Supporting Information for Waite, C.E. et al. 2022. Landscape-scale drivers of liana load across a Southeast Asian forest canopy differ to the Neotropics. ***Journal of Ecology.***

S1: The predictor variables, their associated predictor sets used in the Boosted Regression Tree (BRT) models, and the method of deriving each of the predictor variables. The disturbance variables are multiple canopy gap depths (canopy height of: <2 m, 2 – 5 m, and 5 – 10 m) and areas (25 – 100 m^2, 100 – 500 m^2, >500 m^2). All analysis was conducted in R version 4.1.0 (R Core Team, 2019).

[Category] Variable name	Predictor Set	Method of Derivation	Units	Spatial resolution (m)
Distance to gaps <2m height, 25 – 100m^2 Distance to gaps <2m height, 100 – 500m^2 Distance to gaps <2m height, >500m^2 Distance to gaps <5m height, 25 – 100m^2 Distance to gaps <5m height, 100 – 500m^2 Distance to gaps <5m height, >500m^2 Distance to gaps <10m height, 25 – 100m^2 Distance to gaps <10m height, 100 – 500m^2 Distance to gaps <10m height, >500m^2	LiDAR, UAS	Canopy gaps were derived by thresholding the LiDAR and UAS canopy height models at different heights (<2 m, 2 – 5 m and 5 – 10 m) and areas (25 – 100 m^2, 100 – 500 m^2, >500 m^2) to produce 18 layers (9 LiDAR, 9 UAS) containing individual gaps as polygons. The distance of each tree crown centroid to its nearest gap edge (m) was calculated using the dist2line function in the R package geosphere version 1.5.1 (Hijmans et al., 2019). This makes the most ecological sense as lianas may be present throughout gaps, including the edge, and commonly infest crowns by climbing the trunk which, in the absence of knowing the exact trunk location, is likely near the centroid of the tree crown.	m	1 0.17
Mean top of crown height	LiDAR, UAS	Canopy height models (CHM) were derived from the LiDAR and UAS data. The tree crown shapefiles were overlaid on the CHM rasters and elevation values for each pixel comprising the tree crown were taken. The mean value for each tree crown was used as we feel it is slightly more impervious to small errors (branches protruding above the	m	1 0.17

		canopy, errors in the LiDAR pulse readings or UAS point cloud etc.) than maximum or minimum values.		
Mean slope angle	LiDAR, UAS, Surface	Slope values were derived from the surface-collected topographic data, the LiDAR data, and the UAS data using ArcGIS version 10.4. For the surface data, the data collected from the sample points (20m resolution) were interpolated using Inverse Distance Weighting. For the LiDAR and UAS data, slope was calculated from the digital terrain models. The tree crown shapefiles were overlain on the three raster layers (surface-, LiDAR-, UAS-derived slope) and values for each pixel comprising the tree crown taken. The mean value of all pixels was then taken for each tree crown due to the layers being interpolations with no true minimum or maximum.	^{o}	1 0.17 2.71
Soil ECEC Soil copper Soil phosphorus Soil pH	Surface	The data collected from the surface sample points (50m resolution) were interpolated using Ordinary Kriging in R (variogram information in Supporting Information S2). The tree crown shapefiles were overlain on these interpolated raster layers and values for each pixel comprising the tree crown taken. The mean value of all pixels was then taken for each tree crown due to the layers being interpolations with no true minimum or maximum.	cmol/kg mg/kg mg/kg	2.71
Distance to nearest infested neighbour	UAS	The distance from each individual tree to its nearest neighbour that was infested with lianas was calculated using the nndist function in the package	m	0.17

		spatstat version 1.61 (Baddeley et al., 2015) in R.		
Crown area	UAS	Tree crown area was calculated by determining the size of the pixels comprising the orthomosaic and multiplying this by the number of pixels in the crown. This is not a calibrated measure but as it is only used as a comparison between relative tree sizes to examine potential differences in liana load, specific, calibrated values are not necessary.	m^2	0.17

S2: Variogram model fit parameters for the soil variables used to generate soil raster layers via Ordinary Kriging.

