

Little evidence of management change in California's forest offset program

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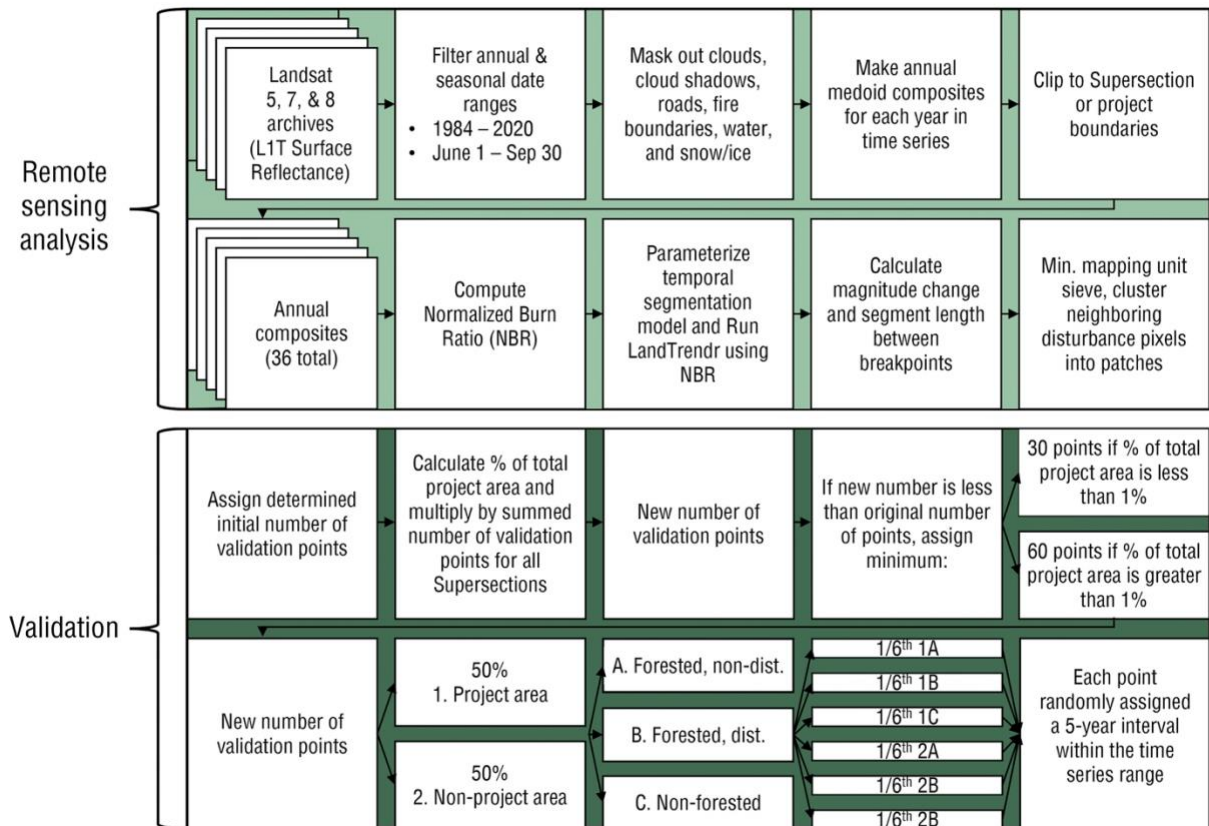
Supplementary Table 1: Forest owner types and definitions.

Class	Description
Corporate	Corporate-owned
TIMO/REIT	Timberland investment management organizations/real estate investment trusts
Tribal	Native American Tribal lands
Family	Individuals, families, trusts, estates, and family partnerships
Other	Conservation and natural resource organizations., unincorporated partnerships, and associations

Supplementary Table 2: Project size, credits, and baseline percent of Common Practice by ownership type for all ARB-credited IFM projects at the time of writing ($n = 117$).

