Chapter 7: Looking ahead

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1 Mitigation and adaptation

The two central responses to climate risk for any sector are mitigation and adaptation. Mitigation refers to the policies, practices, and international agreements that lead to lower greenhouse gas (GHG) emissions. Adaptation, the planning and practices engaged in to manage the risk of a changing climate, is an independent concern from mitigation. It is clear now that all sectors will need proactive adaptation, irrespective of the actions taken toward mitigation.

For the coffee sector, mitigation is synonymous with sustainable environmental practices, and many coffee farms are already performing well. GHGs can be released in the course of coffee production through the application of fertilizers and pesticides, direct fuel and electricity use, depulping and fermentation resulting in methane, and release of nutrients from the soil. Account for all of these, traditional and commercial coffee polycultures have a low carbon footprint, while monocultures produce 50% more GHGs (van Rikxoort et al., 2014).

One of the largest sources of CO_2 is deforestation, where there is evidence of both positive and negative interactions with coffee. Coffee plantations reinforces the ties between forests and the economy, resulting in lower deforestation rates in some regions like Ethiopia (Hylander et al., 2013). Elsewhere, such as in Indonesia, periods of high coffee prices have induced increases in deforestation (O'Brien and Kinnaird, 2003). We show that coffee suitability will shift rapidly as a result of climate change. Even where shade trees are maintained, the carbon impact of the loss of forest is far greater (Baker, 2013). For this reason, it is important for the shifts of coffee cultivation to take place solely within present agricultural regions, or in conjunction with reforestation programs, to maintain the balance of carbon.

The coffee industry also receives direct benefits from forests. Coffee farms near forests and their wild pollinators are 20% more productive and produce 27% fewer peaberries (Ricketts et al., 2004). By maintaining forest cover, coffee farms can benefit themselves both directly and through the climate.

While mitigation has long-term consequences, coffee farmers can achieve immediate benefits and lessen the impacts of climate change through adaptation. For example, shade trees in coffee plantations can decrease the temperatures to which plants are exposed by up to 4°C (Jaramillo, 2005). One reason why climate change is such a great risk to coffee producing countries is because many coffee farmers are poor and have a lower capacity to adapt to climate change.

coffee&climate (2015) provides an extensive overview not only of approaches to adaptation, but of the equally important process of evaluating climate vulnerability. Baca et al. (2014) identify nine axes of vulnerability through focus groups, and associate each with a parameter to measure and track:

Road type	Time from the farm to the collection center, time from the farm to the nearest market, type of road from the farm to the collection center or nearest market
Transport of products	Type of transportation from the farm to the market, time from the farm to the bus stop
Quality of housing	Housing material, basic services
Access to and availability of water	Source of water for drinking or post-harvest processing, availability of water during the year, distance to the water source, water quality
Conservation	Area of forest around the water source, area of forest to keep in the farm
Soil and fertility	Soil type, soil slope, mulch of leaves, soil depth
Food and health	Number of symptoms of human disease, number of times that person is attended by a doctor, dependency of external products
Migration	Type and time
Variability of yield	Average farm yield in four years compared to the local average

They also identify modes of adaptation for addressing each of these vulnerabilities, and the parameter that provide opportunities for new practices.

Variability of post-harvest infrastructure	Types or forms to dry coffee
Pollution	Waste management, release of fermentation residues into water, management of agrochemical containers, coffee waste management, area burning annually
Management of shade trees and reforestation	Number of trees cut, number of trees planted
Access to education	Level of education, quality of technical assistance, crops for which receive technical assistance, types of media accessed
Level of knowledge of farming system	Registration practices and activities, coffee intercropping, pests and diseases
Organization	Participation, time, benefits
Knowledge of laws and policies	Policies about coffee sector, environmental laws, land polices
Access to credit	Term of credit, interest rate of credit, opportunity of credits
Diversification of income	Number of sources of income
Access to specialty markets	Destined for sale, special market access
Access to technologies	Varieties, drip irrigation, water harvesting

This kind of broad thinking is essential to addressing the adaptation problem in coffee. Small-scale farmers will have a more difficult time adapting to climate change than large-scale ones. As a result, climate change will result not only in changes in coffee cultivation, but will also produce winners and losers amongst the groups planting them.

