Land Tenure Security and Deforestation: Experimental Evidence from Uganda

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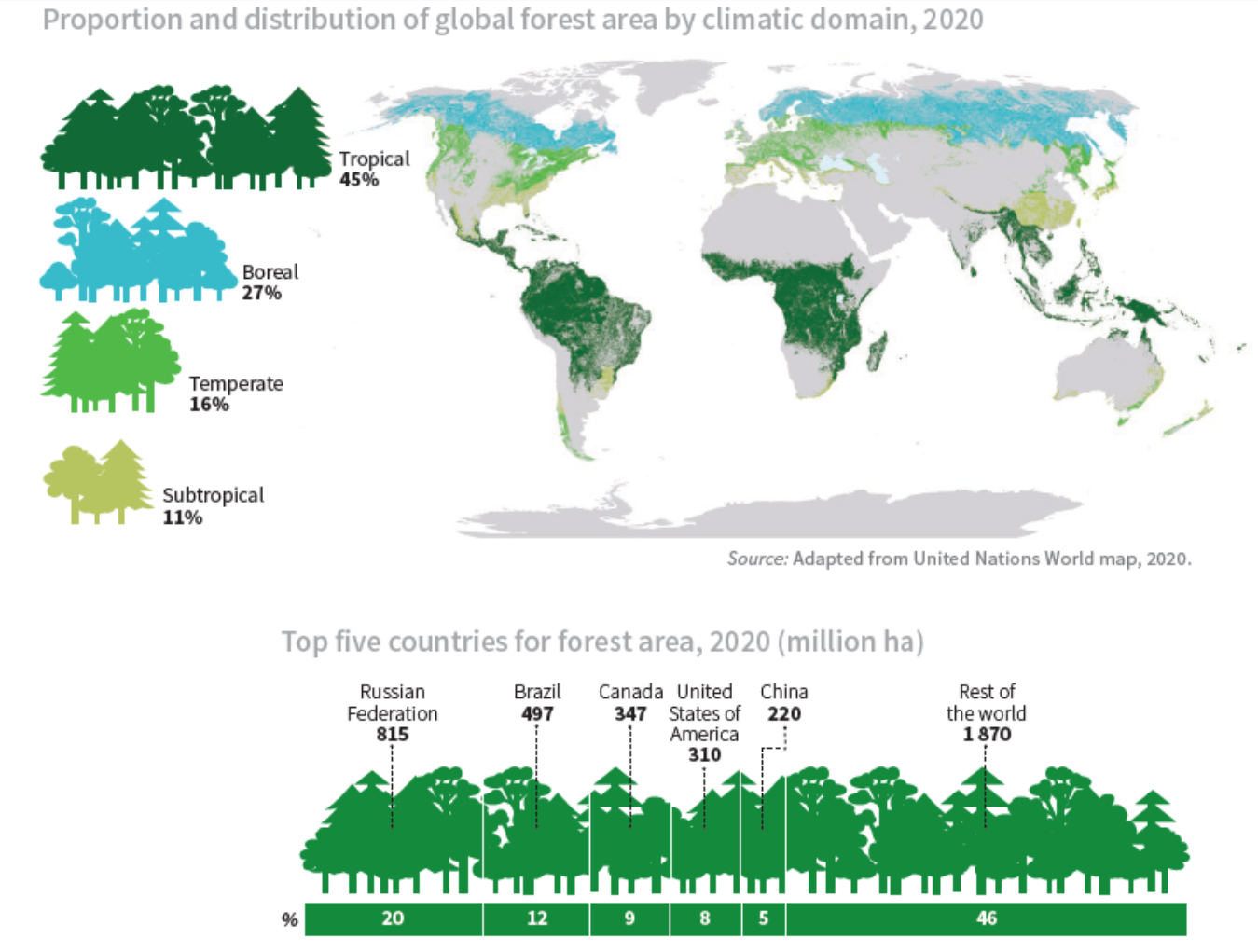
Introduction

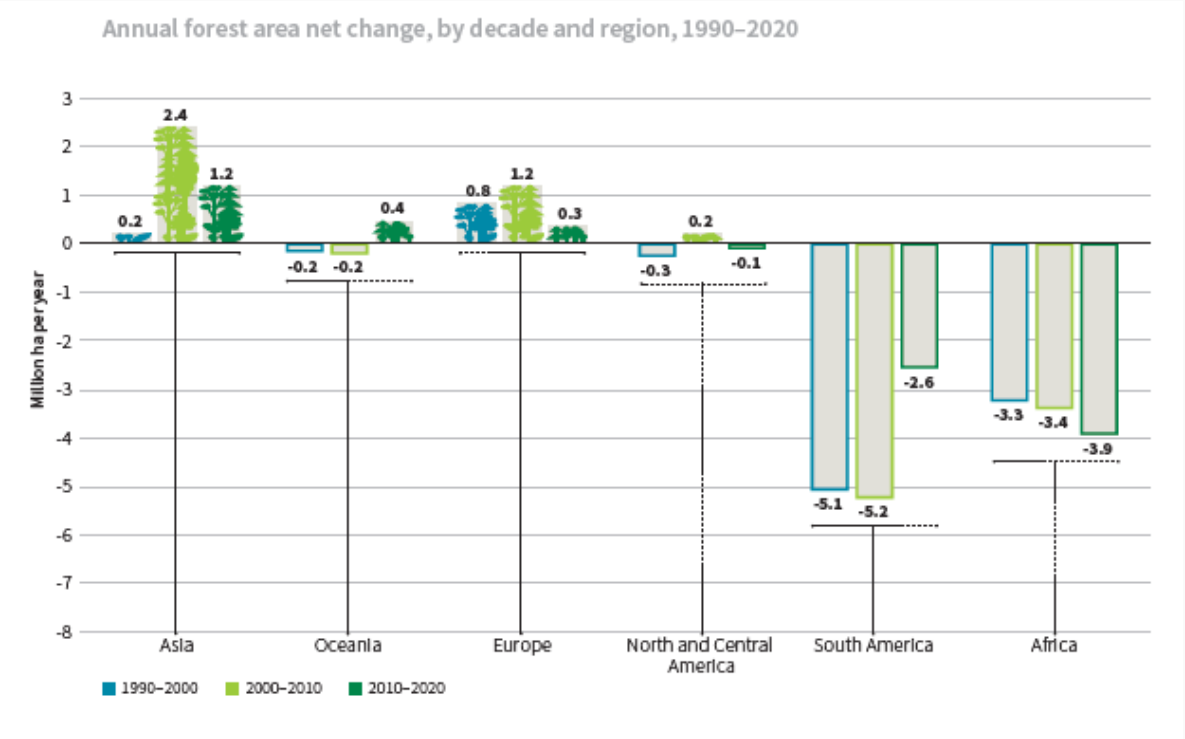
31% of the earth's land area is covered in forest



