

# Using Satellite Imagery in Economics Research

Joel Ferguson

GAIN GSS  
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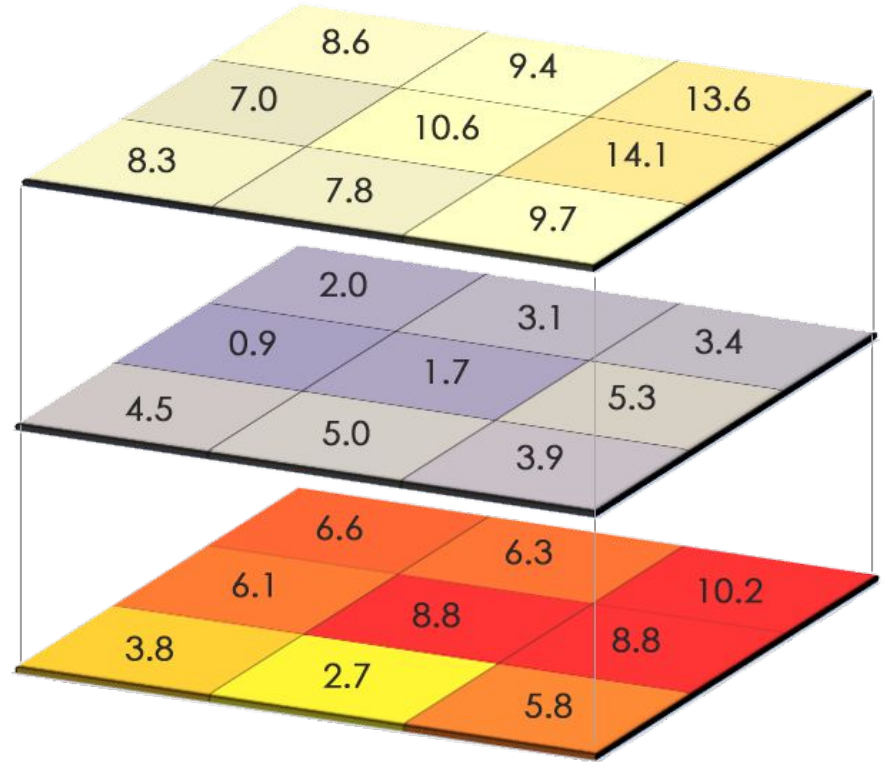
# Roadmap

- Satellite Imagery Basics
- Overview of Available Sensors and Typical Applications
- Accessing and Working with Satellite Imagery
- Notable Pitfalls of Satellite Imagery
- Examples from my Research

# Basics

# Satellite Imagery Raster Data

- Easiest to think of satellite imagery as **raster data**: stacked pixels with associated coordinate reference system + transform
- Different layers correspond to different **bands**: portions of the electromagnetic spectrum



Source: [GISGeography](https://www.gisgeography.com/)

