Appendix 1. Supporting methods and results.

A1.1. Matching method

Comparison of median standardized bias (MSB) between covariate matching using Mahalanobis distance versus propensity scores.

Table A1.1.1: Comparison of median standardized bias (MSB) between propensity score and covariate matching using Mahalanobis distance. Standardized bias is the absolute value of the difference of means in the treated and matched control subsamples as a percentage of the square root of the average sample variance in both groups. See Table 1 for variable definitions.

Matching Estimator	Rice ratio	Log avg. slope	% tree cover (2000)	Log avg. mkt. influence	Log avg. pop. density (2000)	Median
Mahalanobis distance	0.5266	0.5811	0.2228	0.0728	0.0048	**0.2228**
Propensity score	0.0974	0.0583	0.0407	0.0262	0.0727	**0.0583**

A1.2. Bias balance

Bias balance assessment among treated and untreated communes, and among matched pair stratifications.

Table A1.2.1. Covariate means for treatment and control group before and after propensity score matching

	Rice ratio		Log avg. slope		% tree cover (2000)		Log avg. mkt. influence		Log avg. pop. density (2000)	
Group	T	C	T	C	T	C	T	C	T	C
Unmatched	29.02	48.99	1.60	1.40	40.20	42.49	6.7315	6.8958	4.6702	4.8558
Matched	29.02	31.45	1.60	1.5779	40.20	41.13	6.7315	6.7018	4.6702	4.5982

Table A1.2.2. Stratification balance based on ELC crop group* between matched treatment and control communes

	Rice ratio		Log avg. slope		% tree cover (2000)		Log avg. mkt. influence		Log avg. pop. density (2000)	
Group	T	C	T	C	T	C	T	C	T	C
Crop 1	23.85	23.54	1.68	1.59	39.10	45.02	6.3081	6.1402	4.33	4.23
Crop 2	38.07	34.01	1.48	1.44	36.89	35.02	7.0581	6.9271	5.19	5.03
Crop 3	27.35	34.88	1.61	1.64	42.60	42.02	6.8146	6.9218	4.60	4.83

* Crop group: 1 = rubber; 2 = cassava, oil palm, sugar, cashew, teak; 3 = unknown

** No statistically significant differences among treatment and control means

Table A1.2.3. Stratification balance based on rate of ELC land conversion between matched treatment and control communes

	Rice Ratio		Log avg. slope		% tree cover (2000)		Log avg. mkt. influence		Log avg. pop. density (2000)	
Group	T	C	T	C	T	C	T	C	T	C
Rapid	24.90	26.90	1.66	1.63	43.06	38.72	6.64	6.47	4.68	4.51
Gradual or No Change	30.87	33.50	1.567	1.56	38.91	42.22	6.78	6.81	4.67	4.64

** No statistically significant differences among treatment and control means

Table A1.2.4. Stratification balance based on % of province land area in ELC between matched treatment and control communes

	Commune size (ha)		Log avg. slope		% tree cover (2000)		Log avg. mkt. influence		Log avg. pop. density (2000)	
Group	T	C	T	C	T	C	T	C	T	C
< 11%	28.45	37.50	1.5884	1.6472	29.6304	24.1971	7.2099	7.2282	4.6751	4.7972
11-20%	31.41	28.47	1.5884	1.4998	41.2949	44.5637	6.4219	6.3725	4.6785	4.4872
> 20%	26.23	30.36	1.6105	1.6256	47.7489	50.9500	6.7460	6.7022	4.6544	4.5800

** No statistically significant differences among treatment and control means

A1.3. Matching sensitivity analysis

Rosenbaum bounds were calculated using the R package 'rbounds' (Keele 2010) to check for sensitivity of results to unobserved factors that might bias selection into the treatment group (Rosenbaum and Rubin 1983, DiPrete and Gangl 2004, Blackman et al. 2015). Specifically, we used the Rosenbaum procedure adapted for binary outcomes with the test statistic, Γ, ranging from 1.0 to 2.0. Results for national-level matching analysis showed a critical value, Γ^*, above which the results for ATT would no longer be significant at the 5 percent level, of 1.3. In other words, our findings would remain significant with matched pairs differing in their odds of treatment by 30%. Given the likely level of unobserved heterogeneity in a national-level analysis, and combined with a balanced stratification, this is a satisfactory level of sensitivity from which to make preliminary inferences.