Source: Global Forest Resources Assessment 2020

We have lost 178 M ha of forest since 1990

Tropical forest is important for all of us



Source: Global Forest Resources Assessment 2020

- Land use change= 12–20% greenhouse gas emissions
- Tropical deforestation threatens biodiversity, watershed function, rural livelihoods
- Problem acute in sub-Saharan Africa

Securing land tenure *may* be a good policy for conservation, and insecure tenure is pervasive

- Land tenure security required to implement deforestation programs (PES, community forestry, etc.), but lack of robust evidence on effectiveness
  - 30% of global population has registered property rights
  - In Africa: $<$ 10% (World Bank 2022)

- Identification challenge:
  - Individual characteristics may cause titling and land use decisions simultaneously (Unmotivated person $\Rightarrow$ no title, low production; unproductive land $\Rightarrow$ no title, low production)
  - Reverse causality: land clearing $\Leftrightarrow$ property rights

Theoretical predictions on property rights and deforestation ambiguous

- Standard theory of property rights:
  - Private land with clear rights $\rightarrow$ better resource management (Demsetz, 1967)
- Deforestation effect depends on context
  - Capital intensive forest extraction: tenure security *can increase* deforestation (Farzin, 1984)
  - Labor intensive forest extraction: tenure security may reduce deforestation
  - Alternative approach: if agriculture is capital intensive, high insecurity can increase forest cover (Liscow 2013)
- Punchline: ambiguity. Production in Uganda low capital intensity for both ag and forest.

Background

Uganda is an interesting place to explore this

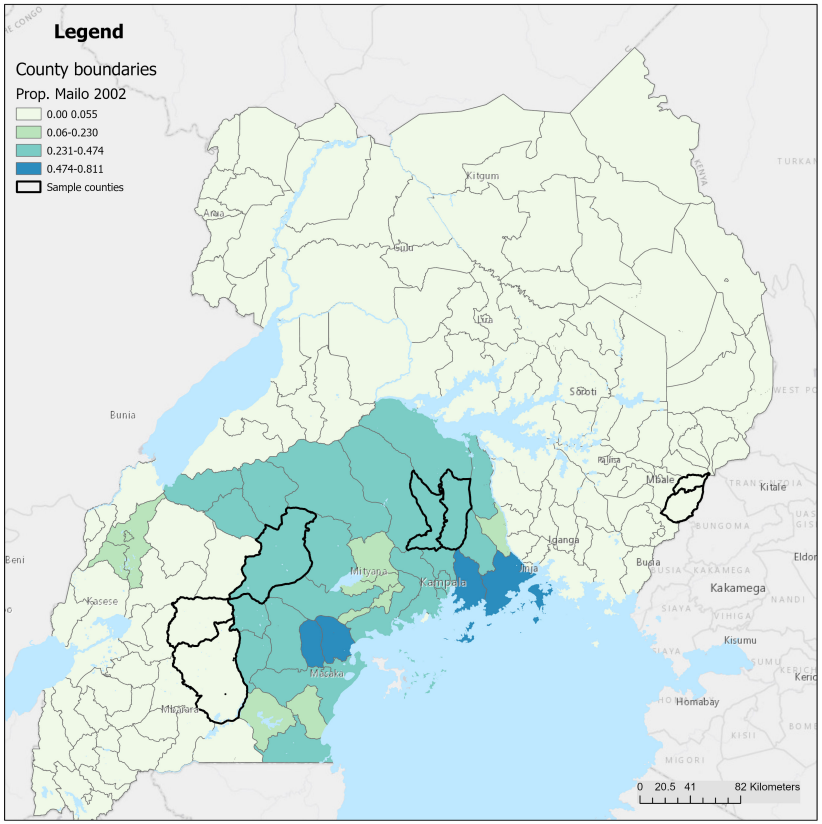
- 2001-2022: Total tree cover decreased by 12%
- = 463 MT of CO2 equivalents (2019: 5.8 MT emissions from non-land use sources)
- Tenure is kind of complicated in Uganda
- 2016: 26% of land had a formal certificate documenting tenure

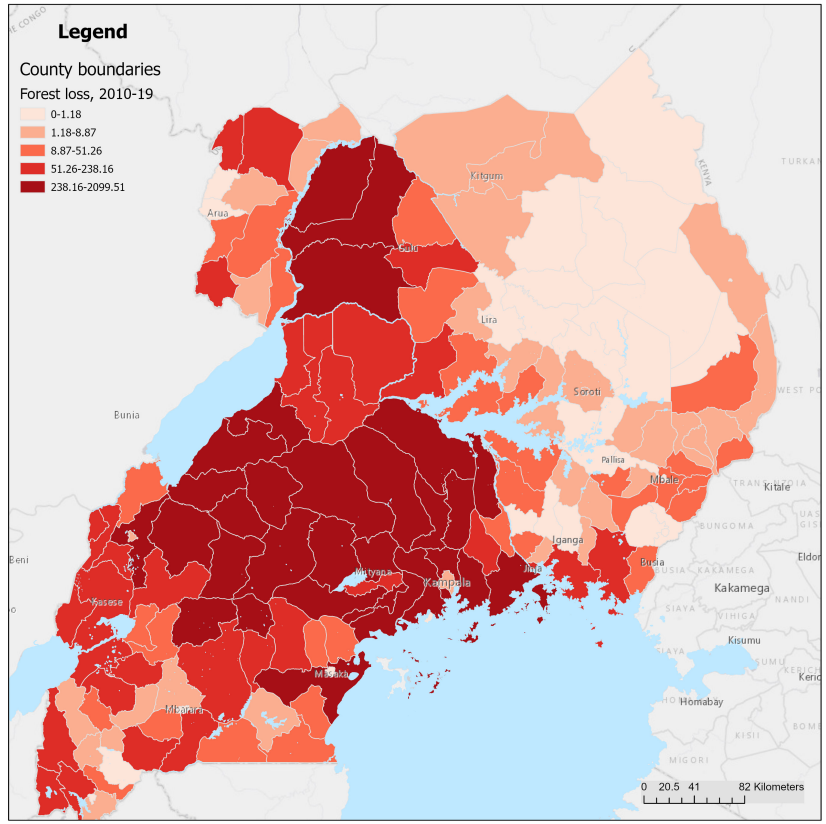
Background: Uganda land tenure history

Source: Giblin (2012). *Azania: Archaeological Research in Africa*, 47: 64-80.