# Bands of Landsat 8

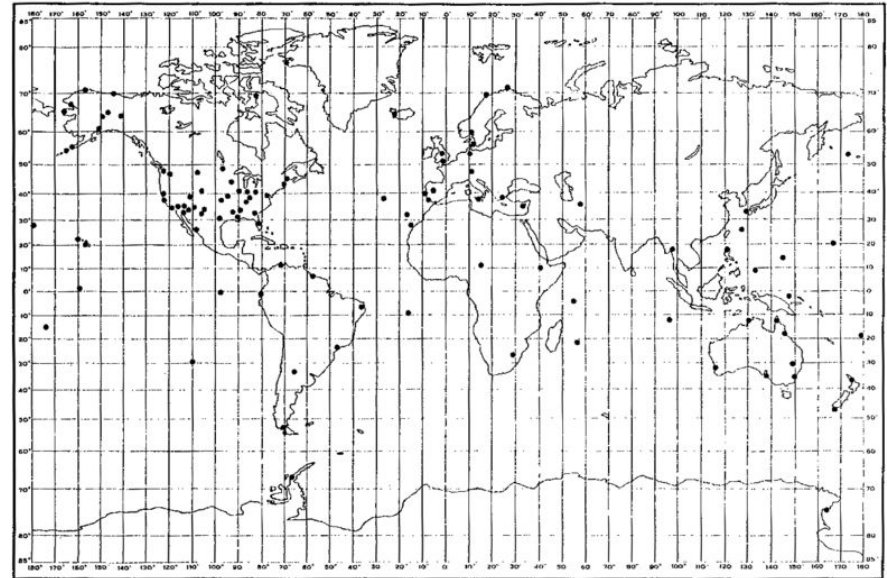
Name	Units	Min	Max	Scale	Offset	Wavelength	Description
SR_B1		1	65455	2.75e-05	-0.2	0.435-0.451 µm	Band 1 (ultra blue, coastal aerosol) surface reflectance
SR_B2		1	65455	2.75e-05	-0.2	0.452-0.512 µm	Band 2 (blue) surface reflectance
SR_B3		1	65455	2.75e-05	-0.2	0.533-0.590 µm	Band 3 (green) surface reflectance
SR_B4		1	65455	2.75e-05	-0.2	0.636-0.673 µm	Band 4 (red) surface reflectance
SR_B5		1	65455	2.75e-05	-0.2	0.851-0.879 µm	Band 5 (near infrared) surface reflectance
SR_B6		1	65455	2.75e-05	-0.2	1.566-1.651 µm	Band 6 (shortwave infrared 1) surface reflectance
SR_B7		1	65455	2.75e-05	-0.2	2.107-2.294 µm	Band 7 (shortwave infrared 2) surface reflectance
SR_QA_ AEROSOL							Aerosol attributes

Source: Google Earth Engine

# Coordinate Reference Systems & Transforms

- **Coordinate Reference System (CRS):** Rule for assigning coordinates to location on Earth
- **Transform:** Assigns pixel corners coordinates
- Together, a CRS and a Transform allow us to map rasters

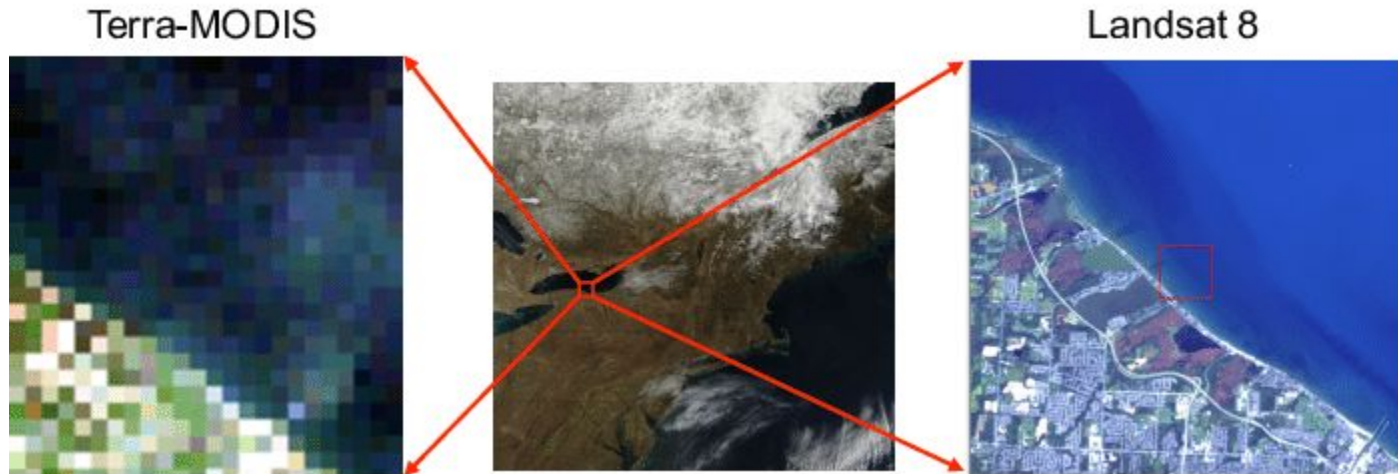
Doppler Satellite Ground Stations Providing Data for WGS 72 Development.



