

Voluntary sustainability standards can mitigate deforestation-export trade-offs

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A. Supplementary Figures

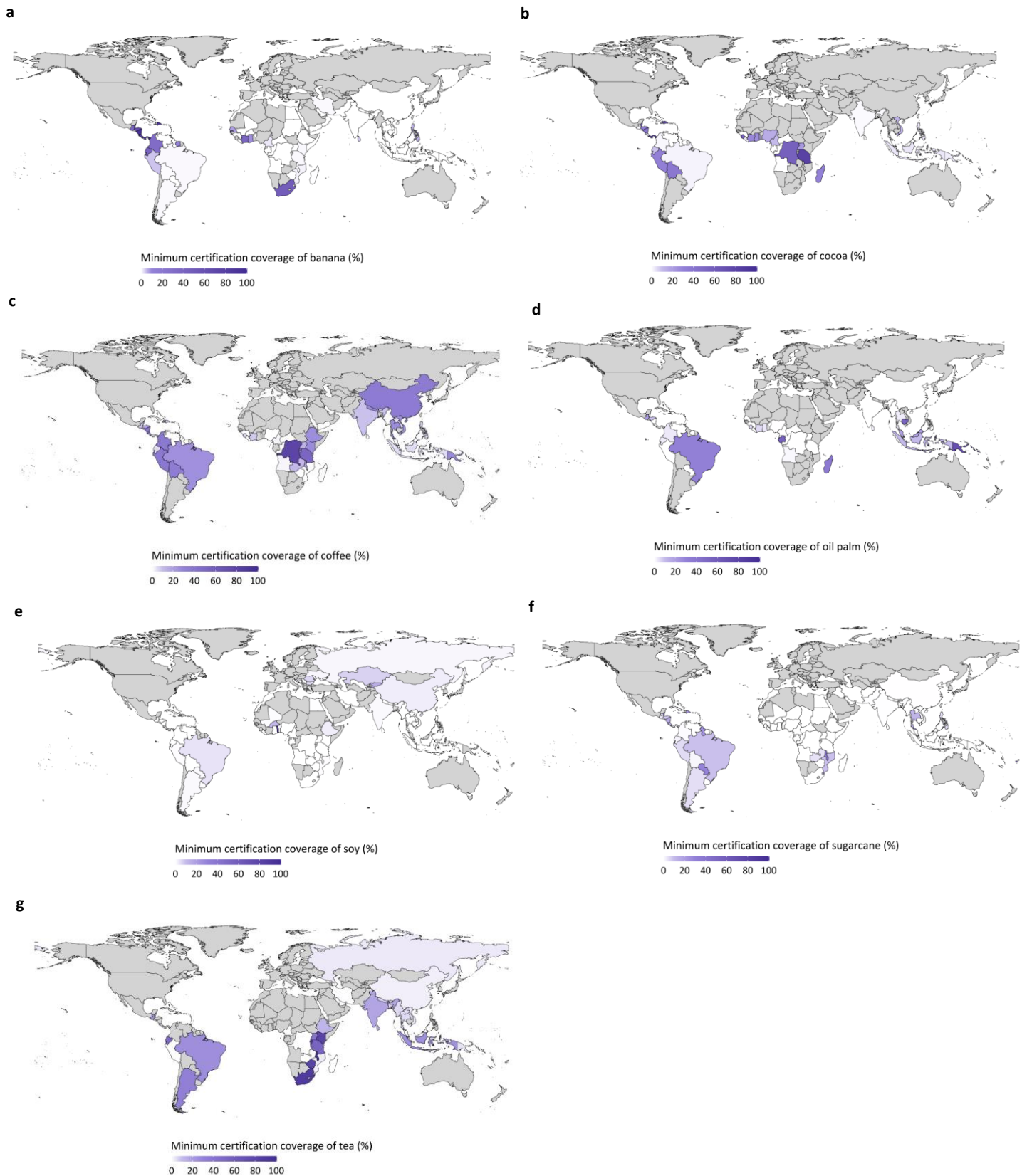
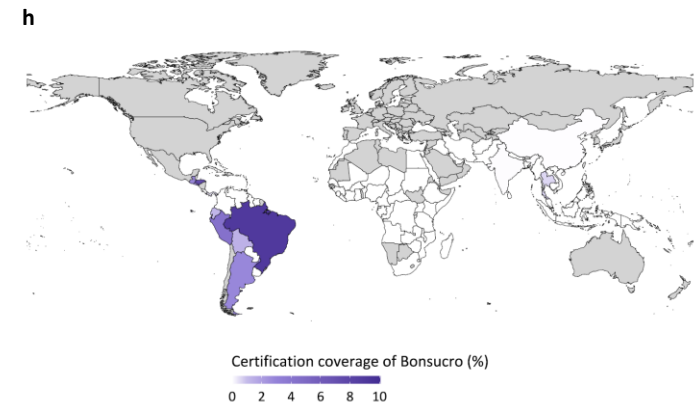
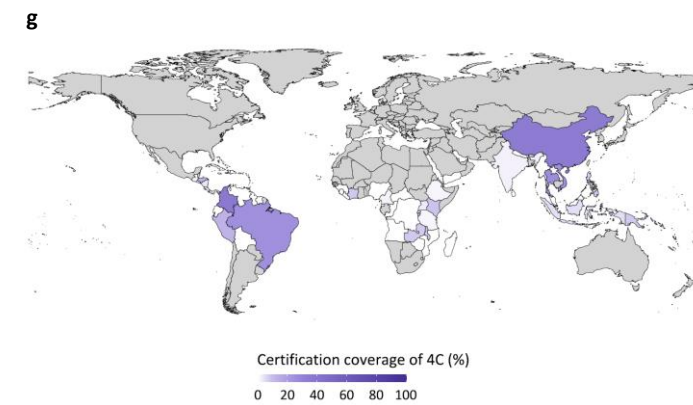
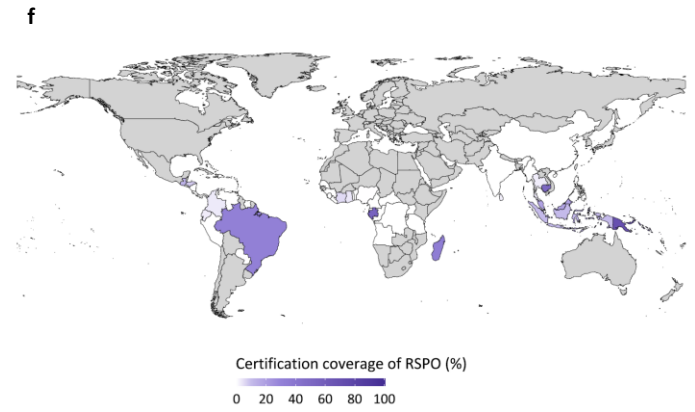
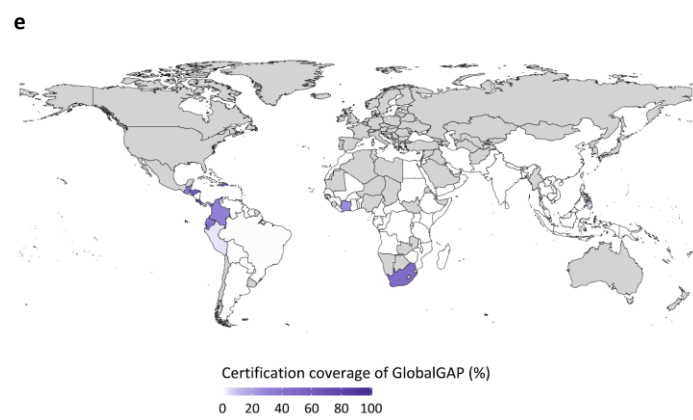
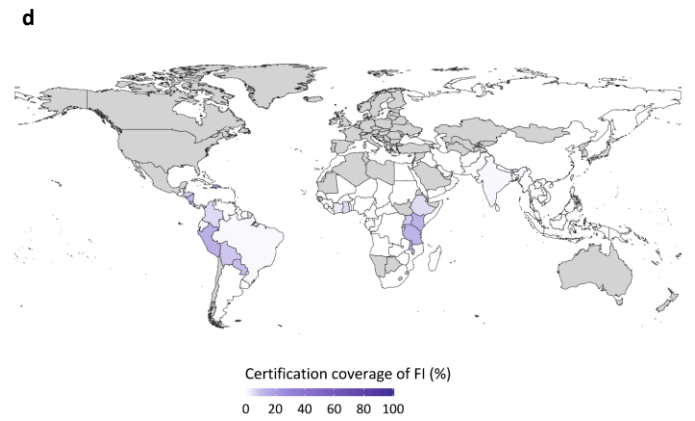
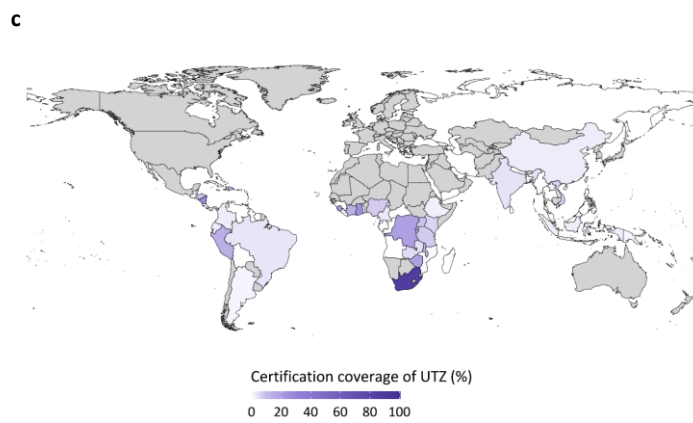
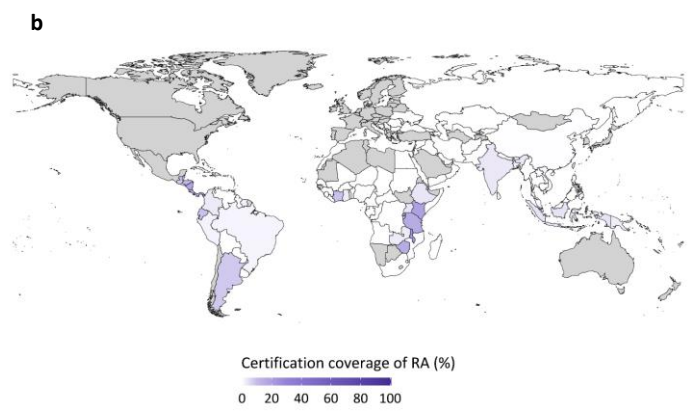
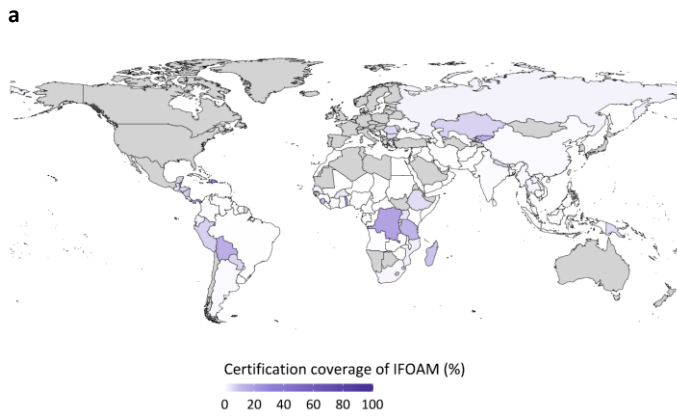


Figure A1 | Geographical distribution of VSS coverage per commodity. Average share of certified area over total production area across countries for (a) banana, (b) cocoa, (c) coffee, (d) oil palm, (e) soy, (f) sugarcane, and (g) tea over 2012-2020. *Notes:* Figures are based on the minimum certified production area, assuming full overlap, which is a conservative measure of geographical spread. The sample includes all non-OECD producer countries with a minimum area threshold of 500 ha and 0.05% of national cropland devoted to the commodity (N=3,929 commodity-country observations).



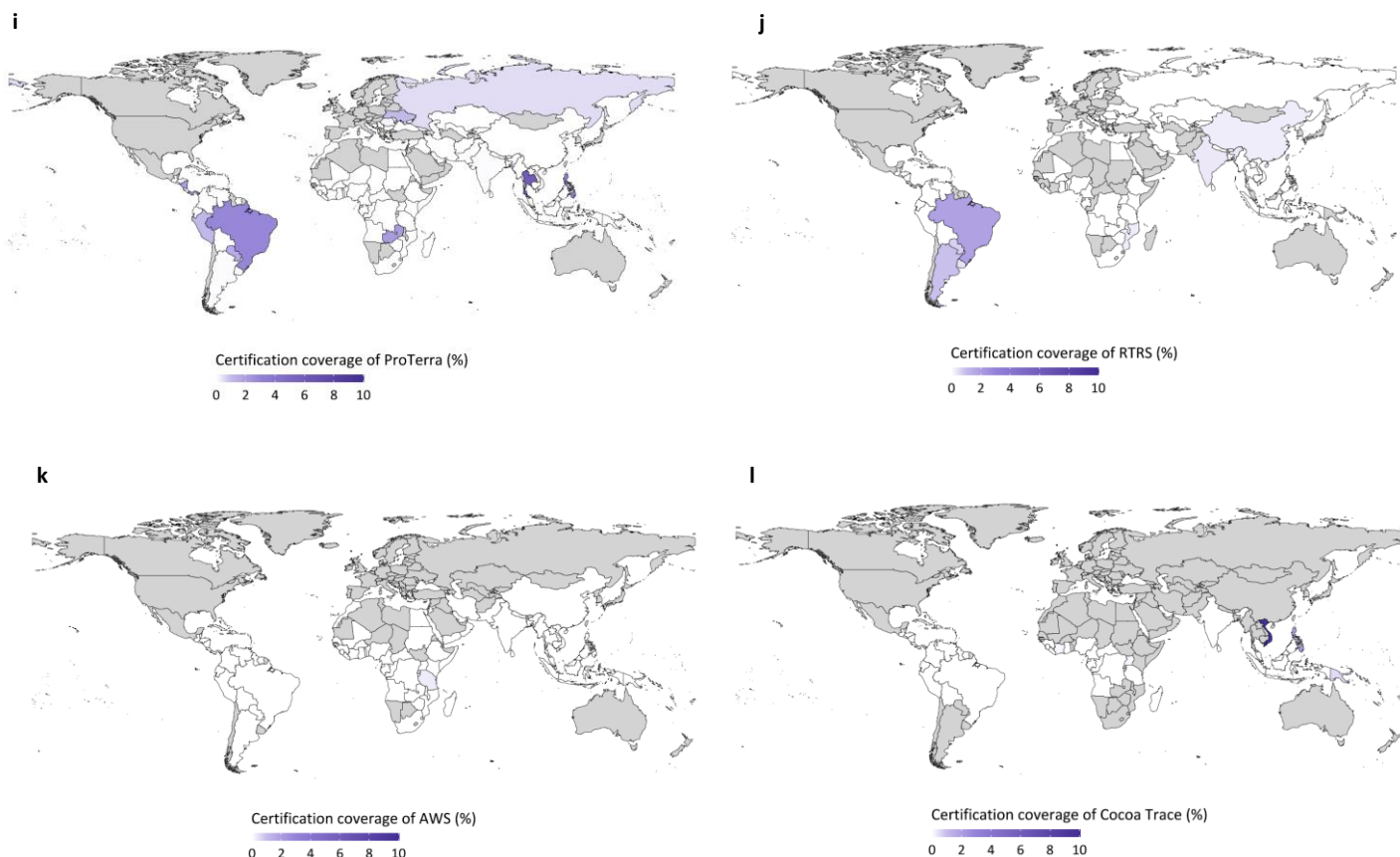


Figure A2 | Geographical distribution of VSS coverage per VSS. Average share of certified area over the total production area by these VSS across countries for (a) IFOAM (umbrella organization representing organic VSS), (b) Rainforest Alliance, (c) UTZ, (d) Fairtrade International, (e) GlobalGAP, (f) Roundtable on Sustainable Palm Oil (RSPO), (g) 4C, (h) Bonsucro, (i) ProTerra, (j) Alliance for Water Stewardship, (k) Cocoa Trace, and (l) Round Table on Responsible Soy (RTRS) over 2012-2020. *Notes:* The scale for figures h-l ranges from 0-10% instead of 0-100% as the share of certified area is much lower for these VSS. The sample includes all non-OECD producer countries with a minimum area threshold of 500 ha and 0.05% of national cropland devoted to the commodity (N=3,929 commodity-country observations).

