The role of functional leaf traits in pathogenic transmission in agroforestry systems

Stephanie Gagliardi[1], Marney E. Isaac [1,2], Jacques Avelino[3]

[1] Department of Physical and Environmental Sciences, University of Toronto Scarborough, M1C 1A4, Scarborough, Canada
[2] Department of Geography, University of Toronto, M5S 3G3, Toronto, Canada
[3] Centre de Coopération Internationale en Recherche Agronomique pour le Développement, UPR 106, Turrialba, Costa Rica

Objectives

This study examines how shade tree canopy and leaf functional trait variation in coffee agroforestry systems adjusts raindrop and wind energy and how these changes in abiotic processes affect coffee leaf rust (CLR).

We hypothesize that:

(1) Leaf functional traits in shade tree canopies will modify raindrop and wind energy;

(2) Abiotic modifications will mediate CLR dispersal and incidence.

Experimental design

Measurements were taken from the coffee agroforestry research trial established by the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), in Turrialba, Costa Rica.

Raindrop energy

We measured throughfall kinetic energy (TKE) using Tübingen splash cups[1] under single and multi-strata canopies of different tree species (**Figure 1**).

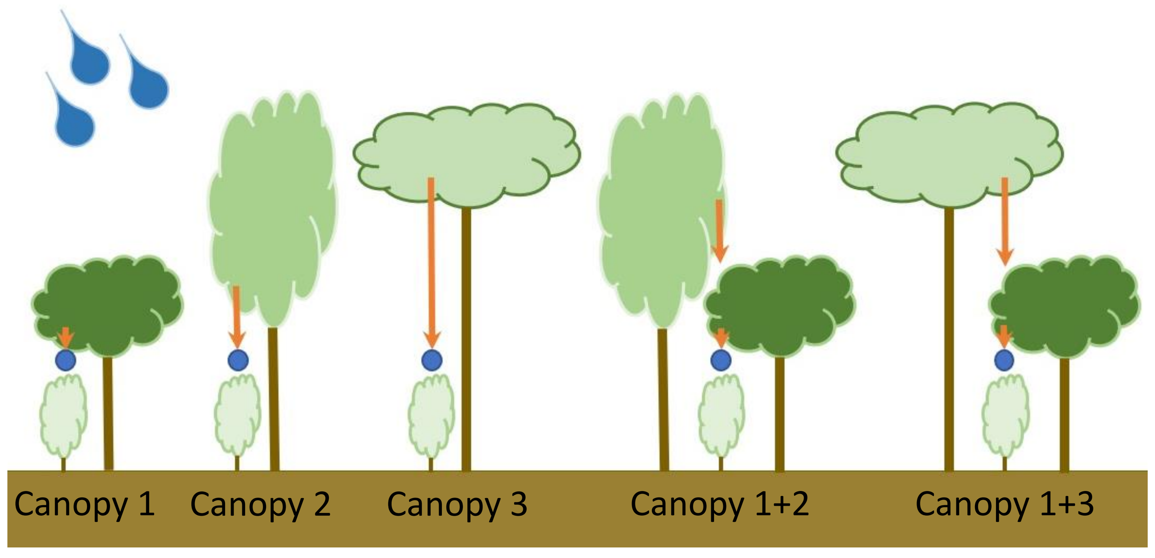

Figure 1. Tübingen splash cups (●) positioned under different shade tree canopies in coffee agroforestry systems: *Erythrina poeppigiana* (Canopy 1); *Terminalia amazonia* (Canopy 2); *Chloroleucon eurycyclum* (Canopy 3).

Based on TKE data from open canopy positions, we found that total rainfall amount best predicted TKE[2,3]. This relationship was used to model TKE across rainfall events.

Wind energy

Using a single tree species, we measured wind speed using portable environmental sensors on the windward and leeward sides of differently sized trees (**Figure 2**). These measurements were paired with volumetric CLR spore trapping using Burkard traps.

