

Spatial incentives to upscale the benefits of tree islands in smallholder oil palm plantations in Indonesia: Evidence from a spatially explicit coordination game

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Background

EFForTS-BEE

(Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems-biodiversity enrichment experiment)

- Established and monitored 52 tree islands and 4 reference control plots
- Oil palm yields and ecological indicators
- In an industrial oil palm plantation in Jambi, Indonesia since 2013.

Tree island size

- Larger tree islands → greater biodiversity and ecosystem-function benefits (Zemp et al., 2023)
- Habitat configuration matters as much as total habitat amount (Kremen et al., 2007; Tschardt et al., 2012)
- Smallholder plots are too small to host large tree islands alone

Coordination for large tree islands

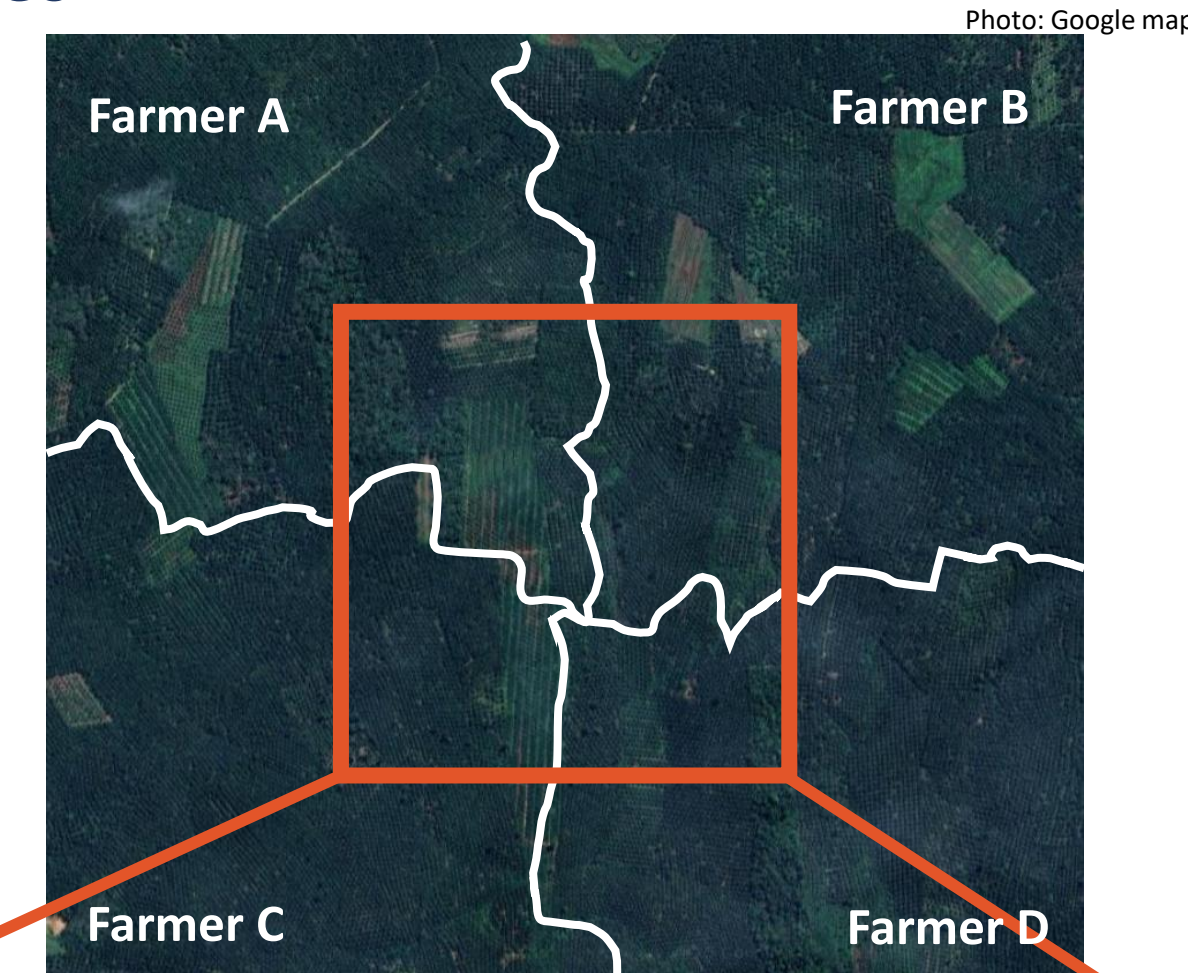
- Larger tree islands require pooling land across neighboring farms
- Conventional PES rewards individual action only — not spatial arrangement (Nguyen et al., 2022)