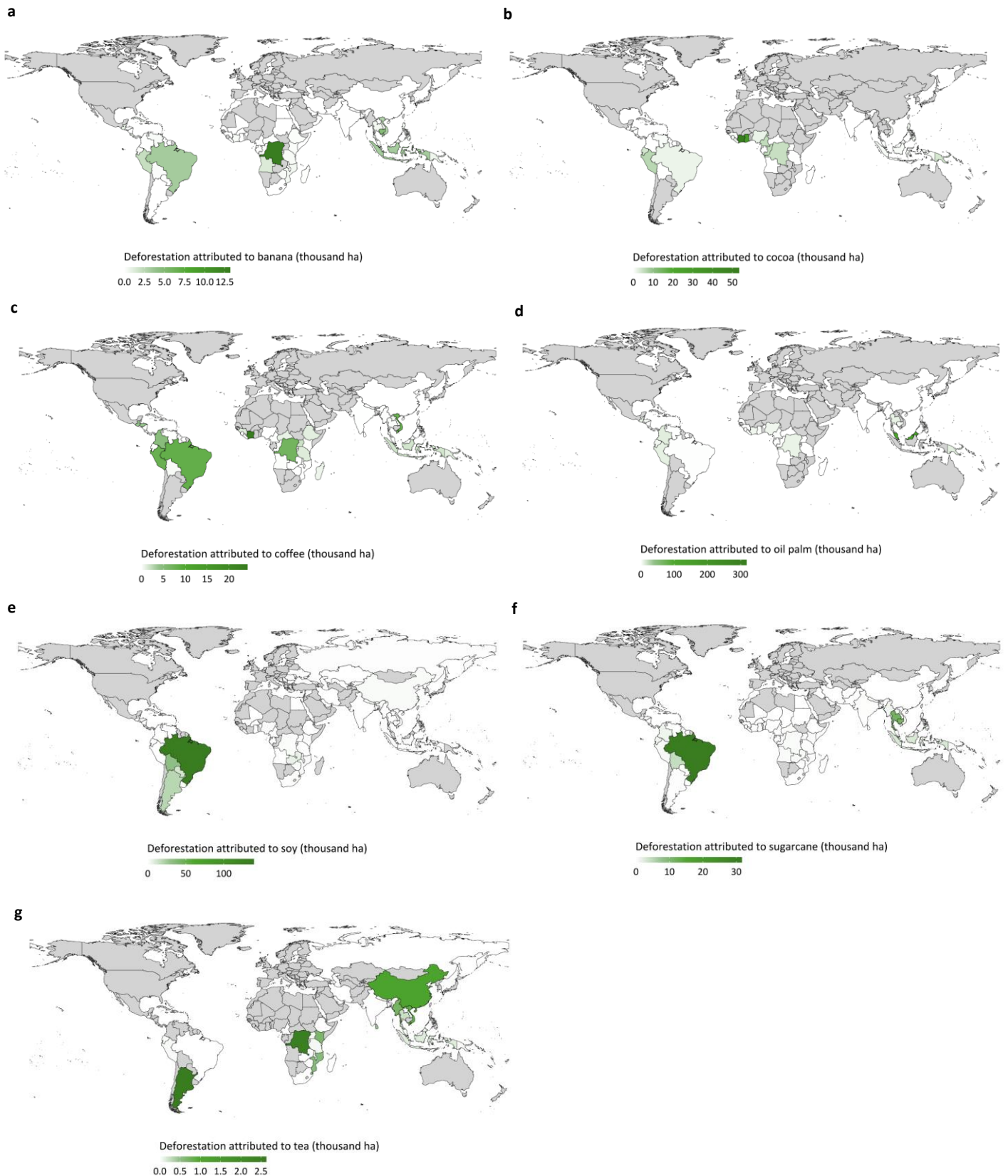


Figure A3 | Geographical distribution of deforestation attribution per commodity. Average deforestation attribution (thousand ha) across countries for (a) banana, (b) cocoa, (c) coffee, (d) oil palm, (e) soy, (f) sugarcane, and (g) tea over 2012-2020. *Notes:* Different scales are used across commodities to focus on within-commodity patterns. The sample includes all non-OECD producer countries with a minimum area threshold of 500 ha and 0.05% of national cropland devoted to the commodity (N=3,929 commodity-country observations).

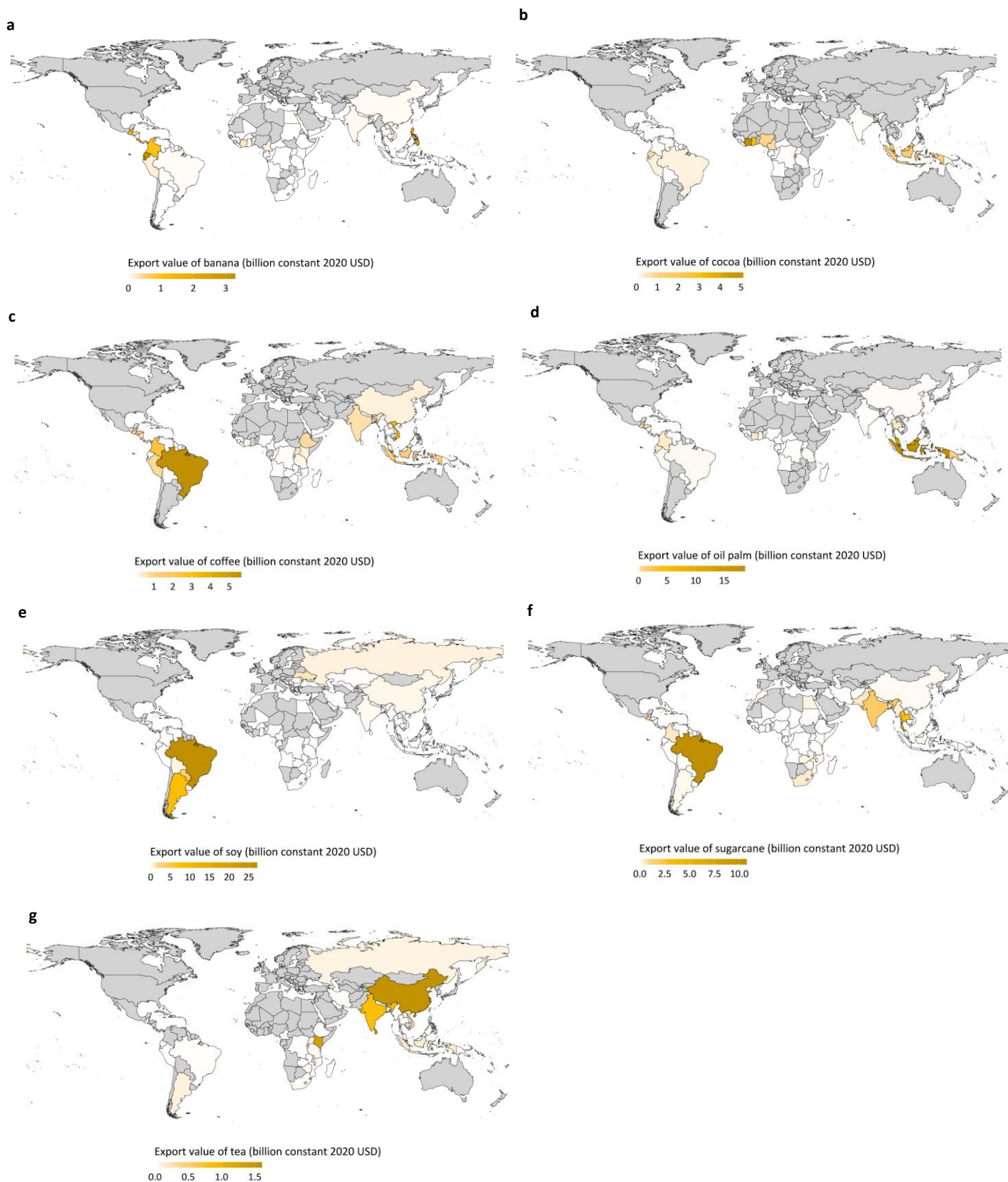


Figure A4 | Geographical distribution of export value per commodity. Average export value (billion constant 2020 USD) across countries for (a) banana, (b) cocoa, (c) coffee, (d) palm oil, (e) soy, (f) sugarcane, and (g) tea over 2012-2020. *Notes:* Different scales are used across commodities to focus on within-commodity patterns. The sample includes all non-OECD producer countries with a minimum area threshold of 500 ha and 0.05% of national cropland devoted to the commodity (N=3,929 commodity-country observations).

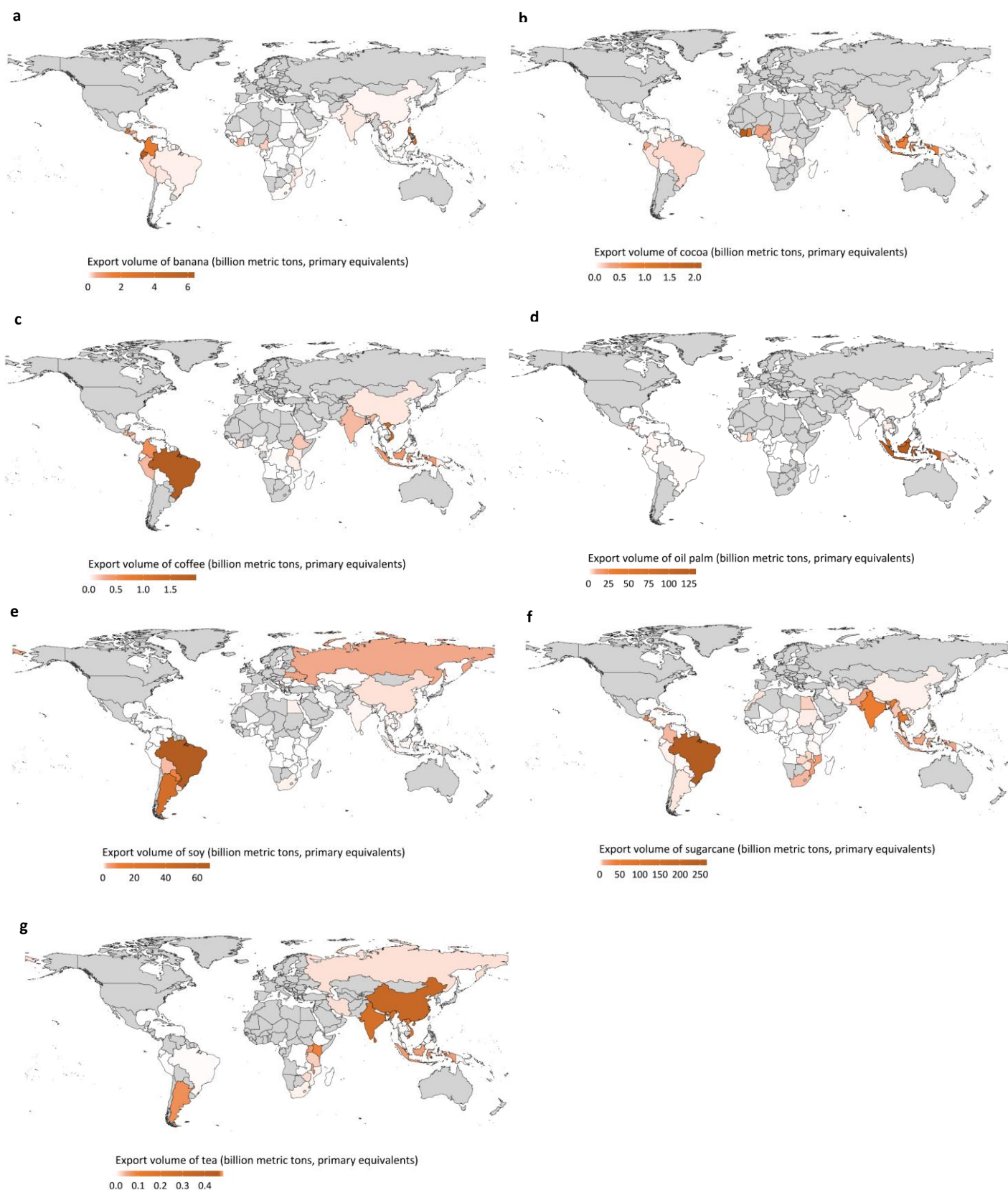


Figure A5 | Geographical distribution of export volume per commodity. Average export volume (billion metric tons, in primary equivalents) across countries for (a) banana, (b) cocoa, (c) coffee, (d) palm oil, (e) soy, (f) sugarcane, and (g) tea over 2012-2020. *Notes:* Different scales are used across commodities to focus on within-commodity patterns. The sample includes all non-OECD producer countries with a minimum area threshold of 500 ha and 0.05% of national cropland devoted to the commodity (N=3,929 commodity-country observations).

B. Supplementary Tables

Table A1 | List of product lines included in the study

HS6	Correspondence with HS12	Description
Banana		
80300	80310 & 80390	Bananas, (including plantains), fresh or dried
Cocoa		
180100	180100	Cocoa beans; whole or broken, raw or roasted
180310	180310	Cocoa; paste, not defatted
180320	180320	Cocoa; paste, wholly or partly defatted
180400	180400	Cocoa; butter, fat and oil
180500	180500	Cocoa; powder, not containing added sugar or other sweetening matter
Coffee		
90111	90111	Coffee; not roasted or decaffeinated
90112	90112	Coffee; decaffeinated, not roasted
90121	90121	Coffee; roasted, not decaffeinated
90122	90122	Coffee; roasted, decaffeinated
Palm oil		
120710	120710	Oil seeds: palm nuts and kernels, whether or not broken
151110	151110	Palm oil and its fractions, crude, not chemically modified
151190	151190	Palm oil and its fractions, other than crude, whether or not refined, but not chemically modified
Soy		
120100	120110 & 120190	Soya beans: whether or not broken
120810	120810	Flours and meals: of soya beans
150710	150710	Vegetable oils: soya-bean oil and its fractions, crude, whether or not degummed, not chemically modified
150790	150790	Vegetable oils: soya-bean oil and its fractions, other than crude, whether or not refined, but not chemically modified
Sugarcane		
121292	121293	Sugar cane: of a kind used primarily for human consumption, fresh, chilled, frozen or dried, whether or not ground
170111	170113 & 170114	Sugars: cane sugar, raw, in solid form, as specified in Subheading Note 2 to this chapter, not containing added flavouring or colouring matter
170191	170191	Sucrose: chemically pure, containing added flavouring or colouring matter, in solid form
170199	170199	Sucrose: chemically pure, not containing added flavouring or colouring matter, in solid form
170310	170310	Sugars: molasses, from sugar cane, resulting from the extraction or refining of sugar
Tea		
90210	90210	Tea, green; [not fermented], in packings not exceeding 3 kg
90220	90220	Tea, green; [not fermented], in packings exceeding 3 kg
90230	90230	Tea, black; [(partly) fermented tea], in packings not exceeding 3 kg
90240	90240	Tea, black; [(partly) fermented tea], in packings exceeding 3 kg

