

Article

Supplementary data

Assessing typhoon-induced canopy damage using vegetation indices in the Fushan Experimental Forest, Taiwan

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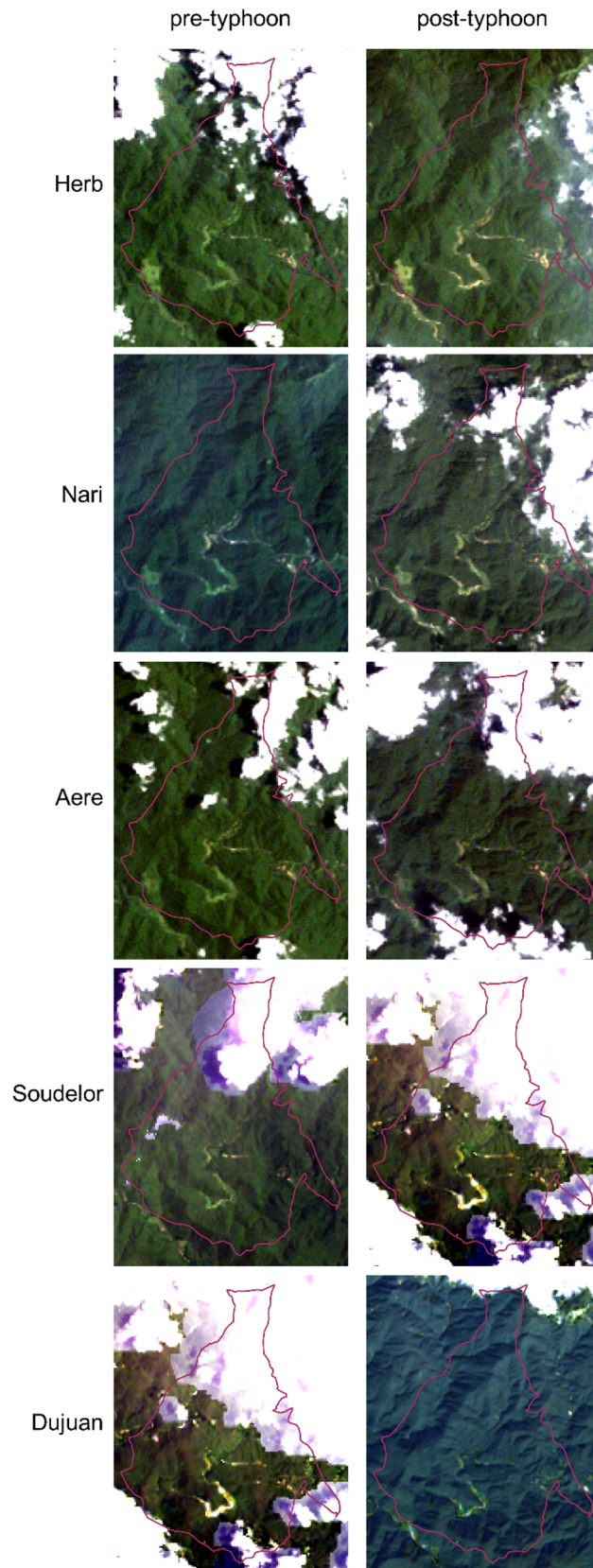


Figure S1. True colors composites of the forest cover and clouds (white) of the Fushan Experimental Forest (FEF, delimited in red) before and after each of the five studied typhoons. The image after Typhoon Soudelor is the same image used for before Typhoon Dujuan. The cloud cover, inevitable in the FEF, was removed for the analysis along with haze detected through the pre-processing steps.

Table S1. Spearman's ρ for the correlation between pre-disturbance VIs (VI_{t0}) and ΔVI associated with the typhoons. All $p < 0.001$.