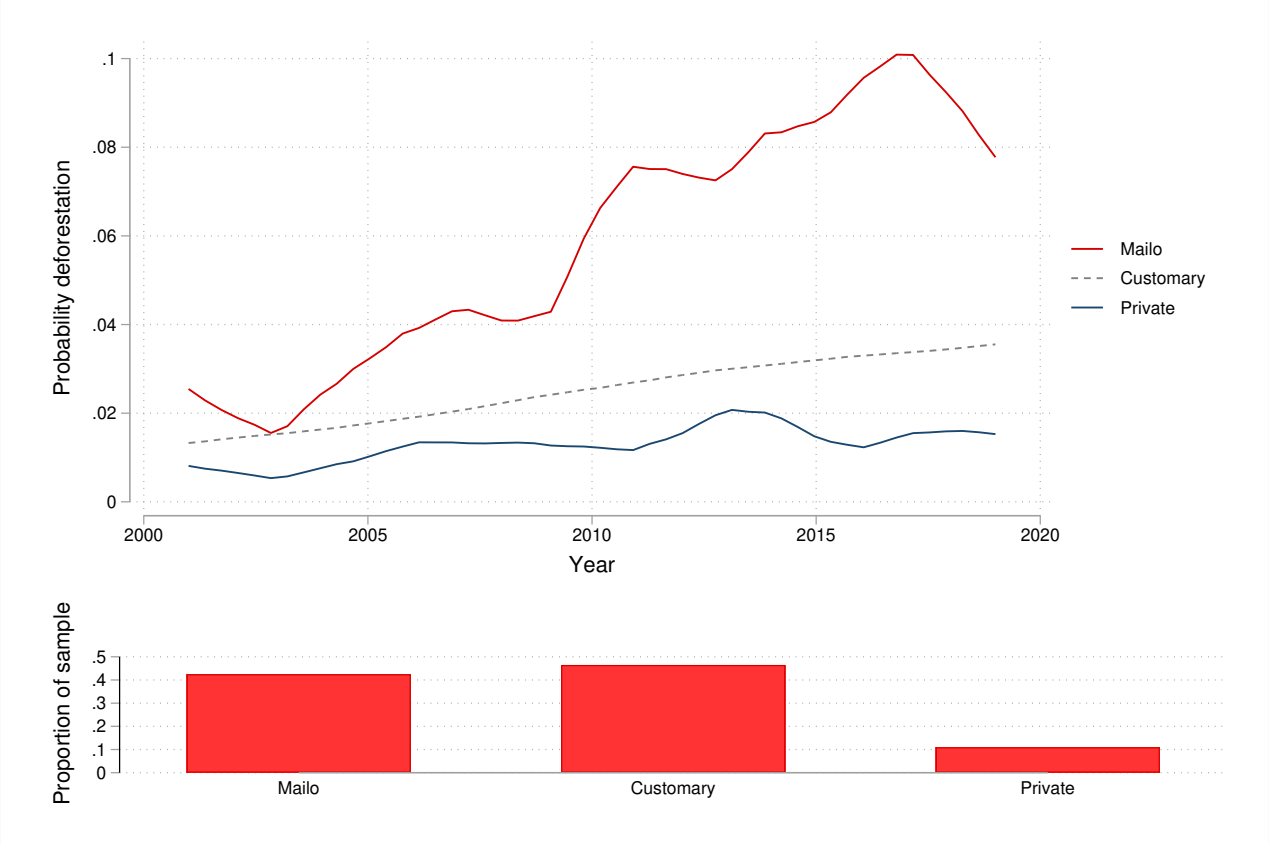
- Prior to 1894: customary tenure in diverse forms
  - 1894 to 1962: Uganda a protectorate of the British Empire
- 1900 agreement creates 4 tenure categories; 1962-1975: no individual ownership; 1975: return to 1900 categories
  1. Freehold and leasehold ("private")
  2. Customary
  3. *Mailo*: Created from land acquired by British from Buganda Kingdom – hybrid of customary and private
     - Absentee landlords / no rental arrangement
     - Lack of proof of occupancy
     - 23% believe they will be evicted if let land fallow

Mailo tenure is in areas with high deforestation





Deforestation trends across time steeper in mailo; decrease as titling becomes more common



From Walker et al. (2022): Graph shows smoothed probability of deforestation by year within counties that have more than the mean levels of mailo, customary, or private tenure within them. Bars indicate proportion of observations falling in each category – this is equivalent to the proportion of baseline forest within each subgroup in the year 2002. The sample here includes grid cells with 50% forest cover in 2000.

Empirical strategy

Sampling

1. Forest cover data (Hansen et al 2022): Selected regions with most dense forest and highest historical deforestation
2. Within these, selected districts with high historical deforestation and high probability of forest access (dense forest)
3. Latitude and longitude of village locations, 3km buffer around each: dropped if no forests
4. From sample, randomly selected 28 villages per region, plus replacement buffer
5. Research firm, with village chiefs, listing of hh with forest access
6. Randomly selected 20 households, aiming for 1680 households total (achieved 1632)

Experiment & Survey

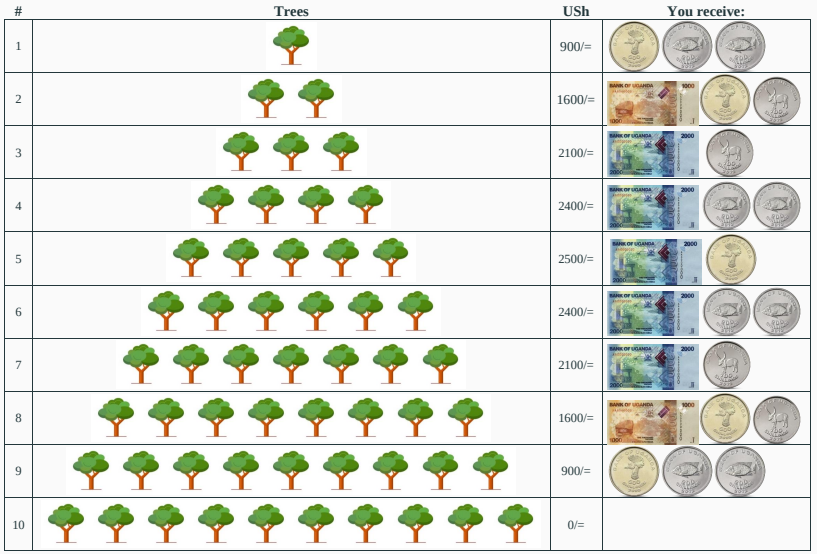
- Participants responsible for a "forest" of 12 trees that could be harvested and regrow (1 tree for every 5 left standing)