Tree islands of EFForTS-BEE:
Islands in different sizes ($25\text{ m}^2 \sim 160\text{ m}^2$) of native trees and natural vegetation without any chemical inputs.

Coordination Game to test Payments for Ecosystem Services (PES)

- Research question: which PES designs best promote coordinated tree-island placement?
- Framed lab-in-the-field experiment: Spatially explicit game to compare different policy incentives



Methods

Coordination Game

(Tablet screen of farmer A)

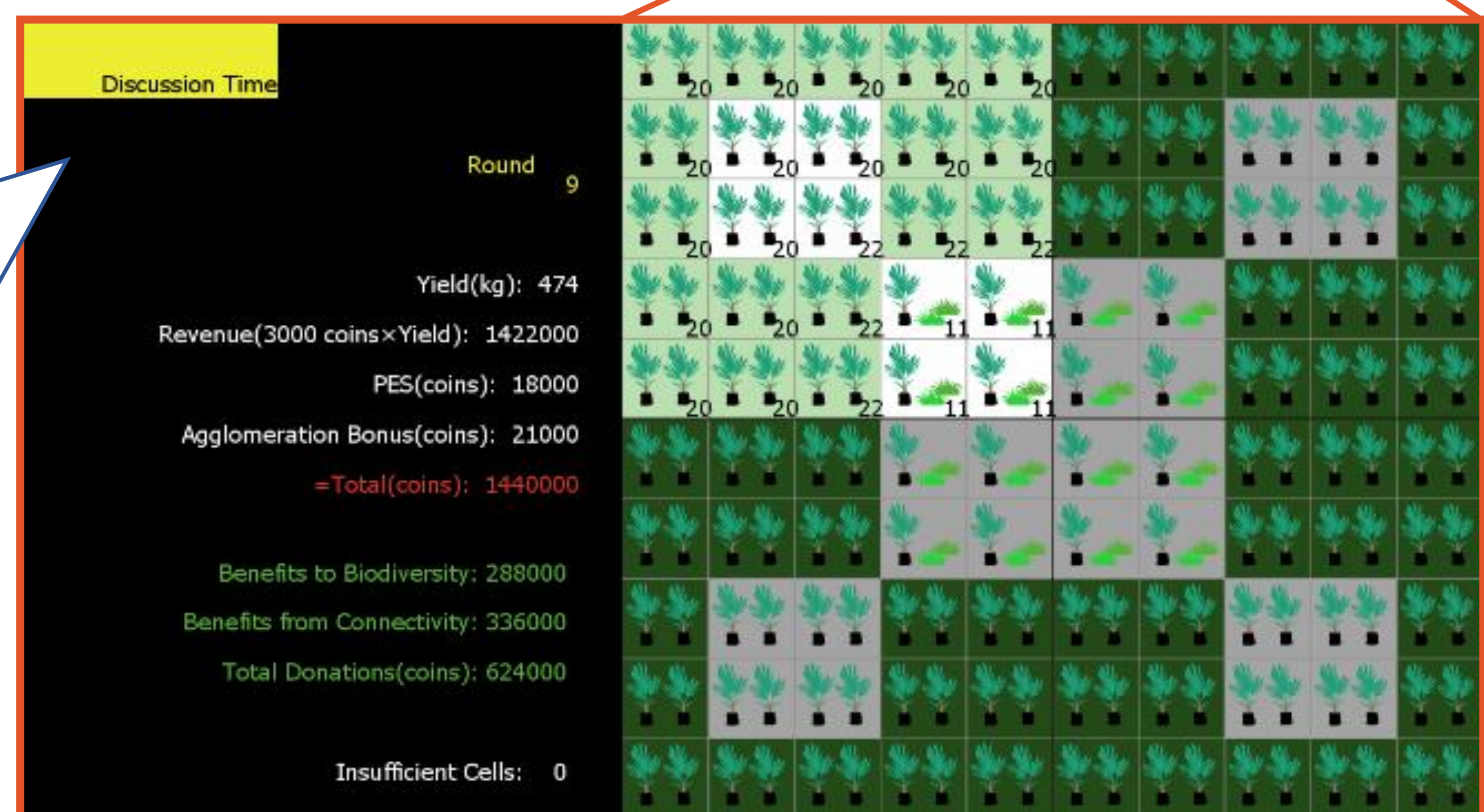
- 4-player** groups; each manages a 5×5 stylized oil palm plot
- 8 cells in white are convertible to tree islands per player
- Tree islands: lowers own yield, raises neighboring cells' yield
- Environmental donation** triggered at 16 group-wide tree islands; larger donation if centrally clustered
- Each round: Discussion → Decisions privately → See results
- 12 rounds** in total