Owner Class		All	Corporate	TIMO/REIT	Tribal	Family	Other
Number of projects		117	38	19	18	7	35
Percent of total projects		100%	32.5%	16.2%	15.4%	6%	29.9%
Hectares	Mean	16,429	10,884	23,831	28,424	2,092	14,939
	Min	216	621	909	263	622	216
	Max	205,071	47,349	113,651	204,110	5,009	183,415
	Sum	1,922,148	413,589	452,780	511,634	14,645	522,856
	Percent of total project hectares	100%	21.6%	23.6%	26.7%	0.8%	27.3%
Credits	Mean	1,497,415	922,587	2,037,595	4,356,018	508,416	673,619
	Min	777	4,343	52,124	362,722	137,902	777
	Max	15,769,238	7,277,766	6,249,083	16,085,960	1,182,019	3,586,399
	Sum	175,197,565	35,058,314	38,714,297	78,408,327	3,558,911	23,576,659
	Percent of total	100%	19.6%	21.6%	43.7%	2%	13.1%
Baseline percent of Common Practice*	Mean	134%	142.2%	117.6%	144.2%	145%	126.3%
	Mean weighted by credits	136%	152.3%	115.9%	144.6%	127.8%	117.5%
	Mean weighted by hectares	116%	129.3%	113.9%	124.8%	119.2%	109.2%
	Min	63.1%	64.8%	100%	100%	100%	63.1%
Max		267%	267%	163.2%	241.7%	256.1%	242.4%

* Common Practice values from project listing documents



Supplementary Figure 1: Remote sensing analysis and validation process diagram.

Supplementary Table 3: Differences between Supersections, all projects, and credited projects (the projects used for the primary analysis) for the mean annual percentage of total area disturbed between 1986 and 2020. Differences were tested for each ownership class and regional aggregation of Supersections—EPA Level 1 Ecoregions. Disturbance rates were calculated using a sample of the unmatched data due to the enormous quantity of points in the full dataset. For each ownership class or region, p-values for projects compare project disturbance rate to Supersection disturbance rate; p-values for credited projects compare credited project disturbance rate to Supersection disturbance rate. In 4 of 8 regions, Great Plains ($p < 0.001$), Marine West Coast Forest ($p < 0.001$), North American Desert ($p = 0.032$), and Northwestern Forested Mountains ($p < 0.001$), disturbance rates were statistically higher for all Supersections than all project areas within the region.