Table A1.3.1. Rosenbaum sensitivity analysis results.

Unconfounded p-value estimate		0.0036
Gamma	Lower Bound	Upper Bound
1.0	0.00364	0.00364
1.1	0.00093	0.01199
1.2	0.00023	0.03077
1.3	0.00006	0.06501
1.4	0.00001	0.11775
1.5	0.00000	0.18870
1.6	0.00000	0.27423
1.7	0.00000	0.36845
1.8	0.00000	0.46483
1.9	0.00000	0.55757
2.0	0.00000	0.64234
Note: Gamma is odds of differential assignment to treatment due to unobserved factors		

A1.4. Representativeness assessment

Comparison of distributions of empirical and case study samples for crop type, percent forest cover, …. The number of expected cases was given by multiplying the probability of ELC records per category or percentile by the total sample size of cases derived from case study synthesis. Because of the small sample size (30) and possibility of zero observed cases, Fisher's Exact Test was used to assess whether the observed number of cases was statistically significantly different from the empirical probability of ELC records per category or percentile. Contingency tables were calculated by comparing the expected and observed frequencies of cases for a given category or percentile versus all other categories or percentiles. The null hypothesis was that there are no non-random differences in the distributions of observed and expected values.

Table A1.4.1. Crop Type

Crop Type	Expected	Observed	Reject H_0	p-value
Rubber	15.3363	12	0	0.6042
Cassava	0.9417	1	0	1.0000
Sugarcane	2.0179	5	0	0.4238
Cashew	0.8072	0	0	1.0000
Oil Palm	0.6726	0	0	1.0000
Teak	0.8072	3	0	0.6120
Other or Unspecified	9.4170	9	0	1.0000

Table A1.4.2. Percent forest cover in 2000

% Forest Cover	Expected	Observed	Reject H_0	p-value
0-10	1.3453	2	0	1.0000
11-20	2.4215	2	0	1.0000
21-30	2.8251	2	0	0.6707
31-40	3.0942	2	0	0.6707
41-50	3.9013	4	0	1.0000
51-60	3.3632	6	0	0.4716
61-70	2.6906	2	0	0.6707
71-80	2.5561	1	0	0.3533
81-90	5.3812	4	0	0.7306
91-100	2.4215	5	0	0.4238

Table A1.4.3. Population Density

Log Pop. Density	Expected	Observed	Reject H_0	p-value
0.5-1.029	2.1525	3	0	1.0000
1.030-1.559	2.6906	1	0	0.6120
1.560-2.089	4.7085	4	0	1.0000
2.090-2.619	4.7085	3	0	0.7065
2.620-3.149	7.1300	4	0	0.5062
3.150-3.679	3.3632	5	0	0.7065
3.680-4.209	1.7489	5	0	0.4238
4.210-4.739	1.4798	4	0	0.3533
4.740-5.269	1.6143	0	0	0.4915
5.270-5.800	0.4036	1	0	1.0000

Table A1.4.4. Market Price 2008

Market price for natural rubber was estimated by interacting global commodity price in 2008 with a market influence index (Verburg et al. 2011).

Market Price	Expected	Observed	Reject H_0	p-value
-7.200 to -6.201	1.8834	3	0	1.0000
-6.200 to -5.201	0.8072	1	0	1.0000
-5.200 to -4.201	1.0762	1	0	1.0000
-4.200 to -3.201	1.4798	0	0	1.0000
-3.200 to -2.201	4.8430	4	0	1.0000
-2.200 to -1.201	2.9596	1	0	0.6120
-1.200 to -0.201	4.3049	3	0	1.0000
-0.200 to 0.799	6.5919	4	0	0.5062
-1.200 to 0.799	4.4395	6	0	0.7306
1.800 to 2.800	1.6143	7	0	0.1455

A1.5. Qualitative comparative analysis

Table A1.5.1. Lists of candidate causal conditions of indirect land use change (iLUC)