Soil variable	Model	Nugget	Sill	Range (m)
Copper	Spherical	0.032	0.39	72.0
ECEC	Spherical	0.001	0.20	98.0
pH	Exponential	0.002	0.15	98.7
Phosphorus	Spherical	0.081	0.21	19.0

S3: UAS-based data collection and processing

A DJI Phantom 3 Advanced was used to acquire images of the forest canopy with all flights taking place between 14th and 16th June 2016. The flight plan for the survey of the 50-ha plot was designed with, and flown using, Map Pilot software version 1.5.1. It consisted of 9 individual flights with the same parameters (altitude: 30 m above the canopy surface; speed: 4 m/s; image overlap: 90% forward, 90% side). Each flight consisted of parallel tracks, covering a portion of the 50-ha plot (overlapping with other flights to allow image matching and stitching of multiple flights into one orthomosaic) and a buffer of surrounding vegetation, outside the 50-ha plot (~50-ha in total), to minimise edge-effects affecting the images of the plot in processing. The flight tracks were uploaded to the UAS, and the surveys flown autonomously, with the exception of launch and landing; here we identified canopy gaps large enough to launch/land the UAS, and manually piloted it through the gaps, to ensure maximal pilot control and minimal risk of collision with vegetation. The flights were conducted during calm conditions to prevent wind effects on leaves (McNeil, 2016). The integrated three-waveband (RGB) Sony EXMOR 1/2.3" 12-megapixel camera has a narrow 94^{o} field of view lens and fast 1/8000s shutter speed to reduce 'fish-eye' image distortion and image blur. On-board GPS and GLONASS positioning enabled autonomous flights (up to ~23 minutes) and geo-tagging of acquired images with the GPS location and elevation of the UAS at the point of capture.

S4: Occupied aircraft-based LiDAR data collection and processing

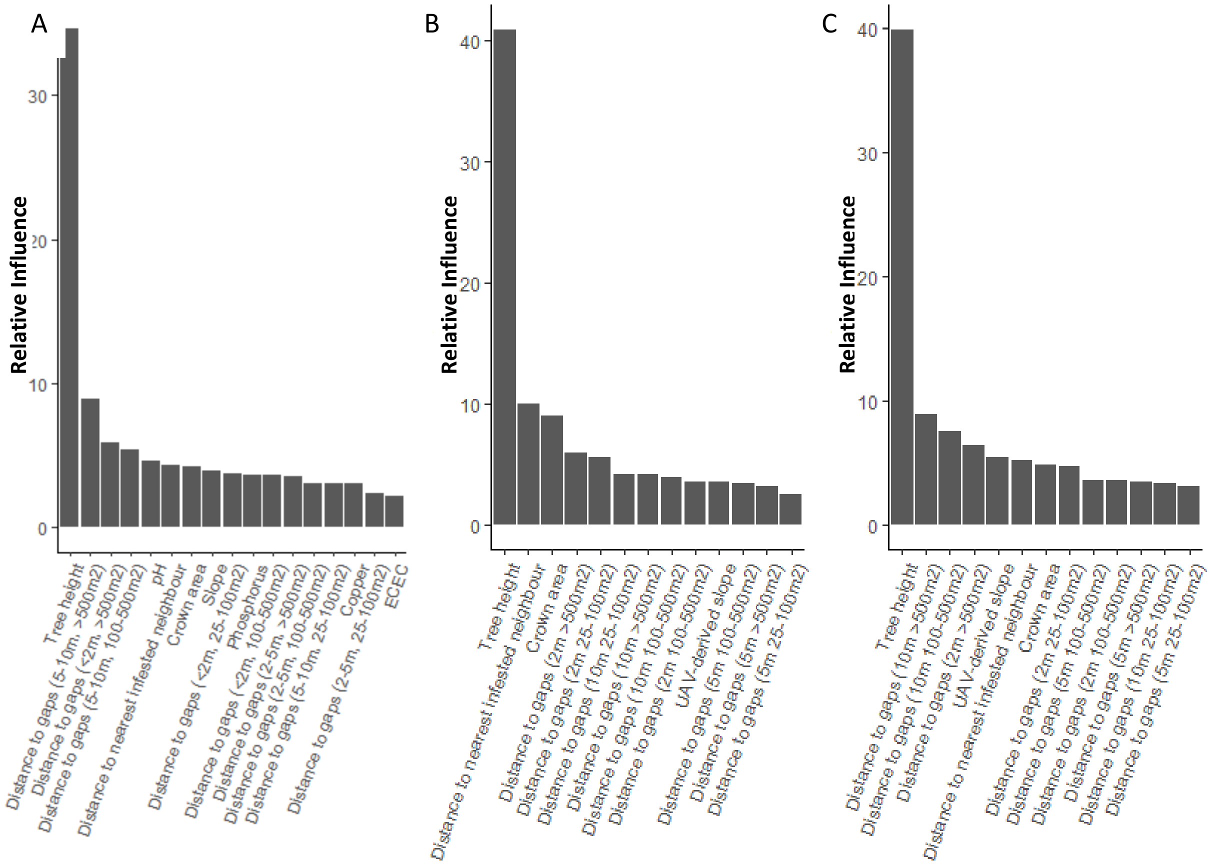
LiDAR data for Danum were acquired by the Natural Environment Research Council Airborne Research Facility (NERC ARF) on the 2nd November 2014. The data were captured from a Dornier 228 aircraft, recording 10 flight lines over ~64 minutes at an average altitude of 2378 m. During flight, the aircraft's position was recorded using a differential GPS, with positional information relayed from a base station with a known position, and the aircraft's orientation (roll, pitch, and bearing) recorded through the Inertial Measuring Unit (IMU). The sensors on-board the aircraft included the Leica ALS50-II LiDAR system (1064 nm; hit rate: 2.9 points/m^2; ~15 cm in Z). The data from this system were pre-processed by NERC's Data Analysis Node and supplied in LAS 1.2 (binary data) and ASCII file formats with horizontal and vertical datum projected in WGS84 UTM Zone 50N. These were processed in LAStools to provide a canopy height model and digital terrain model with a spatial resolution of 1m that were clipped to the extent of the 50 ha plot. The LiDAR data have been published previously in Chandler et al. (2021) and Shenkin et al. (2019).

