Intraspecific leaf trait variation in tropical agroforestry systems: a case study of shade-grown coffee

Marney E. Isaac[1], Adam R. Martin[1], Stephanie Gagliardi[1], Serra Buchanan[1], Karel Van den Meersche[2,3] and Bruno Rapidel[2,4]

[1] Department of Physical and Environmental Sciences and Centre for Critical Development Studies, University of Toronto Scarborough, 1265 Military Trail, Toronto, ON. Canada, M1C 1A4.
[2] Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica.
[3] CIRAD, UMR Eco&Sols (Ecologie Fonctionnelle & Biogéochimie des Sols et des Agroécosystèmes), 34060 Montpellier, France.
[4] CIRAD, UMR SYSTEM, 2 Place Viala, 34060 Montpellier, France
[5]

Plant functional traits in agroecology

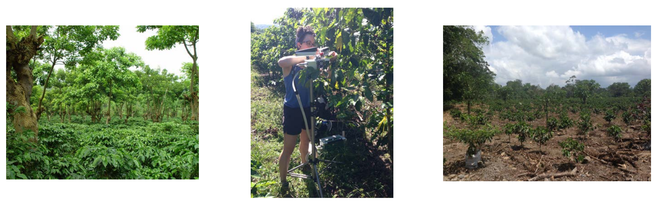
- Measuring the variation in functional traits – the physiological, morphological and chemical characteristics of plants – provides insight into plant response to environmental stimuli and plant influence on ecosystem function (Westoby & Wright 2006).
- The Leaf Economic Spectrum (LES) describes trade offs in leaf traits along a resource acquiring and resource conserving spectrum (Wright et al. 2004).
- The extent, causes, and consequences of within-species trait variation of cultivated crops is unknown (Garnier and Navas 2012; Isaac and Martin 2015; Wood et al. 2015).

Using coffee (*Coffea arabica* var. Caturra), one of the world's most important commodity crops, in Central American agroforestry systems as a case study, we present findings from multiple comparative studies that ***quantify patterns of intraspecific leaf trait variation***. These four studies chart coffee leaf traits across: **Study 1**) **shade tree diversity**, **Study 2**) **fertilization levels**, **Study 3**) **climatic conditions**, and **Study 4**) **plant ontogeny**.

Methodology

Leaf trait variation in coffee across:

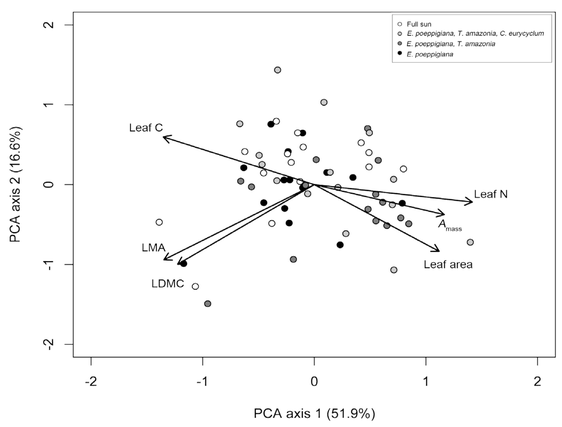
Study 1: shade tree diversity
Study 2: fertilization levels
Study 3: climatic conditions
Study 4: plant ontogeny



For each leaf collected:

Physiological traits: area and mass-based light saturated photosynthesis (A_{max}, A_{mass}; μmol CO_2 m^{-2} s^{-1})
Morphological traits: leaf area (cm^2), leaf mass per area (LMA; g m^{-2}), leaf thickness (mm)
Chemical traits: total carbon (C) and nitrogen (N) (% mass basis)

Study 1: Shade tree diversity



Low photosynthesis, leaf nitrogen
High leaf mass per area
⟷
High photosynthesis, leaf nitrogen
Low leaf mass per area

Resource-limited conditions ⟷ **Resource-rich conditions**

Fig. 1

Study 1 conclusions

- The position of a coffee plant along the LES (as described by a principal component analysis score) was best explained by light availability,
- This position did not vary systematically with shade tree composition (Fig 1).

General Conclusions

1. We demonstrate considerable intraspecific variation in key coffee physiological and morphological leaf traits.
2. Patterns of bivariate and multivariate intraspecific trait variation in coffee are consistent with, but weaker than, well-documented interspecific patterns.
3. Research in this field is critical for i) developing new diagnostics for appropriate management of shade and other agricultural management practices, and ii) understanding how agroecosystem structure and function respond to both natural and anthropogenic environmental change.