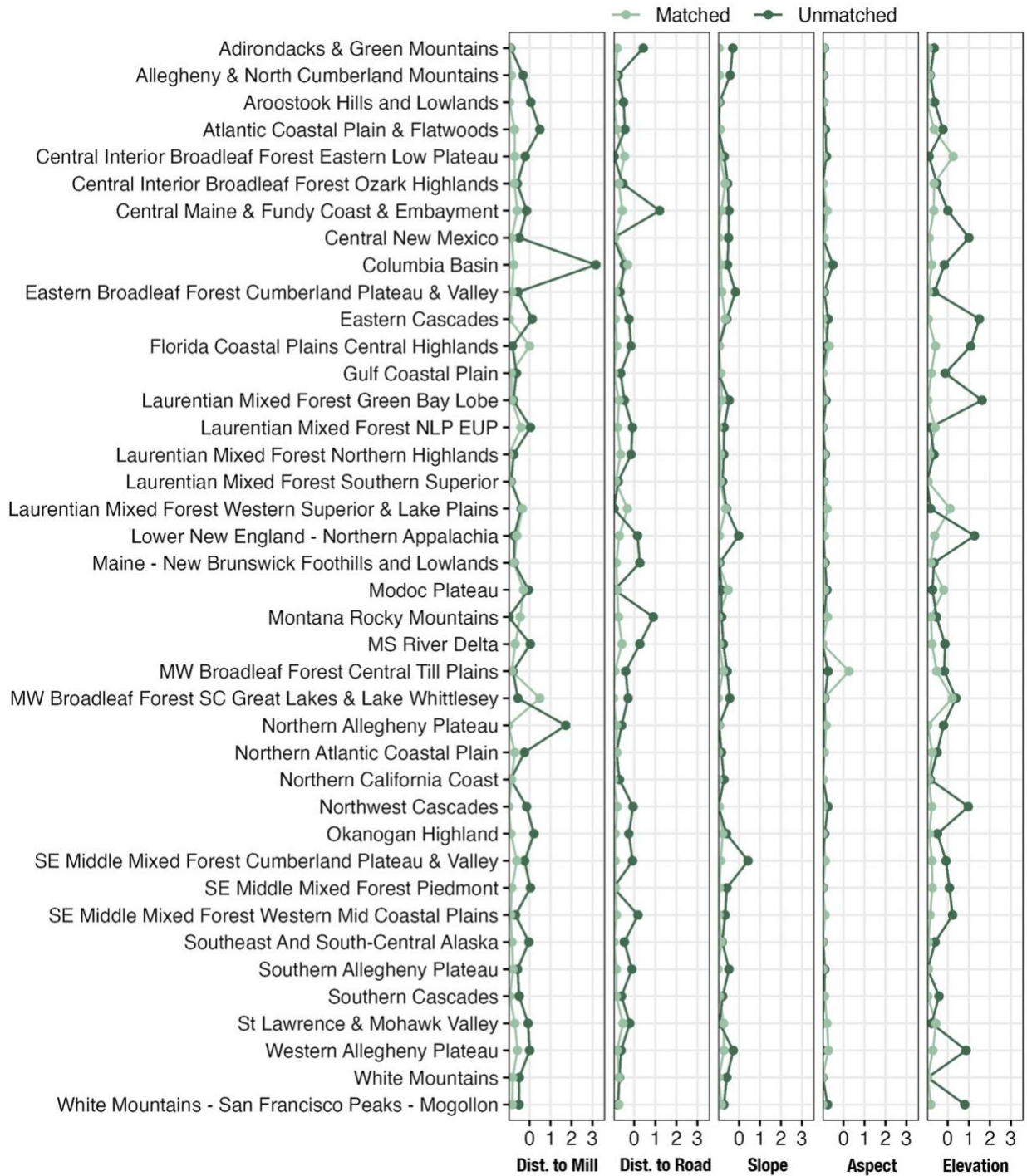
Ownership Class / Region	Area type	Sample (ha)	Mean Annual % Dist.	SD	p
All	Projects	7,497	0.196%***	0.044	<0.001
	Credited Projects	5,814	0.164%***	0.041	<0.001
	Supersections	7,497	0.227%	0.048	
Owner: Corporate	Projects	2,224	0.228%***	(0.048)	<0.001
	Credited Projects	1,382	0.143%***	(0.038)	<0.001
	Supersections	1,814	0.353%	(0.059)	
Owner: TIMO/REIT	Projects	1,687	0.214%***	(0.046)	<0.001
	Credited Projects	1,219	0.166%***	(0.041)	<0.001
	Supersections	762	0.428%	(0.065)	
Owner: Tribal	Projects	2,290	0.161%***	(0.04)	<0.001
	Credited Projects	2,081	0.174%***	(0.042)	<0.001
	Supersections	1,824	0.102%	(0.032)	
Owner: Family	Projects	222	0.237%***	(0.049)	<0.001
	Credited Projects	129	0.11%***	(0.033)	<0.001
	Supersections	2,956	0.18%	(0.042)	
Owner: Other	Projects	1,074	0.17%	(0.041)	0.29
	Credited Projects	1,004	0.179%	(0.042)	0.12
	Supersections	141	0.15%	(0.039)	
Region: Eastern Temperate Forests	Projects	2,498	0.195%	(0.044)	0.35
	Credited Projects	1,615	0.12%***	(0.035)	<0.001
	Supersections	2,492	0.201%	(0.045)	
Region: Great Plains	Projects	254	0.23%***	(0.048)	<0.001
	Credited Projects	254	0.23%***	(0.048)	<0.001
	Supersections	198	0.001%	(0.004)	
Region: Marine West Coast Forest	Projects	1,093	0.037%***	(0.019)	<0.001
	Credited Projects	884	0.04%***	(0.02)	<0.001
	Supersections	1,145	0.011%	(0.01)	
Region: Mediterranean California	Projects	293	0.419%	(0.065)	0.75
	Credited Projects	188	0.328%**	(0.057)	0.0047
	Supersections	289	0.41%	(0.064)	
Region: North American Deserts	Projects	37	0.131%**	(0.036)	0.032
	Credited Projects	37	0.131%**	(0.036)	0.032
	Supersections	40	0.238%	(0.049)	
Region: Northern Forests	Projects	1,453	0.176%	(0.042)	0.1
	Credited Projects	1,268	0.178%	(0.042)	0.2
	Supersections	1,488	0.189%	(0.043)	
Region: Northwestern Forested Mountains	Projects	1,708	0.292%***	(0.054)	<0.001
	Credited Projects	1,422	0.261%***	(0.051)	<0.001
	Supersections	1,665	0.467%	(0.068)	
Region: Temperate Sierras	Projects	147	0.032%	(0.018)	0.18
	Credited Projects	147	0.032%	(0.018)	0.18
	Supersections	149	0.019%	(0.014)	
Region: Tropical Wet Forests	Projects	14	0.018%	(0.013)	0.24
	Credited Projects	31	0.059%	(0.024)	-
	Supersections	2,498	0.195%	(0.044)	