Chandler, C.J., Van Der Heijden, G.M., Boyd, D.S., Cutler, M.E., Costa, H., Nilus, R. and Foody, G.M., 2021. Remote sensing liana infestation in an aseasonal tropical forest: addressing mismatch in spatial units of analyses. Remote Sensing in Ecology and Conservation, 7(3), pp.397-410.

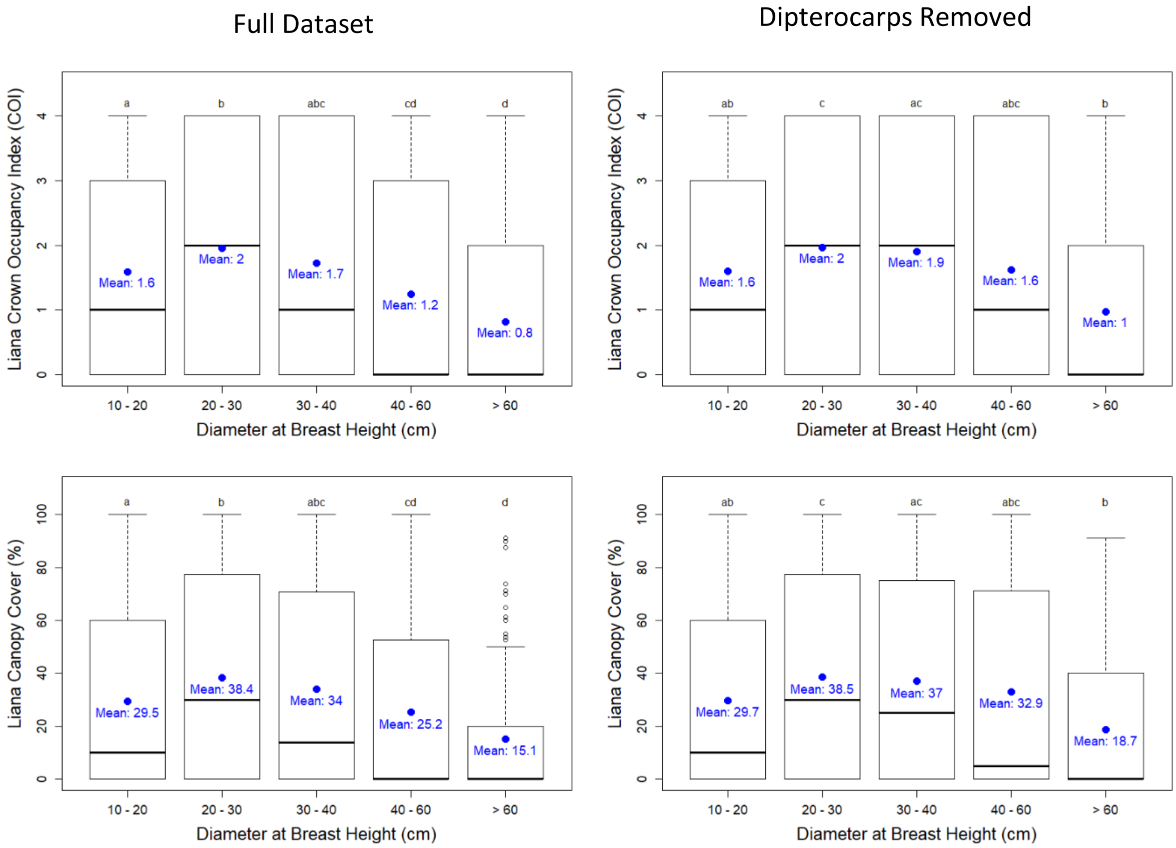
Shenkin, A., Chandler, C.J., Boyd, D.S., Jackson, T., Disney, M., Majalap, N., Nilus, R., Foody, G., bin Jami, J., Reynolds, G., Wilkes, P., Cutler, M.E.J., van der Heijden, G.M.F., Burslem, D.F.R.P., Coomes, D.A., Bentley, L.P. and Malhi, Y. 2019. The world's tallest tropical tree in three dimensions. Frontiers in Forests and Global Change, 2, p.32.