Study 3: Climatic conditions

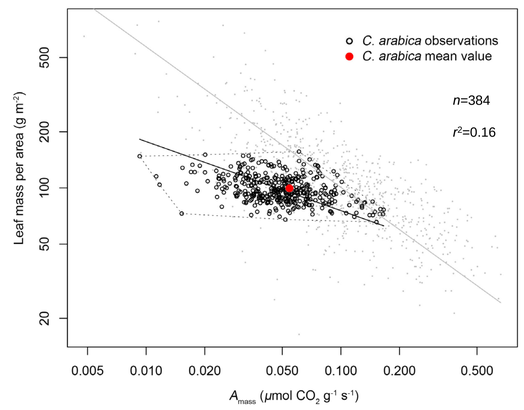


Fig. 3

Study 3 conclusions

- Physiological and morphological intraspecific trait co-variation followed known patterns (Fig 3).
- Variation in physiological traits was best explained by the site, while variation in chemical traits was best explained by management treatments within sites (25-36%) (Fig 4).

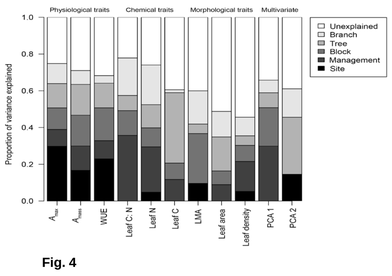


Fig. 4

Study 2: Fertilization levels

Study 2 conclusions

- Physiological intraspecific traits vary within a site, at different fertilization levels (Fig 2).

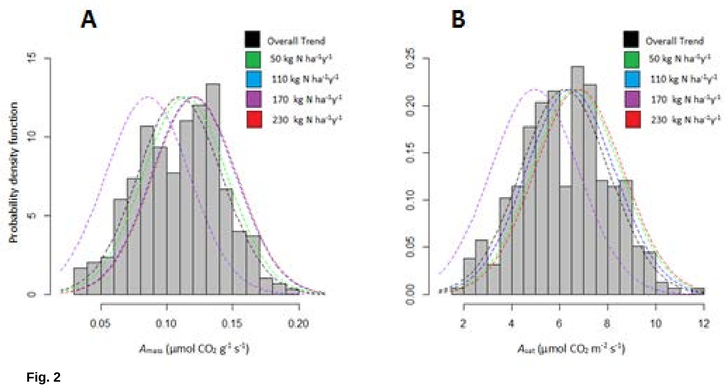


Fig. 2

Study 4: Plant ontogeny

Study 4 conclusions

- Morphological intraspecific traits, and to some extent, physiological intraspecific traits vary predictably with ontogeny (Fig 5).

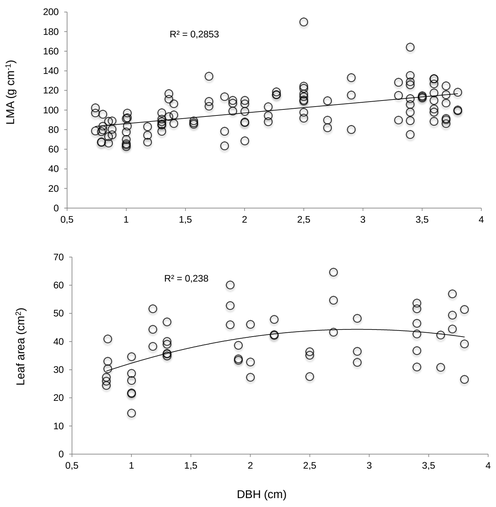


Fig. 5

References:
Gagliardi S, AR Martin, E de M Virginio Filho, B Rapidel and ME Isaac (2015) Intraspecific leaf economic trait variation partially explains coffee performance across agroforestry management regimes. Agriculture Ecosystems & Environment 200: 151-160.
Garnier E and ML Navas (2012) A trait-based approach to comparative functional plant ecology: concepts, methods and applications for agroecology. A review. Agronomy for Sustainable Development 32: 365–399.
Martin AR and ME Isaac (2015) Plant functional traits in agroecosystems: a blueprint for research. Journal of Applied Ecology 52:1425-1435.
Martin AR, B Rapidel, O Roupsard, K Van den Meersche, E de M Virginio Filho, M Barrios and ME Isaac (2016) Intraspecific trait variation across multiple scales: the leaf economics spectrum in coffee, under review
Westoby, M. and Wright, I.J. (2006) Land-plant ecology on the basis of functional traits. Trends in Ecology & Evolution 21: 261–268.
Wood SA, DS Karp, F DeClerck, C Kremen, S Naeem and CA Palm (2015) Functional traits in agriculture: agrobiodiversity and ecosystem services. Trends in Ecology & Evolution 30: 531-539.
Wright IJ, PB Reich, M Westoby, et al. (2004) The worldwide leaf economics spectrum. Nature 428: 821-827.

This research was undertaken with funding from the Canada Research Chairs program and a Natural Sciences and Engineering Research Council of Canada Discovery Grant to ME Isaac.