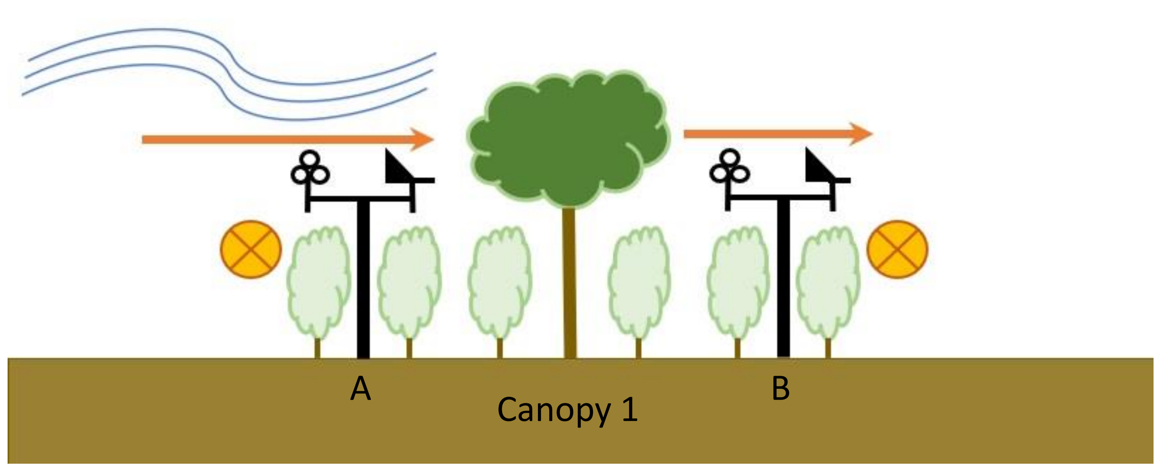

Figure 2. Wind anemometers and wind vanes were placed on the windward (A) and leeward (B) sides of *E. poeppigiana* trees (Canopy 1) with paired Burkard traps (⊗).

Study plot measurements

All shade tree canopies and leaf functional traits were measured. Plant-level CLR incidence was estimated as the average percentage of leaves with CLR infection from three branches (top, middle, bottom strata)[4].

Results

(1) Shade tree canopies modify raindrop and wind energy

TKE measured beneath all canopies was consistently higher than in open canopy conditions.

- This confirms that shade tree canopies interact with rainfall events[2,5] in managed agroforestry systems.

Wind speeds were consistently lower on the leeward side of canopies compared to the windward side (**Figure 3**).

- This indicates that tree canopies in agroforestry systems act as windbreaks on the farm-scale.