S5: Boosted Regression Tree (BRT) model results across both liana load assessments (liana presence-absence [P/A], and crown occupancy index [COI]) for the different predictor sets (UAS and surface data, UAS data only, and LiDAR and surface). The relative influence (RI) of each predictor is shown, as well as the direction of this influence. Where the model contribution reflected a negative relationship with liana presence/absence or COI, we made the relative influence value negative for display purposes.

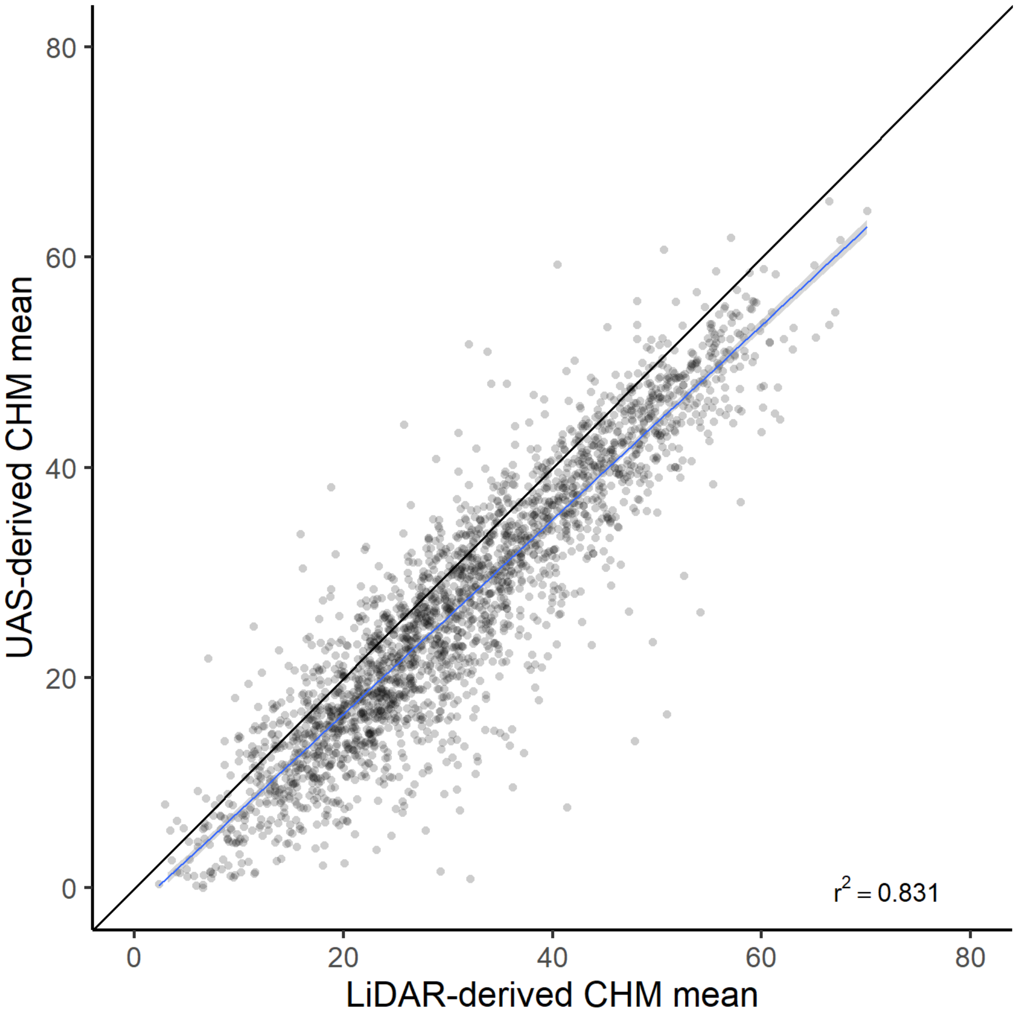
	Relative influence (%) of each predictor																
	Gaps									**Height**	**Area**	**Slope**	**Distance to nearest infested neighbour**	**Soil**			
	<2m height, 25 – 100m²	**<2m height, 100 – 500m²**	**<2m height, >500m²**	**2 – 5m height, 25 – 100m²**	**2 – 5m height, 100 – 500m²**	**2 – 5m height, >500m²**	**5 – 10m height, 25 – 100m²**	**5 – 10m height, 100 – 500m²**	**5 – 10m height, >500m²**					**pH**	**Cu**	**P**	**ECEC**
P/A																	
UAS & Surface	-4.51	-2.61	-4.65	-1.88	-2.41	-2.24	-3.34	-2.93	-3.47	-40.04	-7.83	-2.81	-8.86	2.54	3.39	-3.43	3.04
UAS	-5.41	-3.60	-5.98	-2.50	-3.40	-3.44	-4.01	-3.87	-4.19	-41.10	-9.18	-3.62	-9.72				
LiDAR & Surface	-2.53	-5.77	-10.19	-3.07	-2.57	-6.30	-3.55	-3.34	-2.92	-41.36		-2.50		2.97	5.22	-4.98	2.73
COI																	
UAS & Surface	-3.70	-3.59	-5.90	-2.38	-2.58	-3.51	-2.65	-5.36	-8.96	-34.60	-4.23	-3.97	-4.38	4.62	2.99	-3.65	2.17
UAS	-3.80	-3.67	-6.21	-2.33	-3.33	-3.78	-3.30	-5.86	-9.06	-45.39	-3.92	-4.76	-4.98				