Source: NOAA

# Spatial Resolution and Revisit Rate

- **Spatial Resolution:** Size of pixels in space  
E.g. Landsat pixels are 30m x 30m
- **Revisit Rate:** How often a picture is taken of a given location, also called “Temporal Resolution”



# Sensor Overview

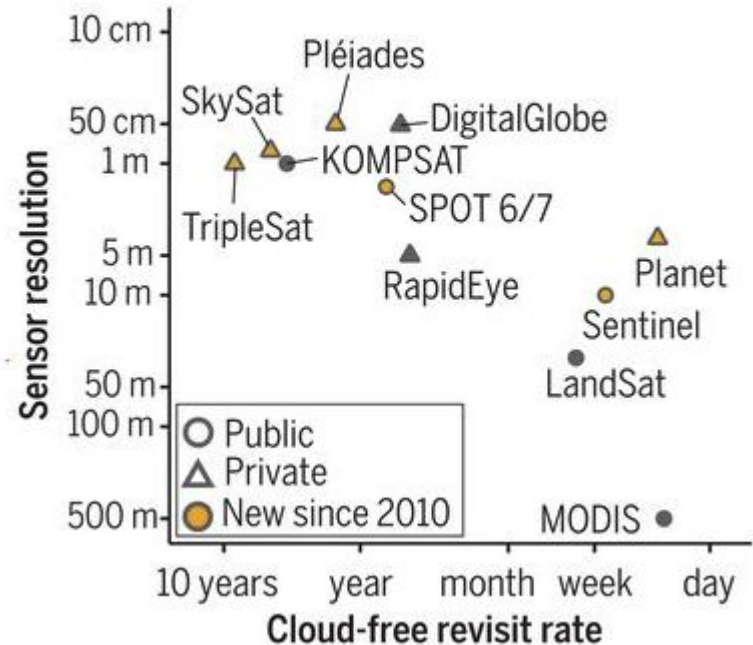


# Sensor Overview

Broadly, three kinds of imagery widely used in economics research:

- Night-time lights
- Medium resolution multispectral (e.g. Landsat)
- High resolution visible spectrum (e.g. Planet)

**Satellite resolution and revisit rate, Africa 2019**



Source: Burke et al (2021) Science

# Nighttime Lights

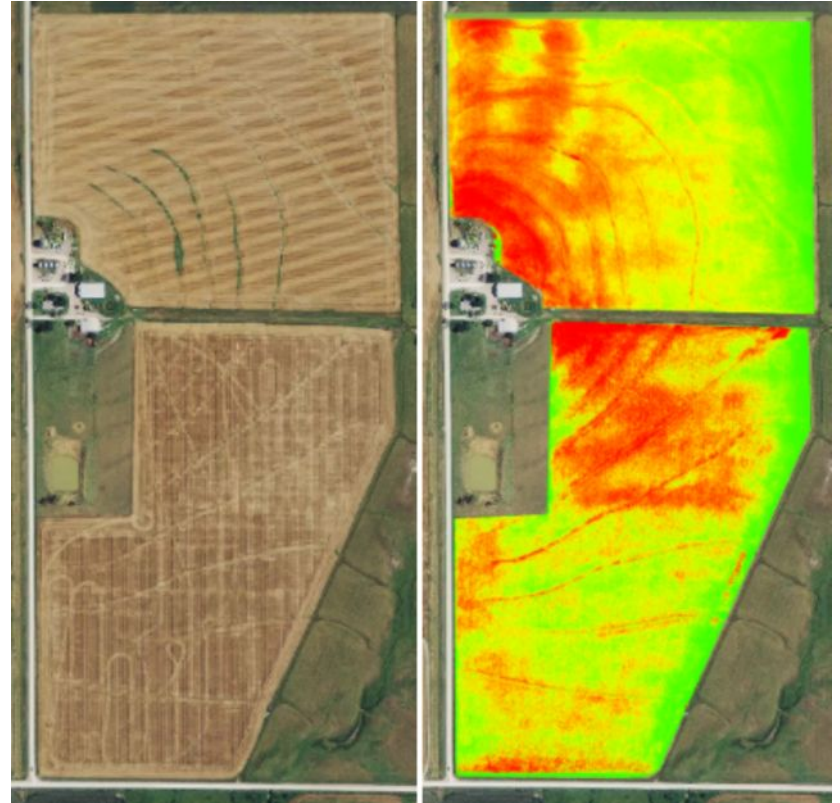
- Two sensors: DMSP 1992-2013 and VIIRS 2012-Present
- Widely used as a proxy for economic output
- Notably: does not work well for very low-income locations