Table A2 | List of producing countries included in the study (125) by continent

Africa	Americas	Asia	Europe	Oceania
Angola	Argentina	Afghanistan	Bulgaria	Fiji
Burundi	Antigua and Barbuda	Azerbaijan	Bosnia and Herzegovina	Micronesia (Federated States of)
Benin	Bahamas (the)	Bangladesh	Croatia	Kiribati
Burkina Faso	Belize	Brunei Darussalam	Moldova (the Republic of)	Papua New Guinea
Central African Republic (the)	Bolivia (Plurinational State of)	Bhutan	Montenegro	Solomon Islands
Côte d'Ivoire	Brazil	Cambodia	Romania	Tonga
Cameroon	Barbados	China	Russian Federation (the)	Tuvalu
Congo (the Democratic Republic of the)	Colombia	Cyprus	Serbia	Vanuatu
Congo (the)	Costa Rica	Georgia	Ukraine	Samoa
Comoros (the)	Cuba	Indonesia		
Cabo Verde	Dominica	India		
Egypt	Dominican Republic (the)	Iran (Islamic Republic of)		
Ethiopia	Ecuador	Iraq		
Gabon	Grenada	Jordan		
Ghana	Guatemala	Kazakhstan		
Guinea	Guyana	Kyrgyzstan		
Gambia (the)	Honduras	Lao People's Democratic Republic (the)		
Guinea-Bissau	Haiti	Lebanon		
Equatorial Guinea	Jamaica	Sri Lanka		
Kenya	Saint Lucia	Maldives		
Liberia	Nicaragua	Myanmar		
Morocco	Panama	Malaysia		
Madagascar	Peru	Nepal		
Mali	Paraguay	Oman		
Mozambique	El Salvador	Pakistan		
Mauritius	Suriname	Philippines (the)		
Malawi	Trinidad and Tobago	Korea (the Democratic People's Republic of)		
Niger (the)	Uruguay	Syrian Arab Republic (the)		
Nigeria	Saint Vincent and the Grenadines	Thailand		
Rwanda	Venezuela (Bolivarian Republic of)	Timor-Leste		
Sudan (the)		Uzbekistan		
Senegal		Viet Nam		
Sierra Leone		Yemen		
Somalia				
Sao Tome and Principe				
Eswatini				
Seychelles				
Chad				
Togo				
Tanzania (the United Republic of)				
Uganda				
South Africa				
Zambia				
Zimbabwe				

Table A3 | Data description

Concept	Variable	Data source
Outcome variables of interest		
Commodity-driven deforestation	Deforestation attribution area (<i>DA</i>) (ha)	Singh and Persson ¹
Commodity-driven deforestation per export value	Deforestation attribution area per unit of export value (<i>DAEVA</i>) (ha per constant 2020 USD)	Singh and Persson ¹ and Base pour l'Analyse du Commerce International (BACI) ²
Commodity-driven deforestation per export volume	Deforestation attribution area per unit of export volume (<i>DAEVO</i>) (ha per metric tons in primary equivalents)	Singh and Persson ¹ and Base pour l'Analyse du Commerce International (BACI) ²
Independent variables of interest		
VSS-specific certified area	IFOAM certified area (ha) RA certified area (ha) UTZ certified area (ha) FI certified area (ha) GlobalGAP certified area (ha) RSPO certified area (ha) 4C certified area (ha) Bonsucro certified area (ha) ProTerra certified area (ha) RTRS certified area (ha) AWS certified area (ha) Cocoa Trace certified area (ha)	Compilation of data from standard-setting organizations (The Research Institute of Organic Agriculture (FiBL) and the specific VSS organizations)
Total certified area	Minimum certified area (<i>CA</i>) (ha) (assumes full overlap between VSS) Maximum certified area (<i>CA</i>) (ha) (assumes no overlap between VSS)	
Control variables		
National production	Harvested commodity area (ha)	FAOSTAT ³ , imputations based on other sources mentioned in the data cleaning file
Global production	Global harvested commodity area (ha)	FAOSTAT ³
Population pressure	Population size Population growth	World Bank ⁴ World Bank ⁴
Growth of the economy	GDP (constant 2020 USD)	UN data ⁵
Openness to investment	FDI (constant 2020 USD)	World Bank ⁴
Public governance	Governance index (0-5) National forest-related policies (#) Quality of infrastructure (1-5)	World Bank ⁶ Wuepper and co-authors ⁷ World Bank ⁴
Climate	Precipitation anomalies Temperature anomalies	Climatic Research Unit (University of East Anglia) and NCAS ⁸ Climatic Research Unit (University of East Anglia) and NCAS ⁸
National trade costs	WTO membership (0/1) Export-restricting NTMs imposed by producer country (#)	World Trade Organization ⁹ Global Trade Alert ¹⁰
Trade costs at the border	Import-restricting NTMs imposed by other countries (#) Regional trade agreements Average tariff rates (%)	Global Trade Alert ¹⁰ Mario Larch ¹¹ TRAINS ¹² , imputations following Bemelmans and co-authors ¹³

Note: Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil; RTRS – Round Table on Responsible Soy; AWS – Alliance for Water Stewardship.

Table A4 | Overview of VSS coverage in the sample by crop

	Full sample			VSS sample		
	N	Number of countries	Mean share of certified production area (St. dev.)	N	Number of countries	Mean share of certified production area (St. dev.)
Banana	866	98	6.59 (20.44)	218	42	26.17 (33.91)
Cocoa	485	56	15.02 (25.35)	246	34	29.62 (28.91)
Coffee	546	62	14.63 (23.84)	333	43	23.98 (26.60)
Oil palm	410	47	8.69 (20.74)	132	21	26.99 (29.08)
Soy	580	68	2.13 (11.38)	179	30	6.91 (19.71)
Sugarcane	721	82	4.11 (14.69)	195	33	15.19 (25.12)
Tea	321	38	21.79 (31.89)	216	30	32.39 (34.19)
Total	3,929	125	9.10 (21.71)	1,519	90	23.53 (29.66)

Table A5 | Overview of VSS coverage in the sample by VSS

	Full sample			VSS sample			Establishment year
	N	Number of countries	Mean share of certified production area (St. dev.)	N	Number of countries	Mean share of certified production area (St. dev.)	
IFOAM	3,929	125	3.60 (14.30)	1,129	78	12.54 (24.49)	1991
RA	3,929	125	2.90 (12.72)	573	42	19.88 (27.80)	1987
UTZ	3,929	125	4.37 (12.47)	409	39	14.45 (19.22)	2002
FI	3,929	125	2.34 (9.62)	371	36	18.52 (20.85)	1997
GlobalGAP	3,929	125	3.71 (13.98)	99	26	32.44 (27.99)	1997
RSPO	3,929	125	7.59 (19.01)	114	17	27.29 (27.67)	2004
4C	3,929	125	3.93 (9.23)	172	27	12.49 (12.82)	2005
Bonsucro	3,929	125	0.76 (3.83)	53	15	10.39 (10.04)	2009
ProTerra	3,929	125	0.97 (7.67)	66	18	19.03 (28.79)	2005
RTRS	3,929	125	0.07 (0.32)	52	7	0.83 (0.75)	2006
AWS	3,929	125	0.00 (0.06)	6	2	0.82 (0.43)	2008
Cocoa Trace	3,929	125	0.23 (2.11)	15	5	7.29 (9.96)	2008
Total	3,929	125	9.10 (21.71)	3,929	125	9.10 (21.71)	

Note: Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil; RTRS – Round Table on Responsible Soy; AWS – Alliance for Water Stewardship.

Table A6 | Descriptive statistics

Pooled sample summary information							Within-FE summary information					
Variable	N	Mean	St. Dev.	Min	Max	Singletons	N without within-country-commodity-FE variation	N without within-year-FE variation	N without within-country-year-FE variation	Within-country-commodity variation (%)	Within-year variation (%)	Within-country-year variation (%)
Deforestation attribution area (DA) (ha)	3,737	3.05	3.48	0	14.30	0	122	0	139	57.27	99.64	75.65
Deforestation attribution area per unit of export value (DAEVA) (ha per constant 2020 USD)	3,437	0.17	4.10	0	145.50	0	172	0	215	85.34	99.56	86.25
Deforestation attribution area per unit of export volume (DAEVO) (ha per metric tons in primary equivalents)	3,437	98.36	2,672.28	0	121,360.40	0	131	0	141	88.98	99.84	93.53
Minimum certified area (CA) (ha)	3,929	23,639.59	128,492.2	0	1,780,000	0	1,477	0	493	28.61	99.95	89.06
Maximum certified area (CA) (ha)	3,929	33,786.43	179,256.2	0	2,870,767		1,477		493	28.52	99.95	88.83
Harvested commodity area (ha)	3,929	10.55	2.47	2.31	18.12	0	21	0	0	11.06	99.99	69.83
Global harvested commodity area (ha)	3,929	2.95E+07	3.85E+07	3,512,349	1.27E+08	0	0	0	0	6.93	99.86	90.49
Population size	3,929	7.31E+07	2.32E+08	10,828	1.42E+09	0	0	0		2.63	99.99	
Population growth (%)	3,929	1.69	1.14	-2.90	11.79	0	0	0		40.98	99.75	
GDP (constant 2020 USD)	3,929	3.51E+11	1.56E+12	3.95E+07	1.51E+13	0	0	0		13.66	99.99	
FDI (constant 2020 USD)	3,929	9.07E+09	4.42E+10	- 2.60E+10	4.63E+11	0	0	0		18.18	99.96	
Governance index (0-5)	3,929	2.01	0.57	0.25	3.65	0	0	0		16.80	99.98	
National forest-related policies (#)	3,929	13.19	11.01	0	61	0	683	0		21.70	99.31	
Quality of infrastructure (1-5)	3,929	2.62	0.36	1.56	3.78	0	26	0		34.51	99.94	
Precipitation anomalies	3,929	-0.03	1.01	-3.77	3.53	0	21	0		88.28	96.99	

Temperature anomalies	3929	1.49	0.68	-1.16	3.66	0	21	0		80.58	86.04	
WTO membership (0/1)	3,929	0.90	0.31	0	1	0	3,322	0		29.32	99.85	
Export-restricting NTMs imposed by producer country (#)	3,929	2.86	4.46	0	54	0	1,074	0	203	52.35	98.43	85.67
Import-restricting NTMs imposed by other countries (#)	3,929	38.52	23.95	0	122	0	1,565	0	576	57.83	96.45	84.11
Regional trade agreements	3,929	12.91	32.07	0	325	0	1,217	0		24.70	99.56	
Average tariff rates (%)	3,929	1.26	1.09	0	4.87	0	121	0	11	55.76	98.52	78.83

Table A7 | Overview of criteria in deforestation stringency score

Dimension	Criterium	Criterium stringency score	Relevance	
Deforestation prevention	Prohibition of secondary or natural forest conversion	Conversion allowed or not mentioned	0	Conversion prohibition is central to deforestation reduction
		Conversion prohibited but with exemptions (e.g., smallholder allowances, legal mandates)	0.5	
		Conversion prohibited without exemptions	1	
	Prohibition of primary forest conversion	Conversion allowed or not mentioned	0	Conversion prohibition is central to deforestation reduction
		Conversion prohibited but with exemptions (e.g., smallholder allowances, legal mandates)	0.5	
		Conversion prohibited without exemptions	1	
	Prohibition of production in High Conservation Value (HCV) or High Carbon Stock (HCS) areas	No prohibition or not mentioned	0	Highly relevant due to their critical ecological functions
		Conversion is prohibited with exemptions (e.g., smallholder allowances, legal mandates)	0.5	
		Conversion is prohibited without exemptions	1	
	Prohibition of production in protected areas	No prohibition or not mentioned	0	Crucial to respect existing legal protections
		Conversion is prohibited with exemptions (e.g., smallholder allowances, legal mandates)	0.5	
		Conversion is prohibited without exemptions	1	
	Criteria including a cut-off date to prohibit deforestation	No	0	Might imply a more stringent prohibition of forest conversion
		Yes	1	
	Clear definition of forest types that may not be converted	No	0	Without definitions, criteria risk inconsistency
Yes, but not aligned with internationally accepted definitions (e.g., FAO or IPCC)		0.5		
Yes, aligned with internationally accepted definitions (e.g., FAO or IPCC)		1		
Criteria to ensure adherence to national conventions and legislation on deforestation		No	0	Vital to ensure enforcement with national standards and best practices
Yes	1			
Conservation and restoration of natural ecosystems	Environmental impact assessment for new and/or existing production	No impact assessments required	0	Necessary for accountability
		Yes	1	
	Enhance conservation of natural ecosystems	No	0	Important for reversing deforestation trends
		Yes	1	
	Restoration of negative impact from production activities on the natural ecosystem	No	0	Important for reversing deforestation trends
Yes	1			

Location and land rights	Delineation of farm boundaries	No requirement	0	Very important for traceability and accountability
		Partial delineation (e.g., GPS points per producer)	0.5	
		Full delineation (e.g., polygons for all certified plots)	1	
	Land title and legal use rights	No requirement	0	Foundational for resolving disputes and preventing land grabs
		Requirements include dispute resolution measures	1	
	Protection on local and indigenous rights	No	0	Key to reducing social conflict and ensuring equitable outcomes
		Yes	1	
Sustainable land use practices	Promotion of agroforestry	No requirement	0	Encourages sustainable production practices, and might improve forest conservation
		Agroforestry encouraged but without quantifiable targets	0.5	
		Agroforestry promotion with quantifiable targets	1	

Table A8 | Weights used for the deforestation stringency score

Criticality of the criteria		Explicitness of the criteria	
		Implicit Room for interpretation	Explicit No room for interpretation
Not covered	Not included in the requirements.	0.00	0.00
Optional	Optional criteria, non-compliance restricts permission to make claims on the criteria, but does not affect certification status.	0.25	0.50
Minor	Non-compliance does not require immediate corrective action, additional audits or suspension from certification.	0.50	0.75
Major dealbreaker	Non-compliance requires immediate corrective action assessed in an additional audit and suspension from certification if not resolved.	0.75	1.00

Table A9 | Overview of criteria in procedural stringency score

Mechanism	Attribute name	Scoring guidance	Score
Enforcement	Regular on-site audit	No on-site audit is required after initial certification audit	0
		A certain number of on-site audits are required within the certificate validity period (when this latter is longer than 1 year), but less than annually	(number of audits required within certificate validity period)/(number of years of certificate validity)
		There is a procedure requiring that on on-site audits are conducted at least annually	1
	Sample size and selection	There is no procedure to determine sample size and selection	0
		There is a procedure requiring that sample size is at least the square root of the number of members/farms/producers OR There is a procedure requiring that sample selection is representative of risk and/or type of activities	0.5
		There is a procedure requiring that sample size is at least the square root of the number of members/farms/producers AND There is a procedure requiring that sample selection is representative of risk and/or type of activities	1
	Stakeholders input	There is no procedure requiring that the input of affected stakeholders (internal and external) is taken into account in the certification process	0
		There is a procedure requiring to interview workers during the audit OR There is a procedure requiring that external stakeholders are consulted during the certification process	0.5
		There is a procedure requiring to interview workers during the audit OR There is a procedure requiring that external stakeholders are consulted during the certification process; AND There is a procedure that guarantees the protection of interviewed/consulted stakeholders OR The VSS organisation provides whistleblowing channels for workers or stakeholders to provide inputs or raise issues	1
	Unannounced audits	There is no procedure that require certification bodies to conduct unannounced audits	0
		There is a procedure that allows certification bodies to conduct unannounced audits	0.5
		There is a procedure that requires certification bodies to conduct a certain number of unannounced audits	1
	Certification/ compliance status outcome transparency	No public information on the certification status or compliance level is provided by the VSS organisation	0
		The VSS organisation makes the list of certified entities and their certification status publicly available	0.5
		The VSS organisation makes the list of certified entities, their certification status AND individual audit reports publicly available	1
	Complaint and dispute settlement system	There is no complaint and dispute settlement system	0
		There is a procedure for stakeholders to raise complaints to the VSS organisation about certified entities' compliance	0.5
		There is a procedure for stakeholders to raise complaints to the VSS organisation about certified entities' compliance AND There are procedures to facilitate the filing of complaints (e.g. translation services, confidentiality guarantee, funding support, "workers voice" technology or smartphone allegation channels)	1

Complaint and dispute settlement system outcome transparency	The VSS organisation does not publicly disclose information about complaints and their outcomes	0
	The VSS organisation publishes aggregated information about complaints	0.5
	The VSS organisation publishes information about individual complaints and their outcomes	1
Corrective actions	There is no procedure that requires certified entities to address non-compliances through corrective actions	0
	There is a procedure that requires certified entities to address non-compliances through corrective actions	0.5
	There is a procedure that requires certified entities to address non-compliances through corrective actions AND There is a procedure that requires the verification of the implementation of corrective actions	1
Sanctions	There is no procedure to sanction non-compliance	0
	In case of (repeated, unaddressed, and/or major) non-compliances, the certificate/membership can be suspended or withdrawn	1
Independent third-party auditing	Audits are conducted by auditors from the VSS organisation (second-party auditing) or from the certified entity (first-party auditing)	0
	Audits are conducted by auditors from an organisation that is different but not independent from the VSS organisation (e.g. the auditing organisation was established by the VSS organisation; the VSS organisation requires that audits are conducted by a specific auditing organisation)	0.5
	Audits are conducted by an organisation that is different and independent from the VSS organisation	1
Certification bodies competence	There is no procedure requiring that certification bodies are ISO accredited	0
	There is a procedure that requires certification bodies to be ISO accredited	1
Certification bodies performance	There is no oversight procedures on certification bodies	0
	There is a procedure that requires certification bodies to regularly self-report on their performance, or that requires them to be assessed by an accreditation body regularly	0.5
	There is a procedure for the VSS organisation to conduct regular oversight activities on certification bodies (e.g. performance assessments, shadow audits)	1
Auditors competence	There is no procedure that requires auditors to be trained	0
	There is a procedure that requires auditors to be trained on ISO standards	0.5
	There is a procedure that requires auditors to be trained on ISO standards AND to be trained or experienced in the issues that the VSS organisation aims to tackle	1
Auditors independence	There are no procedures that further guarantee auditors' independence from the certified entity	0
	There is a policy requiring the absence of conflict of interest between auditors and the certified entity	0.5
	There is a policy requiring the absence of conflict of interest between auditors and the certified entity AND there is a procedure limiting the number of subsequent audits an auditor can conduct for the same certified entity AND/OR there is an audit allocation system	1

Note: Adapted from Depoorter and Marx¹⁴.

