

The inequities of human-elephant coexistence: Deterrent strategies and crop protection costs in Thailand

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Online Resource 1. Supplementary Tables S1–S8 containing deterrent descriptions, descriptive sample summaries and statistical model and post hoc results.

Table S1. Deterrent categories and site-specific descriptions based on local implementations in Ruam Thai Village, Thailand.

Deterrent	Description
Night guarding	Overnight field guarding using human presence and auditory cues (e.g. shouting, clapping) to deter elephants and prevent crop damage.
Electric fence	Electrified wire (1–2 strands) connected to bamboo/wood vertical posts. Powered by a 12-V battery, typically solar-charged.
Firecrackers	Small explosive devices (“ping-pong bombs”) deployed by hand or slingshot to deter elephants with a loud bang.
Spinning lights/spotlights	Solar-powered lights that flash/rotate continuously or trigger via motion sensor.
Bottle fence	Glass bottles (2–3) hung at approximately 10 m intervals on rope or wire around field perimeters to produce an audible alert when disturbed.
Siren system	A perimeter rope line connected to a trip-wire alarm switch that activates when the line is disturbed.
Trench	A deep, narrow ditch, approximately 3 m deep, dug along the park border or around individual farms to prevent entry by elephants.

Table S2. Descriptive characteristics of household survey respondents (N = 223) in Ruam Thai Village, Thailand, including demographics, number of farms managed, perceived ability to coexist with elephants and frequency of elephant encounters.

Characteristic	n	%
Gender		
Male	129	57.8%
Female	94	42.2%
Age		
18-25	6	2.7%
26-35	18	8.1%
36-45	57	25.6%
46-55	75	33.6%
56-65	50	22.4%
66+	17	7.6%
Number of farms		
1	150	67.3%
2	64	28.7%
3	9	4.0%
Perceived ability to coexist with elephants		
Can coexist	50	22.4%
Can not coexist	173	77.6%
Frequency of elephant encounters		
Never	17	7.6%
Less than once per month	62	27.8%
Once per month	44	19.7%
Once per week	44	19.7%
Several times per week	36	16.1%
Every night	20	9.0%

Table S3. Descriptive characteristics of farm profiles from the household survey conducted with 223 farmers in Ruam Thai Village, Thailand (N = 305 farm profiles), including crop species, plot size (rai), deterrent types used, number of deterrents used, and elephant-caused economic loss (THB). Plot size was reported for n = 251 farm profiles. Percentages do not sum to 100% because multiple deterrents could be reported for a single farm profile.

	n	%
Crop species		
Pineapple	157	51.5%
Rubber	62	20.3%
Mango	46	15.1%
Jackfruit	29	9.5%
Oil palm	11	3.6%
Plot size (rai)		
Median (range)	10 (1–20)	–
≤5	77	30.7%
>5–10	138	55.0%
>10–15	19	7.6%
>15	17	6.8%
Deterrent type		
Night guarding	200	65.6%
Electric fence	176	57.7%
Firecrackers	144	47.2%
Spinning lights/spotlights	103	33.8%
Bottle fence	90	29.5%
Siren system	17	5.6%
Trench	12	3.9%
Gunshots	0	0.0%
Deterrent quantity		
Median (range)	2 (0–6)	–
0	52	17.0%
1	38	12.5%
2	66	21.6%
3	65	21.3%
4	53	17.4%
5	21	6.9%
6	10	3.3%
Elephant-caused economic loss		
No loss (0)	84	27.5%
Low loss (<25,000)	194	63.6%
High loss (≥25,000)	27	8.9%

Table S4. Summary of tests for the crop species $\times$ plot size interaction across deterrent strategies, including the number of deterrents and presence/absence of each deterrent type. The table reports interaction term p -values and asterisks (*) indicate statistical significance ($\alpha = 0.05$). For significant interactions, model-predicted responses at 5 rai and 10 rai are reported for each crop species with 95% confidence intervals. These plot sizes represent the 25th percentile (5 rai) and median (10 rai) in the sample. Post hoc pairwise comparisons are shown using Tukey tests with Bonferroni correction. Blank cells indicate non-significant interactions.

