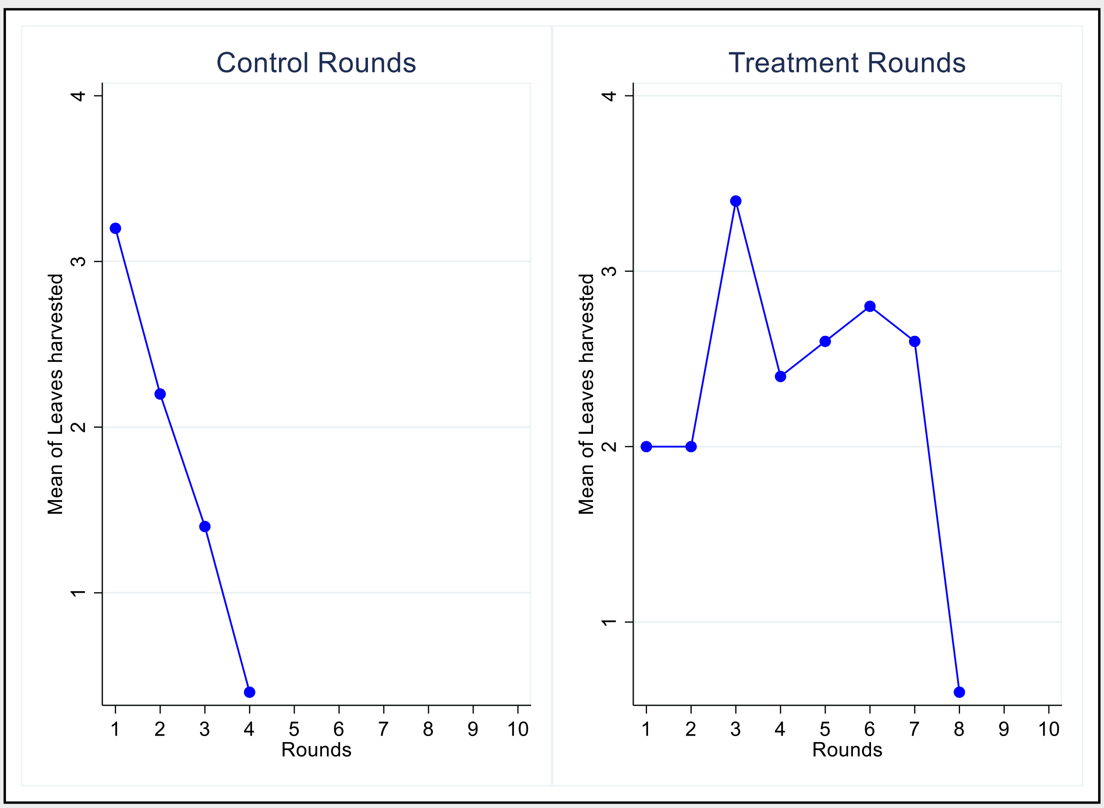

Figure 3. Average Harvest Trends of Leaves

6 Conclusion

This activity creates the opportunity for students to understand the rationale behind and some of the challenges of payments for ecosystems services. In addition, it introduces the students to the concept of multipurpose species, which is common in many ecosystems. Through the exercises, the students get to analyze how individual and group harvest decisions can affect species population dynamics and create environmental challenges. They are also exposed to the implementation of a PES scheme, leading to their assessment of how the approach can be effective or not. We believe the debriefing questions (see Appendix C: Post-Game Activities) offer a great platform for encouraging critical thinking and reaching the learning objectives. The game was successfully implemented in-person, but it can be easily adapted to an online classroom.[9] The game also has the potential to fit in various course levels. Different formats can be designed around the PES scheme for the treatment rounds. The PES could be based on proportional individual payments rather than group equal payments. It could also include a lump sum disbursement rather than recurrent payments throughout the rounds.

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[9] We have provided supplementary materials to run the game online using video conferencing software. The editor will share them upon request.