Table A10 | Full regression results for the overall VSS effect on deforestation attribution (ha)

Model	1	2	1 with sample of model 2	3	1 with sample of model 3	1 with tree cover density of 10%	1 with tree cover density of 75%
Min certified area (ha)	0.016 (0.023)	0.026 (0.018)	0.016 (0.023)	0.031 (0.031)	0.027 (0.030)	0.009 (0.024)	-0.009 (0.030)
Generalized residual				-0.000 (0.000)			
Harvested area (ha)	1.807 (1.224)	-1.763 (1.839)	1.827 (1.230)	-1.054 (2.576)	-1.027 (2.556)	1.611 (1.238)	3.214** (1.325)
Harvested area ² (ha ²)	- 0.125*** (0.046)	-0.004 (0.070)	-0.126*** (0.046)	-0.023 (0.091)	-0.024 (0.091)	-0.117** (0.047)	-0.182*** (0.054)
Harvested area worldwide (ha)	-1.188 (0.830)	-0.917 (0.973)	-1.190 (0.831)	-0.614 (0.748)	-0.659 (0.722)	-1.203 (0.823)	-0.875 (0.939)
Total population (#)	-0.430 (2.291)		-0.448 (2.302)	3.029 (2.514)	3.138 (2.541)	-0.142 (2.283)	-3.394 (2.802)
Population growth (%)	0.933*** (0.242)		0.932*** (0.242)	0.806*** (0.288)	0.805*** (0.285)	0.889*** (0.239)	0.968*** (0.258)
GDP (constant 2020 USD)	0.557 (0.461)		0.567 (0.464)	-0.123 (0.494)	-0.099 (0.491)	0.400 (0.462)	0.588 (0.540)
FDI (constant 2020 USD)	0.010* (0.006)		0.010* (0.006)	0.022** (0.008)	0.021** (0.008)	0.009* (0.005)	0.010 (0.006)
World Governance Index	- 1.341*** (0.376)		-1.344*** (0.377)	-1.163** (0.538)	-1.230** (0.562)	-1.198*** (0.402)	-2.131*** (0.396)
National forest-related policies (#)	-0.009 (0.023)		-0.008 (0.023)	0.044* (0.025)	0.047** (0.024)	-0.012 (0.022)	-0.025 (0.027)
Logistics performance index	-0.336 (0.398)		-0.336 (0.398)	-0.269 (0.571)	-0.305 (0.564)	-0.392 (0.400)	-0.275 (0.425)
Precipitation anomalies	-0.000 (0.048)		-0.001 (0.048)	-0.006 (0.050)	-0.006 (0.051)	-0.004 (0.047)	0.021 (0.049)
Temperature anomalies	0.162** (0.074)		0.161** (0.074)	0.126* (0.066)	0.126* (0.070)	0.159** (0.073)	0.080 (0.079)
Constant	29.957 (41.247)	55.526*** (17.613)	29.951 (41.457)	-9.508 (33.410)	-11.335 (35.015)	30.160 (41.547)	74.064 (46.504)
Observations	3,647	3,315	3,315	1,689	1,689	3,650	3,531
Pseudo R squared	0.956	0.980	0.955	0.961	0.961	0.953	0.962
Chi ² first stage				24.99			

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A11 | Full regression estimates for the crop-specific VSS effects on deforestation attribution (ha)

Model	1	2	1 with sample of model 2	3	1 with sample of model 3	1 with tree cover density of 10%	1 with tree cover density of 75%
Min certified area (ha) x							
Banana	0.121 (0.077)	0.120* (0.068)	0.121 (0.077)	0.099 (0.102)	0.101 (0.101)	0.106* (0.063)	0.164 (0.177)
Cocoa	0.231** (0.095)	0.229** (0.089)	0.232** (0.095)	0.144** (0.059)	0.150** (0.058)	0.229** (0.096)	0.140** (0.065)
Coffee	0.083** (0.039)	0.084** (0.037)	0.083** (0.039)	0.040 (0.052)	0.049 (0.052)	0.080** (0.033)	0.146 (0.193)
Oil palm	-0.048** (0.023)	-0.020 (0.026)	-0.048** (0.023)	-0.096** (0.046)	-0.090* (0.046)	-0.064** (0.027)	-0.054* (0.031)
Soy	0.032 (0.071)	-0.157* (0.095)	0.032 (0.078)	0.064 (0.064)	0.069 (0.061)	0.037 (0.068)	-0.054 (0.106)
Sugarcane	0.010 (0.041)	0.002 (0.043)	0.009 (0.041)	0.036 (0.048)	0.041 (0.050)	0.018 (0.041)	-0.017 (0.042)
Tea	-0.009 (0.094)	0.006 (0.096)	-0.010 (0.093)	0.018 (0.079)	0.016 (0.078)	-0.023 (0.093)	0.141 (0.104)
Generalized residual				0.000 (0.000)			
Harvested area (ha)	2.065* (1.219)	-1.920 (1.760)	2.088* (1.224)	-1.089 (2.655)	-1.094 (2.666)	1.880 (1.226)	3.312** (1.341)
Harvested area ² (ha ²)	- 0.133***	0.003	-0.134***	-0.022	-0.022	-0.125***	-0.183***
	(0.046)	(0.067)	(0.046)	(0.094)	(0.094)	(0.046)	(0.055)
Harvested area worldwide (ha)	-0.951 (0.848)	-0.775 (0.988)	-0.953 (0.848)	-0.501 (0.731)	-0.478 (0.721)	-0.911 (0.842)	-0.735 (0.971)
Total population (#)	-1.331 (2.321)		-1.362 (2.329)	2.945 (2.621)	2.669 (2.614)	-0.939 (2.336)	-4.025 (2.875)
Population growth (%)	0.893*** (0.234)		0.891*** (0.234)	0.796*** (0.282)	0.783*** (0.288)	0.845*** (0.230)	0.963*** (0.255)
GDP (constant 2020 USD)	0.530 (0.465)		0.538 (0.469)	-0.086 (0.502)	-0.109 (0.505)	0.362 (0.469)	0.592 (0.540)
FDI (constant 2020 USD)	0.009* (0.006)		0.009* (0.006)	0.021*** (0.008)	0.022*** (0.008)	0.009* (0.005)	0.010 (0.006)
World Governance Index	- 1.340***		-1.342***	-1.308**	-1.226**	-1.194***	-2.094***
	(0.363)		(0.365)	(0.536)	(0.558)	(0.388)	(0.385)
National forest-related policies (#)	-0.010 (0.022)		-0.010 (0.023)	0.053** (0.026)	0.049* (0.025)	-0.014 (0.021)	-0.028 (0.026)
Logistics performance index	-0.329 (0.389)		-0.329 (0.389)	-0.333 (0.586)	-0.281 (0.550)	-0.388 (0.390)	-0.282 (0.417)
Precipitation anomalies	-0.003 (0.048)		-0.003 (0.048)	-0.005 (0.050)	-0.006 (0.051)	-0.006 (0.047)	0.020 (0.049)
Temperature anomalies	0.137* (0.074)		0.135* (0.075)	0.107 (0.074)	0.104 (0.069)	0.133* (0.073)	0.067 (0.080)
Constant	41.437 (41.911)	54.163*** (17.537)	41.686 (42.110)	-9.800 (35.511)	-4.565 (35.033)	38.911 (42.840)	82.533* (47.346)
Observations	3,647	3,315	3,315	1,689	1,689	3,650	3,531
Pseudo R squared	0.957	0.981	0.956	0.962	0.962	0.954	0.963
Chi ² first stage				569.52			

Note: *** p < 0.01, ** p < 0.05, * p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A12 | Full regression estimates for the VSS-specific effects on deforestation attribution (ha)

Model	1	2	1 with sample of model 2	1 with tree cover density of 10%	1 with tree cover density of 75%
IFOAM	0.026* (0.013)	0.038** (0.015)	0.026* (0.014)	0.024* (0.013)	0.032* (0.017)
RA	-0.026*** (0.010)	-0.013 (0.017)	-0.027*** (0.010)	-0.025** (0.010)	-0.026** (0.013)
UTZ	0.074* (0.044)	0.064* (0.034)	0.074* (0.045)	0.073* (0.044)	0.049 (0.051)
FI	0.059** (0.028)	0.078*** (0.028)	0.059** (0.028)	0.068*** (0.026)	-0.007 (0.057)
GlobalGAP	-0.028 (0.045)	-0.031 (0.060)	-0.028 (0.045)	-0.023 (0.045)	-0.073 (0.053)
RSPO	-0.053* (0.032)	-0.038 (0.031)	-0.053* (0.032)	-0.067** (0.032)	-0.050 (0.040)
4C	-0.009 (0.020)	-0.028 (0.018)	-0.009 (0.020)	-0.011 (0.021)	-0.006 (0.026)
Bonsucro	0.030 (0.028)	0.026 (0.028)	0.030 (0.028)	0.038 (0.028)	0.003 (0.026)
ProTerra	-0.011 (0.027)	-0.001 (0.011)	-0.012 (0.027)	-0.013 (0.027)	0.006 (0.025)
Harvested area (ha)	2.022 (1.283)	-1.979 (2.170)	2.052 (1.290)	1.831 (1.281)	3.239** (1.408)
Harvested area ² (ha ²)	-0.135*** (0.049)	0.000 (0.082)	-0.136*** (0.050)	-0.127*** (0.049)	-0.181*** (0.058)
Harvested area worldwide (ha)	-1.424 (0.987)	-0.706 (1.057)	-1.428 (0.989)	-1.348 (0.977)	-1.133 (1.068)
Total population (#)	-1.086 (2.387)		-1.114 (2.401)	-0.684 (2.385)	-3.921 (2.957)
Population growth (%)	0.820*** (0.226)		0.817*** (0.227)	0.788*** (0.220)	0.873*** (0.239)
GDP (constant 2020 USD)	0.484 (0.450)		0.493 (0.453)	0.327 (0.454)	0.514 (0.549)
FDI (constant 2020 USD)	0.009 (0.006)		0.009 (0.006)	0.009 (0.005)	0.009 (0.006)
World Governance Index	-1.301*** (0.331)		-1.301*** (0.332)	-1.164*** (0.353)	-2.106*** (0.416)
National forest-related policies (#)	-0.000 (0.026)		0.000 (0.026)	-0.006 (0.024)	-0.012 (0.031)
Logistics performance index	-0.460 (0.373)		-0.460 (0.373)	-0.518 (0.374)	-0.421 (0.408)
Precipitation anomalies	0.017 (0.048)		0.017 (0.049)	0.012 (0.047)	0.038 (0.048)
Temperature anomalies	0.139* (0.076)		0.137* (0.077)	0.134* (0.076)	0.055 (0.078)
Constant	48.009 (48.228)	54.403*** (18.750)	48.198 (48.545)	44.552 (48.245)	90.462 (55.277)
Observations	3,647	3,315	3,315	3,650	3,531
Pseudo R squared	0.957	0.981	0.956	0.955	0.963

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation. Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil.

Table A13 | Full regression estimates for the VSS-specific effects on deforestation attribution (ha)

Model	3	1 with sample of model 3
IFOAM	0.032** (0.013)	0.040*** (0.012)
Other VSS	-0.017 (0.018)	-0.005 (0.017)
Generalized residual IFOAM	2.64e-06 (4.88e-06)	
Generalized residual other VSS	3.59e-07* (2.18e-07)	
Controls	Yes	Yes
Observations	887	887
Pseudo R squared	0.933	0.933
Chi² first stage IFOAM	21.26	
Chi² first stage Other VSS	38.28	
RA	-0.023* (0.012)	-0.009 (0.012)
Other VSS	0.100** (0.045)	0.092** (0.043)
Generalized residual RA	2.49e-05*** (6.30e-06)	
Generalized residual other VSS	-5.57e-07** (2.24e-07)	
Controls	Yes	Yes
Observations	517	517
Pseudo R squared	0.978	0.977
Chi² first stage RA	9.9*10 ⁷	
Chi² first stage Other VSS	19.82	
UTZ	0.078 (0.063)	0.065 (0.061)
Other VSS	0.074 (0.051)	0.086 (0.052)
Generalized residual UTZ	-3.10e-07 (1.10e-06)	
Generalized residual other VSS	1.11e-06 (9.51e-07)	
Controls	Yes	Yes
Observations	419	419
Pseudo R squared	0.920	0.919
Chi² first stage UTZ	62.25	
Chi² first stage Other VSS	28.29	
FI	0.084* (0.048)	0.049 (0.039)
Other VSS	-0.032 (0.063)	0.009 (0.062)
Generalized residual FI	-2.34e-06*** (8.73e-07)	
Generalized residual other VSS	9.71e-07 (6.43e-07)	
Controls	Yes	Yes
Observations	396	396
Pseudo R squared	0.923	0.920
Chi² first stage FI	54.00	
Chi² first stage Other VSS	37.08	
GlobalGAP	-0.122* (0.062)	-0.182*** (0.054)
Other VSS	-0.429*** (0.124)	-0.456*** (0.154)
Generalized residual GlobalGAP	-6.27e-05* (3.70e-05)	
Generalized residual other VSS	1.78e-04** (7.65e-05)	
Controls	Yes	Yes
Observations	139	140
Pseudo R squared	0.949	0.941
Chi² first stage GlobalGAP	3.47	
Chi² first stage Other VSS	16.60	
RSPO	-0.055	-0.063

	(0.045)	(0.048)
Other VSS	-0.079**	-0.031
	(0.033)	(0.035)
Generalized residual RSPO	5.79e-07	
	(1.91e-06)	
Generalized residual other VSS	2.68e-05***	
	(7.36e-06)	
Controls	Yes	Yes
Observations	82	82
Pseudo R squared	0.988	0.986
Chi² first stage RSPO	340.20	
Chi² first stage Other VSS	19.29	
4C	-0.013	-0.032
	(0.072)	(0.073)
Other VSS	-0.194	0.201
	(0.379)	(0.496)
Generalized residual 4C	-1.91e-05**	
	(9.69e-06)	
Generalized residual other VSS	1.62e-05**	
	(6.55e-06)	
Controls	Yes	Yes
Observations	159	159
Pseudo R squared	0.888	0.880
Chi² first stage 4C	1.7*10 ⁹	
Chi² first stage Other VSS	11.86	
Bonsucro	-0.070	-0.040
	(0.057)	(0.065)
Other VSS	0.145	0.156
	(0.097)	(0.112)
Generalized residual Bonsucro	4.96e-06	
	(1.49e-05)	
Generalized residual other VSS	2.22e-06	
	(4.26e-06)	
Controls	Yes	Yes
Observations	96	96
Pseudo R squared	0.980	0.980
Chi² first stage Bonsucro	10.91	
Chi² first stage Other VSS	23.19	
ProTerra		
Other VSS		
Generalized residual ProTerra		
Generalized residual other VSS		
Controls		
Observations		
Pseudo R squared		
Chi² first stage ProTerra		
Chi² first stage Other VSS		

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation. The machine learning approach (LASSO) did not find suitable instruments for RA and 4C. Instead the set of instrumental variables with the highest correlation was selected. No instrumental variables were found for Proterra due to a too small sample size. Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil.

