During this fellowship period, I continued my work on defining the response of crop timing metrics (such as planting and harvest date) to local climate change. My work was part of a broader effort to define the effect of land use change in Brazil on agricultural productivity. Previous studies have shown that deforestation to make way for agriculture will affect local climate, such as changes in rainfall patterns. The physical climate change resulting from deforestation, in turn, has been shown to alter agricultural productivity through a variety of pathways. I explored one pathway in which the change in wet season onset and length drives a shift in planting, harvest, and crop intensity decisions from 2003 to 2017.

Defining this pathway requires field-level (500m) soybean planting and harvest data across Brazil, which are scarce because data collection requires extensive and hard-to-scale survey work. To this end, I used satellite imagery from the Moderate Resolution Imaging Spectroradiometer (MODIS) to produce a field-resolution map of planting and harvest dates across Brazil over the past 15 years. Surface reflectance from MODIS imagery, when converted to the Enhanced Vegetation Index (EVI), closely follow the seasonal progression of soy development from planting to harvest. My method applied timeseries analysis techniques adapted from established estimation methods to these EVI timeseries. These computations were performed in Google Earth Engine (GEE), a platform for geospatial analysis on Google's infrastructure that offers ready access to the satellite data, high computational speed and automatic parallelization that are essential for the analysis of images that span Brazil's vast land area. My planting and harvest date estimates were validated with a 10-year survey dataset comprising 90 soy farms in the soy "hotspot" of Mapitoba, located in northeastern Brazil. Initial evaluation suggests RMSE of about 10 days for both planting date and harvest date estimates. The crop timing maps produced with this method can be used to trace spatial and temporal changes in farmer behavior in response to weather forcings, and thus help predict how farmers will shift planting and harvesting in response to anomalies in future climate.

Currently, I am producing a set of land cover classifications that will serve as masks to my planting and harvest date maps. Thousands of training points for center pivot irrigation, single and double cropped soy, natural vegetation, and non-soy agriculture will inform land cover maps that allow me to filter crop timing decisions based on the presence of irrigation, crop type, and crop intensity.

Scientifically, my research contributes to the multidisciplinary effort of fusing multiple sources of information to estimate variables, and their error, in the absence of a validation dataset. My field-level maps of soy planting and harvest dates in Brazil can serve as input to crop models in order to understand how soy yields have historically responded to climate variability. They are a significant improvement over the a priori guesses of crop timing that are currently used. The broader impact of my work is to improve our understanding of how global and local climate change impacts agricultural productivity through shifts in crop timing decisions. If planting dates in areas affected by deforestation-induced climate change are already constricted by the length of the wet season, further shortening due to deforestation may render double cropping impossible or force planting to suboptimal dates. This feedback loop could contribute to an economic argument for the preservation of natural vegetation.