Causal conditions	Type variable	Sub-category	Operationalization	
			Description/justification	Fuzzy membership score
Land use change rate (LCRATE)	Contextual	Rapid	Rate of land change <= 2 years or described in source as rapid, unexpected, or surprising.	1
		Gradual	Rate of land change > 2 years or described in source as gradual or occurring in multiple phases over time.	0
		None	Confirmation of no land change reported in source	0
Compensation (COMP)	Contextual	Yes	Some form of individual compensation described, for example monetary or land exchange	1
		No	No information described	0
Employment (EMP)	Contextual	Full	Local community members employed in activities related to LSLA	1
		Partial	Only some local community members employed due to insufficient employment opportunities, competition from immigrants, or by choice as form of resistance.	0
		None	No employment opportunities offered through LSLA	0
Displacement (DISP)	Casual	Yes	Description of community displacement and/or out-migration resulting from LSLA	1
		No	No information described	0
Rubber (TREE)	Casual	Yes	LSLA with the presence of rubber	1
		No	Otherwise	0
Immigration (IMM)	Casual	Yes	LSLA has resulted in in-migration, usually from migrants seeking employment	1
		No	No information described	0
Conflict (CONF)	Contextual	Direct	Evidence of direct confrontation between ELC and community. Examples include reported land disputes (LICAHDO), re-taking or stopping use of LSLA land through force or threat of force	1
		Indirect	Evidence of political, legal, or otherwise non-physical contestation of ELC by community members. For example, a more conflictual livelihood context (Oberlack et al., 2016), contested compensation, political advocacy	0.5
		Both	Some combination of direct and indirect conflict	1

Table A1.5.2. Lists of cases associated with attributes and causal multiple-pathways