Table A14 | Canopy cover thresholds in VSS requirements

VSS	Standard version	Forest definition	Canopy cover threshold from forest definition
IFOAM	v2005	No	NA
	v2012	No	NA
	v2014	No	NA
RA	v4 2010	Yes	No
	v1.2 2017	Yes	No
	v1 2020	Yes	10%
UTZ	v1.0 2009	Yes	No
	v1 2014	Yes	10%
FI	v1.0 2011	No	NA
	v2.0 2019	Yes	10%
GlobalGAP	v4.0 2011	No	NA
	v5.0 2013	No	NA
RSPO	v 2007	Yes	No
	v 2013	Yes	No
	v 2018	Yes	60%-80%
4C	v1.4 2010	NA	NA
	v2.1 2015	Yes	No
	v4.0 2020	Yes	10%
ProTerra	v2.9.5 2011	NA	NA
	v3.0 2014	NA	NA
	v4.0 2018	No	NA
RTRS	v1.0 2010	Yes	35%
	v2.0 2013	Yes	35%
	v3.0 2016	Yes	35%
Bonsucro	v3.0 2011	Yes	10-30%
	v4.0 2014	Yes	10-30%
AWS	v1.0 2014	Yes	No
	v2.0 2019	Yes	No
Cocoa Trace	v1.0-5.0	NA	NA

Note: Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil; RTRS – Round Table on Responsible Soy; AWS – Alliance for Water Stewardship.

Table A15 | Robustness checks of model 1 for the overall VSS effect on deforestation attribution (ha)

Robustness check	Zero deforestation dummy	Maximum certified area instead of minimum	Maximum certified area with-out cut-off of certification ratios above 100	Omit harvested area as control variable	Inclusion of remaining forest area as control variable	Only use deforestation data with a quality index above 0.3	Include overseas territories
Min certified area (log ha)	0.025 (0.038)						
Zero certification (0/1)	0.091 (0.368)						
Max certified area (ha)		0.015 (0.023)	0.015 (0.023)				
Min certified area (ha)				0.041 (0.030)	0.015 (0.022)	0.025 (0.027)	0.016 (0.023)
Harvested area (ha)	1.817 (1.226)	1.813 (1.225)	1.812 (1.225)		2.034* (1.236)	0.411 (1.154)	1.805 (1.223)
Harvested area ² (ha ²)	-0.126*** (0.046)	-0.126*** (0.046)	-0.126*** (0.046)		-0.136*** (0.047)	-0.067* (0.041)	-0.125*** (0.046)
Harvested area worldwide (ha)	-1.178 (0.834)	-1.187 (0.832)	-1.187 (0.832)	-3.270*** (0.903)	-1.046 (0.790)	-1.729** (0.694)	-1.199 (0.831)
Total population (#)	-0.404 (2.276)	-0.415 (2.291)	-0.413 (2.290)	2.281 (2.686)	-0.891 (2.329)	1.578 (2.040)	-0.412 (2.290)
Population growth (%)	0.930*** (0.243)	0.934*** (0.242)	0.933*** (0.242)	0.739*** (0.258)	0.828*** (0.275)	0.882*** (0.255)	0.925*** (0.242)
GDP (constant 2020 USD)	0.548 (0.464)	0.559 (0.461)	0.559 (0.461)	0.110 (0.374)	0.455 (0.439)	0.657 (0.465)	0.558 (0.461)
FDI (constant 2020 USD)	0.010* (0.006)	0.010* (0.006)	0.010* (0.006)	0.010* (0.006)	0.009* (0.006)	0.011*** (0.004)	0.010* (0.006)
World Governance Index	-1.349*** (0.376)	-1.335*** (0.376)	-1.336*** (0.376)	-0.769 (0.506)	-1.406*** (0.387)	-1.417*** (0.436)	-1.339*** (0.376)
National forest-related policies (#)	-0.008 (0.022)	-0.009 (0.023)	-0.009 (0.023)	-0.021 (0.025)	-0.010 (0.022)	0.007 (0.019)	-0.008 (0.022)
Logistics performance index	-0.345 (0.407)	-0.336 (0.398)	-0.336 (0.398)	-1.164*** (0.444)	-0.404 (0.407)	-0.056 (0.454)	-0.340 (0.398)
Precipitation anomalies	-0.000 (0.048)	0.000 (0.048)	0.000 (0.048)	-0.039 (0.056)	0.002 (0.048)	-0.008 (0.047)	-0.000 (0.048)
Temperature anomalies	0.163** (0.074)	0.162** (0.074)	0.162** (0.074)	0.196** (0.081)	0.162** (0.074)	0.127* (0.072)	0.162** (0.074)
Forest area (1,000 ha)					-2.045 (2.002)		29.784 (41.217)
Constant	29.305 (40.940)	29.564 (41.198)	29.507 (41.191)	26.582 (44.997)	62.156 (57.165)	6.363 (39.320)	3,665 (0.956)
Observations	3,647	3,647	3,647	3,647	3,647	2,438	3,665
Pseudo R squared	0.956	0.956	0.956	0.949	0.956	0.973	0.956

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A16 | Full regression estimates of model 1 for the overall VSS effect on deforestation attribution (ha) to assess indirect land use change

Approach	Five-year attribution period	Deforestation to other commodities	Deforestation to other commodities without controlling for certification to other commodities
Min certified area (ha)	0.007 (0.022)	-0.009 (0.007)	-0.008 (0.007)
Min certified area of other commodities (ha)		0.016 (0.014)	
Harvested area (ha)	1.661 (1.221)	0.040 (0.411)	0.037 (0.412)
Harvested area ² (ha ²)	-0.118** (0.047)	0.004 (0.018)	0.004 (0.018)
Harvested area worldwide (ha)	-0.572 (0.856)	-0.186 (0.320)	-0.180 (0.320)
Total population (#)	-0.271 (2.414)	-1.112 (0.979)	-1.185 (0.931)
Population growth (%)	0.821*** (0.228)	0.213*** (0.061)	0.210*** (0.062)
GDP (constant 2020 USD)	0.521 (0.428)	-0.044 (0.108)	-0.020 (0.101)
FDI (constant 2020 USD)	0.010 (0.006)	-0.003*** (0.001)	-0.003*** (0.001)
World Governance Index	-1.421*** (0.305)	-0.470*** (0.177)	-0.471*** (0.177)
National forest-related policies (#)	-0.034* (0.018)	0.052*** (0.011)	0.050*** (0.010)
Logistics performance index	-0.338 (0.382)	-0.200* (0.102)	-0.183* (0.099)
Precipitation anomalies	-0.021 (0.036)	-0.044*** (0.007)	-0.043*** (0.007)
Temperature anomalies	0.124 (0.081)	0.050** (0.021)	0.047** (0.021)
Constant	18.792 (44.024)	37.232* (19.230)	38.050** (18.688)
Observations	3,634	3,719	3,719
Pseudo R squared	0.967	0.977	0.977

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A17 | Full regression estimates of model 1 for the crop-specific VSS effects on deforestation attribution (ha) to assess indirect land use change

Approach	Five-year attribution period	Deforestation to other commodities	Deforestation to other commodities without controlling for certification to other commodities
Min certified area (ha) x			
Banana	0.115* (0.061)	-0.001 (0.021)	-0.001 (0.021)
Cocoa	0.216** (0.107)	-0.026*** (0.006)	-0.024*** (0.007)
Coffee	0.022 (0.026)	-0.012 (0.011)	-0.011 (0.011)
Oil palm	-0.040 (0.026)	-0.020** (0.009)	-0.019** (0.009)
Soy	0.063 (0.068)	0.039 (0.035)	0.038 (0.036)
Sugarcane	-0.045 (0.063)	0.020** (0.008)	0.019** (0.008)
Tea	-0.002 (0.058)	-0.028 (0.019)	-0.030* (0.018)
Min certified area of other commodities (ha) x			
Banana		-0.003 (0.027)	
Cocoa		0.047 (0.039)	
Coffee		0.025 (0.028)	
Oil palm		0.028 (0.030)	
Soy		0.013 (0.027)	
Sugarcane		0.011 (0.026)	
Tea		-0.025 (0.044)	
Harvested area (ha)	1.842 (1.191)	0.172 (0.396)	0.118 (0.411)
Harvested area ² (ha ²)	-0.124*** (0.046)	-0.001 (0.017)	0.001 (0.018)
Harvested area worldwide (ha)	-0.471 (0.850)	-0.062 (0.321)	-0.079 (0.337)
Total population (#)	-1.238 (2.413)	-1.156 (0.963)	-1.186 (0.915)
Population growth (%)	0.791*** (0.219)	0.207*** (0.059)	0.206*** (0.060)
GDP (constant 2020 USD)	0.525 (0.428)	-0.066 (0.105)	-0.038 (0.100)
FDI (constant 2020 USD)	0.009 (0.006)	-0.002** (0.001)	-0.002** (0.001)
World Governance Index	-1.444*** (0.287)	-0.508*** (0.184)	-0.510*** (0.181)
National forest-related policies (#)	-0.035* (0.018)	0.054*** (0.011)	0.053*** (0.011)
Logistics performance index	-0.327 (0.378)	-0.206** (0.101)	-0.192** (0.098)
Precipitation anomalies	-0.023 (0.036)	-0.041*** (0.007)	-0.041*** (0.007)
Temperature anomalies	0.109 (0.083)	0.051** (0.020)	0.048** (0.021)
Constant	33.665 (44.157)	35.719* (18.950)	36.375* (18.614)
Observations	3,634	3,719	3,719
Pseudo R squared	0.967	0.978	0.978

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A18 | Full regression estimates of model 1 for the VSS-specific effects on deforestation attribution (ha) to assess indirect land use change

Approach	Five-year attribution period	Deforestation to other commodities	Deforestation to other commodities without controlling for certification to other commodities
IFOAM	0.027*** (0.010)	-0.002 (0.004)	-0.004 (0.005)
RA	-0.010 (0.008)	-0.004 (0.006)	-0.006 (0.006)
UTZ	0.072 (0.051)	0.006 (0.009)	0.006 (0.014)
FI	0.026 (0.027)	-0.027*** (0.010)	-0.012 (0.013)
GlobalGAP	-0.020 (0.048)	0.051*** (0.015)	-0.001 (0.023)
RSPO	-0.039 (0.039)	0.000 (0.013)	-0.013 (0.012)
4C	0.032 (0.025)	-0.041*** (0.014)	-0.005 (0.018)
Bonsucro	-0.046 (0.049)	0.015 (0.010)	0.006 (0.010)
ProTerra	-0.020 (0.029)	-0.001 (0.003)	0.007** (0.003)
IFOAM certification of other commodities		-0.019*** (0.004)	
RA certification of other commodities		0.013 (0.011)	
UTZ certification of other commodities		0.002 (0.009)	
FI certification of other commodities		-0.041*** (0.010)	
GlobalGAP certification of other commodities		0.044*** (0.012)	
RSPO certification of other commodities		-0.001 (0.010)	
4C certification of other commodities		-0.037*** (0.008)	
Bonsucro certification of other commodities		0.020*** (0.005)	
ProTerra certification of other commodities		-0.002 (0.003)	
Harvested area (ha)	1.738 (1.219)	0.013 (0.383)	0.040 (0.420)
Harvested area ² (ha ²)	-0.119** (0.047)	0.005 (0.016)	0.004 (0.018)
Harvested area worldwide (ha)	-1.014 (0.909)	-0.179 (0.287)	-0.122 (0.359)
Total population (#)	-1.548 (2.437)	-1.128 (0.772)	-1.054 (0.933)
Population growth (%)	0.729*** (0.223)	0.193*** (0.046)	0.201*** (0.061)
GDP (constant 2020 USD)	0.381 (0.407)	-0.070 (0.101)	-0.017 (0.105)
FDI (constant 2020 USD)	0.009 (0.006)	0.001 (0.001)	-0.002** (0.001)
World Governance Index	-1.390*** (0.259)	-0.556*** (0.131)	-0.476*** (0.178)
National forest-related policies (#)	-0.031 (0.021)	0.055*** (0.008)	0.051*** (0.011)
Logistics performance index	-0.437 (0.361)	-0.078 (0.076)	-0.187* (0.097)
Precipitation anomalies	-0.015 (0.037)	-0.029*** (0.007)	-0.043*** (0.007)
Temperature anomalies	0.106 (0.080)	0.036* (0.020)	0.046** (0.021)
Constant	54.122	38.514**	34.436*

	(46.761)	(15.718)	(19.284)
Observations	3,634	3,719	3,719
Pseudo R squared	0.968	0.980	0.977

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation. Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil.

Table A19 | Full regression estimates of model 1 for the overall VSS effect on deforestation attribution (ha) interacted with the substantive and procedural stringency scores

Weights	Equal weights				Factor analysis			
Assumption	Full overlap		No overlap		Full overlap		No overlap	
Min certified area (ha) x	0.100**				0.083**			
	(0.048)				(0.036)			
Max certified area (ha) x			0.169**				0.091**	
			(0.067)				(0.039)	
Banana		-0.499		-0.033		0.373		0.370
		(1.413)		(1.244)		(0.247)		(0.256)
Cocoa		0.885*		1.078**		0.251**		0.188
		(0.461)		(0.511)		(0.119)		(0.117)
Coffee		0.099		0.067		0.069		0.067
		(0.064)		(0.086)		(0.044)		(0.059)
Oil palm		0.604		0.211		0.122		-0.002
		(0.403)		(0.425)		(0.102)		(0.130)
Soy		0.050		0.016		0.044		0.095
		(0.087)		(0.180)		(0.080)		(0.139)
Sugarcane		1.408**		0.669**		0.274		0.156
		(0.673)		(0.310)		(0.222)		(0.115)
Tea		1.289*		0.719**		0.279**		0.167*
		(0.721)		(0.315)		(0.131)		(0.097)
Min certified area (ha) x	0.015				0.023			
Substantive stringency x	(0.015)				(0.015)			
Max certified area (ha) x			0.016				0.019	
Substantive stringency x			(0.015)				(0.012)	
Banana		-0.097		-0.119		-0.048		-0.082
		(0.095)		(0.104)		(0.091)		(0.106)
Cocoa		0.028		0.054		0.007		0.003
		(0.024)		(0.036)		(0.029)		(0.030)
Coffee		0.029		0.027		0.028		0.024
		(0.020)		(0.019)		(0.019)		(0.016)
Oil palm		0.017		0.010		0.018		0.043
		(0.057)		(0.060)		(0.079)		(0.072)
Soy		0.011		-0.041		0.011		-0.043
		(0.065)		(0.111)		(0.062)		(0.090)
Sugarcane		-0.193		-0.084		0.026		0.019
		(0.144)		(0.070)		(0.032)		(0.025)
Tea		0.043		0.048**		0.050		0.061*
		(0.035)		(0.025)		(0.048)		(0.034)
Min certified area (ha) x	-0.090**				-0.072***			
Enforcement stringency x	(0.035)				(0.024)			
Max certified area (ha) x			-0.148***				-0.074***	
Enforcement stringency x			(0.052)				(0.025)	
Banana		0.585		0.224		-0.196		-0.138
		(1.174)		(1.030)		(0.214)		(0.214)
Cocoa		-0.531		-0.729*		-0.021		0.030
		(0.360)		(0.425)		(0.082)		(0.079)
Coffee		-0.065		-0.019		-0.022		-0.023
		(0.062)		(0.093)		(0.031)		(0.056)
Oil palm		-0.461		-0.190		-0.102		-0.073
		(0.334)		(0.338)		(0.089)		(0.081)
Soy		-0.022		0.026		-0.029		-0.051
		(0.058)		(0.118)		(0.047)		(0.077)
Sugarcane		-0.955**		-0.464***		-0.190**		-0.115***
		(0.408)		(0.168)		(0.093)		(0.027)
Tea		-1.100*		-0.639**		-0.386***		-0.265***
		(0.613)		(0.253)		(0.132)		(0.068)
Harvested area (ha)	1.552	2.062*	1.597	2.320**	1.577	1.962	1.626	2.059*
	(1.194)	(1.184)	(1.223)	(1.165)	(1.242)	(1.237)	(1.252)	(1.201)
Harvested area ² (ha ²)	-0.113**	-0.131***	-0.114**	-0.141***	-0.112**	-0.127***	-0.115**	-0.132***
	(0.045)	(0.045)	(0.046)	(0.044)	(0.047)	(0.047)	(0.047)	(0.046)
Harvested area worldwide	-1.149	-0.961	-1.039	-1.060	-1.070	-0.899	-1.103	-0.912
(ha)	(0.911)	(0.965)	(0.878)	(0.975)	(0.884)	(0.983)	(0.850)	(0.947)
Total population (#)	-0.811	-1.720	-0.726	-1.945	-0.961	-1.335	-0.898	-1.569
	(2.256)	(2.474)	(2.246)	(2.474)	(2.353)	(2.548)	(2.361)	(2.498)
Population growth (%)	0.942***	0.882***	0.920***	0.848***	0.939***	0.895***	0.916***	0.883***
	(0.240)	(0.222)	(0.241)	(0.224)	(0.247)	(0.233)	(0.247)	(0.233)