Response	Interaction term p-value	Crop species	Predicted at 5 rai	95% CI at 5 rai	Predicted at 10 rai	95% CI at 10 rai	Direction of prediction	Post hoc groupings	Units/scale
Number of deterrents	0.014*	Pineapple	2.32	2.03–2.65	2.65	2.37–2.96	Increase	Pineapple = Rubber = Mango = Jackfruit > Oil palm	Predicted mean count
		Rubber	2.14	1.84–2.49	2.25	1.84–2.75	Increase		
		Mango	2.23	1.89–2.63	2.44	1.86–3.20	Increase		
		Jackfruit	2.24	1.81–2.78	2.48	1.66–3.70	Increase		
		Oil palm	1.50	1.02–2.19	1.10	0.53–2.30	Decrease		
Night guarding	0.015*	Pineapple	71.70	60.56–80.72	87.40	79.21–92.65	Increase	Pineapple = Rubber = Mango = Jackfruit > Oil palm	Predicted probability (%)

Response	Interaction term p-value	Crop species	Predicted at 5 rai	95% CI at 5 rai	Predicted at 10 rai	95% CI at 10 rai	Direction of prediction	Post hoc groupings	Units/scale
		Rubber	56.60	42.53–69.70	64.70	47.12–79.08	Increase		
		Mango	57.30	42.41–71.02	66.00	41.43–84.25	Increase		
		Jackfruit	65.00	44.86–80.95	78.80	43.57–94.73	Increase		
		Oil palm	20.40	5.62–52.32	6.58	0.41–54.66	Decrease		
Electric fence	0.255								
Firecrackers	0.010*	Pineapple	0.21	0–22.91	47.10	1.28–98.40	Increase	Pineapple > Rubber = Mango = Jackfruit = Oil palm	Predicted probability (%)
		Rubber	0.00	0–0.86	0.01	0–2.25	Increase		
		Mango	0.01	0–2.59	0.08	0–91.94	Increase		
		Jackfruit	0.00	0–9.81	0.03	0–99.86	Increase		
		Oil palm	0.00	0–9.91	2.15E-07	0–99.51	Increase		
Spinning lights/spotlights	0.736								

Response	Interaction term p-value	Crop species	Predicted at 5 rai	95% CI at 5 rai	Predicted at 10 rai	95% CI at 10 rai	Direction of prediction	Post hoc groupings	Units/scale
Bottle fence	0.950								
Siren system	1.000								
Trench	0.625								

Table S5. Likelihood-ratio (LR) χ^2 tests from multinomial logistic regression models evaluating associations between economic loss category (high loss, low loss and no loss) and two sets of predictors: Model 1 (plot size and number of deterrents) and Model 2 (presence/absence of individual deterrent types). Outcomes are reported as LR χ^2 values (p) with $df = 2$ for all tests. Asterisks (*) indicate significant relationships ($\alpha = 0.05$). Dashes (–) indicate predictors not evaluated because of insufficient coverage across economic loss categories.

Predictor	Pineapple (n = 157)	Rubber (n = 62)	Mango (n = 46)	Jackfruit (n = 29)	Oil palm (n = 11)
Model 1: Farm-level predictors					
Plot size (rai)	0.028 (0.986)	4.082 (0.130)	1.327 (0.515)	0.774 (0.679)	8.814 (0.012)*
Number of deterrents	42.502 (<0.001)*	10.950 (0.004)*	21.697 (<0.001)*	10.473 (0.005)*	6.308 (0.043)*
Model 2: Deterrent presence/absence predictors					
Night guarding	7.870 (0.020)*	0.746 (0.689)	0.924 (0.630)	0.436 (0.804)	0.001 (0.999)
Electric fence	2.085 (0.353)	3.174 (0.205)	1.372 (0.504)	3.076 (0.215)	0.001 (0.999)
Firecrackers	6.997 (0.030)*	4.633 (0.099)	5.748 (0.056)	4.699 (0.095)	–
Spinning lights/spotlights	1.338 (0.512)	4.002 (0.135)	3.035 (0.219)	5.167 (0.076)	0.001 (0.999)
Bottle fence	1.070 (0.586)	7.621 (0.022)*	0.247 (0.884)	2.447 (0.294)	0.001 (0.999)
Siren system	3.900 (0.142)	–	1.936 (0.380)	2.062 (0.357)	–
Trench	2.497 (0.287)	3.187 (0.203)	0.913 (0.634)	0.000 (0.999)	–

Table S6. Summary of post hoc results from Likelihood-ratio (LR) χ^2 tests (Table S5) for economic loss in relation to farm characteristics (crop species and plot size) and deterrent strategies (number of deterrents and presence/absence of deterrent types). Blank cells indicate non-significant relationships ($\alpha = 0.05$), whereas populated cells show statistically significant results. Post hoc Tukey comparisons with Bonferroni correction are reported, including estimated means (for number of deterrents and plot size) or probabilities (%) (for presence of deterrent types) $\pm$ their respective standard errors. Symbols $>$ and $=$ denote post hoc groupings and directionality of loss categories. A dash (–) indicates categories with insufficient data to estimate values. The $\wedge$ symbol indicates statistically significant differences between variables where post hoc tests could not be conducted due to insufficient sample sizes; means $\pm$ standard errors are still presented.