#	Case ID	Cartodb ID	Deal Year	Location	Sources	Candidate focus conditions							Outcome conditions			Pathways$^{7.5}$
						LCRATE	EMP	CONF	TREE	COMP	DISP	IMM	iLUC^{10}	iLUC$^{7.5}$	iLUC^{5}	
1	36	36	2011	Ta Veng District; Ratanakiri Province	Baird, I. G. (2017)	1	0	1	1	0	0	0	0	0	0	LCRATE*TREE*~EMP*~DISP*~IMM*CONF
2	110	110	2012	Veun Sai District; Ratanakiri Province	Baird, I. G. (2017)	0	0	1	1	0	0	0	0	0	0	~LCRATE*TREE*~COMP*~EMP*~DISP*~IMM*CONF
3	168	168	2000	Boribor;Teuk Phos;Samaki Meanchey;Krakor Districts; Kampong Chhnang and Pursat Provinces	Beban, A., So, S. and Un, K. (2017)	0	0	0.5	0	0	1	0	1	1	1	NP
4	15	15	2000	Preah Sihanouk Province	Beban, A., So, S. and Un, K. (2017)	0	0	0	0	1	1	0	1	1	1	~LCRATE*~TREE*COMP*~EMP*DISP*~IMM*~CONF
5	151	151	2006	Beng Commune; Sre Ambel District; Koh Kong Province	Dwyer, M. B. (2015); Bristol, G. (2007)	1	1	1	0	1	0	0	0	0	0	LCRATE*~TREE*COMP*EMP*~DISP*~IMM*CONF
6	152	152	2006	Botum Sakor District; Koh Kong Province	Dwyer, M. B. (2015); Bristol, G. (2007)	1	1	1	0	1	0	0	0	0	0	LCRATE*~TREE*COMP*EMP*~DISP*~IMM*CONF
7	138	138	2006	Kbal Damrey Commune; Kratie Province	Neef, A., Touch, S., & Chiengthong, J. (2013)	1	1	0.5	0	0	0	0	1	1	1	NP
8	135	135	2006	Kbal Damrey Commune; Kratie Province	Neef, A., Touch, S., & Chiengthong, J. (2013)	1	1	0.5	0	0	0	0	0	0	1	NP
9	128	128	2006	Kbal Damrey Commune; Kratie Province	Neef, A., Touch, S., & Chiengthong, J. (2013)	0	1	0.5	0	0	0	0	1	1	1	NP
10	62	62	2005	Sesan District; Stung Treng Province	Baird, I. G., & Fox, J. (2015)	1	1	0.5	1	1	0	1	1	1	1	NP
11	162	162	2005	Sesan District; Stung Treng Province	Baird, I. G., & Fox, J. (2015)	1	1	0.5	1	1	0	1	1	1	1	NP
12	111	111	2009	Veun Sai District; Ratanakiri Province	Baird, I. G., & Fox, J. (2015)	1	0	1	1	0	0	0	1	1	1	LCRATE*TREE*~EMP*~DISP*~IMM*CONF
13	278	278	2011	Mondulkiri Province	Milne, S. (2015)	1	0	1	1	0	0	0	1	1	1	LCRATE*TREE*~EMP*~DISP*~IMM*CONF
14	169	169	2011	Kratie Province	Milne, S. (2015)	0	0	0	1	0	0	0	1	1	1	~LCRATE*TREE*~COMP*~EMP*~DISP*~IMM*~CONF
15	188	188	2007	Koum Choar Commune; O'Ya Dav District; Ratanakiri Province	Gironde, C., & Peeters, A. (2015, June)	1	0	1	1	1	1	1	1	1	1	LCRATE*TREE*COMP*~EMP*DISP*CONF
16	87	87	2009	Malik Commune; Andoung Meas District; Ratanakiri Province	Gironde, C., & Peeters, A. (2015, June)	1	0	1	1	1	1	1	1	1	1	LCRATE*TREE*COMP*~EMP*DISP*CONF
17	55	55	2011	Malik Commune; Andoung Meas District; Ratanakiri Province	Gironde, C., & Peeters, A. (2015, June)	0	0	0.5	1	0	1	1	1	1	1	NP
18	259	259	2011	Malik Commune; Andoung Meas District; Ratanakiri Province	Gironde, C., & Peeters, A. (2015, June)	1	1	1	1	0	1	1	0	1	1	LCRATE*TREE*~COMP*EMP*DISP*IMM*CONF
19	18	18	2011	Khsem commune, Keio Seima district, Kratie Province	Lamb, V., Schoenberger, L., Middleton, C., & Un, B. (2017)	1	1	1	0	0	1	0	0	0	1	LCRATE*~TREE*~COMP*EMP*DISP*~IMM*CONF
20	156	156	2010	Omlaing commune, Oral district, Kampong Speu Province	Scheidel, A. (2016); EJatlas, 2015a	1	1	1	0	0	1	0	0	0	0	LCRATE*~TREE*~COMP*EMP*DISP*~IMM*CONF
21	22	22	2011	Omlaing commune, Oral district, Kampong Speu Province	Scheidel, A. (2016); EJatlas, 2015a	1	1	1	0	0	1	0	0	0	0	LCRATE*~TREE*~COMP*EMP*DISP*~IMM*CONF
22	21	21	2010	Thpong district, Kamping Speu province	Scheidel, A. (2016); EJatlas, 2015a	0	0	1	0	0	1	0	1	1	1	NP
23	154	154	2005	Trapang Phlang commune, Chhouk district, Kampot province	Scheidel, A. (2016); EJatlas, 2015a	1	0	1	1	0	0	0	1	1	1	LCRATE*TREE*~EMP*~DISP*~IMM*CONF
24	253	253	2008	Khsuem commune, Snuol district, Kratie Province	Schoenberger, L. (2017)	1	0	1	1	1	0	0	1	1	1	LCRATE*TREE*~EMP*~DISP*~IMM*CONF
25	24	12	2010	Khsuem commune, Snuol district, Kratie Province	Schoenberger, L. (2017)	1	0	1	1	0	0	0	1	1	1	LCRATE*TREE*~EMP*~DISP*~IMM*CONF
26	155	153	2008	Snoul district, Kratie province	Licadho. 2009	0	0	0.5	0	0	1	0	0	0	0	NP
27	204	262	2005	Dak Dam commune, O Raing district, Mondulkiri province	Vize, J., and M; Hornung. 2013	1	1	1	0	1	1	1	1	1	1	LCRATE*~TREE*COMP*EMP*DISP*IMM*CONF
28	88	79	2008	Botum Sakor National Park; Koh Kong Province	Drbohlav, P., and J.; Hejkrlik. 2018	1	0	1	1	1	1	0	1	1	1	LCRATE*TREE*COMP*~EMP*DISP*CONF
29	78	68	2008	Campong Thom province	Perroulaz, G., C; Fioroni, and G. Carbonnier. 2015	1	0	0.5	1	0	0	0	1	1	1	NP
30	219	277	2011	Seda commune, Lumphat district, Ratanakiri province	Chea, R. P. & P. 2015	0	0	0.5	0	0	0	0	0	0	1	NP