Source: Yao (2019) IMF Finance & Development

# Multispectral Imagery

- Imagery with multiple bands, often with some outside of the visible spectrum is referred to as **multispectral**
- Most common multispectral measure: **NDVI**, a proxy for biomass,  $(\text{near infrared} - \text{red}) / (\text{near infrared} + \text{red})$



Source: [botlink](#)

# Other measures derived from Multispectral Imagery

- Aerosol Optical Depth (AOD): proxy for air pollution
- Normalized Difference Flood Index (NDFI): measures standing water
- Enhanced Vegetation Index (EVI): A measure more closely associated with crop biomass than NDVI
- Thermal Anomalies: Used for detecting active fires
- Optical Trapezoidal Model (OPTRAM): measure of soil moisture

# High Resolution Visible Spectrum/Panchromatic Imagery

- **Visible Spectrum:** Red, Blue, and Green bands used to make imagery similar to that displayed by our computers
- **Panchromatic:** Greyscale imagery
- Used for object detection and related tasks
- Sources: Google Static Maps, Planet, Spot



Source: Suri et al (2019) AEJ:AE

# Other Lesser-Known Imagery

- **Hyperspectral:** Many (often 100+) bands spanning a wide range of electromagnetic spectrum
- **Radio:** Used for measuring topography (SRTM) and changes in groundwater (GRACE)
- **LIDAR:** Used to construct 3D representations of features on the ground (e.g. buildings)

# Accessing Imagery

# Google Earth Engine

The screenshot displays the Google Earth Engine web interface. At the top, the Google Earth Engine logo is on the left, and a search bar with the text "Search places and datasets..." is in the center. On the right, there are icons for help, chat, and a user profile labeled "innate-marking-268422".

The main interface is divided into three horizontal panels:

- Left Panel (Scripts):** A sidebar with a "Filter scripts..." search bar and a "NEW" button. It lists user folders and scripts under "Owner (2)", "Writer", "Reader", and "Archive".
- Center Panel (New Script \*):** A code editor with a toolbar containing "Get Link", "Save", "Run", "Reset", and "Apps". The code in the editor is:

```
7 }  
8 }  
9 }  
10 var ls8 = ee.ImageCollection("LANDSAT/LC08/C02/T1_L2").  
11   filterBounds(box).  
12   filterDate("2018-01-01", "2018-12-31").  
13   map(applyScaleFactors).  
14   median();  
15 }  
16 var visualization = {  
17   bands: ['SR_B4', 'SR_B3', 'SR_B2'],  
18   min: 0.0,  
19   max: 0.3,  
20 };  
21 }  
22 Map.addLayer(ls8, visualization, 'True Color (432)');  
23 }
```
- Right Panel (Inspector Console Tasks):** A panel with tabs for "Inspector", "Console", and "Tasks". The "Console" tab is active, showing the instruction "Use print(...) to write to this console." and a large empty text area.

Below the script editor is a map view showing a satellite image of a region in West and East Africa. The map includes labels for countries like Mauritania, Mali, Niger, Chad, Sudan, Eritrea, Ethiopia, Somalia, Tanzania, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Ghana, Togo, Benin, Nigeria, Djibouti, Yemen, Oman, and India. A large satellite image patch is overlaid on the map, covering parts of Mali, Niger, and Chad. The map interface includes navigation controls (compass, pan, zoom) and a "Layers" panel on the right side.

Source: Google Earth Engine



# Google Earth Engine

- Browser uses Javascript, Python API also available
- Large collection of publicly available imagery and other rasters such as weather data
- Free Google Cloud compute, operations optimized to run quickly on servers

# USGS EarthExplorer



EarthExplorer

Help Feedback Login

Search Criteria Data Sets Additional Criteria Results

Search Criteria Summary (Show)

Clear Search Criteria

## 1. Enter Search Criteria

To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the [help documentation](#)), and/or choose a date range.

