Tree island area in oil palm agroforests directly and indirectly drives evaporative fraction

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1. Structural equation modelling

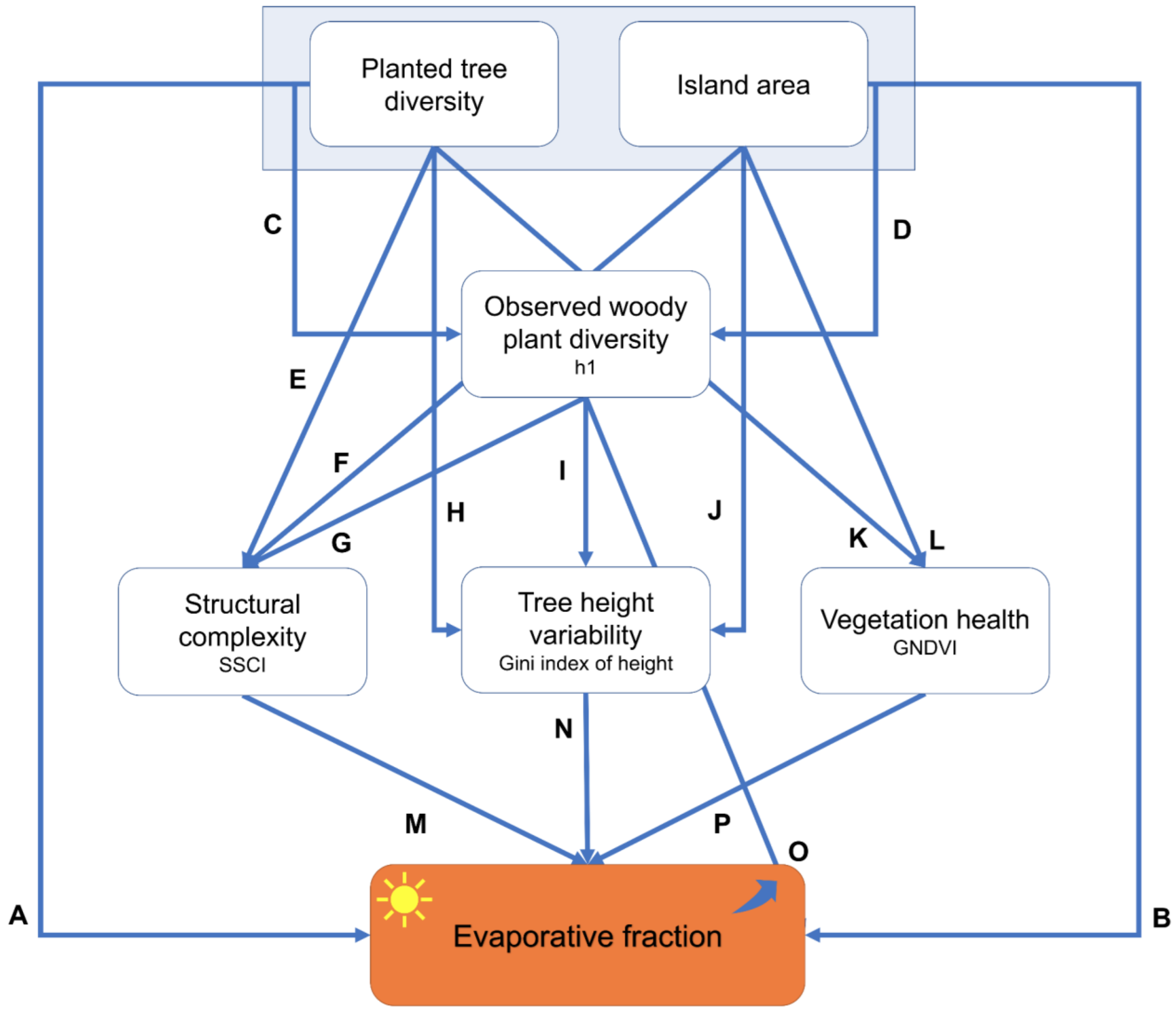

Figure S1: Conceptual model describing the potential drivers influencing Evaporative fraction.

Table S1: Mechanistic framework linking studied variables with evaporative fraction.