Predictor	Pineapple (n = 157)	Rubber (n = 62)	Mango (n = 46)	Jackfruit (n = 29)	Oil palm (n = 11)
Model 1: Farm-level predictors					
Plot size (rai)					$\wedge$ No Loss (9.4 ± 1.2) Low Loss (4.5 ± 1.8) High Loss ($5.0 \pm -$)
Number of deterrents	High Loss (4 ± 0.6) $>$ Low Loss (3 ± 0.1) $>$ No Loss (2 ± 0.2)	High Loss (2 ± 1.0) $=$ Low Loss (2 ± 0.2) $>$ No Loss (1 ± 0.3)	Low Loss (3 ± 0.3) $>$ High Loss (2 ± 0.3) $>$ No Loss (1 ± 0.3)	Low Loss (3 ± 0.5) $=$ High Loss (3 ± 1.2) $>$ No Loss (1 ± 0.4)	$\wedge$ No Loss (0 ± 0.4) Low Loss (2 ± 1.2) High Loss ($2 \pm -$)

Predictor	Pineapple (n = 157)	Rubber (n = 62)	Mango (n = 46)	Jackfruit (n = 29)	Oil palm (n = 11)
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Model 2: Deterrent presence/absence predictors

Night guarding

High Loss (100.0 ± 0.0%)
 =
 Low Loss (94.4 ± 2.5%)
 >
 No Loss (45.9 ± 8.3%)

Electric fence

Firecrackers

High Loss (80.0 ± 20.0%)
 =
 Low Loss (69.7 ± 4.9%)
 >
 No Loss (18.9 ± 6.5%)

—

Spinning lights/spotlights

Predictor	Pineapple (n = 157)	Rubber (n = 62)	Mango (n = 46)	Jackfruit (n = 29)	Oil palm (n = 11)
Bottle fence		Low Loss (40.0 ± 9.1%) > No Loss (0.0 ± 0.0%) = High Loss (0.0 ± −)			
Siren system		—			—
Trench					—

Table S7. Descriptive characteristics of pineapple farmers interviewed in Ruam Thai Village, Thailand (N = 71), including demographics, farm distance to Kuiburi National Park's border, elephant encounter frequency, deterrent investment (THB/rai/harvest), elephant-caused yield loss and night guarding effort. Continuous variables are summarised using median (range) or mean $\pm$ SD based on distribution. Categories for distance, deterrent investment, yield loss and guarding effort were created for descriptive purposes only, as continuous values were used for all statistical analyses.

Characteristic	n	%
Gender		
Male	31	43.7%
Female	40	56.3%
Age		
26–35	3	4.2%
36–45	20	28.2%
46–55	27	38.0%
56–65	15	21.1%
≥ 66	6	8.5%
Distance to protected area (m)		
Median (range)	1,000 (20–2,000)	–
1–500	24	33.8%
501–1,000	19	26.8%
1,001–1,500	16	22.5%
1,501–2,000	12	16.9%
Elephant encounter frequency		
Never	11	15.5%
Less than once per month	4	5.6%
Once per month	9	12.7%
Once per week	21	29.6%
Several times per week	10	14.1%
Every night	16	22.5%
Deterrent investment (THB/rai/harvest)		
Median (range)	221 (0–30,501)	–
0	12	16.9%
1–500	36	50.7%
501–2,500	19	26.8%
2,501–10,000	2	2.8%
>10,000	2	2.8%
Elephant-caused yield loss (%)		
Median (range)	2.3 (0.0–96.6)	–
0	20	28.2%
0.1–20	36	50.7%
20.1–40	8	11.3%
40.1–60	4	5.6%
60.1–80	1	1.4%
80.1–100	2	2.8%
Night guarding effort (%)		
Mean $\pm$ SD	33.0 $\pm$ 43.0	–
0	22	31.0%
0.1–20	25	35.2%
20.1–99.9	5	7.0%
100	19	26.8%

Table S8. Likelihood-ratio (LR) χ^2 tests from two models evaluating crop protection practices in relation to elephant exposure and impact predictors: (1) financial investment in deterrents (THB/rai/harvest) and (2) night guarding effort (%). For each model, the table reports LR χ^2 statistics, degrees of freedom (df) and p-values for distance to the protected area (PA), elephant encounter frequency and proportion of yield lost to elephant-caused crop damage. Asterisks (*) indicate significant relationships ($\alpha = 0.05$).

Predictor	LR χ^2	df	p
Model 1: Financial investment in deterrents (THB/rai/harvest)			
Distance to the PA	0.07	1	0.800
Elephant encounter frequency	13.55	5	0.019*
Elephant-caused yield loss	8.24	1	0.004*
Model 2: Night guarding effort (%)			
Distance to the PA	5.06	1	0.024*
Elephant encounter frequency	10.00	5	0.075
Elephant-caused yield loss	11.22	1	<0.001*