February 25, 2015

In my studies at Stanford thus far, I have learned about food and agriculture through my major in Earth Systems and minor in Economics. I have thus gained a well-rounded understanding of how supply and demand interact, what sustainable agriculture can look like on a smaller and larger scale, and how agricultural economics affect international food security. I am excited to take my studies even further through applied statistics and remote sensing in my research this summer.

In doing this work, I will gain the guidance of Professor David Lobell, a mentor I have long aspired to work with at Stanford. I will gain and build a close mentorship with Meha Jain, during which she will teach me how to work with large-scale remote sensing data, code in R software, and conduct statistically rigorous analyses. Lastly, I will gain entrance into a lab group and a long-term project that are both complimentary to my studies as I enter my fourth year at Stanford.

This work will foster the growth in my ability to interpret and convey information about climate change and agriculture, and by combining disciplines in statistics and my studies in environmental sciences, I hope to grow from this experience by building relationships with these mentors, gaining an applied and interdisciplinary understanding of my education, and acquiring experience that will prepare me for employment in this field. The opportunities that excite me most in my field include use of remote sensing, statistical analysis, and coding in R to measure constraints and inputs on fields and directly communicate needs to farmers for precise and efficient farming. I am thus excited to embark on this opportunity, learn more about how I can build this skill set, and contribute to the field of food security research.

, Class of 2016
Major: Earth Systems, Sustainable Food and Agriculture, **Minor**: Economics
Faculty Advisor: David Lobell, PhD
Post-doctoral Advisor (daily supervision)**:** Meha Jain

Strategies for Agricultural Adaptation to Climate Change in India

Introduction
Since the start of the Green Revolution in the 1940's, new technologies have been introduced across agricultural communities worldwide. Many were particularly successful in South Asia, where improved irrigation, fertilizers, and crop varieties have led to unprecedented gains in agricultural production. The Green Revolution is credited with diminishing the incidence of famine in India, through adoption of dwarfed wheat and rice varieties.

Research over the past decade has identified a new and formidable challenge to agriculture: global climate change. Warming global temperatures will impact major staple crop yields worldwide, some models suggesting yield declines of up to 30% in some regions, including South Asia (Morton 2007; Lobell et al. 2008; 2011). Wheat is one major crop that is predicted to experience severe yield declines due to climate change, with existing studies verifying that warmer temperatures are already reducing wheat yields (Lobell et al. 2011). South Asia is considered to be particularly vulnerable due to a projected warming of 2 to 3°C by mid-century. This is especially problematic, as wheat grown in northern India provides over 20% of the calories consumed across the subcontinent (FAO, 2011). With possible yield losses of 30%, this implies a harsh disruption in yields, consumption, and food security in India.

To address warming temperatures, farmers in India have begun adapting wheat-growing practices. Most notably, some have begun shifting planting dates earlier in the season to avoid terminal heat stress towards the end of the growing season. Yet, it remains unclear whether and to what extent an early sowing strategy impacts crop yields.

Objectives
The overall objective of our research is to evaluate the impact of an early sowing strategy on wheat crop yields in India, with respect to seasonal temperature trends. To accomplish this, we will analyze high-resolution remote satellite imaging data, and build models incorporating existing government data on crop yields and temperatures. These studies should provide a basis for policy recommendations, for example through partnering organizations including the International Maize and Wheat Improvement Center (CIMMYT). Results will also provide a baseline comparison for future studies of heat-tolerant wheat varieties.

Methods
The study regions will include Punjab and eastern Uttar Pradesh/Bihar, two regions that are a part of the Indo-Gangetic Plain region, which provides 15% of global wheat

production. These regions are also predicted to face high levels of warming in the upcoming decades.

To determine crop area, and to estimate sowing times and crop yields, we will analyze image data from satellites. Most remote sensing to map sow dates has been done using MODIS (Moderate-Resolution Imaging Spectroradiometer), an instrument that provides remote sensing scans of the Earth daily with 250 meters resolution. MODIS has been used to measure the phenologies of agricultural crops, which can give an estimate of sow date. However, this approach will likely prove inadequate for fields in the regions we are studying. In India, field sizes are much smaller than the imaging resolution afforded by MODIS. Therefore, we are developing a system that better fits field sizes and can map sow dates at the level of a field at these sites.