Path	Relationship	Mechanisms	Prediction
A O	Planted tree diversity ↓ EF / Observed woody diversity ↓ EF	I - A higher tree diversity creates complementary effects that lead to a more efficient use of energy and therefore higher EF.	A higher (planted / spontaneous) diversity increases EF (Bigelow, 2001; González-Espinosa et al., 2004; Wang et al., 2021).
B	Island area ↓ EF	I - In a larger tree island, the effect of trees over oil palm is stronger, creating a more forest-like microclimate. II - Greater edge length in larger tree islands increases the area influenced by edge effects, where EF is typically higher.	In larger tree islands, EF is higher (Cregg and Dix, 2001).
C	Planted Tree diversity ↓ Observed woody plant diversity	I - Planted trees attract animals that spread seeds (zoochory) and thereby facilitate natural regeneration. II - Planted trees modify environmental conditions, create niches that support natural regeneration.	Observed woody plant diversity is higher in islands with higher planted tree diversity (Paterno et al., 2016; Tinya et al., 2019).

E G	Planted tree diversity ↓ Structural complexity Observed woody plant diversity ↓ Structural complexity	I - Different species occupy different parts of the growing space.	Structural diversity in oil palm increases through higher planted tree diversity and observed woody plant diversity (Zemp et al., 2019; Kikuchi et al., 2024).
I	Observed woody plant diversity ↓ Tree height variability	I - A higher diversity of woody plants also results in a higher morphological diversity, focusing here on tree height.	Higher observed woody plant diversity leads to higher tree height variability.
J	Island area ↓ Tree height variability	I – Larger tree islands harbor a greater diversity of tree species. II – Higher tree diversity results in an increased variability of tree height.	Higher diversity in larger tree islands (Drakare et al., 2006) leads to higher tree height variability in these tree islands (Marks et al., 2016).
L	Island area ↓ Vegetation health	I - Larger tree islands contribute to more homogeneous microclimatic conditions, thereby fostering enhanced vegetation health. II - Within larger tree islands, there is a greater richness of tree species, thereby amplifying vegetation health.	Larger tree islands increase vegetation health.
D	Island area ↓ Observed woody plant diversity	I - Bigger islands receive more seeds from outside. II - Bigger islands harbor greater tree diversity by providing more niches (Island Biogeography theory).	Larger tree islands have more observed woody plant species than smaller tree islands (Zahawi and Augspurger, 2006; Holl et al., 2020; Zemp et al., 2023; Paterno et al., 2024).
F	Island area ↓	I - Larger tree islands provide greater opportunities for spatial diversification.	Larger tree island have higher structural complexity (Zemp et al., 2019).

	Structural complexity		
H	Planted tree diversity ↓ Tree height variability	I - Higher tree diversity increases tree height variability due to interspecific differences in morphology and growth strategy.	Higher planted tree diversity increases variability in tree height (Marks et al., 2016).
K	Planted tree diversity ↓ Vegetation health	I - A higher diversity of planted trees enhances vegetation health, as a greater number of species increases the potential for beneficial interactions among species.	Vegetation health increases with greater planted tree diversity (Cayuela et al., 2006; Pau et al., 2012; Mapfumo et al., 2016).
M	Structural complexity ↓ EF	I - In a more complex island, there are more layers to capture radiation and transform it into latent heat. II – More complex structures provide more surface area, which increases ET.	Higher structural complexity increases EF (Ehbrecht et al., 2017; Ren et al., 2018; Forzieri et al., 2020; Wang et al., 2021).
N	Tree height variability ↓ EF	I - Higher variability in tree height increases surface roughness. II - Higher surface roughness facilitates heath fluxes.	Higher tree height variability increases EF (Chen et al., 2020; Barbeta et al., 2023).
P	Vegetation health ↓ EF	I - Low health of vegetation reduces the ability to convert radiation into latent heat.	Higher vegetation health increases EF (Yang and Wang, 2011; Er-Raki et al., 2013; Zhou and Wang, 2016).