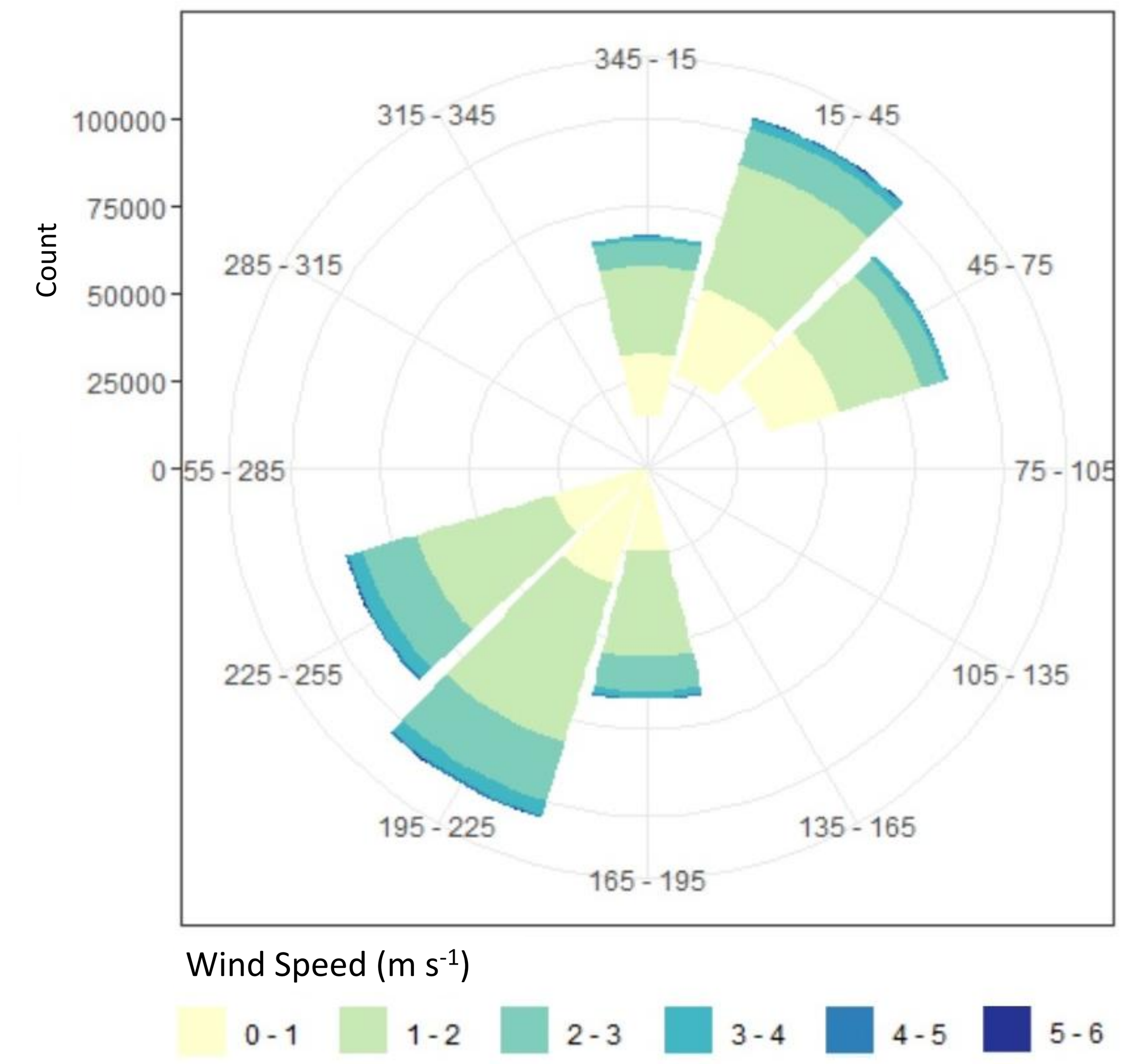

Figure 3. Wind rose diagram of wind speeds from the windward side (165–255°) and the leeward side (345–75°) of all sampled shade trees. Colours represent wind speed categories. Counts refer to the frequency wind speeds were recorded. Note the frequency of high wind speeds is greater on the windward side.

(2) Canopy and leaf traits modify raindrop and wind energy

Canopy characteristics and leaf functional traits varied interspecifically (**Figure 4**) and intraspecifically across study plots similar to previous studies[6].