Geocoder KML/Shapefile Upload

Select a Geocoding Method

Feature (GNIS)

**Search Limits:** The search result limit is 100 records; select a Country, Feature Class, and/or Feature Type to reduce your chances of exceeding this limit.

US Features World Features

Feature Name

(use % as wildcard)

State

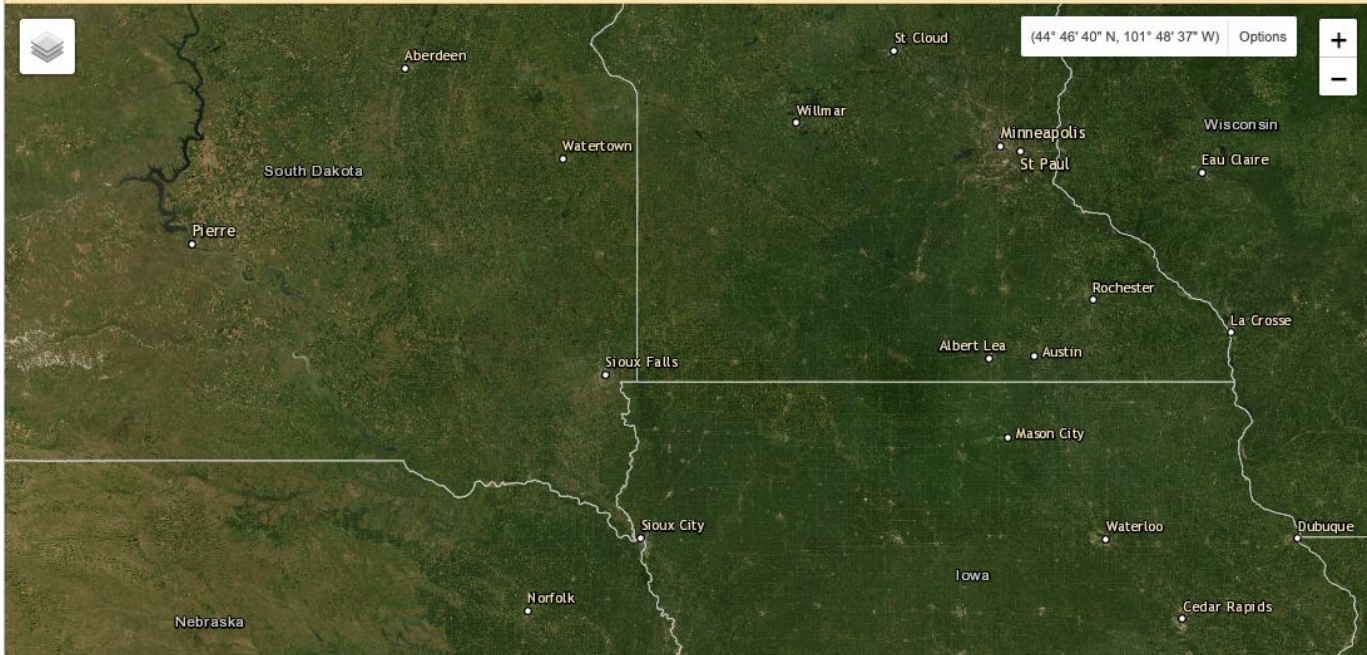
All

Feature Type

All

Show Clear

Polygon Circle Predefined Area



Source: USGS EarthExplorer

# Other Useful Tools

## Python

- **Rasterio:** Working with raster data
- **Geopandas:** Working with vector data (e.g. shapefiles)
- **Pillow:** Working with non-georeferenced imagery