2. Scale independence of EF

Workflow:

1. Select 400 m^2 (n = 13) and 1600 m^2 (n = 13) tree islands.
2. Apply negative buffer to simulate smaller tree islands:
   a. For 1600 m^2 tree islands:
      i. 10 m buffer → 400 m^2
      ii. 15 m buffer → 100 m^2
      iii. 17.5 m buffer → 25 m^2
   b. For 400 m^2 tree islands:
      i. 5 m buffer → 100 m^2
      ii. 7.5 m buffer → 25 m^2
2. For each original plot size group:
   a. Fit a linear model: EF ~ size
   b. Fit a mixed-effects model: EF ~ size + (1|ID) using tree island ID as random effect

Table S2: Scale independence of EF

Model	Slope	SE	R^2 (adj.)	p - value	Random effect variance
1600 m^2 Linear	0.0004	0.00062	- 0.012	0.52	
1600 m^2 Linear mixed effects	0.0004	0.00029		0.17	0.003
400 m^2 Linear	0.0016	0.00142	0.009	0.26	
400 m^2 Linear mixed effects	0.0016	0.001		0.12	0.001

3. LST min, LST mean and LST max vs. plot size

Workflow:

1. Use tree island polygons to clip land surface temperature (LST) orthomosaics.
2. For each tree island, extract:
   a. Mean LST of all pixels
   b. Mean of the 1% highest LST values
   c. Mean of the 0.5% lowest LST values
3. Test for differences between tree island area groups using the Kruskal-Wallis test (non-parametric).

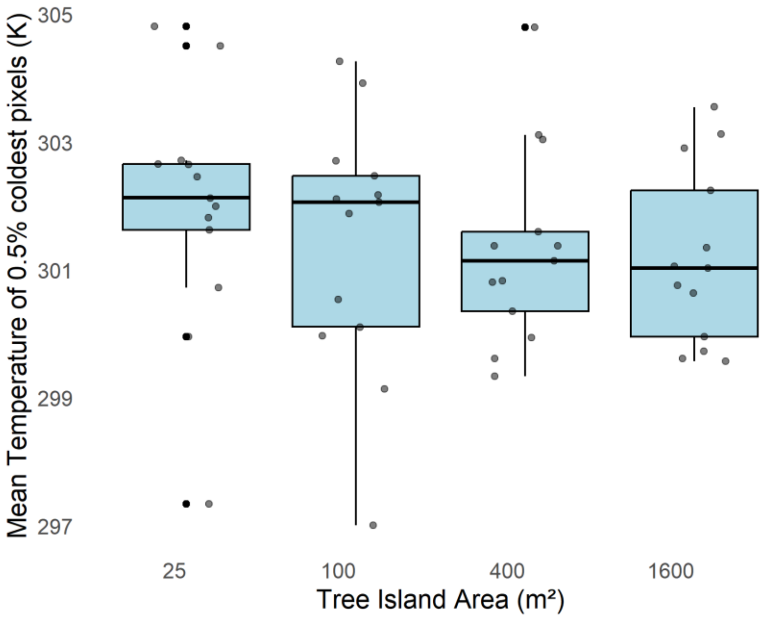

Figure S2: Mean land surface temperature of the 0.5% coldest pixels within each tree island, grouped by tree island area. No significant differences were found between island area groups (Kruskal-Wallis test, p = 0.48).