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Appendix: Game Materials

This appendix contains the following documents

A. Game Instructions/Student Handout
B. Student Decision Recording Sheet
C. Post-Game Activities
D. Suggested Reading List
E. Forest Resource Spreadsheet for Instructor
F. Payoffs Calculation Spreadsheet for Instructor
G. Payoffs Calculation Spreadsheet for Student

The Excel spreadsheets for Appendices E, F, and G are available upon request online through AETR.

Appendix A: Game Instructions/Student Handout

Overview:

In tropical ecosystems, forests are used for both their timber products and nontimber products (i.e. fruits, leaves, barks, seeds, etc.). Various species are harvested for both timber and nontimber products, and the harvest of one product could affect the other. For instance, overharvesting of leaves can influence the growth of the tree or overharvesting the seeds/fruits could affect the species' population dynamic. Species in these multiharvest situations are under higher human pressures.

In this game, students harvest from the same forest resource. Each tree in this forest produces two different valuable products: timber and leaves. During each round of the game, each student must choose the quantity of both resources to harvest for profit. The forest is a renewable resource, meaning that trees and leaves can grow back. The game also integrates a payment for ecosystem services (PES), which compensates the entire group of forest users if certain conservation targets are met in a given round.

Time estimate: 30–45 minutes to play

Number of participants: 5 players[10] and 1 moderator

Student learning objectives:

1. Calculate individual and group profit-maximizing harvest decisions
2. Graph group harvest decisions and resource stocks over time
3. Demonstrate the tragedy of the commons in the absence of conservation policies for multipurpose resources
4. Analyze how PES may alter the individual/group harvest decisions and stocks of both timber and nontimber resources

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Introduction:

We are going to participate in a natural resource management game, where you will earn money from harvesting from a forest. Each group will have 5 people who will make decisions on their own about how to use the forest resource. Each group will also have 1 moderator.

The trees in this forest produce two different valuable products that can be harvested to earn points. The first product is the timber from a tree. Timber is a valuable production material used to build and produce other wooden products. The second product is the leaves from a tree. Leaves are a valuable material that can be used as mulch, biomass, or even as an ingredient in animal feed/fodder.

Forest setup and harvesting:

The forest from which you harvest has a beginning stock of 50 trees. Each tree is represented by two colored markers or colored Excel cells. One color represents the timber and the other represents the leaves on the tree.

During each round of the game, you will individually and privately select the quantity of trees to harvest and the quantity of trees from which to harvest leaves. If you harvest a tree, you automatically harvest the leaves, too. However, it is possible to only harvest the leaves without harvesting the tree.

[10] Note, this game can be easily adapted for different numbers of players. We recommend setting the initial stock of the forest (i.e. number of trees) equal to the number of forest managers multiplied by 10. The PES threshold should then be set to 70 percent of this value, rounded to the nearest whole tree.

Payoffs:

Table 1 shows your earnings in points based on the number of trees and the number of leaves you choose to harvest.

Table 1: Payoffs from harvesting leaves and trees

Timber		**Leaves**	
Units	**Net Profit**	**Units**	**Net Profit**
1	600	1	40
2	1,100	2	80
3	1,400	3	110
4	1,600	4	130
5	1,500	5	150
6	1,300	6	140
7	1,200	7	140
8	800	8	120
9	200	9	120
10	-500	10	100

For example, in a given round if you choose to harvest two trees with leaves and harvest leaves from three additional trees, you would then have harvested a total of 2 units of timber for 1,100 points and 3 units of leaves for 110 points. Your total earnings in this round would be 1,210 points.

Submitting harvest decisions:

Without talking to other members of your group, you will decide the number of trees you would like to harvest and the number of leaves to harvest. Submit these to your moderator without revealing your decisions to others.

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 payoff tables (**Table 1**).

If the players in the group submit harvest decisions that are greater than the remaining number of trees or leaves, the moderator will evenly divide the available resource among the 5 players, and any remainder will be discarded.

Stages of game and forest regrowth:

There will be two stages of this game, each consisting of 10 rounds. You can think of a round as equivalent to a year or harvesting season.