Note: SD = standard deviation; p = p-value statistic calculated from Pairwise Wilcoxon rank-sum tests between either all observations across projects and Supersections or credited projects and Supersections for the respective owner class or region. (* p <0.1; ** p <0.05; *** p <0.01).

Supplementary Table 4: LandTrendr and Global Forest Watch (GFW) summaries and

comparison**18. A1:** Sum of LandTrendr disturbances between 1986 and 2020 (km2); **B1:** Sum of GFW disturbances (km2) applying LandTrendr mask 2000-2020; **A2:** Sum of LandTrendr disturbances that occurred 2000 or later (km2); **B2:** Sum of GFW disturbances with LandTrendr disturbances that occurred before 2000 masked, as well as other masks used in LandTrendr pre-processing steps (km2).

Supersection	A1	B1	A2	B2	B1 / A2	B2 / A2
Adirondacks & Green Mountains	2,725	1,585	892	491	1.78	0.55
Allegheny & North Cumberland Mountains	9,112	4,077	3,037	1,702	1.34	0.56
Aroostook Hills and Lowlands	1,401	1,409	476	351	2.96	0.74
Atlantic Coastal Plain & Flatwoods	51,213	38,425	15,227	11,592	2.52	0.76
Central Interior Broadleaf Forest Eastern Low	3,247	2,631	1,081	718	2.43	0.66
Central Interior Broadleaf Forest Ozark Highlands	6,929	3,848	2,109	1,230	1.82	0.58
Central Maine & Fundy Coast & Embayment	3,148	1,546	871	583	1.78	0.67
Central New Mexico	396	215	90	38	2.4	0.42
Columbia Basin	675	826	206	154	4.01	0.75
Eastern Broadleaf Forest Cumberland Plateau	5,001	2,868	1,582	1,014	1.81	0.64
Eastern Cascades	3,746	2,263	967	712	2.34	0.74
Florida Coastal Plains Central Highlands	2,797	2,481	742	532	3.34	0.72
Gulf Coastal Plain	68,222	49,905	21,002	16,411	2.38	0.78
Laurentian Mixed Forest Green Bay Lobe	1,537	1,162	478	338	2.43	0.71
Laurentian Mixed Forest NLP EUP	6,907	3,303	2,231	1,447	1.48	0.65
Laurentian Mixed Forest Northern Highlands	1,835	1,770	560	357	3.16	0.64
Laurentian Mixed Forest Southern Superior	2,371	1,286	719	447	1.79	0.62
Laurentian Mixed Forest Western Superior & Lake Plains	1,052	1,056	371	230	2.85	0.62
Lower New England - Northern Appalachia	4,440	2,262	1,467	683	1.54	0.47
Maine - New Brunswick Foothills and Lowlands	3,973	1,566	1,132	704	1.38	0.62
Modoc Plateau	589	456	125	77	3.63	0.62
Montana Rocky Mountains	6,250	3,324	1,572	1,076	2.11	0.68
MS River Delta	3,215	3,007	1,142	885	2.63	0.77
MW Broadleaf Forest Central Till Plains	177	98	48	12	2.05	0.26
MW Broadleaf Forest SC Great Lakes & Lake Whittles	306	263	92	35	2.88	0.38
Northern Allegheny Plateau	1,651	901	533	284	1.69	0.53
Northern Atlantic Coastal Plain	13,465	10,318	4,290	3,198	2.4	0.75
Northern California Coast	3,059	810	638	420	1.27	0.66
Northwest Cascades	20,217	5,813	5,044	3,942	1.15	0.78
Okanogan Highland	8,669	3,589	2,473	1,938	1.45	0.78
SE Middle Mixed Forest Cumberland Plateau & Valley	6,576	6,204	1,993	1,503	3.11	0.75
SE Middle Mixed Forest Piedmont	69,638	45,750	21,067	16,275	2.17	0.77
SE Middle Mixed Forest Western Mid Coastal Plains	33,611	23,238	11,457	9,271	2.03	0.81
Southeast And South-Central Alaska	4,486	1,091	1,458	230	0.75	0.16
Southern Allegheny Plateau	3,680	2,262	1,151	688	1.97	0.6
Southern Cascades	11,033	3,890	2,902	1,934	1.34	0.67
St Lawrence & Mohawk Valley	426	331	137	73	2.42	0.53
Western Allegheny Plateau	497	325	151	68	2.15	0.45
White Mountains	9,586	5,091	2,832	1,938	1.8	0.68
White Mountains-San Francisco Peaks-Mogollon	624	399	110	44	3.63	0.4
Mean	9,462	6,041	2,861	2,091	2.20	0.62