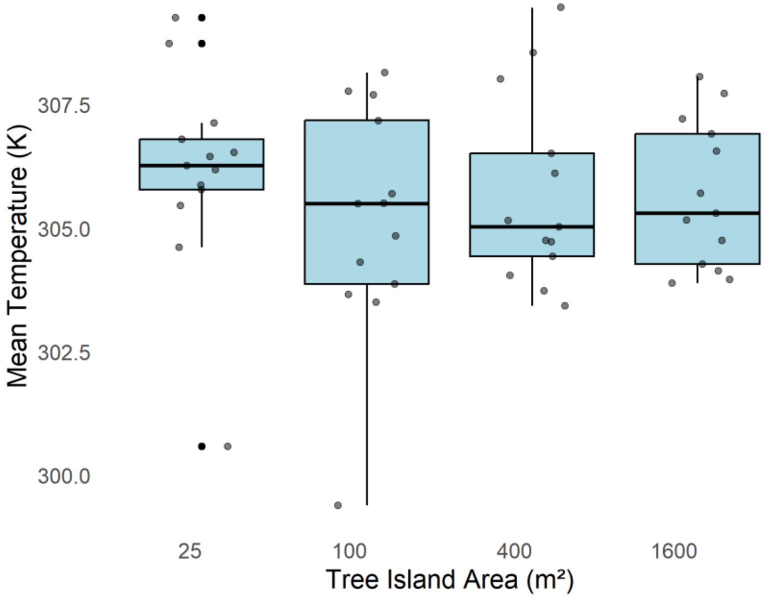

Figure S3: Mean land surface temperature of all pixels within each tree island, grouped by tree island area. No significant differences were found between island area groups (Kruskal-Wallis test, p = 0.5).

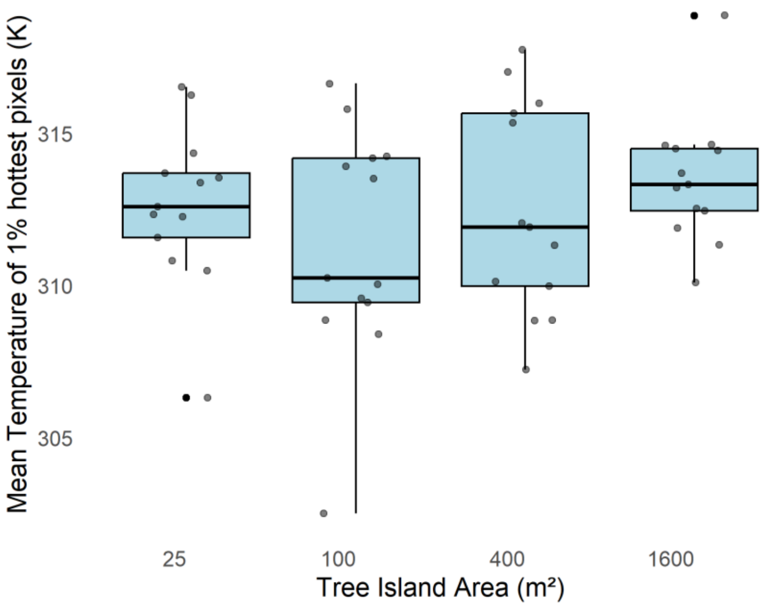

Figure S4: Mean land surface temperature of the 1% hottest pixels within each tree island, grouped by tree island area. No significant differences were found between island area groups (Kruskal-Wallis test, p = 0.48).

4. Edge gradients of EF

Workflow:

1. Generate concentric bands (0.5 m width) for each tree island of 100 m^2, 400 m^2 and 1600 m^2.
2. Calculate the area of each band.
3. Use the bands as spatial masks to extract EF values from QWater Model raster outputs.
4. Fit a linear mixed-effects model with edge distance as fixed effect, tree island ID as a random effect and band area as weights:

   (EF ~ edge distance + (1|Plot), weights = 1 / area).

Table S3: Mixed random effects model results.

Tree island area	Edge gradient	EF ~ Distance + (1 | Plot), weights = 1/area	Marginal R^2	Conditional R^2
100 m^2 + 400 m^2 + 1600 m^2	0 – 5 m	Distance: n.s.		
400 m^2 + 1600 m^2	0 – 10 m	Distance: $p < 0.05$	0.011	0.943
100 m^2	0 – 4.5 m	Distance: n.s.		
400 m^2	0 – 9.5 m	Distance: $p < 0.001$	0.074	0.934
1600 m^2	0 – 17.5 m	Distance: $p < 0.05$	0.003	0.993