Specifically, we will analyze data from Landsat Satellite images. The maps we will produce using Landsat data will allow us to determine precisely, at 30 meters spatial resolution, the sowing date of individual smallholder fields. The reason Landsat is less commonly used is because these images have a low temporal frequency, with an overpass frequency of 16 days, which makes it difficult to capture phonological changes throughout the agricultural growing season. To compensate for the less frequent collection in satellite data, we will use Agricultural Production Systems sIMulator (APSIM) to run regressions on the images with simulated management strategies to predict sowing dates and yields. Thus, we will produce more accurate estimates for a more spatially refined number of fields.

To validate our conclusions from the satellite data, we will use results from a pool of social surveys, to be conducted this March by Meha Jain and David Lobell. Our approach of combining Landsat data with APSIM is novel, and we expect it will significantly advance the mapping of smallholder fields from space. Past approaches for small fields have relied mainly on social surveys, which can be costly and are thus often smaller in scale. If we can develop and validate the satellite-based methods, we can access 30 years of data (defining historic sowing dates for our study) for thousands of farmers across India.

We will next link these sow date maps produced using Landsat with information on regional wheat crop yields collected from the Indian government, as well as seasonal temperature records, to assess whether or not early sowing correlates with higher yields. We will also test whether farmers are more likely to adopt earlier sowing strategies after years that have been unseasonably warm, since warm winters may incentivize farmers to sow earlier the following year to reduce the negative impact of terminal heat stress on yields.

We will also use Skybox Image data to refine our analysis and modeling of sow date, climate and crop yields to even higher resolution of individual farmers' fields. Skybox is a new satellite that provides both high resolution and high temporal frequency data. David Lobell's group is one of the first research teams that will have access to Skybox imagery for research, which will be provided at a resolution of 2 meters every week, and should therefore allow us to map unprecedented parameters including crop yield, pest outbreaks, and water stress.

Work Plan

Previous Experience: I have become familiar with international food economics by taking the course, "World Food Economy", and the role of major crops in these interactions in David Lobell's course, "Feeding Nine Billion". I have done independent research last summer with Rosamond Naylor and Walter Falcon on the role of biotechnology in developing alternative staple crops, and I've grown very comfortable with creating models in Excel to analyze short-run regressions.

Spring Quarter: I will learn more about using R and statistical techniques to remotely study farmer decisions in agriculture by enrolling in 1-2 directed reading units with my faculty advisors, Econ 102B, where I can learn about linear regression models, multiple regressions, and use of random and instrumental variables. This is paired with enrollment in STATS 195, a 1-unit course introduction to using R. I will gain general foundations and background that will help me start my research this summer.

Summer Quarter: I will work in Y2E2 starting in late June. The project will last 10 weeks:

Week 1: I will familiarize myself with available web databases.

Weeks 2-5: I will collect and collate all the primary data on crop production through remote sensing and satellite imaging (Landsat and Skybox), and I will examine data using statistical analysis through R programming.

Weeks 6-7: I will continue to analyze the data, and create summary tables, graphs and figures to support findings.

Weeks 8-10: I will write a rough draft manuscript that reports our analysis, conclusions, and recommendations, as well as prepare a poster for presentation.

Future Plans

I anticipate that this summer research project might lead to a subsequent honors thesis project, for example, fieldwork to implement and evaluate improvements to a specific wheat cropping strategy. In particular, future studies may explore the impact of heat-tolerant wheat varieties (through analysis of imaging data), as well as optimal strategies for the spread and adoption of best agricultural practices (through field trials). Under this mentorship, I will also gain important skills in using large-scale remote sensing data, coding in R Project software, and conducting statistically rigorous analysis, which will be essential in conducting further projects within David Lobell's group at FSE.

Tentative Budget

Description	Requested Budget	Total Requested Budget
Student Stipend	$640/week (40hr work week)	$6,400
Total:		$6,400

Sources Cited

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