	$EVI_{t0}-\Delta EVI$	$NDII_{t0}-\Delta NDII$	$NDVI_{t0}-\Delta NDVI$	$SAVI_{t0}-\Delta SAVI$
Aere	-0.53	-0.65	-0.59	-0.54
Dujuan	-0.35	-0.21	-0.35	-0.12
Herb	-0.58	-0.65	-0.52	-0.53
Nari	-0.13	-0.23	-0.30	-0.20
Soudelor	-0.56	-0.30	-0.43	-0.56

Table S2. Spearman's ρ (p-value) between corresponding ΔVIs of the five typhoons (p adjustment for multiple comparisons using the Bonferroni method). Notable, Bonferroni adjustment can lead to p-values equal to 1, especially when sample size is large as the adjustment rescale the probability by the sample size to give conservative estimations.

		Dujuan	Herb	Nari	Soudelor
Aere	EVI	0.19 (<0.01)	0.21 (<0.01)	0.14 (<0.01)	0.25 (<0.01)
	SAVI	0.26 (<0.01)	0.27 (<0.01)	0.33 (<0.01)	0.34 (<0.01)
	NDVI	-0.02 (1)	0.05 (0.32)	0.13 (<0.01)	-0.03 (1)
	NDII	0.12 (<0.01)	0.11 (<0.01)	0.10 (<0.01)	0.16 (<0.01)
Herb	EVI	-0.04 (1)			
	SAVI	0.04 (1)			
	NDVI	-0.10 (<0.01)			
	NDII	-0.11 (<0.01)			
Nari	EVI	0.16 (<0.01)	0.20 (<0.01)		
	SAVI	0.05 (0.21)	0.25 (<0.01)		
	NDVI	-0.01 (1)	0.55 (<0.01)		
	NDII	0.04 (0.96)	0.27 (<0.01)		
Soudelor	EVI	-0.08 (<0.01)	0.07 (<0.01)	0.16 (<0.01)	
	SAVI	-0.06 (0.01)	0.15 (<0.01)	0.37 (<0.01)	
	NDVI	-0.03 (1)	0.45 (<0.01)	0.37 (<0.01)	
	NDII	-0.06 (0.02)	0.22 (<0.01)	0.23 (<0.01)	

Table S3. β Coefficients of ordinary least squares linear models between topographical variables and changes in vegetation index values caused by Typhoons Aere, Herb, Nari, and Soudelor in relation to topographical variables: elevation, terrain slope, TPI-derived position, and aspects (converted into 8 cardinal directions). Sample size of 4593. Significant differences levels are shown with * ($p < 0.05$), ** ($p < 0.001$), and *** ($p < 0.001$).

	Aere			
	ΔEVI	$\Delta NDII$	$\Delta NDVI$	$\Delta SAVI$
Elevation (m)	-0.00003529 (0.00001068) ***	-0.00009016 (0.000008106) ***	-0.00001476 (0.000006311) *	-0.00002596 (0.000008195) **
Slope (°)	-0.0004695 (0.0000634) ***	-0.0007998 (0.00004812) ***	-0.0003305 (0.00003747) ***	-0.0006621 (0.00004866) ***
TPI-derived				
Lower slope	0.005569 (0.004247)	0.01021 (0.003224) **	-0.001328 (0.00251)	0.004673 (0.003259)
Middle slope	0.007804 (0.004111)	0.009621 (0.00312) **	-0.0009958 (0.00243)	0.006537 (0.003155) *

<i>Ridge</i>	0.01704 (0.004279) ***	0.0001348 (0.003248)	-0.001251 (0.002529)	0.01407 (0.003284) ***
<i>Upper slope</i>	0.01153 (0.004278) **	0.002697 (0.003247)	-0.00223 (0.002528)	0.009396 (0.003283) **
<i>Valley</i>	0.002572 (0.004207)	0.009338 (0.003193) **	-0.0004187 (0.002486)	0.002566 (0.003229)
Aspects				
<i>North</i>	-0.0152 (0.002449) ***	0.008234 (0.001859) ***	-0.0111 (0.001448) ***	-0.0243 (0.00188) ***
<i>North East</i>	-0.002327 (0.002497)	0.004052 (0.001896) *	-0.003118 (0.001476) *	-0.00756 (0.001917) ***
<i>North West</i>	-0.0001527 (0.002317)	0.00106 (0.001759)	-0.001534 (0.001369)	-0.01147 (0.001778) ***
<i>South</i>	0.01297 (0.00205) ***	0.0007686 (0.001556)	0.00364 (0.001211) **	0.009091 (0.001573) ***
<i>South East</i>	0.005905 (0.002266) **	0.005824 (0.00172) ***	0.00369 (0.001339) **	0.005264 (0.001739) **
<i>South West</i>	0.01513 (0.002222) ***	-0.004584 (0.001686) **	-0.002157 (0.001313)	0.006108 (0.001705) ***
<i>West</i>	0.01608 (0.002526) ***	-0.004507 (0.001917) *	-0.000307 (0.001493)	0.003436 (0.001939) .
<i>R²</i>	0.08107	0.1261	0.05407	0.1505
Adjusted <i>R²</i>	0.07826	0.1234	0.05118	0.1479