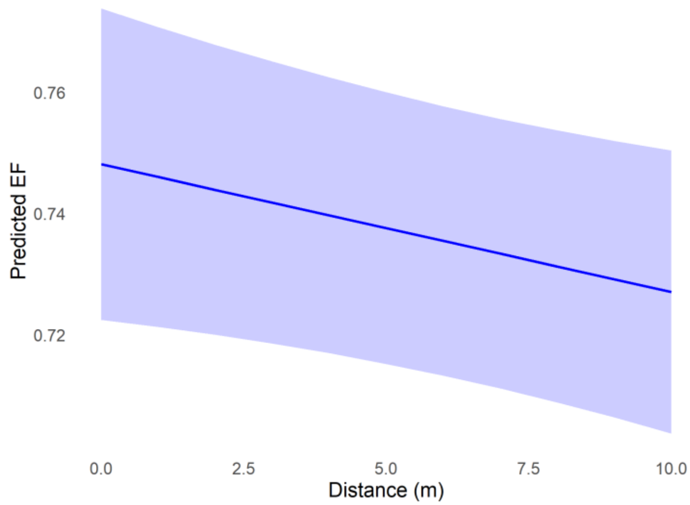

Figure S5: Predicted evaporative fraction for 400 m^2 and 1600 m^2 as function of edge distance. Predictions based on a linear mixed-effects model with distance as fixed effect and tree island as random intercept (EF = 0.748 + -0.0021 * Distance). EF decreased significantly with distance (-0.0021 ± 0.001 SE, p = 0.0386). The model explained 1.1% of the variance with fixed effects (marginal R^2), and 94.3% including random effects (conditional R^2).

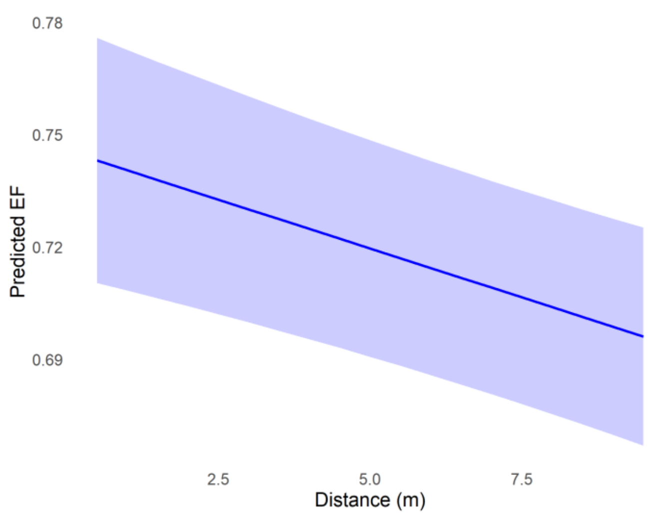

Figure S6: Predicted evaporative fraction for 400 m^2 as function of edge distance. Predictions based on a linear mixed-effects model with distance as fixed effect and tree island as random intercept (EF = 0.746 + -0.0052 * Distance). EF decreased significantly with distance (-0.0052 ± 0.00125 SE, p = 0.00004). The model explained 7% of the variance with fixed effects (marginal R^2), and 93.4% including random effects (conditional R^2).

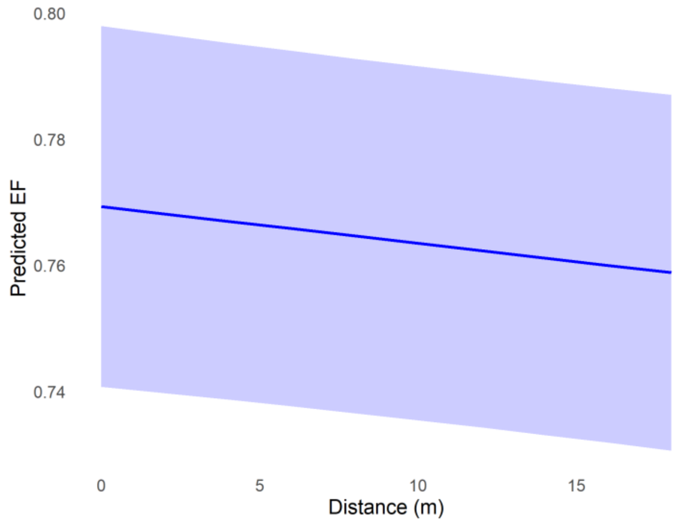

Figure S7: Predicted evaporative fraction for 1600 m^2 as function of edge distance. Predictions based on a linear mixed-effects model with distance as fixed effect and tree island as random intercept (EF = 0.769 + -6e-04 * Distance). EF decreased significantly with distance (-0.00058 ± 0.00024 SE, $p = 0.016$). The model explained 0.3% of the variance with fixed effects (marginal R^2), and 99.3% including random effects (conditional R^2).

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