Treatment groups

Treatment groups	Rounds		
	1-4 (Baseline stage)	5-8 (PES stage)	9-12 (Bonus stage)
Control (N=140)	none	none	none
Conventional payment (N=140)	none	Conventional payment	Conventional payment + Agglomeration bonus
Size-threshold payment (N=140)	none	Size-threshold payment	Size-threshold payment + Agglomeration bonus

Conventional payments	Size-threshold payments	Agglomeration bonus
\$ per 🌴 (No spatial coordination, No strategic uncertainty)	\$ per 🌴 if 🌴 > 16 (No spatial coordination)	<u>Bonus</u> if spatially arranged 🌴 🌴 🌴 🌴 🌴 🌴 🌴 🌴 🌴

At the end of the 12 rounds, one round was randomly selected for payment



Study site and sample

420 randomly selected smallholder oil palm farmers from 18 villages in Jambi, Indonesia

Figure: Map of the study area, showing Jambi province within Indonesia (left panel) and the distribution of sample villages across Jambi's regencies (right panel). Regency borders are delineated by solid lines; the hatched polygon denotes the city of Jambi.

Results

Number of tree islands

- Both PES designs increase the number of tree islands vs. Control
- Agglomeration bonus leads to significantly more islands specifically in the center (the contiguous-cluster zone)

Success of size-threshold and agglomeration

- PES stage: Size-threshold payment significantly raises threshold success
- Bonus stage: Tree-island placement concentrates toward the center

Analytical approach:

- At the group level, one observation per group per round
- For the binary outcomes, we estimate random-effects panel probit models, including the lagged dependent variable, village fixed effects, and robust standard errors, with an interaction of treatment and stage to identify effects within each experimental phase.
- Marginal effects and pairwise comparisons obtained through post-estimation contrasts

Size-threshold and agglomeration success

	Threshold success		Connectivity success	
	PES	Bonus	PES	Bonus
Conventional payment vs Control	0.103 (0.069)	0.222*** (0.074)	0.026 (0.033)	0.274*** (0.060)
Threshold payment vs Control	0.235*** (0.069)	0.261*** (0.075)	0.005 (0.031)	0.209*** (0.060)
Threshold payment vs Conventional payment	0.132* (0.065)	0.039 (0.080)	-0.21 (0.036)	-0.064 (0.072)
Observations	1,188	1,188	1,188	1,188

Share of cells converted to tree islands by stage and treatments