Dujuan				
	Δ EVI	Δ NDII	Δ NDVI	Δ SAVI
Elevation (m)	-0.0002092 (0.00001342) ***	-0.0001377 (0.000007541) ***	-0.0001466 (0.000008505) ***	-0.00008655 (0.000009963) ***
Slope (°)	-0.00005076 (0.00007966)	-0.0002938 (0.00004477) ***	-0.0002135 (0.00005049) ***	0.00001726 (0.00005915)
TPI-derived				
<i>Lower slope</i>	-0.03056 (0.005336) ***	-0.01494 (0.002999) ***	-0.01721 (0.003382) ***	-0.0227 (0.003962) ***
<i>Middle slope</i>	-0.02518 (0.005165) ***	-0.01739 (0.002903) ***	-0.0155 (0.003274) ***	-0.02076 (0.003836) ***
<i>Ridge</i>	-0.01421 (0.005377) **	-0.01848 (0.003022) ***	-0.01217 (0.003408) ***	-0.01403 (0.003993) ***
<i>Upper slope</i>	-0.0204 (0.005374) ***	-0.01829 (0.003021) ***	-0.01402 (0.003407) ***	-0.01781 (0.003991) ***
<i>Valley</i>	-0.03372 (0.005286) ***	-0.0155 (0.002971) ***	-0.01949 (0.003351) ***	-0.02469 (0.003925) ***
Aspects				
<i>North</i>	0.004264 (0.003077)	-0.0008964 (0.00173)	0.005272 (0.001951) **	-0.001499 (0.002285)
<i>North East</i>	0.02306 (0.003138) ***	-0.0155 (0.001764) ***	-0.005104 (0.001989) *	0.01526 (0.00233) ***
<i>North West</i>	0.006154 (0.002911) *	-0.001222 (0.001636)	-0.004555 (0.001845) *	0.003387 (0.002162)
<i>South</i>	-0.01879 (0.002575) ***	0.007293 (0.001447) ***	-0.00207 (0.001632)	-0.009208 (0.001912) ***

<i>South East</i>	-0.007419 (0.002847) **	0.003153 (0.0016) *	-0.002928 (0.001805)	-0.002211 (0.002114)
<i>South West</i>	-0.01351 (0.002792) ***	0.005316 (0.001569) ***	-0.00488 (0.00177) **	-0.004284 (0.002073) *
<i>West</i>	-0.006855 (0.003174) *	-0.003773 (0.001784) *	-0.007315 (0.002012) ***	-0.001902 (0.002357)
R^2	0.116	0.1524	0.08968	0.05766
Adjusted R^2	0.1133	0.1498	0.08689	0.05478