Note: * = and, ~ = absence of, + = or; → = sufficient for; LCRATE = Land use change rate; EMP = employment; CONF = conflict; TREE = rubber; COMP = compensation; IMM = immigration; DISP = displacement. NP = no pathway; iLUC^{10}, iLUC$^{7.5}$, iLUC^{5} present iLUC associated with the threshold value of the forest loss rate at 10%, 7.5%, 5%, respectively; Pathways7.5 presents the pathway associated with either iLUC or the absence of iLUC at 7.5%. Case ID = unique identifier linking ELCs reported in the case studies to the corresponding georeferenced boundaries. Cartodb ID = "Unique record identifier from Open Development Cambodia dataset. Available at: https://opendevelopmentcambodia.net/profiles/economic-land-concessions/."

Table A1.5.3. Solution formula for iLUC and the absence of iLUC with sensitivity analysis

Solution	Justification & conditions	Solution formula	Cases Covered (Case ID)	Con.	Cov.
A1	Outcome condition iLUC with a threshold value of 10%	LCRATE* CONF*(TREE*~EMP*~DISP*~IMM + COMP*DISP (TREE*~EMP*DISP + ~TREE*EMP*IMM)) + ~LCRATE*~IMM*~CONF*~EMP*(TREE*~COMP*~DISP + ~TREE*COMP*DISP) → iLUC	36,111,278,154, 253, 188, 87, 88, 169, 15, 204	0.920	0.605
A2	Outcome condition iLUC with a threshold value of 7.5%	LCRATE* CONF*(TREE*(~EMP*~DISP*~IMM + COMP*~EMP*DISP + ~COMP*EMP*DISP*IMM) + ~TREE*COMP*EMP*DISP*IMM) + ~LCRATE*~EMP*~IMM*~CONF (TREE*~COMP* *~DISP + ~LCRATE*~TREE*COMP*DISP) → iLUC	36,111,278,154, 253, 188, 87, 88, 169, 15, 204, 259	0.926	0.625
A3	Outcome condition iLUC with a threshold value of 5%	LCRATE* CONF*(TREE*(~EMP*~DISP*~IMM + COMP*~EMP*DISP) + ~COMP*EMP*DISP*IMM + ~TREE*COMP*EMP*DISP*IMM)) + ~LCRATE*~EMP* ~CONF* (TREE*~COMP *~DISP*~IMM + ~TREE*COMP*DISP*~IMM) → iLUC	36,111,278,154, 253, 188, 87, 88, 169, 15, 204, 259	0.926	0.543
B1	Outcome condition, the absence of iLUC with a threshold value of 10%	CONF*(~DISP*~IMM (~LCRATE*TREE*~COMP*~EMP + LCRATE*~TREE*COMP*EMP) + LCRATE*~COMP*DISP*EMP*(~TREE*~IMM + *TREE*IMM) → no iLUC	110, 151, 152, 18, 156, 22, 259	1	0.636
B2	Outcome condition, the absence of iLUC with a threshold value of 7.5%	~IMM*CONF*(~LCRATE*TREE*~COMP*~EMP*~DISP + LCRATE*~TREE* EMP*(COMP*~DISP + ~COMP*DISP)) → no iLUC	110, 151, 152, 18, 156, 22	1	0.6
B3	Outcome condition, the absence of iLUC with a threshold value of 5%	~DISP*~IMM*CONF*(~LCRATE*TREE*~COMP*~EMP + LCRATE*~TREE*COMP*EMP) → no iLUC	110, 151, 152	1	0.429

Note: * = and, ~ = absence of, + = or; → = sufficient for.

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