- Payoffs for cut trees calculated as follows:

$$\pi = ah_{it} - \frac{1}{2}bh_{it}^2$$

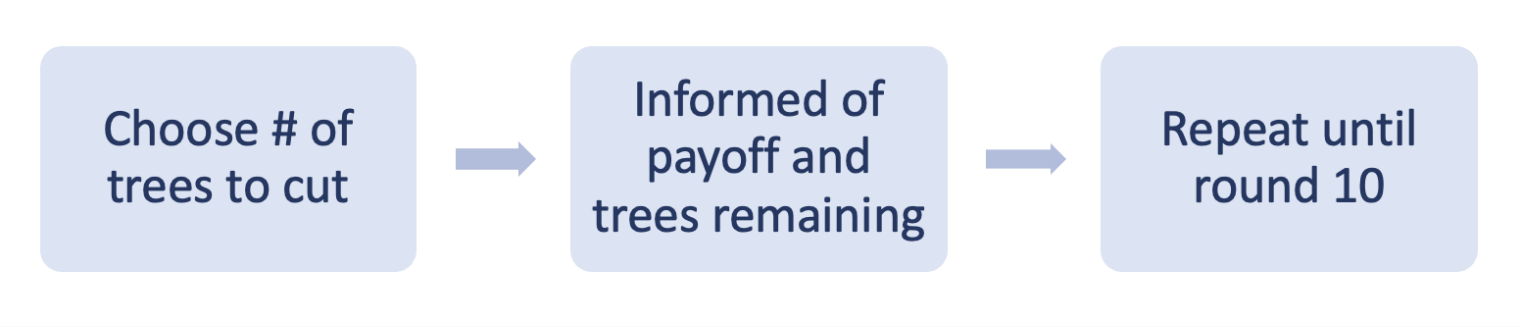
  where h_{it} number of trees harvested in each round

- Each round enumerator calculated profit and trees remaining and informed participants



⏩ Optimal choice

Experiment & Survey



- Randomized into 3 groups:
  - Secure: as above
  - Insecure: 20 percent chance eviction each round (game ends)
  - Certificate: insecure but chance to purchase certificate to remove risk
- Certificate group received additional 1000 UGX and Insecure 2000 UGX to compensate
- Survey questions captured demographic and economic info, risk/time preferences (hypothetical), trust game (incentivized)

Calibration of payoffs based on pilot data and previous surveys

- 2018 survey of charcoal producers by Walker provided inputs for payoff function
- Certificate price in our experiment $=$ 1.3 x profit from harvesting one tree; similar to same relative cost in real life
- Ali and Duponchel (2018) report that 23% mailo tenants believe they will be evicted if they let land fallow

How does land insecurity treatment affect forest extraction?

- Estimate the following:

$$\bar{h}_{it} = \alpha + \rho_t + \beta_1 Insecure_i + \beta_2 Certif_i + \gamma X_i + \epsilon_{it}$$

  - $\bar{h}_{it} = \frac{h_{it}}{S_{it}} \forall S_{it} > 0$, where S is stock
  - *Insecure*: whether participant in insecure group
  - *Certificate*: whether participant in certificate group
  - ρ_t is a fixed effect for round
  - X_i: unbalanced controls, additional covariates in some specifications

- Expectations:
  - Insecure land tenure increases deforestation relative to secure land tenure: $\beta_1 > 0$
  - Certification improves perceived land tenure security and thus $\beta_1 > \beta_2$

Does the experience of Mailo tenure affect participant play?

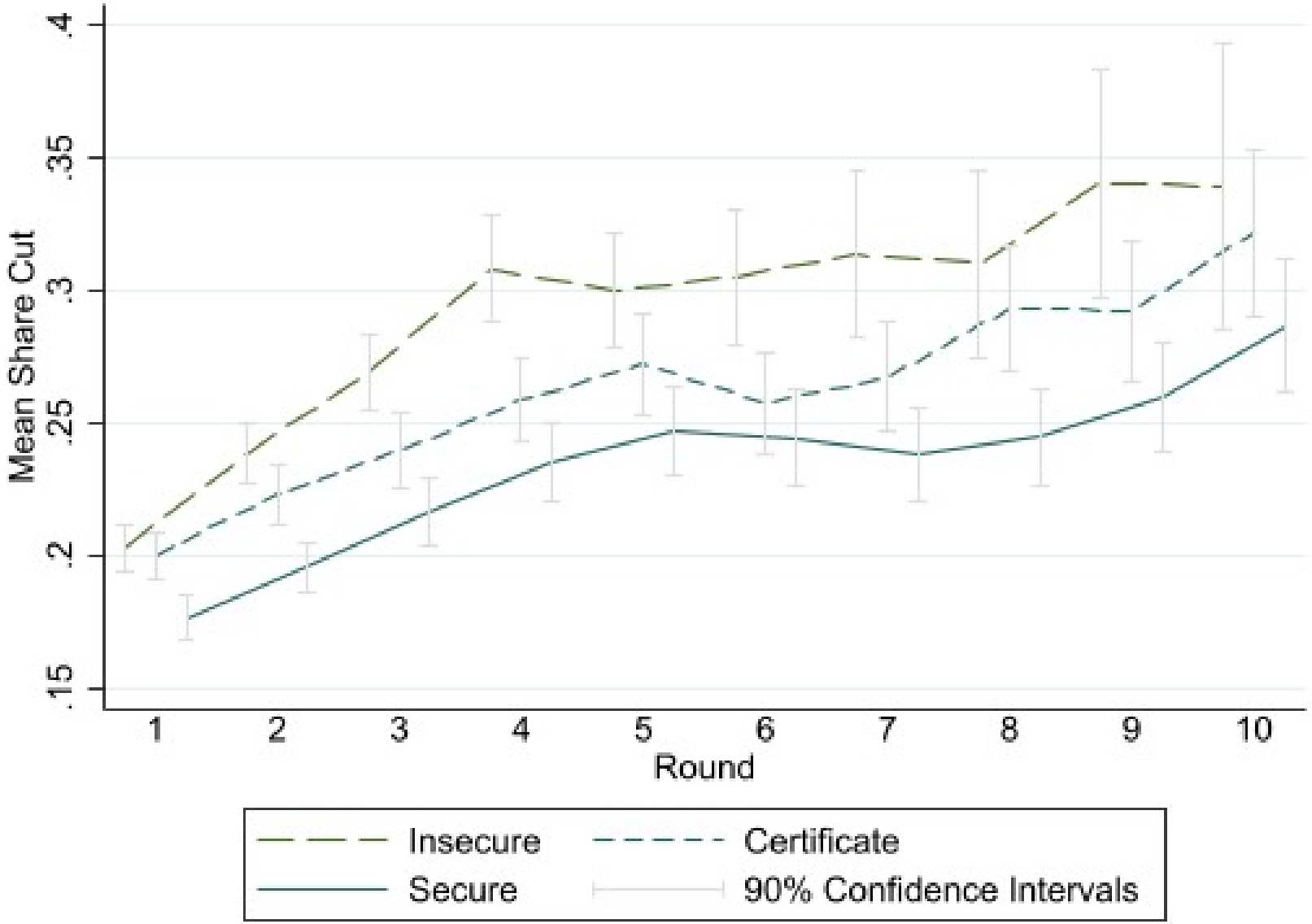
- Interact each of treatment categories with village-level share of mailo tenure
- Estimate the following:

$$\bar{h}_{it} = \alpha + \rho_t + \theta_1 Insecure_i \times Mailo_v + \theta_2 Certif_i \times Mailo_v + \theta_3 Insecure_i + \theta_4 Certif_i + \delta Mailo_v + \gamma X_i + \epsilon_{it}$$

- If real experience of land tenure effects behavior in game, expect $\theta_1 > 0$ and $\theta_2 < 0$.

Results

Share trees cut highest for insecure, then certificate, then secure tenure



Insecure arm 23-25% higher extraction; certificate arm half that

DV: Share trees cut each round	(1)	(2)	(3)	(4)	(5)
Insecure	0.055***	0.055***	0.056***	0.053***	0.059***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Certificate	0.027***	0.027***	0.026***	0.025***	0.025***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Unbalanced controls:	N	Y	Y	Y	Y
Additional controls:	N	N	Y	Y	Y
Enumerator FE:	N	N	N	Y	N
Village FE:	N	N	N	N	Y
Observations	12558	12558	12558	12558	12558
Mean Secure Group	0.230	0.230	0.230	0.230	0.230
SD Secure Group	0.220	0.220	0.220	0.220	0.220
P-value Insecure=Certificate	0.000	0.000	0.000	0.000	0.000

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. OLS estimates. Unit of observation is a person-round. All estimates control for round fixed effects. Unbalanced controls include: age, household size, whether the respondent could obtain money from village/community savings if in need, whether the respondent could obtain money from selling trees or charcoal if in need, whether land owned is used for people to live on, patience, mailo land tenure, private land tenure. Additional controls include: asset index, sex, education, risk tolerance, land area, and whether or not respondent/household sells trees for or produces charcoal. Robust standard errors in parentheses. Missing observations for control variables replaced with the median value. All estimates control for missing observations.

Why doesn't certificate group behavior converge to secure group behavior?

- 81% of participants in certificate group purchase certificate; 95% in the second or third round
- Take up higher for those in mailo villages
- Certificate purchasers less likely to produce charcoal, use land for grazing, more likely to have mobile money (but TTT coefficient same as ITT)
- Estimated effects from sample split according to trust play shows higher deforestation rates from those with low trust

Experience with Mailo increases certification effect

DV: Share trees cut each round	(1)	(2)	(3)	(4)	(5)
Insecure	0.058***	0.056***	0.057***	0.053***	0.057***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Insecure X % Mailo Village	-0.005	-0.010	-0.009	0.007	-0.006
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Certificate	0.035***	0.034***	0.031***	0.030***	0.031***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Certificate X % Mailo Village	-0.047**	-0.048**	-0.040**	-0.039**	-0.043**
	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
% Mailo Village	-0.078***	-0.077***	-0.069***	-0.061***	0.047**
	(0.014)	(0.014)	(0.014)	(0.014)	(0.019)
Unbalanced controls:	N	Y	Y	Y	Y
Additional controls:	N	N	Y	Y	Y
Enumerator FE:	N	N	N	Y	N
District FE:	N	N	N	N	Y
Observations	12558	12558	12558	12558	12558
Mean Secure Group	0.230	0.230	0.230	0.230	0.230
SD Secure Group	0.220	0.220	0.220	0.220	0.220

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. OLS estimates. Unit of observation is a person-round. All estimates control for round fixed effects. Unbalanced controls include: age, household size, whether the respondent could obtain money from village/community savings if in need, whether the respondent could obtain money from selling trees or charcoal if in need, whether land owned is used for people to live on, and patience. Additional controls include: asset index, sex, education, risk tolerance, land area, and whether or not respondent/household sells trees for or produces charcoal. Robust standard errors in parentheses. Missing observations for control variables replaced with the median value. All estimates control for missing observations.

Conclusion

Tenure insecurity increases deforestation; certification helps

- Land tenure insecurity significantly increases forest extraction rates by 23-25%
- Certification reduces this by half.
- Historical legacies matter. Participants living in villages with a higher share of mailo land respond more strongly to certification
- Results suggest that improving land tenure security through certification may be an effective way to curb deforestation, though externalities remain
- Caveats to experimental setting: Non-trivial costs not included, frictions, off-setting effects on credit etc.

Thank you!

Thanks especially to the communities that welcomed us and to Ezra Rwakazooba for outstanding project management.