	Herb			
	Δ EVI	Δ NDII	Δ NDVI	Δ SAVI
Elevation (m)	0.0001944 (0.00001686) ***	0.0001083 (0.000009304) ***	0.0001842 (0.000009514) ***	0.000174 (0.000007538) ***
Slope (°)	0.001922 (0.0001001) ***	-0.0006796 (0.00005524) ***	-0.001335 (0.00005648) ***	0.0002023 (0.00004475) ***
TPI-derived				
<i>Lower slope</i>	0.01576 (0.006705) *	0.01959 (0.0037) ***	0.01807 (0.003784) ***	0.01516 (0.002998) ***
<i>Middle slope</i>	0.02612 (0.00649) ***	0.02539 (0.003582) ***	0.02192 (0.003662) ***	0.02211 (0.002902) ***
<i>Ridge</i>	0.03048 (0.006756) ***	0.02716 (0.003729) ***	0.01731 (0.003812) ***	0.02343 (0.003021) ***
<i>Upper slope</i>	0.02972 (0.006754) ***	0.02514 (0.003727) ***	0.01778 (0.003811) ***	0.02296 (0.003019) ***
<i>Valley</i>	0.01029 (0.006642)	0.01938 (0.003665) ***	0.0148 (0.003748) ***	0.01258 (0.00297) ***
Aspects				
<i>North</i>	0.02831 (0.003867) ***	-0.03096 (0.002134) ***	-0.04697 (0.002182) ***	-0.005157 (0.001729) **
<i>North East</i>	0.004868 (0.003943)	-0.006437 (0.002176) **	-0.0135 (0.002225) ***	-0.003432 (0.001763) .
<i>North West</i>	0.05379 (0.003658) ***	-0.06196 (0.002019) ***	-0.09137 (0.002064) ***	-0.01571 (0.001635) ***
<i>South</i>	0.02357 (0.003236) ***	-0.02846 (0.001786) ***	-0.03873 (0.001826) ***	0.0004406 (0.001447)
<i>South East</i>	0.005861 (0.003578)	-0.007186 (0.001974) ***	-0.009821 (0.002019) ***	-0.001257 (0.0016)
<i>South West</i>	0.04813 (0.003508) ***	-0.05416 (0.001936) ***	-0.07343 (0.001979) ***	-0.0005378 (0.001568)
<i>West</i>	0.06995 (0.003988) ***	-0.06206 (0.002201) ***	-0.09636 (0.00225) ***	-0.006547 (0.001783) ***
R^2	0.2222	0.3417	0.5179	0.2046
Adjusted R^2	0.2198	0.3397	0.5164	0.2021

	Nari			
	Δ EVI	Δ NDII	Δ NDVI	Δ SAVI
Elevation (m)	0.00005388 (0.00001055) ***	0.00002031 (0.000007871) **	0.00008019 (0.00001109) ***	0.00005605 (0.000006911) ***

Slope (°)	0.0006255 (0.00006264) ***	-0.0009953 (0.00004673) ***	-0.00178 (0.00006586) ***	-0.0007978 (0.00004103) ***
TPI- derived				
<i>Lower slope</i>	-0.007739 (0.004196) .	0.002984 (0.00313)	0.007037 (0.004411)	0.002897 (0.002748)
<i>Middle slope</i>	-0.005112 (0.004062)	0.002878 (0.00303)	0.007623 (0.00427)	0.005059 (0.00266) .
<i>Ridge</i>	-0.0005486 (0.004228)	0.0004385 (0.003154)	0.003827 (0.004445)	0.007862 (0.002769) **
<i>Upper slope</i>	-0.001701 (0.004226)	0.001574 (0.003153)	0.005035 (0.004443)	0.006219 (0.002768) *
<i>Valley</i>	-0.008054 (0.004156) .	0.0006958 (0.003101)	0.00338 (0.00437)	0.0001384 (0.002723)
Aspects				
<i>North</i>	0.007007 (0.00242) **	-0.0273 (0.001805) ***	-0.07093 (0.002544) ***	-0.03146 (0.001585) ***
<i>North East</i>	-0.002127 (0.002467)	-0.01668 (0.001841) ***	-0.03405 (0.002594) ***	-0.0145 (0.001616) ***
<i>North West</i>	0.02046 (0.002289) ***	-0.03262 (0.001708) ***	-0.09489 (0.002407) ***	-0.04186 (0.001499) ***
<i>South</i>	-0.005763 (0.002025) **	-0.0004742 (0.001511)	-0.001021 (0.002129)	-0.006348 (0.001326) ***
<i>South East</i>	-0.002812 (0.002239)	-0.0001757 (0.00167)	0.005556 (0.002354) *	-0.002741 (0.001467) .
<i>South West</i>	-0.005576 (0.002195) *	-0.01195 (0.001638) ***	-0.03011 (0.002308) ***	-0.01723 (0.001438) ***
<i>West</i>	0.008823 (0.002496) ***	-0.02321 (0.001862) ***	-0.06352 (0.002624) ***	-0.02542 (0.001635) ***
R^2	0.07899	0.2163	0.4684	0.2786
Adjusted R^2	0.07618	0.2139	0.4668	0.2764