The forest will grow at the end of each round. For every 5 trees standing (with or without leaves), 1 tree will be replenished and added back to the game board. Any leaves harvested grow back during the next round.

If there are less than 5 trees remaining, no additional trees will grow, and the game ends.

End of round:

At the end of each round, the moderator will show you the forest and announce:

1. Total number of trees harvested
2. Number of trees from which leaves were harvested by the group
3. Number of trees in the forest after regrowth

If you have read and understand all of the instructions above, you may now begin Stage 1 of the game. Use the decision sheet (Table 2 in Appendix B: Student Decision Recording Sheet) to record all of your decisions in the game and track your earnings.

Stage 1 will last for 10 rounds or until the resource is depleted, whichever comes first.

Payments for ecosystem services and forest management:

Now suppose that because of concerns about resource depletion, the government has decided to implement a payment for ecosystem services (PES) program, which rewards groups of forest managers for not overusing the forest.

The PES program works as follows. In addition to earnings from your individual harvest decisions, the government is offering a bonus payment of 2,500 points to be split equally among all players if there are **at least 35 trees** still standing at the end of a round.

Each player in the group will receive an equal share, 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 bonus payment.

For example, suppose that each of the participants in your group harvests 2 trees. At the end of the round, the moderator would announce that 10 trees (2 trees × 5 managers) were removed, leaving 40 trees in the forest. Since the remaining number of trees is greater than the 35 trees threshold, each member will earn an additional 500 tokens on top of the 1,100 tokens profit they make from each harvesting 2 trees.

All other characteristics of the forest, payoffs, and rules of the game remain the same.

If you have read and understand all of the instructions above, you may now begin Stage 2 of the game. Use the decision sheet (Table 3 in Appendix B: Student Decision Recording Sheet) to record all of your decisions in the game and track your earnings.

Stage 2 will last for 10 rounds or until the resource is depleted, whichever comes first.

Appendix B: Student Decision Recording Sheet

Table 2: Forest Manager Decision Sheet (Stage 1)

ROUND NO.	QUANTITY OF TIMBER HARVESTED	QUANTITY OF LEAVES HARVESTED	EARNINGS FROM TIMBER	EARNINGS FROM LEAVES	TOTAL EARNINGS
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Table 3: Forest Manager Decision Sheet (Stage 2)

ROUND NO.	QUANTITY OF TIMBER HARVESTED	QUANTITY OF LEAVES HARVESTED	EARNINGS FROM TIMBER	EARNINGS FROM LEAVES	PES BONUS	TOTAL EARNINGS
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Appendix C: Post-Game Activities

Individual and group data analysis:

1. Graph your individual harvest decisions for trees and leaves over the rounds of the game. Create a separate graph for Stage 1 and Stage 2. Place units harvested on the vertical axis and rounds on the horizontal axis.
2. Using data collected from your group, calculate and graph the average group harvest for trees and leaves over the rounds of the game. Create a separate graph for Stage 1 and Stage 2. Place units harvested on the vertical axis and rounds on the horizontal axis.
3. Using a new graph, plot the stock of trees in the forest over the rounds of the game for Stage 1 and Stage 2.

Discussion questions:

1. How did individual and group decisions compare to what you might expect based on traditional microeconomic theory? What might explain any divergences?
2. How well did groups sustain cooperation in Stage 1 vs. Stage 2 of the game? Why?
3. How might the government make the PES program more effective? What would be the tradeoffs associated with these changes?
4. Other than forests, what types of environmental and natural resource problems do you think could be managed using PES programs? What might be some of the challenges?

Appendix D: Suggested Reading List

1. Hardin, G. 1968. “The Tragedy of the Commons.” *Science* 162(3859):1243–1248.
2. Feeny, D., F. Berkes, B.J. McCay, and J.M. Acheson. 1990. “The Tragedy of the Commons: Twenty-Two Years Later.” *Human Ecology* 18(1):1–19.
3. Ostrom, E. 2009. “Social-Ecological Systems: A General Framework for Analyzing Sustainability of Social-Ecological Systems.” *Science* 325(5939):419–422.

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