Appendix

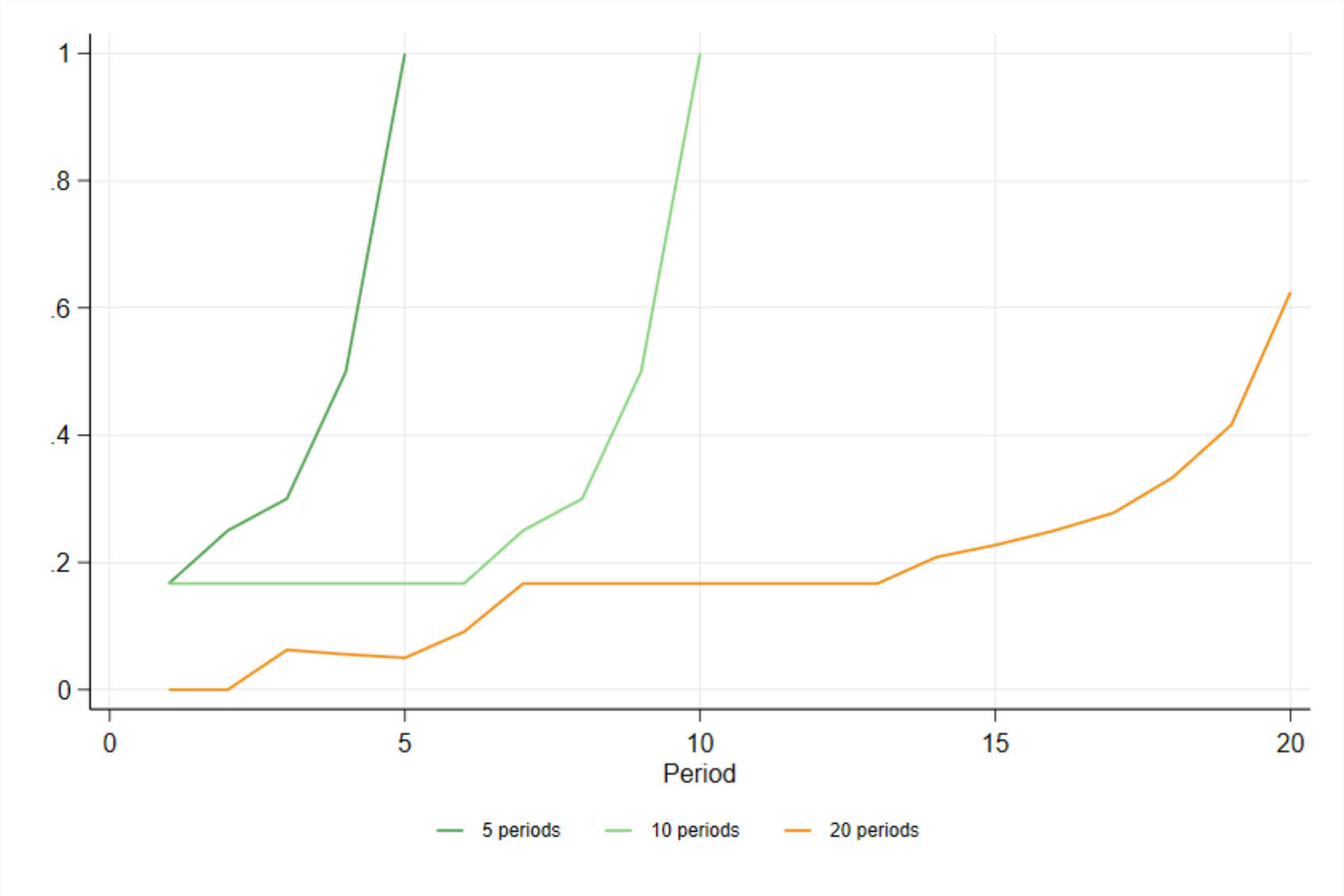
Literature

- Natural resource extraction in tropical countries:
  - Incentives to over-extract under common-access structure (Cardenas, 2003); communication can improve outcomes (Ostrom, 2006); compensation remedying exploitation (Handberg and Angelsen, 2015, 2019; Yehouenou et al., 2023)

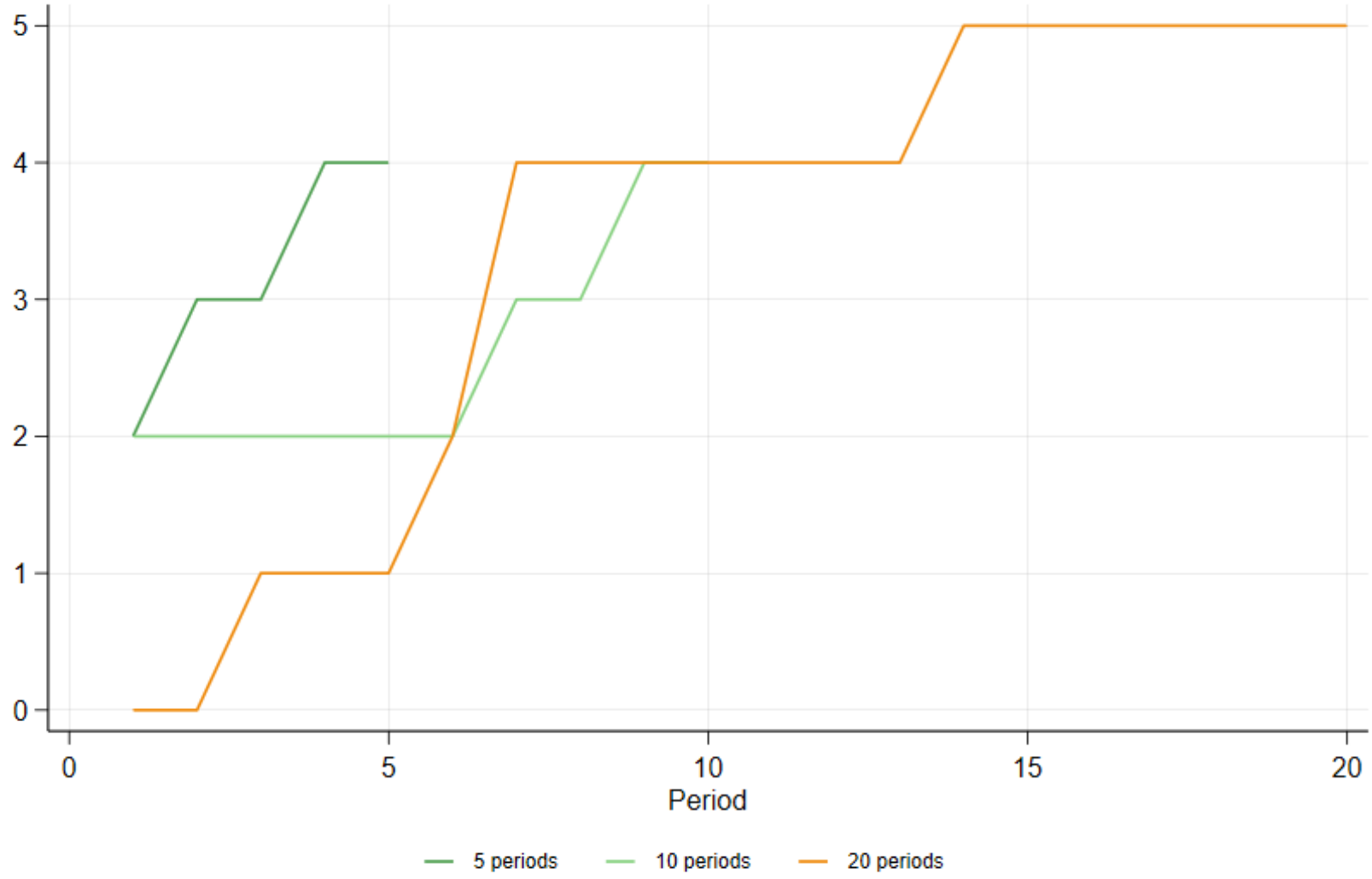
- Correlation between ownership security and forest cover:
  - In Uganda (Walker et al, 2022); Brazil (Baragwanath and Bayi, 2020), Ecuador (Holland et al., 2017), and Colombia (Velez et al., 2020) small, short-term reductions in deforestation following formalization.
  - Brazil (Probst et al., 2020), Nicaragua (Liscow, 2013), Ecuador (Butaine et al., 2015) negative or zero environmental effects