Soudelor				
	Δ EVI	Δ NDII	Δ NDVI	Δ SAVI
Elevation (m)	0.00001339 (0.00001226)	0.00005662 (0.000007217) ***	0.0000776 (0.000009192) ***	0.00001558 (0.00001007)
Slope (°)	-0.0005366 (0.00007282) ***	-0.0005488 (0.00004285) ***	-0.0005062 (0.00005457) ***	-0.0005458 (0.00005981) ***
TPI- derived				
<i>Lower slope</i>	0.02833 (0.004878) ***	0.01622 (0.00287) ***	0.03373 (0.003656) ***	0.02672 (0.004006) ***
<i>Middle slope</i>	0.03733 (0.004721) ***	0.01867 (0.002778) ***	0.03878 (0.003539) ***	0.03373 (0.003878) ***
<i>Ridge</i>	0.05028 (0.004915) ***	0.01954 (0.002892) ***	0.04037 (0.003684) ***	0.04326 (0.004037) ***
<i>Upper slope</i>	0.04192 (0.004913) ***	0.01845 (0.002891) ***	0.0392 (0.003682) ***	0.03692 (0.004035) ***
<i>Valley</i>	0.02646 (0.004832) ***	0.0156 (0.002843) ***	0.0355 (0.003621) ***	0.02583 (0.003968) ***

Aspects				
North	-0.03411 (0.002813) ***	0.003283 (0.001655) *	-0.0104 (0.002108) ***	-0.02853 (0.002311) ***
North East	-0.01368 (0.002868) ***	0.00352 (0.001688) *	0.0005863 (0.00215)	-0.01034 (0.002356) ***
North West	-0.02275 (0.002661) ***	-0.003127 (0.001566) *	-0.02141 (0.001994) ***	-0.02285 (0.002186) ***
South	0.009047 (0.002354) ***	0.006933 (0.001385) ***	-0.01055 (0.001764) ***	0.004163 (0.001933) *
South East	0.006639 (0.002603) *	0.01223 (0.001532) ***	0.001845 (0.001951)	0.004986 (0.002138) *
South West	-0.0001445 (0.002552)	-0.0003172 (0.001502)	-0.01908 (0.001913) ***	-0.004376 (0.002096) *
West	0.001316 (0.002901)	-0.001154 (0.001707)	-0.01971 (0.002174) ***	-0.003195 (0.002383)
R^2	0.1308	0.08613	0.1146	0.1295
Adjusted R^2	0.1282	0.08333	0.1119	0.1269

Table S4. Multiple comparisons on mean disturbances for different aspect and topographical position index (TPI) derived categories. Adjusted p values, multiple comparisons based on [1]. Significance levels are shown with † ($p < 0.05$), ‡ ($p < 0.01$), and * ($p < 0.001$).