Supplementary Figure 2: Comparing improvement between unmatched and matched points. Standardized mean difference statistics shown for numeric variables in the matching model between matched and unmatched points for each Supersection.

Supplementary Table 5: Improved balance between unmatched and matched points. For each variable used in the matching model, the standardized mean difference (SMD) for project and Supersection points is reported, as well as the p-value (p) resulting from Pairwise Wilcoxon rank-sum tests indicating whether a significant difference was found between project and Supersection for each variable for the matched and unmatched datasets.

	Unmatched				Matched			
	Supersection	Project	SMD	p	Supersection	Project	SMD	p
Number of points	340,449	376,431			83,296	83,296		
Elevation (mean)	572.7 (514.94)	698.3 (623.76)	0.22	<0.001***	638.5 (520.49)	624.6 (508.53)	0.027	<0.001***
Slope (mean)	8.5 (7.84)	9 (8.21)	0.066	<0.001***	9.5 (8.31)	9.1 (7.92)	0.047	<0.001***
Aspect (mean)	183.2 (100.64)	182.9 (100.24)	0.003	0.087	182.8 (101.39)	180.9 (99.73)	0.018	<0.001***
Dist. to road (mean)	8.7(17.22)	7.4 (10.41)	0.088	<0.001***	8.6 (13.87)	8.3 (13.76)	0.025	<0.001***
Dist. to mill (mean)	403.3 (744.61)	340 (629.62)	0.092	<0.001***	505 (819.71)	507.6 (832.7)	0.003	<0.001***

Note: Values in parentheses = standard deviations; SMD = standard mean deviation; p = p-value statistic (** p<0.01, ** p<0.05, * p<0.1)

Supplementary Table 6: Random effects model coefficients for three years before and after project commencement. Coefficients resulted from difference-in-difference analysis for three years before and after project commencement, stratified by owner type. Six-year dummy variables and twelve landcover dummy variables are not displayed.

Variable	All	Corporate	TIMO/REIT	Tribal	Family	Other
After project commencement	0.0000155 (-0.000402)	0.000464 (-0.000377)	-0.000976* (-0.0005)	-0.00214*** (-0.000261)	-0.0000444 (-0.00065)	0.000801 (-0.000718)
Type: project	-0.000615* (-0.000318)	-0.000881*** (-0.000273)	-0.00137*** (-0.000445)	-0.0000302 (-0.000175)	-0.000843* (-0.000445)	-0.0000904 (-0.000595)
After project commencement x type: project	0.000152 (-0.000422)	0.000266 (-0.00036)	-0.000841 (-0.000585)	0.00025 (-0.000234)	0.00137** (-0.000566)	0.00051 (-0.000778)
Elevation	-0.000000597 (-0.000000379)	0.000000126 (-0.000000343)	0.00000116 (-0.00000113)	-0.000000212 (-0.000000312)	-0.000000273 (-0.000000626)	-0.00000107 (-0.00000115)
Slope	-0.0000134 (-0.0000153)	0.0000108 (-0.0000129)	-0.000124*** (-0.0000283)	-0.00001 (-0.00000865)	-0.0000148 (-0.0000211)	-0.0000663* (-0.0000365)
Aspect	0.0000011 (-0.00000104)	0.00000165* (-0.00000088)	0.00000215 (-0.00000142)	-0.000000885 (-0.000000597)	-0.00000111 (-0.00000127)	-0.00000127 (-0.0000019)
Distance to road	0 (0)	0.000586*** (-0.000134)	0.000406** (-0.000199)	-0.0000628 (-0.0000652)	0.00102*** (-0.000251)	0.00143*** (-0.000271)
Distance to mill	-0.000514** (-0.000216)	-0.0000787 (-0.000165)	-0.00069** (-0.000306)	-0.00169*** (-0.000217)	0.00101*** (-0.000285)	-0.000351 (-0.000345)
PDSI	-0.00000054 (-0.000000466)	0.00000176*** (-0.000000437)	-0.00000221*** (-0.000000841)	-0.00000164*** (-0.000000298)	-0.00000203** (-0.000000792)	-0.000000501 (-0.000000843)
Max temp	0.0000277*** (-0.00000627)	0.0000271*** (-0.00000594)	0.0000212 (-0.0000171)	-0.0000237*** (-0.00000416)	0.0000106* (-0.0000064)	0.00000912 (-0.0000146)
Min temp	-0.00000693 (-0.00000967)	0.0000563*** (-0.00000998)	-0.00000235 (-0.0000286)	-0.000000512 (-0.00000595)	-0.00000789 (-0.0000152)	-0.0000194 (-0.0000213)
Constant	0 (0)	-0.00404 (-0.00986)	-0.000932 (-0.0105)	0.0156*** (-0.00249)	0 (0)	0 (0)
Observations	229044	447732	164625	393662	96203	44231
Num. unique IDs	33284	64211	24026	58157	13761	6434