GDP (constant 2020 USD)	0.446 (0.472)	0.493 (0.451)	0.445 (0.478)	0.437 (0.446)	0.482 (0.469)	0.488 (0.453)	0.496 (0.471)	0.441 (0.452)
FDI (constant 2020 USD)	0.010* (0.006)	0.008 (0.006)	0.010* (0.006)	0.008 (0.006)	0.010* (0.006)	0.009 (0.006)	0.010* (0.006)	0.009 (0.006)
World Governance Index	-1.473*** (0.393)	-1.358*** (0.401)	-1.493*** (0.380)	-1.273*** (0.411)	-1.436*** (0.383)	-1.419*** (0.397)	-1.422*** (0.385)	-1.343*** (0.398)
National forest-related policies (#)	-0.007 (0.023)	-0.004 (0.023)	-0.006 (0.022)	-0.000 (0.023)	-0.004 (0.022)	-0.005 (0.023)	-0.004 (0.022)	-0.005 (0.022)
Logistics performance index	-0.365 (0.394)	-0.386 (0.380)	-0.362 (0.394)	-0.369 (0.381)	-0.340 (0.407)	-0.378 (0.391)	-0.341 (0.409)	-0.388 (0.382)
Precipitation anomalies	-0.004 (0.048)	-0.011 (0.044)	-0.003 (0.047)	0.001 (0.048)	-0.007 (0.048)	-0.007 (0.049)	-0.004 (0.047)	0.001 (0.050)
Temperature anomalies	0.167** (0.074)	0.155** (0.075)	0.164** (0.073)	0.150** (0.075)	0.164** (0.074)	0.140* (0.076)	0.162** (0.074)	0.142* (0.074)
Constant	40.797 (42.971)	49.697 (46.765)	37.025 (41.714)	55.690 (47.647)	40.610 (43.950)	42.279 (47.228)	39.521 (43.013)	47.871 (46.394)
Observations	3,647	3,647	3,647	3,647	3,647	3,647	3,647	3,647
Pseudo R squared	0.957	0.958	0.957	0.958	0.957	0.958	0.957	0.958

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A20 | Full regression estimates for the overall VSS effect on deforestation attribution per unit of export value (ha per constant 2020 USD)

Model	1	2	1 with sample of model 2	3	1 with sample of model 3	1 with tree cover density of 10%	1 with tree cover density of 75%
Min certified area (ha)	-0.530** (0.236)	-0.565* (0.338)	-0.484* (0.254)	-0.317*** (0.114)	- 0.319*** (0.116)	-0.449* (0.265)	-0.892*** (0.285)
Generalized residual				-0.000 (0.000)			
Harvested area (ha)	31.296** (12.422)	-28.561 (25.916)	29.972** (13.668)	-1.523 (9.900)	-1.623 (10.022)	30.962** (13.529)	28.014*** (8.335)
Harvested area ² (ha ²)	-2.014*** (0.730)	0.878 (1.197)	-1.926** (0.796)	-0.215 (0.364)	-0.210 (0.370)	-1.982** (0.789)	-1.865*** (0.502)
Harvested area worldwide (ha)	14.203*** (4.751)	23.442** (9.497)	13.667*** (4.622)	-6.516 (4.166)	-6.542 (4.181)	13.951*** (4.704)	15.673*** (5.218)
Total population (#)	-25.925 (16.151)		-31.138 (22.263)	-11.652 (11.342)	-11.696 (11.305)	-27.157 (17.670)	-18.109 (17.903)
Population growth (%)	2.539*** (0.932)		3.228* (1.841)	-3.584 (2.274)	-3.590 (2.287)	2.350*** (0.901)	3.200** (1.524)
GDP (constant 2020 USD)	-9.029** (4.193)		-10.278** (5.114)	-3.103* (1.615)	-3.101* (1.618)	-7.375* (3.786)	-15.210** (7.168)
FDI (constant 2020 USD)	-0.047* (0.027)		-0.046 (0.028)	-0.068 (0.043)	-0.067 (0.043)	-0.054** (0.027)	-0.047 (0.039)
World Governance Index	13.708** (5.692)		11.494*** (4.406)	-1.386 (2.900)	-1.404 (2.912)	10.824** (4.592)	22.705*** (7.806)
National forest- related policies (#)	-1.226** (0.575)		-1.188** (0.537)	0.061 (0.088)	0.061 (0.089)	-1.073** (0.468)	-1.691** (0.681)
Logistics performance index	1.251 (3.093)		1.711 (2.583)	0.429 (0.836)	0.431 (0.840)	2.524 (2.909)	-2.843 (3.665)
Precipitation anomalies	-0.172 (0.371)		-0.064 (0.276)	-0.209 (0.303)	-0.209 (0.304)	-0.010 (0.368)	-0.706 (0.537)
Temperature anomalies	0.727 (1.043)		0.495 (1.007)	0.013 (0.425)	0.013 (0.425)	0.885 (1.060)	0.797 (1.044)
WTO membership	0.010 (1.969)		0.856 (2.146)	7.324*** (1.343)	7.327*** (1.348)	0.883 (1.525)	-1.082 (3.850)
Export-related NTMs (#)	0.689*** (0.263)	1.803** (0.753)	0.714*** (0.245)	0.174 (0.121)	0.173 (0.120)	0.718*** (0.240)	0.604** (0.263)
Import-related NTMs (#)	-0.373*** (0.098)	0.021 (0.063)	-0.380*** (0.086)	0.032** (0.016)	0.031* (0.016)	-0.383*** (0.106)	-0.388*** (0.076)
RTA (#)	-0.127 (0.085)		-0.129 (0.090)	-0.042** (0.020)	-0.043** (0.020)	-0.093 (0.085)	-0.214*** (0.081)
Average tariff rate (%)	0.879 (0.602)	1.844*** (0.479)	0.801 (0.565)	-0.607* (0.325)	-0.607* (0.326)	0.558 (0.437)	1.738** (0.804)
Constant	270.017 (209.968)	-216.857*** (82.790)	399.848 (399.376)	449.125* (231.915)	450.764* (231.802)	254.463 (208.762)	280.006 (259.583)
Observations	3,548	3,182	3,182	1,689	1,689	3,551	3,405
Pseudo R squared	0.953	0.978	0.953	0.512	0.512	0.947	0.963
Chi ² first stage				21.82			

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A21 | Full regression estimates for the crop-specific VSS effects on deforestation attribution per unit of export value (ha per constant 2020 USD)

Model	1	2	1 with sample of model 2	3	1 with sample of model 3	1 with tree cover density of 10%	1 with tree cover density of 75%
Min certified area (ha) x							
Banana	-0.717*** (0.226)	-0.258 (0.515)	-0.678*** (0.255)	-0.361*** (0.112)	-0.363*** (0.113)	-0.675** (0.271)	-0.990*** (0.287)
Cocoa	0.485 (0.353)	-0.302 (0.526)	0.455 (0.307)	-0.041 (0.179)	-0.072 (0.193)	0.485 (0.306)	0.520 (0.425)
Coffee	1.741*** (0.662)	1.055*** (0.265)	1.851** (0.940)	0.659** (0.294)	0.644** (0.298)	1.424*** (0.471)	2.083 (2.145)
Oil palm	-0.137 (0.160)	-0.680* (0.355)	-0.140 (0.160)	-0.291 (0.351)	-0.301 (0.353)	-0.148 (0.170)	-0.091 (0.159)
Soy	0.132 (1.781)	-0.825 (0.827)	0.093 (1.064)	-0.017 (0.197)	-0.019 (0.195)	0.385 (0.759)	1.331 (2.005)
Sugarcane	0.328 (0.260)	-0.282** (0.139)	0.259 (0.255)	-0.772** (0.381)	-0.783** (0.391)	0.266 (0.246)	0.542** (0.262)
Tea	-2.361* (1.358)	1.278* (0.705)	-2.195* (1.292)	0.086 (0.214)	0.086 (0.215)	-1.980 (1.793)	-3.566*** (1.199)
Generalized residual				-0.000 (0.000)			
Harvested area (ha)	31.348** (12.281)	-28.341 (26.761)	30.064** (13.635)	2.032 (8.855)	1.874 (8.907)	31.144** (13.561)	28.010*** (8.346)
Harvested area ² (ha ²)	-2.017*** (0.722)	0.869 (1.233)	-1.931** (0.794)	-0.401 (0.384)	-0.392 (0.382)	-1.992** (0.791)	-1.865*** (0.502)
Harvested area worldwide (ha)	14.201*** (4.752)	23.344** (9.942)	13.664*** (4.623)	-6.333* (3.453)	-6.426* (3.469)	13.952*** (4.711)	15.673*** (5.220)
Total population (#)	-25.901 (16.176)		-31.070 (22.293)	-8.729 (11.189)	-8.585 (11.071)	-27.187 (17.773)	-18.101 (17.911)
Population growth (%)	2.537*** (0.931)		3.224* (1.842)	-3.589 (3.858)	-3.624 (3.872)	2.345*** (0.900)	3.200** (1.523)
GDP (constant 2020 USD)	-9.032** (4.197)		-10.278** (5.121)	-2.891 (1.823)	-2.875 (1.814)	-7.365* (3.798)	-15.221** (7.163)
FDI (constant 2020 USD)	-0.047* (0.027)		-0.046 (0.028)	-0.153 (0.097)	-0.151 (0.100)	-0.053** (0.027)	-0.047 (0.039)
World	13.735** (5.712)		11.517*** (4.429)	-0.956 (2.580)	-0.988 (2.600)	10.864** (4.614)	22.718*** (7.807)
Governance Index	-1.226** (0.580)		-1.187** (0.543)	0.088 (0.077)	0.087 (0.077)	-1.070** (0.477)	-1.692** (0.680)
National forest- related policies (#)							
Logistics performance index	1.240 (3.112)		1.701 (2.605)	0.897 (0.815)	0.894 (0.822)	2.527 (2.956)	-2.843 (3.665)
Precipitation anomalies	-0.173 (0.372)		-0.065 (0.276)	-0.215 (0.269)	-0.216 (0.269)	-0.010 (0.369)	-0.707 (0.537)
Temperature anomalies	0.728 (1.042)		0.496 (1.006)	0.068 (0.419)	0.068 (0.422)	0.886 (1.060)	0.803 (1.045)
WTO membership	-0.002 (1.973)		0.840 (2.147)	7.395*** (1.693)	7.405*** (1.751)	0.869 (1.541)	-1.080 (3.847)
Export-related NTMs (#)	0.687*** (0.262)	1.830** (0.846)	0.712*** (0.244)	0.201 (0.132)	0.201 (0.129)	0.715*** (0.240)	0.604** (0.263)
Import-related NTMs (#)	-0.383*** (0.091)	0.021 (0.059)	-0.385*** (0.083)	0.023 (0.017)	0.023 (0.017)	-0.390*** (0.100)	-0.391*** (0.075)
RTA (#)	-0.127 (0.085)		-0.129 (0.090)	-0.045* (0.023)	-0.045* (0.023)	-0.092 (0.085)	-0.213*** (0.081)
Average tariff rate (%)	0.882 (0.607)	1.844*** (0.479)	0.804 (0.569)	-0.599* (0.333)	-0.600* (0.334)	0.560 (0.441)	1.739** (0.805)
Constant	269.490 (210.508)	-216.373** (84.268)	398.414 (399.790)	372.861** (186.251)	372.339** (185.138)	253.823 (209.773)	280.170 (259.213)
Observations	3,548	3,182	3,182	1,689	1,689	3,551	3,405
Pseudo R squared	0.953	0.978	0.953	0.514	0.514	0.947	0.963
Chi ² first stage				565.72			

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A22 | Full regression estimates for the VSS-specific effects on deforestation attribution per unit of export value (ha per constant 2020 USD)

Model	1	2	1 with sample of model 2	1 with tree cover density of 10%	1 with tree cover density of 75%
IFOAM	-0.486 (0.425)	0.176 (0.334)	-0.478 (0.437)	-0.353 (0.449)	-0.858*** (0.303)
RA	-0.641*** (0.230)	-0.115 (0.198)	-0.632*** (0.226)	-0.633*** (0.214)	-0.343 (0.637)
UTZ	0.509 (0.429)	-0.117 (0.462)	0.458 (0.413)	0.432 (0.423)	0.735** (0.321)
FI	0.490* (0.281)	0.148 (0.362)	0.501* (0.260)	0.517* (0.291)	0.471* (0.280)
GlobalGAP	1.156 (0.873)	0.835 (0.678)	0.975 (0.733)	1.274 (1.126)	1.125** (0.537)
RSPO	-0.153 (0.153)	-0.357 (0.295)	-0.158 (0.153)	-0.157 (0.164)	-0.095 (0.158)
4C	0.684 (1.087)	-0.350 (0.265)	0.700 (0.997)	0.711 (1.040)	0.082 (0.548)
Bonsucro	0.404 (0.282)	0.473* (0.246)	0.412 (0.280)	0.354 (0.270)	0.651** (0.303)
ProTerra	0.507 (0.456)	-0.294 (0.271)	0.496 (0.423)	0.576 (0.529)	0.417* (0.233)
Harvested area (ha)	31.208** (12.264)	-31.139 (26.440)	30.979*** (11.414)	30.832** (13.323)	28.016*** (8.331)
Harvested area ² (ha ²)	-2.009*** (0.720)	0.849 (1.272)	-1.993*** (0.672)	-1.975** (0.777)	-1.865*** (0.501)
Harvested area worldwide (ha)	14.207*** (4.746)	27.935*** (6.819)	14.011*** (4.680)	13.965*** (4.699)	15.676*** (5.219)
Total population (#)	-25.986 (16.172)		-22.450 (15.604)	-27.254 (17.678)	-18.120 (17.908)
Population growth (%)	2.538*** (0.931)		2.565*** (0.921)	2.348*** (0.897)	3.199** (1.522)
GDP (constant 2020 USD)	-9.028** (4.190)		-9.276** (4.123)	-7.372* (3.778)	-15.214** (7.168)
FDI (constant 2020 USD)	-0.047* (0.027)		-0.050* (0.027)	-0.054** (0.027)	-0.047 (0.039)
World Governance Index	13.731** (5.688)		12.243** (4.925)	10.859** (4.589)	22.730*** (7.810)
National forest-related policies (#)	-1.230** (0.580)		-1.221** (0.584)	-1.084** (0.482)	-1.692** (0.681)
Logistics performance index	1.245 (3.086)		1.336 (3.065)	2.502 (2.912)	-2.848 (3.665)
Precipitation anomalies	-0.174 (0.370)		-0.125 (0.360)	-0.013 (0.368)	-0.708 (0.538)
Temperature anomalies	0.729 (1.043)		0.691 (1.042)	0.887 (1.060)	0.797 (1.045)
WTO membership	0.001 (1.970)		0.457 (1.754)	0.862 (1.531)	-1.087 (3.851)
Export-related NTMs (#)	0.689*** (0.263)		0.699*** (0.264)	0.717*** (0.239)	0.604** (0.263)
Import-related NTMs (#)	-0.385*** (0.094)	0.067 (0.045)	-0.376*** (0.091)	-0.394*** (0.101)	-0.388*** (0.076)
RTA (#)	-0.127 (0.084)		-0.124 (0.083)	-0.093 (0.085)	-0.214*** (0.080)
Average tariff rate (%)	0.880 (0.603)	2.005*** (0.497)	0.841 (0.587)	0.561 (0.440)	1.740** (0.804)
Constant	271.340 (210.780)	-267.234** (108.184)	225.890 (213.809)	256.440 (210.124)	280.224 (259.349)
Observations	3,548	3,188	3,188	3,551	3,405
Pseudo R squared	0.953	0.976	0.952	0.947	0.963

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation. Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil.