- Few studies evaluating RCTs:
  - Mixed results (Reyes-Garcia et al. 2012; Goldstein et al., 2018; Fabbri, 2021; Wren-Lewis et al., 2020; Huntington and Shenoy, 2021)

Optimal rate of cutting for different time horizons



Optimal number of trees cut for different time horizons



Back

Households large, most completed primary school, land dependent, 1/4 produce charcoal

	N	Mean	SD	Min	Max
Age (years)	1632	46.52	12.39	18	83
Female	1632	0.17	0.37	0	1
Household size	1632	7.10	3.50	1	30
Some/completed primary school	1630	0.56	0.50	0	1
Some/completed secondary school	1630	0.24	0.43	0	1
Earns income from land	1632	0.99	0.10	0	1
Cuts trees for charcoal	1631	0.26	0.44	0	1
Land used for: farming	1630	0.72	0.45	0	1
Land used for: grazing	1630	0.63	0.48	0	1
Land used for: people to live on	1630	0.29	0.45	0	1
Number of cows raised last year	1631	4.40	11.65	0	160
Asset index	1632	3.26	1.56	0	11
Risk	1630	2.27	1.54	0	4
Patience	1630	6.19	10.14	1	32
Amount sent in trust game	1632	1857.84	938.00	0	4000
Mailo land tenure	1628	0.14	0.35	0	1
Customary land tenure	1628	0.26	0.44	0	1
Private land tenure	1628	0.50	0.50	0	1

Asset index counts the total number of the following assets that the participant has in their home: radio, electricity, television, solar panel, electric stove, gas stove, internet access, mobile phone, bicycle, car/truck, and motorcycle.

Variable	Insecure	Certificate	Secure	Normalized Differences (1)-(2)	(2)-(3)	(1)-(3)
Age (years)	45.872	46.251	47.379	-0.022	-0.064	-0.087**
Female	0.165	0.175	0.167	-0.019	0.015	-0.004
Household size	6.987	6.967	7.332	0.004	-0.074*	-0.068
# People below age 14 in home	2.495	2.513	2.542	-0.006	-0.011	-0.017
Some/completed primary school	0.562	0.562	0.567	0.001	-0.007	-0.006
Some/completed secondary school	0.230	0.248	0.245	-0.030	0.005	-0.025
Years lived in community	34.264	35.625	35.203	-0.061	0.019	-0.043
Earns income from land	0.986	0.992	0.991	-0.044	0.007	-0.038
Total area of all land (acres)	22.741	16.835	17.872	0.045	-0.009	0.037
Total area of farm/grazing land (acres)	11.537	11.756	14.124	-0.006	-0.048	-0.049
Years of access to land	20.805	21.432	21.897	-0.033	-0.024	-0.057
Trees cover more than half of land	0.627	0.644	0.615	-0.024	0.042	0.018
Cuts trees for charcoal	0.254	0.277	0.242	-0.037	0.056	0.019
Land used for: farming	0.706	0.721	0.746	-0.023	-0.039	-0.063
Land used for: grazing	0.639	0.627	0.628	0.018	-0.002	0.016
Land used for: people to live on	0.276	0.332	0.270	-0.086**	0.095**	0.009
Number of cows raised last year	4.288	4.369	4.543	-0.005	-0.011	-0.016
Asset index	3.309	3.183	3.281	0.058	-0.044	0.013
Obtain money: Personal savings	0.447	0.430	0.420	0.023	0.015	0.038
Obtain money: Village/community savings	0.344	0.411	0.325	-0.098**	0.126***	0.028
Obtain money: Loan from bank	0.139	0.132	0.144	0.016	-0.026	-0.010
Obtain money: Loans or gift from friends/family	0.175	0.191	0.204	-0.028	-0.024	-0.051
Obtain money: Sell cattle	0.320	0.322	0.357	-0.003	-0.052	-0.055
Obtain money: Sell trees or charcoal	0.204	0.220	0.178	-0.027	0.075*	0.048
Access to mobile money	0.069	0.049	0.072	0.059	-0.068	-0.009
Risk	2.232	2.295	2.295	-0.029	0.000	-0.029
Patience	6.528	6.723	5.377	-0.013	0.095**	0.082*
Mailo land tenure	0.154	0.149	0.118	0.009	0.064	0.073*
Customary land tenure	0.242	0.291	0.256	-0.078*	0.055	-0.023
Private land tenure	0.483	0.464	0.539	0.027	-0.107**	-0.079*

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. *Asset index* counts the total number of the following assets that the participant has in their home: radio, electricity, television, solar panel, electric stove, gas stove, internet access, mobile phone, bicycle, car/truck, and motorcycle.