Note: Standard errors in parentheses; PDSI = Palmer Drought Severity Index; p = p-value statistic (*** p<0.01, ** p<0.05, * p<0.1)

Supplementary Table 7: Random effects model coefficients for five years before and after project commencement. Coefficients resulted from difference-in-difference analysis for five years before and after project commencement, stratified by owner type. Ten-year dummy variables and twelve landcover dummy variables are not displayed.

Variable	All	Corporate	TIMO/REIT	Tribal	Family	Other
After project commencement	-0.260 (0.220)	-0.0896 (0.161)	0.0291 (0.136)	-1.056*** (0.357)	-1.208 (1.163)	0.154 (0.333)
Type: project	-0.570* (0.291)	-0.583 (0.481)	-0.632** (0.249)	-0.111 (0.0940)	-1.098 (1.045)	0.343 (0.716)
After project commencement x type: project	0.359 (0.256)	0.200 (0.462)	-0.320* (0.189)	0.366* (0.214)	2.135* (1.166)	1.062*** (0.271)
Elevation	-0.000292 (0.000244)	-0.000214 (0.000396)	0.000690 (0.000774)	0.000132 (0.000502)	2.16e-05 (0.000296)	-0.000622 (0.00151)
Slope	0.00413 (0.0100)	0.00288 (0.0112)	-0.0358 (0.0239)	-0.00595 (0.00646)	-0.00324 (0.0256)	-0.0642 (0.0474)
Aspect	5.39e-05 (0.000495)	0.000130 (0.000509)	0.000558 (0.000551)	-0.000439 (0.000388)	-0.000811 (0.00130)	-0.00125 (0.00110)
Distance to road	0.0155** (0.00651)	0.00134 (0.0142)	-0.00499 (0.00707)	0.00816 (0.0391)	0.0693 (0.0735)	0.0765*** (0.0150)
Distance to mill	-0.272* (0.144)	-0.119 (0.177)	0.419*** (0.124)	-1.708*** (0.661)	0.601*** (0.206)	-0.323* (0.180)
PDSI	-8.42e-05 (0.000325)	0.000574* (0.000330)	-0.000920** (0.000399)	-0.000302 (0.000431)	-0.000449** (0.000223)	0.000311 (0.000682)
Max temp	0.00929 (0.00659)	0.00298 (0.00468)	0.00893 (0.0138)	0.00840 (0.0298)	0.00406 (0.00330)	-0.00789 (0.0113)
Min temp	-0.0143 (0.0109)	0.00862 (0.00710)	-0.0327** (0.0166)	-0.0438 (0.0535)	-0.00213 (0.0139)	0.000403 (0.0381)
Constant	-10.32*** (2.014)	-11.29*** (2.474)	-5.358 (4.603)	-4.063 (6.216)	-12.41** (5.033)	-6.274 (12.41)
Observations	229,298	256,964	115,031	308,214	42,419	31,460
Num. unique IDs	32,933	36,957	17,008	44,083	6,217	4,887

Note: Standard errors in parentheses; PDSI = Palmer Drought Severity Index; p = p-value statistic (*** p<0.01, ** p<0.05, * p<0.1)

Supplementary Table 8: Fixed effects model coefficients for three years before and after project commencement. Coefficients resulted from difference-in-difference analysis for five years before and after project commencement, stratified by owner type. Six-year dummy variables are not displayed.