Table A23 | Full regression estimates for the overall VSS effect on deforestation attribution per unit of export volume (ha per metric tons, primary equivalents)

Model	1	2	1 with sample of model 2	3	1 with sample of model 3	1 with tree cover density of 10%	1 with tree cover density of 75%
Min certified area (ha)	-0.611* (0.368)	-0.344 (0.244)	-0.628* (0.377)	-0.231*** (0.083)	-0.237*** (0.083)	-0.523 (0.397)	-0.450 (0.323)
Generalized residual				-0.000 (0.000)			
Harvested area (ha)	42.327*** (9.034)	12.288 (15.385)	43.670*** (8.568)	-2.646 (4.973)	-3.129 (5.025)	40.591*** (8.646)	43.960*** (7.881)
Harvested area ² (ha ²)	-2.562*** (0.497)	-1.225* (0.702)	-2.634*** (0.476)	-0.056 (0.189)	-0.031 (0.192)	-2.479*** (0.483)	-2.629*** (0.439)
Harvested area worldwide (ha)	5.904 (6.076)	15.316** (7.284)	6.078 (6.175)	-8.513* (4.548)	-8.637* (4.546)	6.380 (5.776)	6.157 (6.419)
Total population (#)	11.194 (11.608)		12.747 (11.740)	-25.286** (12.618)	-25.893** (12.594)	7.538 (10.064)	22.923 (16.667)
Population growth (%)	0.765 (0.703)		0.793 (0.670)	-1.180 (0.952)	-1.263 (0.944)	0.788 (0.605)	0.894 (0.852)
GDP (constant 2020 USD)	-4.287 (3.202)		-4.172 (3.285)	-1.715 (2.028)	-1.655 (2.030)	-3.284 (3.149)	-6.241** (2.949)
FDI (constant 2020 USD)	-0.034 (0.043)		-0.036 (0.041)	-0.004 (0.023)	-0.004 (0.023)	-0.041 (0.033)	-0.035 (0.056)
World Governance Index	-1.215 (7.347)		-2.055 (6.775)	-2.111 (2.886)	-2.095 (2.891)	-2.760 (6.137)	-1.067 (7.676)
National forest- related policies (#)	-0.147 (0.354)		-0.124 (0.369)	-0.115** (0.051)	-0.116** (0.050)	-0.249 (0.336)	0.044 (0.403)
Logistics performance index	0.787 (1.964)		0.735 (2.079)	0.971 (0.923)	0.969 (0.931)	0.747 (2.236)	0.383 (2.175)
Precipitation anomalies	-0.455 (0.417)		-0.415 (0.416)	-0.541** (0.264)	-0.539** (0.263)	-0.491 (0.429)	-0.331 (0.411)
Temperature anomalies	-1.057 (0.844)		-1.082 (0.826)	0.412 (0.439)	0.408 (0.441)	-0.830 (0.736)	-1.050 (1.105)
WTO membership	-0.823 (1.702)		-0.643 (1.652)	4.358*** (0.671)	4.334*** (0.668)	-0.636 (1.485)	-0.379 (2.052)
Export-related NTMs (#)	0.816*** (0.290)	1.264*** (0.450)	0.822*** (0.286)	0.203* (0.113)	0.198* (0.115)	0.870*** (0.282)	0.730*** (0.281)
Import-related NTMs (#)	-0.164** (0.082)	0.082* (0.046)	-0.161** (0.082)	0.034*** (0.012)	0.034*** (0.013)	-0.156** (0.079)	-0.189** (0.083)
RTA (#)	-0.067 (0.073)		-0.069 (0.074)	-0.063*** (0.017)	-0.065*** (0.017)	-0.064 (0.068)	-0.081 (0.073)
Average tariff rate (%)	-0.312 (0.559)		-0.336 (0.535)	-0.908* (0.512)	-0.897* (0.506)	-0.446 (0.378)	-0.255 (0.612)
Constant	-325.248 (233.239)	-239.028*** (72.147)	-362.418 (239.871)	678.604** (318.324)	692.431** (317.991)	-284.532 (197.796)	-490.741 (324.677)
Observations	3,548	3,185	3,185	1,689	1,689	3,551	3,405
Pseudo R squared	0.974	0.994	0.974	0.805	0.805	0.970	0.977
Chi ² first stage				21.82			

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A24 | Full regression estimates for the crop-specific VSS effects on deforestation attribution per unit of export volume (ha per metric tons, primary equivalents)

Model	1	2	1 with sample of model 2	3	1 with sample of model 3	1 with tree cover density of 10%	1 with tree cover density of 75%
Min certified area (ha) x							
Banana	-0.802* (0.440)	-0.124 (0.522)	-0.824* (0.452)	-0.363*** (0.091)	-0.369*** (0.092)	-0.656 (0.454)	-0.671 (0.409)
Cocoa	0.125 (0.195)	-0.756 (0.540)	0.116 (0.194)	0.044 (0.159)	0.031 (0.167)	0.160 (0.200)	-0.029 (0.243)
Coffee	-0.272 (0.693)	1.221*** (0.302)	-0.289 (0.661)	0.020 (0.174)	-0.063 (0.161)	0.044 (0.601)	-0.472* (0.262)
Oil palm	-0.336*** (0.092)	-0.080 (0.098)	-0.341*** (0.090)	-0.673*** (0.205)	-0.677*** (0.208)	-0.365*** (0.105)	-0.321*** (0.081)
Soy	0.913* (0.496)	0.667*** (0.212)	0.957** (0.472)	0.017 (0.070)	0.017 (0.070)	0.858* (0.455)	1.738*** (0.600)
Sugarcane	-0.038 (0.355)	0.256 (0.210)	-0.034 (0.339)	-0.453*** (0.166)	-0.469*** (0.166)	-0.112 (0.296)	0.092 (0.333)
Tea	-0.025 (0.240)	1.285*** (0.391)	-0.026 (0.240)	0.274 (0.185)	0.277 (0.189)	-0.026 (0.237)	-0.228 (0.301)
Generalized residual				-0.000** (0.000)			
Harvested area (ha)	42.450*** (9.047)	4.294 (15.345)	43.797*** (8.576)	-0.274 (3.743)	-0.766 (3.830)	40.721*** (8.652)	44.074*** (7.905)
Harvested area ² (ha ²)	-2.569*** (0.498)	-0.867 (0.724)	-2.641*** (0.477)	-0.181 (0.156)	-0.155 (0.160)	-2.486*** (0.484)	-2.635*** (0.441)
Harvested area worldwide (ha)	5.881 (6.081)	16.881** (7.440)	6.052 (6.180)	-7.489* (3.824)	-7.694** (3.872)	6.355 (5.782)	6.145 (6.424)
Total population (#)	11.226 (11.637)		12.790 (11.767)	-25.700** (12.459)	-26.510** (12.558)	7.566 (10.110)	23.039 (16.754)
Population growth (%)	0.767 (0.703)		0.795 (0.670)	-3.216* (1.677)	-3.292* (1.717)	0.789 (0.604)	0.898 (0.852)
GDP (constant 2020 USD)	-4.296 (3.193)		-4.183 (3.274)	-0.931 (1.711)	-0.853 (1.718)	-3.296 (3.144)	-6.264** (2.952)
FDI (constant 2020 USD)	-0.034 (0.043)		-0.036 (0.041)	0.001 (0.025)	0.003 (0.025)	-0.041 (0.033)	-0.035 (0.056)
World Governance Index	-1.223 (7.356)		-2.067 (6.778)	-3.394 (3.069)	-3.333 (3.055)	-2.758 (6.148)	-1.102 (7.689)
National forest- related policies (#)	-0.140 (0.351)		-0.117 (0.366)	-0.099** (0.045)	-0.102** (0.045)	-0.242 (0.333)	0.047 (0.403)
Logistics performance index	0.812 (1.971)		0.763 (2.086)	1.075 (0.827)	1.108 (0.834)	0.777 (2.243)	0.379 (2.177)
Precipitation anomalies	-0.451 (0.418)		-0.410 (0.417)	-0.433** (0.218)	-0.432** (0.217)	-0.486 (0.430)	-0.328 (0.412)
Temperature anomalies	-1.058 (0.847)		-1.082 (0.828)	0.515 (0.466)	0.516 (0.470)	-0.830 (0.737)	-1.042 (1.110)
WTO membership	-0.828 (1.702)		-0.644 (1.653)	3.747*** (1.212)	3.681*** (1.289)	-0.645 (1.494)	-0.366 (2.050)
Export-related NTMs (#)	0.813*** (0.291)		0.819*** (0.286)	0.288** (0.135)	0.282** (0.137)	0.867*** (0.283)	0.725** (0.282)
Import-related NTMs (#)	-0.167** (0.084)	0.095*** (0.026)	-0.164** (0.083)	0.028** (0.011)	0.026** (0.011)	-0.159** (0.080)	-0.191** (0.085)
RTA (#)	-0.067 (0.074)		-0.069 (0.074)	-0.084*** (0.021)	-0.086*** (0.021)	-0.064 (0.068)	-0.081 (0.073)
Average tariff rate (%)	-0.314 (0.558)	0.645 (0.946)	-0.339 (0.534)	-0.895* (0.497)	-0.880* (0.490)	-0.448 (0.378)	-0.257 (0.611)
Constant	-325.820 (233.426)	-222.947*** (84.058)	-363.110 (240.119)	645.841** (289.491)	664.015** (292.731)	-285.005 (198.223)	-492.429 (325.743)
Observations	3,548	3,185	3,185	1,689	1,689	3,551	3,405
Pseudo R squared	0.974	0.994	0.974	0.814	0.814	0.970	0.977
Chi ² first stage				565.72			

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A25 | Full regression estimates for the VSS-specific effects on deforestation attribution per unit of export volume (ha per metric tons, primary equivalents)

Model	1	2	1 with sample of model 2	1 with tree cover density of 10%	1 with tree cover density of 75%
IFOAM	-0.407 (0.271)	0.028 (0.359)	-0.425 (0.275)	-0.386 (0.327)	-0.275 (0.181)
RA	-0.557*** (0.140)	-0.428** (0.177)	-0.559*** (0.141)	-0.537*** (0.138)	-0.753*** (0.203)
UTZ	0.309 (0.386)	0.248 (0.350)	0.303 (0.383)	0.396 (0.440)	0.351 (0.586)
FI	0.305* (0.169)	0.485 (0.400)	0.311* (0.167)	0.302* (0.176)	0.395 (0.252)
GlobalGAP	1.022 (0.938)	0.315 (0.221)	0.983 (0.946)	1.413 (2.085)	0.453 (0.617)
RSPO	-0.316*** (0.098)	-0.273 (0.258)	-0.319*** (0.097)	-0.320*** (0.110)	-0.326*** (0.080)
4C	-0.342* (0.184)	0.008 (0.207)	-0.357* (0.183)	-0.292 (0.178)	-0.361* (0.199)
Bonsucro	0.072 (0.373)	0.547*** (0.199)	0.077 (0.358)	0.011 (0.320)	0.219 (0.333)
ProTerra	0.177 (0.223)	-0.493** (0.198)	0.120 (0.207)	0.180 (0.251)	0.286 (0.225)
Harvested area (ha)	42.321*** (9.053)	6.461 (13.788)	43.681*** (8.596)	40.545*** (8.661)	44.025*** (7.892)
Harvested area ² (ha ²)	-2.562*** (0.498)	-0.996 (0.619)	-2.635*** (0.477)	-2.476*** (0.484)	-2.633*** (0.440)
Harvested area worldwide (ha)	5.942 (6.083)	17.493** (7.719)	6.117 (6.183)	6.416 (5.781)	6.175 (6.423)
Total population (#)	11.304 (11.642)		12.861 (11.782)	7.602 (10.069)	23.011 (16.698)
Population growth (%)	0.765 (0.705)		0.793 (0.672)	0.788 (0.607)	0.892 (0.852)
GDP (constant 2020 USD)	-4.277 (3.222)		-4.161 (3.307)	-3.269 (3.161)	-6.238** (2.954)
FDI (constant 2020 USD)	-0.033 (0.043)		-0.036 (0.042)	-0.041 (0.034)	-0.035 (0.056)
World Governance Index	-1.256 (7.368)		-2.094 (6.792)	-2.805 (6.143)	-1.072 (7.692)
National forest-related policies (#)	-0.153 (0.358)		-0.131 (0.373)	-0.256 (0.342)	0.043 (0.403)
Logistics performance index	0.735 (1.953)		0.680 (2.069)	0.693 (2.224)	0.364 (2.182)
Precipitation anomalies	-0.461 (0.417)		-0.420 (0.416)	-0.497 (0.429)	-0.333 (0.411)
Temperature anomalies	-1.057 (0.844)		-1.083 (0.826)	-0.829 (0.737)	-1.054 (1.106)
WTO membership	-0.841 (1.703)		-0.661 (1.654)	-0.657 (1.485)	-0.389 (2.051)
Export-related NTMs (#)	0.816*** (0.291)		0.821*** (0.286)	0.870*** (0.283)	0.730*** (0.281)
Import-related NTMs (#)	-0.147* (0.082)	0.078** (0.032)	-0.143* (0.081)	-0.140* (0.077)	-0.179** (0.080)
RTA (#)	-0.068 (0.074)		-0.070 (0.074)	-0.065 (0.068)	-0.081 (0.073)
Average tariff rate (%)	-0.310 (0.560)		-0.334 (0.536)	-0.444 (0.378)	-0.253 (0.612)
Constant	-327.719 (234.161)	-240.459*** (79.884)	-365.094 (240.882)	-286.141 (198.171)	-492.800 (325.579)
Observations	3,548	3,185	3,185	3,551	3,405
Pseudo R squared	0.974	0.994	0.974	0.970	0.977

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation. Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil.

