Disentangling the impact of local landscape structure & farm management strategies on pollination services by bees: A case study in Costa Rican coffee

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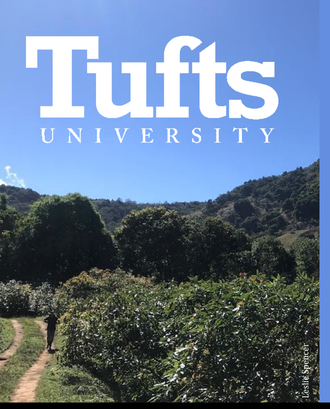

[1] Abstract

- Pollination by animals is a crucial ecosystem service in almost all terrestrial ecosystems, including agro-ecosystems. In the tropics, agriculture poses a threat to wildlife, particularly pollinators.
- In this literature review, I explore how surrounding landscapes and on-farm management practices impact pollinator communities on farms, using coffee agroecosystems in Costa Rica as a case study.
- Coffee is an incredibly valuable agricultural commodity grown in the tropics that supports many small farmers' livelihoods. Understanding fine-scale landscape dynamics is important in coffee, a crop that is impacted by land use change and changing climates.

[2] Guiding Questions

How does a farm's surrounding landscape impact pollinator communities (i.e. community diversity and abundance)?	How do farm management practices (e.g. monocropping, agroforestry, etc.) impact pollinator communities?	What is the value added by nearby forest fragments compared to trees dispersed throughout an agroforest?

[3] Case Study

Coffee (*Coffea arabica*) in Costa Rica

- Coffee is native to Ethiopia; introduced to Costa Rica in the late 1800s, and has been important to their economy and culture ever since (Icafe 2015)
- It is pollinated by a combination of introduced honeybees & native bees in Ethiopia (Ngo et al. 2011), and the same has been well-documented in Costa Rica (Bravo-Monroy et al. 2015, Ricketts 2004a).

European honeybee (*Apis melifera)*
Photo: Shutterstock

Stingless bee (*Heterotrigona itama)*
Photo: S. X. Chui.

- In Costa Rica, coffee is grown along a wide spectrum of methods - from sunny monocultures to biodiverse, shady agroforests – providing an ideal system to study how landscape structure and farm management can shape pollination services to coffee crops.
- Although coffee is self-fertile, there is incentive to understand its pollination ecology because bees are known to increase coffee yields.

Example study site:
A heterogenous coffee landscape in Santa Maria de Dota, Costa Rica made up of urban area, sun-, and shade-grown coffee.

Image: Google Earth

[4] Findings

Impact of surrounding landscape: Evidence of a biodiversity mismatch between nearby forest fragments & pollination services on farm

Case 1: Nearby natural areas support pollination services in adjacent crop land

- Ricketts (2004) found that "forest remnants enhance pollinator activity in surrounding agricultural fields"
  - Coffee plants near forests had more pollinator visits
- Hipolito et al. (2018) found that farms far from natural areas had significantly fewer pollinator visits

Case 2: Nearby natural areas pull bees away from crop land

- e.g. Boreux et al. (2013) found that surrounding natural landscapes were *so* rich in biodiversity and resources for bees that the bees had little incentive to leave the forest to pollinate nearby coffee crops, and they remained in the forest instead of visiting the farm

Impact of farm management strategies:

- Low intensity management with little or no pesticide use promotes pollinator communities on coffee farms (Hipolito et al. 2018)

Importance of bee diversity

- Diverse communities buffer changes in species abundance, thus promoting "spatio-temporal stability" of pollination (Klein 2009)
- The presence of a diverse pollinator community increases coffee yields (Hipolito et al. 2018, Klein 2003, Roubik 2002), which should provide incentive to farmers to create pollinator-friendly farms

[5] Conclusions

Pollination services are multidimensional. The context-dependence of these services means that there is no catch-all management recommendation for to how to manage farms for pollinator persistence. We need to learn how to co-manage for biodiversity and related ecosystem services like pollination (Nicholson *et al.* 2019) in agricultural landscapes.

[6] Next steps

Senior thesis (2020-2021)

- Will use spatial models to understand the distribution of pollination services across heterogeneous agricultural landscapes, such as Costa Rican coffee agroecosystems
- Will adapt the Lonsdorf et al. (2009) model that uses information on available nesting sites and floral resources for pollinators, in addition to foraging ranges, to predict pollinator abundance across a landscape
- Will use existing data sets (i.e. from previously published papers, iNaturalist, etc.) and/or will collect field data in Costa Rica to elucidate available pollinator resources and bee abundance/diversity
- The presence of high-quality habitat and local management decisions are both important factors that impact pollinator communities, the latter being left out of the original Lonsdorf model (Londsdorf *et al.* 2009, Kennedy *et al.* 2013), so I will consider both.

ArcGIS

natural capital PROJECT

- To make spatial models, I will use ArcGIS and InVEST software.
- InVEST, or integrated valuation of ecosystem services and tradeoffs, is software from Stanford's Natural Capital Project that is used alongside ArcGIS and to understand ecosystem services (InVEST 2020).
- Specifically, I will use the InVEST crop pollination model

[6] Acknowledgements

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(8) References

Boreux, V., Kushalappa, C. G., Vaast, P. & Ghazoul, J. Interactive effects among ecosystem services and management practices on crop production: Pollination in coffee agroforestry systems. *Proc. Natl. Acad. Sci. U. S. A.* **110**, 8387–8392 (2013).

Bravo-Monroy, L., Tzanopoulos, J. & Potts, S. G. Ecological and social drivers of coffee pollination in Santander, Colombia. *Agric. Ecosyst. Environ.* **211**, 145–154 (2015).

Hipólito, J., Boscolo, D. & Viana, B. F. Landscape and crop management strategies to conserve pollination services and increase yields in tropical coffee farms. *Agric. Ecosyst. Environ.* **256**, 218–225 (2018).

Kennedy, C. M. *et al.* A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems. *Ecol. Lett.* **16**, 584–599 (2013).

Klein, A. M. Nearby rainforest promotes coffee pollination by increasing spatio-temporal stability in bee species richness. *For. Ecol. Manage.* **258**, 1838–1845 (2009).

Klein, A. M., Steffan-Dewenter, I. & Tscharntke, T. Fruit set of highland coffee increases with the diversity of pollinating bees. *Proc. R. Soc. B Biol. Sci.* **270**, 955–961 (2003).

Lonsdorf, E. *et al.* Modelling pollination services across agricultural landscapes. *Ann. Bot.* **103**, 1589–1600 (2009).

Ngo, H. T., Mojica, A. C. & Packer, L. Coffee plant - pollinator interactions: A review. *Can. J. Zool.* **89**, 647–660 (2011).

Ricketts, T. H. Tropical forest fragments enhance pollinator activity in nearby coffee crops. *Conserv. Biol.* **18**, 1262–1271 (2004).

Roubik, D. W. The value of bees to the coffee harvest. *Nature* **26**, 391–393 (2002).

Nicholson, C. C. et al. Mismatched outcomes for biodiversity and ecosystem services: testing the responses of crop pollinators and wild bee biodiversity to habitat enhancement. Ecol. Lett. 23, 326–335 (2019).