Aspects	EVI				NDII			
	Estimate	Std. Error	t value		Estimate	Std. Error	t value	
North-East = 0	0.26188	0.07426	3.527	‡	0.51249	0.06617	7.745	*
NorthEast-East = 0	0.11913	0.07715	1.544		0.35672	0.05924	6.022	*
NorthWest-East = 0	0.08033	0.06632	1.211		0.94313	0.06452	14.617	*
South-East = 0	-0.05823	0.05694	-1.023		-0.11658	0.04654	-2.505	
SouthEast-East = 0	-0.04732	0.06295	-0.752		-0.40448	0.04701	-8.603	*
SouthWest-East = 0	-0.13418	0.0634	-2.116		0.49118	0.05977	8.218	*
West-East = 0	-0.19072	0.0711	-2.682		0.90585	0.07476	12.118	*
NorthEast-North = 0	-0.14275	0.08496	-1.68		-0.15577	0.07292	-2.136	
NorthWest-North = 0	-0.18155	0.07526	-2.412		0.43064	0.07728	5.573	*
South-North = 0	-0.32012	0.06714	-4.768	*	-0.62907	0.06305	-9.978	*
SouthEast-North = 0	-0.3092	0.07231	-4.276	*	-0.91697	0.0634	-14.464	*
SouthWest-North = 0	-0.39606	0.0727	-5.448	*	-0.02132	0.07336	-0.291	
West-North = 0	-0.4526	0.0795	-5.693	*	0.39336	0.08601	4.574	*
NorthWest-NorthEast = 0	-0.0388	0.07811	-0.497		0.58641	0.07143	8.21	*
South-NorthEast = 0	-0.17737	0.07032	-2.522		-0.47331	0.05572	-8.494	*
SouthEast-NorthEast = 0	-0.16645	0.07528	-2.211		-0.76121	0.05612	-13.565	*
SouthWest-NorthEast = 0	-0.25331	0.07565	-3.348	†	0.13445	0.06716	2.002	
West-NorthEast = 0	-0.30985	0.08221	-3.769	‡	0.54912	0.08079	6.797	*
South-NorthWest = 0	-0.13856	0.05824	-2.379		-1.05972	0.06131	-17.284	*
SouthEast-NorthWest = 0	-0.12764	0.06413	-1.99		-1.34762	0.06167	-21.852	*

SouthWest-NorthWest = 0	-0.21451	0.06457	-3.322	†	-0.45196	0.07187	-6.289	*
West-NorthWest = 0	-0.27104	0.07215	-3.757	‡	-0.03728	0.08474	-0.44	
SouthEast-South = 0	0.01092	0.05438	0.201		-0.2879	0.0425	-6.774	*
SouthWest-South = 0	-0.07595	0.0549	-1.383		0.60776	0.05629	10.797	*
West-South = 0	-0.13248	0.06363	-2.082		1.02243	0.072	14.2	*
SouthWest-SouthEast = 0	-0.08686	0.06111	-1.421		0.89566	0.05668	15.803	*
West-SouthEast = 0	-0.1434	0.06906	-2.076		1.31033	0.07231	18.121	*
West-SouthWest = 0	-0.05654	0.06948	-0.814		0.41467	0.08118	5.108	*
TPI classes								
upper slope-ridge = 0	0.1606	0.04911	3.27	†	0.0018	0.057836	0.031	
middle slope-ridge = 0	0.3687	0.04299	8.576	*	0.012565	0.049763	0.253	
flat slope-ridge = 0	0.82525	0.13674	6.035	*	0.152513	0.133618	1.141	
lower slope-ridge = 0	0.65116	0.0594	10.961	*	-0.0642	0.061537	-1.043	
valley-ridge = 0	0.8391	0.05917	14.182	*	-0.05812	0.06051	-0.961	
middle slope-upper slope = 0	0.2081	0.04311	4.827	*	0.010765	0.049329	0.218	
flat slope-upper slope = 0	0.66465	0.13678	4.859	*	0.150713	0.133457	1.129	
lower slope-upper slope = 0	0.49056	0.05949	8.246	*	-0.066	0.061186	-1.079	
valley-upper slope = 0	0.6785	0.05925	11.451	*	-0.05992	0.060153	-0.996	
flat slope-middle slope = 0	0.45655	0.1347	3.389	‡	0.139948	0.130161	1.075	
lower slope-middle slope = 0	0.28246	0.05455	5.178	*	-0.07676	0.053619	-1.432	
valley-middle slope = 0	0.4704	0.0543	8.664	*	-0.07069	0.052437	-1.348	
lower slope-flat slope = 0	-0.17409	0.1408	-1.236		-0.21671	0.135101	-1.604	
valley-flat slope = 0	0.01385	0.1407	0.098		-0.21064	0.134637	-1.564	
valley-lower slope = 0	0.18794	0.06803	2.763		0.006071	0.063719	0.095	

References

1. Herberich, E.; Sikorski, J.; Hothorn, T. A robust procedure for comparing multiple means under heteroscedasticity in unbalanced designs. *PLoS One* **2010**, *5*, e9788. doi:10.1371/journal.pone.0009788.



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