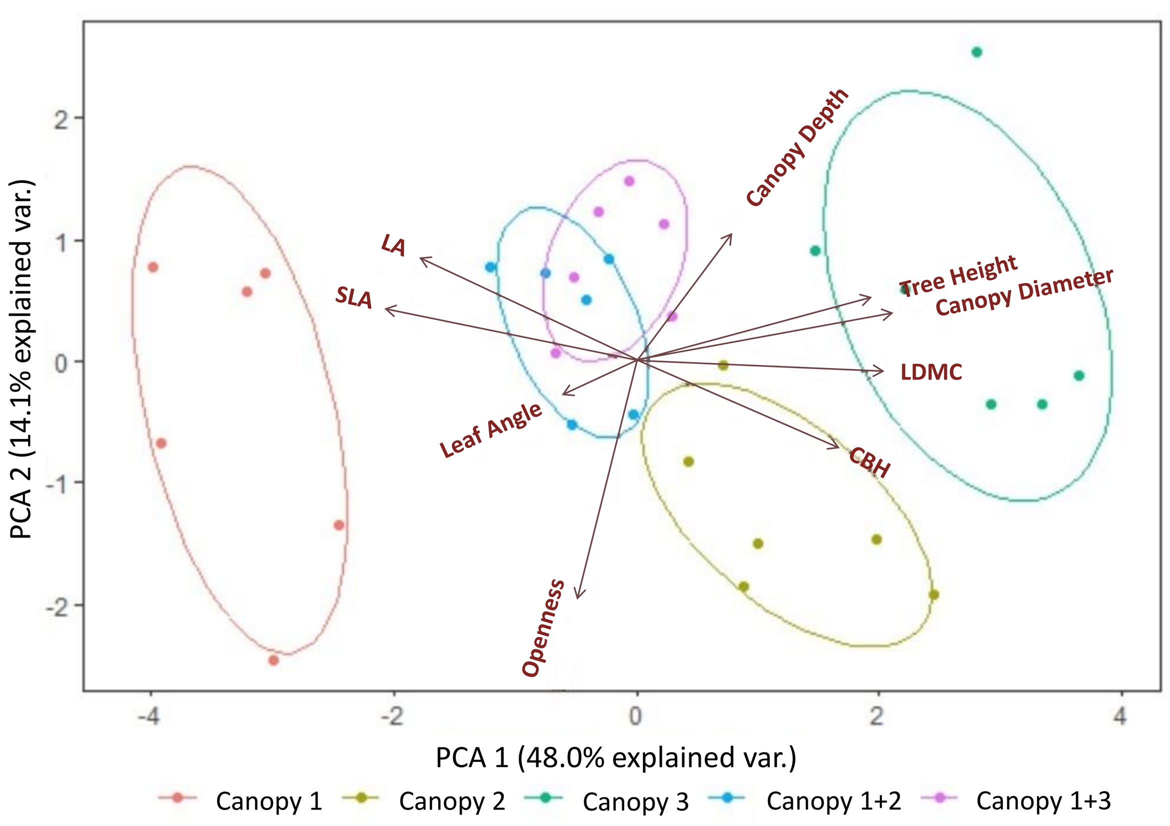

Figure 4. Principal component analysis of interspecific canopy and leaf functional traits. Variables include: leaf area (LA); specific leaf area (SLA); leaf dry matter content (LDMC); leaf angle; canopy depth; tree height; canopy diameter; crown base height (CBH); canopy openness.

Based on these multivariate trait analyses, we found that:

- Shade tree canopies with greater canopy density tended to have greater windbreak effects
- Shade tree canopies with greater openness and smaller canopy depth tended to have lower TKE (**Figure 5**)

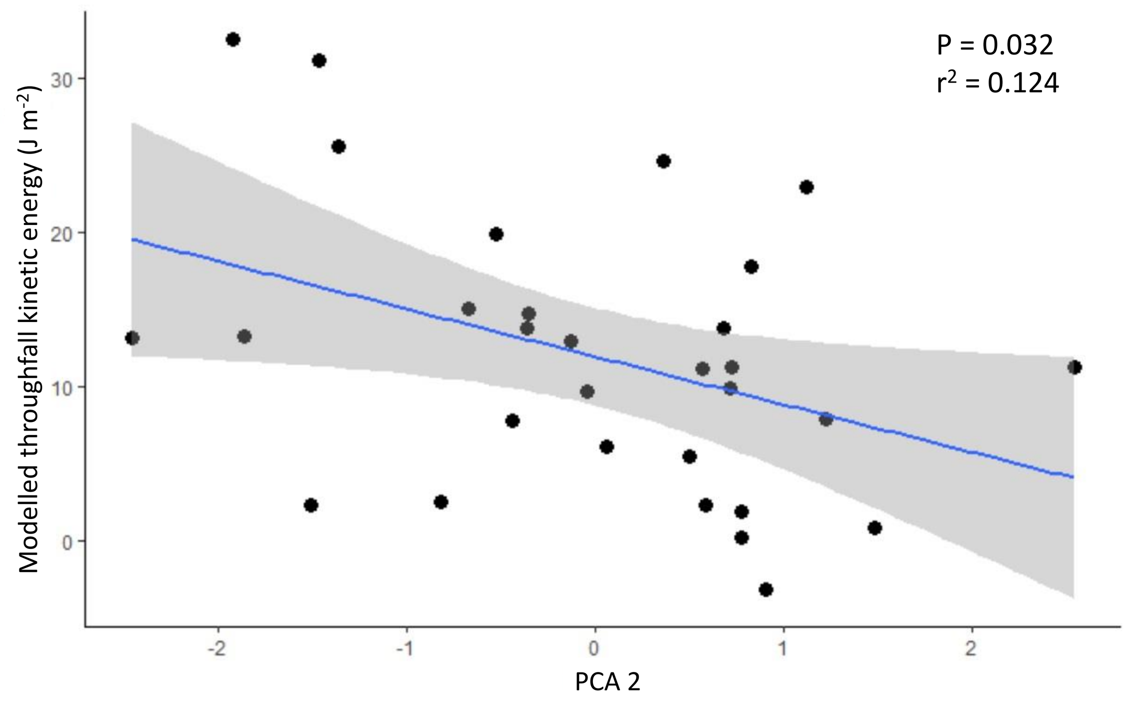

Figure 5. Linear regression between modelled TKE and multivariate shade tree canopy and leaf traits, described by the second PCA "axis" scores.