2 Future opportunities for research

The coffee production database offers many new opportunities for studying the connection between coffee and its environment across the globe. Over the course of our research, we also uncovered a range of topics worth further research.

One of the most important open questions is how to combine suitability, variability, and production analyses. These three dynamics take place on different spatial and temporal scales, whereby suitability is based on static properties, our variability uses global patterns, and the production model represents the effect of weather on crops from year to year. These three are interrelated, and any region that has large production shocks more frequently than every three years, at the extreme, will be unsuitable for coffee, since coffee plants could never get to a sufficient level of maturity.

Another under-studied area is coffee disease. While all of our empirical estimates implicitly capture the effect of coffee disease, these may end up being the most difficult impacts to adapt to. The coffee berry borer's range has rapidly expanded in recent years, and some of these shifts are related to climate (Magina et al., 2011). Jaramillo et al. (2009) find that a 1-2°C increase in temperature would result in large losses from the coffee berry borer, particularly in regions with high-quality Arabica. Data on coffee diseases is not as plentiful as yield data, but can be collected from many sources.

Our study of the coffee market only scratches the surface of many interesting connections between climate and variability, producers and consumer, and prices and trade. The coffee market is global, complex, chaotic, and sophisticated, with many different kinds of stakeholders. Future work would extrapolate the effects of climate on coffee production amounts and locations to determine the consequences for price and demand.

Both of these are related to an all-important topic we struggled with: coffee quality. While coffee quality has physical determinants, its subjective nature make it very difficult to study. However, the structure of futures contracts provides an entry-point, where quality is quantified and varies over both space and time. This data would allow future research to understand the impact of climate on coffee quality, at least at the country-wide level.

Below are some additional analyses that would be informative.

Production Incorporating the role of wind speeds, known to be an important factor in many regions (e.g., Haiti), into the production model.

Production Incorporating the changes in climate-driven harvest area to correct reported yields to reflect damage that reduces yields to the extent that the plant is not harvested at all.

Production Studying the effect of fertilizer on production, captured in the "fixed effects" of each region in our production model.

Production Use the India district data to construct and India model, and incorporate that into the hierarchical global model (see figure 1 in the Appendix).

Prices Disaggregating the country-wide markup values to identify how they differ by coffee type.

A India Production

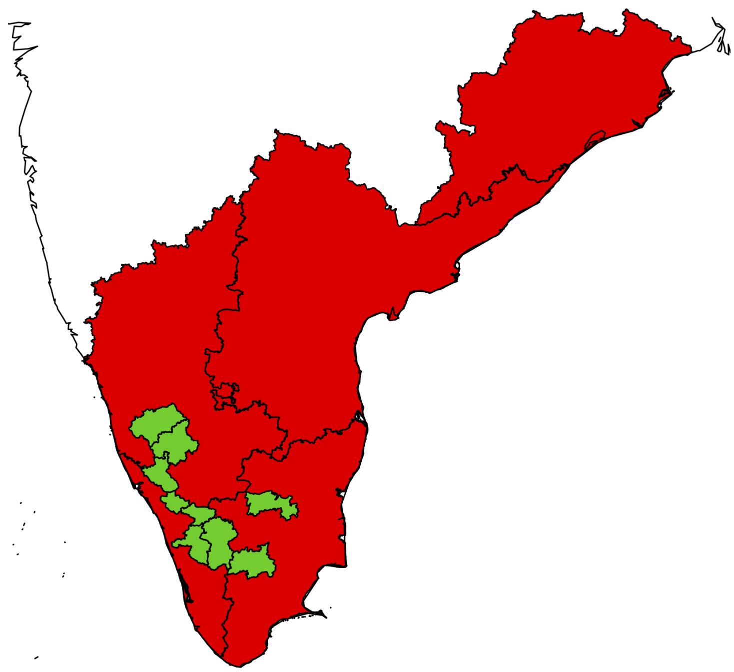

Figure 1: State and district regions with coffee production records.

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