Variable	Certificate	No Certificate	Normalized Difference
Age (years)	47.462	45.998	0.083
Female	0.161	0.179	-0.033
Household size	6.978	6.983	-0.001
# People below age 14 in home	2.344	2.559	-0.087
Some/completed primary school	0.516	0.569	-0.074
Some/completed secondary school	0.280	0.243	0.059
Years lived in community	37.554	35.178	0.104
Earns income from land	1.000	0.990	0.099
Total area of all land (acres)	8.514	18.954	-0.114
Total area of farm/grazing land (acres)	10.137	12.245	-0.063
Years of access to land	21.296	21.450	-0.008
Trees cover more than half of land	0.613	0.649	-0.052
Cuts trees for charcoal	0.161	0.309	-0.249***
Land used for: farming	0.774	0.716	0.095
Land used for: grazing	0.548	0.645	-0.139*
Land used for: people to live on	0.301	0.343	-0.064
Number of cows raised last year	5.581	4.123	0.070
Asset index	3.065	3.230	-0.075
Obtain money: Personal savings	0.462	0.422	0.058
Obtain money: Village/community savings	0.333	0.431	-0.143*
Obtain money: Loan from bank	0.129	0.135	-0.012
Obtain money: Loans or gift from friends/family	0.161	0.199	-0.068
Obtain money: Sell cattle	0.323	0.321	0.002
Obtain money: Sell trees or charcoal	0.204	0.223	-0.032
Access to mobile money	0.118	0.034	0.226***
Risk	2.505	2.251	0.122
Patience	5.258	7.093	-0.129
Mailo land tenure	0.108	0.162	-0.112
Customary land tenure	0.269	0.301	-0.051
Private land tenure	0.527	0.444	0.118

* $p< 0.10$, ** $p<0.05$, *** $p < 0.01$. Compares normalized differences in means for respondents in the certificate treatment group who purchased a certicate vs. did not purchase a certificate. *Asset index* counts the total number of the following assets that the participant has in their home: radio, electricity, television, solar panel, electric stove, gas stove, internet access, mobile phone, bicycle, car/truck, and motorcycle.

Normalized Differences: Cut all trees v. Did not cut all trees

	(1) Cut all trees	(2) Did not cut all trees	(3) Normalized difference
Age (years)	45.391	47.076	-0.096
Female	0.177	0.164	0.024
Household size	7.070	7.117	-0.010
# People below age 14 in home	2.491	2.530	-0.015
Some/completed primary school	0.614	0.539	0.107
Some/completed secondary school	0.229	0.246	-0.028
Years lived in community	34.611	35.218	-0.027
Earns income from land	0.985	0.992	-0.043
Total area of all land (acres)	20.776	18.375	0.018
Total area of farm/grazing land (acres)	13.372	12.079	0.026
Years of access to land	21.304	21.421	-0.006
Trees cover more than half of land	0.594	0.645	-0.074
Cuts trees for charcoal	0.277	0.247	0.048
Land used for: farming	0.760	0.707	0.085
Land used for: grazing	0.642	0.626	0.024
Land used for: people to live on	0.317	0.278	0.060
Number of cows raised last year	4.701	4.253	0.026
Asset index	2.974	3.402	-0.195
Obtain money: Personal savings	0.410	0.444	-0.049
Obtain money: Village/community savings	0.378	0.348	0.044
Obtain money: Loan from bank	0.116	0.150	-0.070
Obtain money: Loans or gift from friends/family	0.216	0.177	0.069
Obtain money: Sell cattle	0.363	0.319	0.067
Obtain money: Sell trees or charcoal	0.234	0.183	0.090
Access to mobile money	0.074	0.059	0.043
Risk	2.369	2.226	0.066
Patience	5.792	6.383	-0.042
Mailo land tenure	0.090	0.165	-0.159
Customary land tenure	0.325	0.231	0.148
Private land tenure	0.482	0.504	-0.031
Insecure treatment group	0.253	0.382	-0.198
Secure treatment group	0.375	0.337	0.056
Certificate treatment group	0.373	0.282	0.138
Observations	542	1090	1632

Robustness checks

1. Drop those who cut all trees in experiment
    - Certificate treatment effect smaller for those who never cut all
2. HAC standard errors
3. Drop those with missing values for land size, other demographics (currently replaced with median plus indicator)
4. Use number of trees cut rather than share
5. Other ideas??

Baseline results dropping participants who cut everything

DV: Share trees cut each round	(1)	(2)	(3)	(4)	(5)
Insecure	0.057***	0.056***	0.057***	0.053***	0.059***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Certificate	0.016***	0.016***	0.016***	0.018***	0.017***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
Unbalanced controls:	N	Y	Y	Y	Y
Additional controls:	N	N	Y	Y	Y
Enumerator FE:	N	N	N	Y	N
Village FE:	N	N	N	N	Y
Observations	8795	8795	8795	8795	8795
Mean Secure Group	0.230	0.230	0.230	0.230	0.230
SD Secure Group	0.220	0.220	0.220	0.220	0.220
P-value Insecure=Certificate	0.000	0.000	0.000	0.000	0.000

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. OLS estimates. Unit of observation is a person-round. All estimates control for round fixed effects. Unbalanced controls include: age, household size, whether the respondent could obtain money from village/community savings if in need, whether the respondent could obtain money from selling trees or charcoal if in need, whether land owned is used for people to live on, patience, mailo land tenure, private land tenure. Additional controls include: asset index, sex, education, risk tolerance, land area, and whether or not respondent/household sells trees for or produces charcoal. Robust standard errors in parentheses. Missing observations for control variables replaced with the median value. All estimates control for missing observations.

Heterogeneity by village-level mailo land tenure - missing observations dropped

DV: Share trees cut each round	(1)	(2)	(3)	(4)	(5)
Insecure	0.057***	0.056***	0.053***	0.049***	0.053***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Insecure X % Mailo Village	-0.006	-0.009	-0.008	0.007	-0.006
	(0.021)	(0.021)	(0.022)	(0.021)	(0.022)
Certificate	0.035***	0.034***	0.031***	0.030***	0.031***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.006)
Certificate X % Mailo Village	-0.046**	-0.046**	-0.045**	-0.045**	-0.048**
	(0.019)	(0.019)	(0.020)	(0.019)	(0.020)
% Mailo Village	-0.077***	-0.077***	-0.070***	-0.061***	0.052***
	(0.013)	(0.014)	(0.014)	(0.015)	(0.020)
Unbalanced controls:	N	Y	Y	Y	Y
Additional controls:	N	N	Y	Y	Y
Enumerator FE:	N	N	N	Y	N
District FE:	N	N	N	N	Y
Observations	12558	12522	12004	12004	12004
Mean Secure Group	0.230	0.230	0.230	0.230	0.230
SD Secure Group	0.220	0.220	0.220	0.220	0.220

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. OLS estimates. Unit of observation is a person-round. All estimates control for round fixed effects. Unbalanced controls include: age, household size, whether the respondent could obtain money from village/community savings if in need, whether the respondent could obtain money from selling trees or charcoal if in need, whether land owned is used for people to live on, and patience. Additional controls include: asset index, sex, education, risk tolerance, land area, and whether or not respondent/household sells trees for or produces charcoal. Robust standard errors in parentheses.

Number of trees cut highest for insecure, then certificate, then secure tenure