(3) Canopy and leaf traits mediate CLR incidence

Variations in abiotic processes did not directly relate to CLR dispersal or incidence. Rather, CLR incidence was significantly related to overstory canopy and leaf functional trait syndromes (**Figure 6**).

- This indicates that plots with taller, wider shade tree canopies with leaves of greater LDMC tended to have a greater incidence of CLR in the understory.

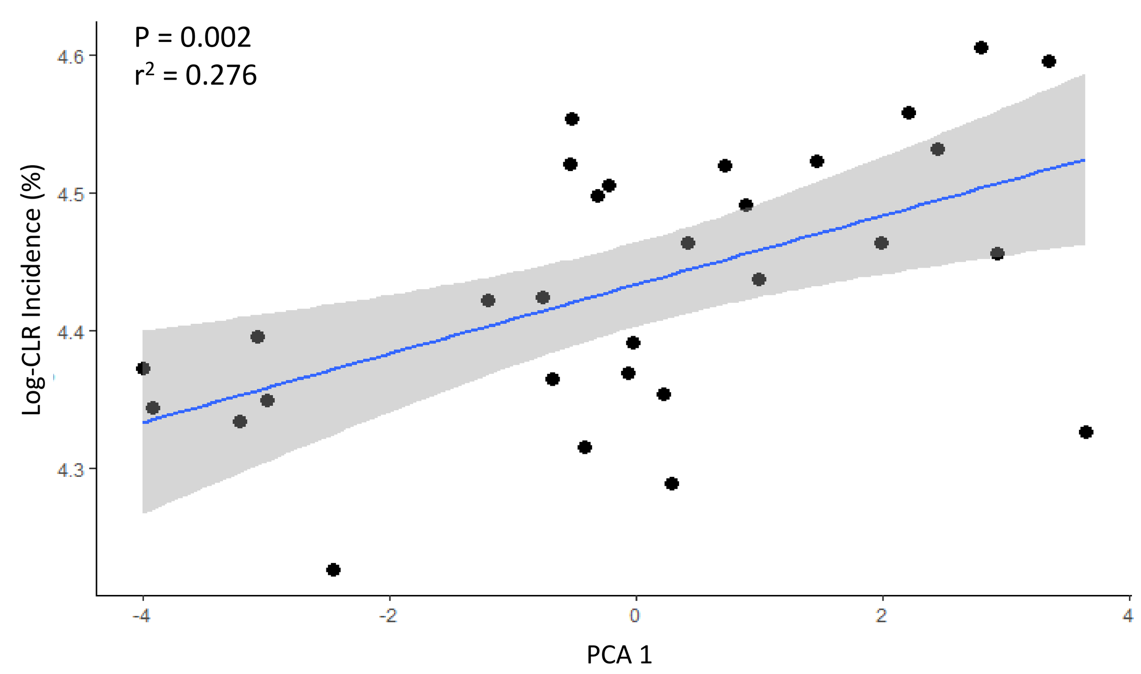

Figure 6. Linear regression between CLR incidence and multivariate shade tree canopy and leaf traits, described by the first PCA "axis" scores.

Conclusions

- Shade tree canopies increase TKE and decrease wind speeds
- Abiotic processes are related to variation of shade tree canopy characteristics and leaf functional traits
- Abiotic processes do not directly relate to CLR variables measured in these studies
- CLR incidence directly relates to variation in shade tree canopy characteristics and leaf functional trait expression

Managing the functional trait variation of shade tree canopies can change the persistence of CLR, adding precision in our understanding of sustainable resistance measures available in agroforestry systems.

References
[1]Scholten *et al.* (2011) J Plant Nutr Soil Sci, 174: 596-601; [2]Geißler *et al.* (2013) PLoS ONE, 8(2):e49618; [3]Park & Cameron (2008) For Ecol Manage, 255:1915-1925; [4]Avelino *et al.* (2012) Ecol Appl, 22(2): 584-596; [5]Nanko *et al.* (2015) Land Degrad Dev, 26:218-226; [6]Wright *et al.* (2004) Nature, 428:821-827.

Contacts: stephanie.gagliardi@utoronto.ca; marney.isaac@utoronto.ca

University of Toronto Scarborough
NSERC CRSNG
CATIE Solutions for environment and development / Soluciones para el ambiente y desarrollo
4th World Congress on Agroforestry
20-22 May 2019
Le Corum Conference Centre
Montpellier, France