Variable	All	Corporate	TIMO/REIT	Tribal	Family	Other
After project commencement	-0.000773 (0.000675)	-0.00169 (0.00111)	7.34e-05 (0.000638)	-0.000906 (0.000511)	-0.00348 (0.00327)	0.000476 (0.00147)
After project commencement x type: project	0.000380 (0.000564)	0.000636 (0.000982)	-0.00115* (0.000623)	0.000461 (0.000750)	0.00398 (0.00286)	0.00118** (0.000554)
PDSI	-1.17e-06*** (3.63e-07)	8.39e-08 (4.91e-07)	-3.08e-06*** (1.00e-06)	-1.02e-06* (5.20e-07)	-2.02e-06 (1.35e-06)	7.25e-07 (1.44e-06)
Max temp	6.47e-05 (5.46e-05)	6.95e-05 (4.28e-05)	-7.91e-05 (8.38e-05)	0.000132** (4.99e-05)	-4.36e-05 (0.000135)	-4.77e-05 (4.28e-05)
Min temp	-0.000108** (4.72e-05)	-0.000106*** (3.03e-05)	4.73e-05 (0.000101)	-0.000168*** (5.09e-05)	-0.000112 (7.27e-05)	6.90e-05** (2.77e-05)
Constant	-0.00434 (0.00898)	-0.00660 (0.00917)	0.0137 (0.00914)	-0.0154* (0.00742)	0.0242 (0.0397)	0.00512 (0.00751)
Observations	382,805	257,997	119,928	308,865	45,187	35,409
R-squared	0.001	0.001	0.001	0.001	0.004	0.001
Num. unique IDs	54,987	37,106	17,318	44,176	6,473	5,157

Note: Standard errors in parentheses; PDSI = Palmer Drought Severity Index; p = p-value statistic (***) p<0.01, ** p<0.05, * p<0.1)

Supplementary Table 9: Fixed effects model coefficients for five years before and after project commencement. Coefficients resulted from difference-in-difference analysis for five years before and after project commencement, stratified by owner type. Ten-year dummy variables are not displayed.

Variable	All	Corporate	TIMO/REIT	Tribal	Family	Other
After project commencement	-0.000172 (0.000599)	-0.000981* (0.000525)	0.000256 (0.000538)	-0.00115 (0.000691)	-0.00174 (0.00250)	-6.24e-05 (0.000783)
After project commencement x type: project	0.000278 (0.000543)	0.000251 (0.000643)	-0.00101** (0.000376)	0.000932 (0.000928)	0.00156 (0.00165)	0.000772 (0.000501)
PDSI	-9.06e-07* (5.05e-07)	-2.76e-07 (2.36e-07)	-8.35e-07 (6.62e-07)	-1.43e-06 (8.66e-07)	8.32e-08 (4.83e-07)	-4.42e-08 (9.82e-07)
Max temp	1.64e-05 (2.01e-05)	1.59e-05 (2.45e-05)	-3.53e-05 (5.05e-05)	1.70e-05 (1.36e-05)	0.000114 (5.15e-05)	4.87e-05 (6.18e-05)
Min temp	-4.35e-05 (2.64e-05)	-3.88e-05** (1.80e-05)	1.67e-05 (5.03e-05)	-5.69e-05* (3.11e-05)	-0.000124* (4.01e-05)	-2.07e-05 (6.37e-05)
Constant	0.00183 (0.00296)	0.00746 (0.00452)	0.00839 (0.00715)	0.00153 (0.00267)	-0.0167 (0.0127)	-0.00940 (0.00905)
Observations	569,336	390,643	184,632	441,336	70,625	54,045
R-squared	0.000	0.000	0.001	0.001	0.002	0.000
Num. unique IDs	54,987	37,106	17,318	44,176	6,473	5,157

Note: Standard errors in parentheses; PDSI = Palmer Drought Severity Index; p = p-value statistic (***) p<0.01, ** p<0.05, * p<0.1)