Table A26 | Full regression estimates for the VSS-specific effects on deforestation attribution per unit of export value (ha per constant 2020 USD) and per export volume (ha per metric tons, primary equivalents)

Model	Deforestation per export value (ha per constant 2020 USD)		Deforestation per export volume (ha per metric tons)	
	3	1 with sample of model 3	3	1 with sample of model 3
IFOAM	-0.127*** (0.040)	-0.131*** (0.037)	-0.109** (0.046)	-0.110*** (0.040)
Other VSS	0.095** (0.040)	0.091** (0.040)	0.058 (0.057)	0.056 (0.056)
Generalized residual IFOAM	-4.39e-06 (7.61e-06)		-3.87e-07 (5.37e-06)	
Generalized residual other VSS	-6.91e-06 (5.02e-06)		-2.13e-06 (4.39e-06)	
Controls	Yes	Yes	Yes	Yes
Observations	887	887	887	887
Pseudo R squared	0.381	0.380	0.869	0.869
Chi² first stage IFOAM	68.91		68.91	
Chi² first stage Other VSS	25.44		25.44	
RA	-0.008 (0.020)	-0.010 (0.019)	-0.035 (0.031)	-0.039 (0.031)
Other VSS	0.033 (0.023)	0.032 (0.023)	0.046 (0.055)	0.045 (0.055)
Generalized residual RA	-3.73e-06 (6.56e-06)		-1.28e-05 (1.12e-05)	
Generalized residual other VSS	-2.06e-06* (1.14e-06)		-1.22e-06 (1.24e-06)	
Controls	Yes	Yes	Yes	Yes
Observations	646	646	646	646
Pseudo R squared	0.189	0.189	0.466	0.465
Chi² first stage RA	843.16		843.16	
Chi² first stage Other VSS	19.58		19.58	
UTZ	-0.150*** (0.048)	-0.130*** (0.045)	-0.174*** (0.052)	-0.148*** (0.050)
Other VSS	0.199*** (0.059)	0.190*** (0.056)	0.195*** (0.063)	0.183*** (0.059)
Generalized residual UTZ	9.21e-06 (5.96e-06)		1.22e-05* (6.98e-06)	
Generalized residual other VSS	-1.89e-06 (3.74e-06)		-2.18e-06 (3.88e-06)	
Controls	Yes	Yes	Yes	Yes
Observations	419	419	419	419
Pseudo R squared	0.193	0.192	0.583	0.581
Chi² first stage UTZ	39.12		39.12	
Chi² first stage Other VSS	37.07		37.07	
FI	0.123*** (0.040)	0.121*** (0.041)	0.208*** (0.033)	0.208*** (0.033)
Other VSS	0.026 (0.077)	0.035 (0.079)	0.081 (0.116)	0.091 (0.118)
Generalized residual FI	-3.04e-06 (4.81e-06)		-2.16e-06 (2.01e-06)	
Generalized residual other VSS	6.69e-06 (6.78e-06)		6.46e-06 (5.51e-06)	
Controls	Yes	Yes	Yes	Yes
Observations	396	396	396	396
Pseudo R squared	0.194	0.194	0.513	0.512
Chi² first stage FI	50.74		50.74	
Chi² first stage Other VSS	49.36		49.36	
GlobalGAP	-0.032 (0.185)	-0.078 (0.156)	0.111 (0.302)	-0.006 (0.200)
Other VSS	-0.718*** (0.161)	-0.775*** (0.253)	-0.761*** (0.269)	-0.785** (0.394)
Generalized residual GlobalGAP	-6.57e-05 (8.95e-05)		-1.85e-04 (1.17e-04)	
Generalized residual other VSS	2.57e-04** (1.16e-04)		3.47e-04** (1.58e-04)	
Controls	Yes	Yes	Yes	Yes

Observations	140	140	140	140
Pseudo R squared	0.446	0.446	0.971	0.971
Chi² first stage GlobalGAP	116.94		116.94	
Chi² first stage Other VSS	14.66		14.66	
RSPO	0.020 (0.072)	0.000 (0.070)	0.067 (0.057)	0.003 (0.049)
Other VSS	-0.067 (0.097)	-0.071 (0.065)	-0.271*** (0.054)	-0.151* (0.088)
Generalized residual RSPO	-2.07e-05** (8.12e-06)		-7.62e-06 (3.20e-06)	
Generalized residual other VSS	-1.03e-06 (2.30e-05)		6.68e-05*** (7.97e-06)	
Controls	Yes	Yes	Yes	Yes
Observations	82	82	82	82
Pseudo R squared	0.267	0.267	0.455	0.453
Chi² first stage RSPO	1600.57		1600.57	
Chi² first stage Other VSS	16.25		16.25	
4C	-0.078 (0.075)	-0.079 (0.068)	-0.080 (0.076)	-0.089 (0.068)
Other VSS	0.331** (0.158)	0.331** (0.146)	0.387* (0.216)	0.380* (0.193)
Generalized residual 4C	-4.62e-05 (3.39e-05)		-8.10e-05* (4.13e-05)	
Generalized residual other VSS	-1.25e-05 (1.47e-05)		-1.31e-05 (1.65e-05)	
Controls	Yes	Yes	Yes	Yes
Observations	196	196	196	196
Pseudo R squared	0.258	0.258	0.599	0.560
Chi² first stage 4C	3.0*10 ⁸		3.0*10 ⁸	
Chi² first stage Other VSS	13.75		13.75	
Bonsucro	-0.108*** (0.038)	0.009 (0.052)	-0.154*** (0.042)	-0.011 (0.056)
Other VSS	0.079* (0.046)	0.082** (0.040)	0.083* (0.048)	0.092** (0.038)
Generalized residual Bonsucro	1.84e-05** (8.50e-06)		3.01e-05*** (9.15e-06)	
Generalized residual other VSS	2.16e-05*** (5.75e-06)		2.73e-05*** (6.27e-06)	
Controls	Yes	Yes	Yes	Yes
Observations	96	96	96	96
Pseudo R squared	0.241	0.240	0.435	0.434
Chi² first stage Bonsucro	10.46		10.46	
Chi² first stage Other VSS	26.63		26.63	
ProTerra				
Other VSS				
Generalized residual ProTerra				
Generalized residual other VSS				
Controls				
Observations				
Pseudo R squared				
Chi² first stage ProTerra				
Chi² first stage Other VSS				

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation. The machine learning approach (rlasso) did not find suitable instruments for 4C for both outcome variables. Instead, the set of instrumental variables with the highest correlation was selected. No instrumental variables were found for Proterra for both outcome variables due to a too small sample size. Abbreviations: IFOAM – International Federation of Organic Agriculture Movements; RA – Rainforest Alliance; FI – Fairtrade International; RSPO – Roundtable on Sustainable Palm Oil.

Table A27 | Robustness checks of model 1 for the overall VSS effect on deforestation attribution per export value (ha per constant 2020 USD)

Robustness check	Zero deforestation dummy	Maximum certified area instead of minimum	No cut-off of certification ratios above 100	Omit harvested area as control variable	Inclusion of remaining forest area as control variable	Only use deforestation data with a quality index above 0.3	Include overseas territories	Cut-off for export volumes above production volumes
Min certified area (log ha)	-0.946** (0.386)							
Zero certification (0/1)	-2.422 (2.446)							
Max certified area (ha)		-0.529** (0.236)	-0.529** (0.236)					
Min certified area (ha)				-0.275 (0.186)	-0.443 (0.328)	-1.392* (0.774)	-0.528** (0.236)	-0.727*** (0.206)
Harvested area (ha)	31.363** (12.415)	31.296** (12.422)	31.296** (12.422)		30.066* (15.359)	38.503*** (11.480)	31.223** (12.354)	31.257*** (7.895)
Harvested area ² (ha ²)	-2.017*** (0.729)	-2.014*** (0.730)	-2.014*** (0.730)		-1.955** (0.899)	-2.264*** (0.638)	-2.010*** (0.726)	-1.947*** (0.473)
Harvested area worldwide (ha)	14.203*** (4.747)	14.203*** (4.751)	14.203*** (4.751)	2.879 (10.924)	14.616*** (5.211)	-40.454*** (9.788)	14.186*** (4.750)	10.075* (5.434)
Total population (#)	-25.817 (16.165)	-25.924 (16.152)	-25.924 (16.152)	-19.128* (10.956)	-19.817 (16.345)	13.366 (17.345)	-25.615 (16.187)	-8.076 (17.797)
Population growth (%)	2.541*** (0.935)	2.539*** (0.932)	2.539*** (0.932)	3.176 (2.088)	2.589*** (0.917)	1.794 (1.507)	2.533*** (0.930)	1.528** (0.657)
GDP (constant 2020 USD)	-9.044** (4.203)	-9.029** (4.193)	-9.029** (4.193)	-14.415*** (4.364)	-9.938** (4.820)	-2.418 (4.549)	-9.048** (4.153)	-5.012 (3.224)
FDI (constant 2020 USD)	-0.047* (0.027)	-0.047* (0.027)	-0.047* (0.027)	-0.035 (0.037)	-0.047* (0.025)	0.108** (0.052)	-0.048* (0.027)	-0.047 (0.033)
World Governance Index	13.734** (5.705)	13.707** (5.692)	13.707** (5.692)	3.716 (6.723)	13.400** (5.373)	-21.753*** (5.921)	13.647** (5.589)	5.260 (7.658)
National forest-related policies (#)	-1.226** (0.560)	-1.226** (0.575)	-1.226** (0.575)	-1.134*** (0.348)	-1.323* (0.708)	-0.085 (0.341)	-1.224** (0.559)	-0.549 (0.413)
Logistics performance index	1.211 (3.053)	1.251 (3.093)	1.251 (3.093)	5.486 (4.428)	0.844 (3.613)	-6.469* (3.854)	1.282 (3.142)	2.210 (1.831)
Precipitation anomalies	-0.173 (0.369)	-0.172 (0.371)	-0.172 (0.371)	-0.253 (0.275)	-0.312 (0.490)	1.008** (0.454)	-0.164 (0.380)	-0.178 (0.345)
Temperature anomalies	0.723 (1.045)	0.727 (1.043)	0.727 (1.043)	0.042 (1.393)	0.759 (1.106)	0.589 (1.212)	0.743 (1.043)	-0.732 (0.786)
WTO membership	-0.002 (1.966)	0.010 (1.969)	0.010 (1.969)	8.076*** (2.574)	0.313 (2.154)	0.484 (2.641)	0.067 (1.914)	2.715 (1.952)
Export-related NTMs (#)	0.687*** (0.263)	0.689*** (0.263)	0.689*** (0.263)	0.930 (0.606)	0.745*** (0.242)	-1.780 (1.112)	0.691*** (0.261)	0.865*** (0.324)
Import-related NTMs (#)	-0.373*** (0.097)	-0.373*** (0.098)	-0.373*** (0.098)	-0.451*** (0.168)	-0.358*** (0.114)	0.216* (0.121)	-0.374*** (0.099)	-0.235*** (0.085)
RTA (#)	-0.126 (0.084)	-0.127 (0.085)	-0.127 (0.085)	-0.021 (0.087)	-0.141 (0.090)	-0.514 (0.439)	-0.126 (0.086)	-0.049 (0.063)
Average tariff rate (%)	0.882 (0.602)	0.879 (0.602)	0.879 (0.602)	0.275 (0.404)	0.890 (0.576)	-1.057 (0.761)	0.876 (0.595)	-0.198 (0.560)
Forest area (1,000 ha)					52.755 (78.158)		266.063 (209.018)	
Constant	270.795 (210.222)	270.007 (209.976)	270.005 (209.976)	596.817** (271.959)	-381.601 (903.790)	462.016 (436.123)	3,548 (0.953)	-46.398 (253.158)
Observations	3,548	3,548	3,548	3,548	3,548	2,360	3,548	3,548
Pseudo R squared	0.953	0.953	0.953	0.940	0.953	0.969	0.953	0.952

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

Table A28 | Robustness checks of model 1 for the overall VSS effect on deforestation attribution per export volume (ha per metric tons, primary equivalents)

Robustness check	Zero deforestation dummy	Maximum certified area instead of minimum	No cut-off of certification ratios above 100	Omit harvested area as control variable	Inclusion of remaining forest area as control variable	Only use deforestation data with a quality index above 0.3	Include overseas territories	Cut-off for export volumes above production volumes
Min certified area (log ha)	-0.856 (0.542)							
Zero certification (0/1)	-0.531 (2.974)							
Max certified area (ha)		-0.608* (0.366)	-0.610* (0.366)					
Min certified area (ha)				-0.020 (0.148)	-0.574 (0.365)	-0.598 (0.488)	-0.613* (0.364)	-0.604* (0.366)
Harvested area (ha)	42.333*** (9.034)	42.330*** (9.034)	42.330*** (9.034)		41.538*** (8.919)	36.705*** (11.823)	42.399*** (9.067)	42.195*** (9.008)
Harvested area ² (ha ²)	-2.563*** (0.497)	-2.563*** (0.497)	-2.563*** (0.497)		-2.521*** (0.493)	-2.288*** (0.676)	-2.568*** (0.500)	-2.555*** (0.496)
Harvested area worldwide (ha)	5.910 (6.072)	5.905 (6.076)	5.905 (6.076)	-6.406 (11.239)	6.279 (6.161)	-35.238*** (7.029)	6.058 (6.064)	5.896 (6.072)
Total population (#)	11.204 (11.607)	11.197 (11.608)	11.197 (11.608)	-10.490 (11.680)	14.519 (12.694)	9.732 (13.361)	11.531 (11.702)	11.161 (11.585)
Population growth (%)	0.765 (0.704)	0.765 (0.703)	0.765 (0.703)	1.574 (1.656)	0.777 (0.654)	1.178* (0.636)	0.785 (0.702)	0.766 (0.703)
GDP (constant 2020 USD)	-4.288 (3.206)	-4.287 (3.202)	-4.287 (3.202)	-12.647** (5.359)	-4.370 (3.253)	-2.107 (3.314)	-4.231 (3.195)	-4.288 (3.195)
FDI (constant 2020 USD)	-0.033 (0.043)	-0.034 (0.043)	-0.034 (0.043)	0.003 (0.053)	-0.036 (0.041)	0.009 (0.027)	-0.036 (0.043)	-0.034 (0.043)
World Governance Index	-1.211 (7.351)	-1.216 (7.348)	-1.216 (7.348)	-4.867 (11.458)	-1.824 (6.873)	-18.030*** (5.724)	-1.335 (7.347)	-1.226 (7.337)
National forest-related policies (#)	-0.148 (0.355)	-0.147 (0.354)	-0.147 (0.354)	-1.422** (0.593)	-0.178 (0.338)	-0.456 (0.362)	-0.145 (0.357)	-0.150 (0.353)
Logistics performance index	0.776 (1.979)	0.786 (1.963)	0.786 (1.963)	2.976 (2.596)	0.505 (1.933)	-2.439 (2.485)	0.740 (1.972)	0.793 (1.959)
Precipitation anomalies	-0.456 (0.419)	-0.455 (0.417)	-0.455 (0.417)	-1.048* (0.610)	-0.439 (0.392)	0.261 (0.369)	-0.447 (0.417)	-0.455 (0.416)
Temperature anomalies	-1.057 (0.844)	-1.058 (0.844)	-1.058 (0.844)	-1.345 (1.001)	-1.144 (0.841)	-0.133 (1.528)	-1.035 (0.838)	-1.056 (0.843)
WTO membership	-0.827 (1.704)	-0.823 (1.702)	-0.823 (1.702)	4.747 (3.273)	-0.692 (1.714)	3.327 (2.446)	-0.788 (1.698)	-0.820 (1.700)
Export-related NTMs (#)	0.815*** (0.291)	0.816*** (0.290)	0.816*** (0.290)	1.025** (0.407)	0.830*** (0.299)	-1.408** (0.680)	0.823*** (0.292)	0.816*** (0.290)
Import-related NTMs (#)	-0.162** (0.083)	-0.163** (0.081)	-0.163** (0.081)	-0.115 (0.143)	-0.153* (0.081)	0.117*** (0.041)	-0.164** (0.082)	-0.162** (0.076)
RTA (#)	-0.067 (0.073)	-0.067 (0.073)	-0.067 (0.073)	-0.004 (0.050)	-0.074 (0.073)	-0.165 (0.128)	-0.068 (0.074)	-0.067 (0.073)
Average tariff rate (%)	-0.311 (0.560)	-0.312 (0.559)	-0.312 (0.559)	-0.527 (0.505)	-0.238 (0.573)	-0.910 (0.841)	-0.314 (0.560)	-0.312 (0.558)
Forest area (1,000 ha)					18.307 (23.029)		-334.913 (235.062)	
Constant	-324.957 (233.793)	-325.346 (233.249)	-325.347 (233.248)	613.876 (375.200)	-589.324 (412.725)	423.802 (270.423)	3,548 (0.974)	-323.927 (232.816)
Observations	3,548	3,548	3,548	3,548	3,548	2,360	3,548	3,548
Pseudo R squared	0.974	0.974	0.974	0.955	0.974	0.969	0.974	0.974

Note: *** p < 0.01, ** p < 0.05, *p < 0.1. The number of observations differs from the full sample due to missing data, singletons, or fixed-effect separation.

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