LiDAR & Surface																	



S6: Variable importance plots showing the relative influence values of each of the variables included in the Boosted Regression Tree models for: (A) liana presence/absence UAS and surface data; (B) liana presence/absence UAS data; and (C) liana COI UAS data. The relative influence of each variable (full variable descriptions given in Table S5 of the main text) is scaled so that the sum adds to 100, with higher numbers indicating a stronger influence on the response.



S7: The relationship between tree diameter at breast height (DBH) binned into size classes (10 – 20cm, 20 – 30, 30 – 40cm, 40 – 60cm and >60 cm) and: (i) median liana crown occupancy index (COI; (0) no lianas in the crown; (1) 1% – 25%; (2) 26% – 50%; (3) 51% – 75%; (4) >75% of the crown covered by liana leaves; Clark & Clark, 1990); and (ii) median liana canopy cover (%) for both the full ground dataset (n = 2,313), and the ground dataset with all dipterocarp individuals removed (n = 2,123). Mean values are shown as blue points with corresponding value given below for each DBH size class. Different letters above error bars indicate significant differences (p = < 0.05) among groups (Wilcoxon rank sum tests with Holm correction).



S8: The relationship between LiDAR-derived and UAS-derived mean tree crown height (m) for the full dataset (n = 2,428). The solid blue line is the regression line and the associated adjusted r^2 is reported, grey shading indicated the 95% confidence intervals, and black lines are the 1:1 lines (i.e., perfect match).