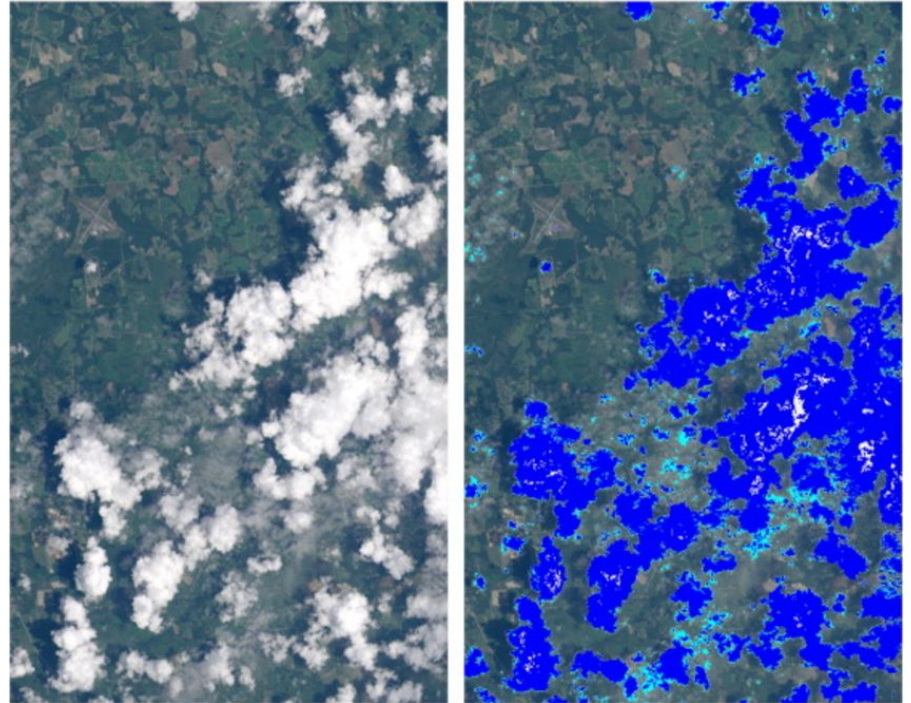
## Other

- **MOSAIKS:** Satellite imagery-derived features which can be used as tabular data

# Pitfalls

# Clouds

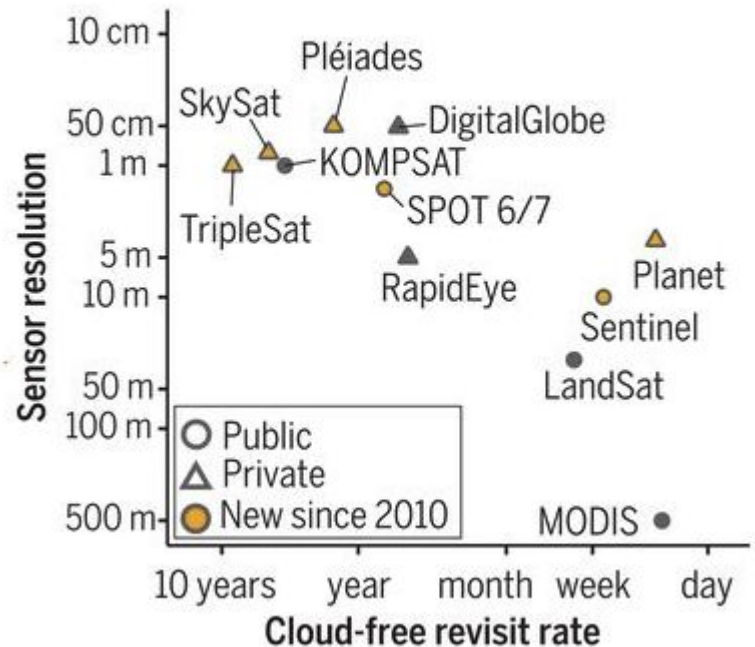
- Clouds lead to measurement error in most indices we care about
- Hard to reliably filter clouds, leads to different composition of timing of imagery over space
- Some places are especially cloudy. May need 3 years of Landsat to make a cloud-free composite in parts of East Africa!



# Spatial vs Temporal Resolution and Temporal Span

- Typically, there is a tradeoff between spatial resolution and revisit rate
- Older satellites are typically lower resolution. High resolution imagery much more available starting 2016
- Private imagery is expensive! \$15k for basic Planet service

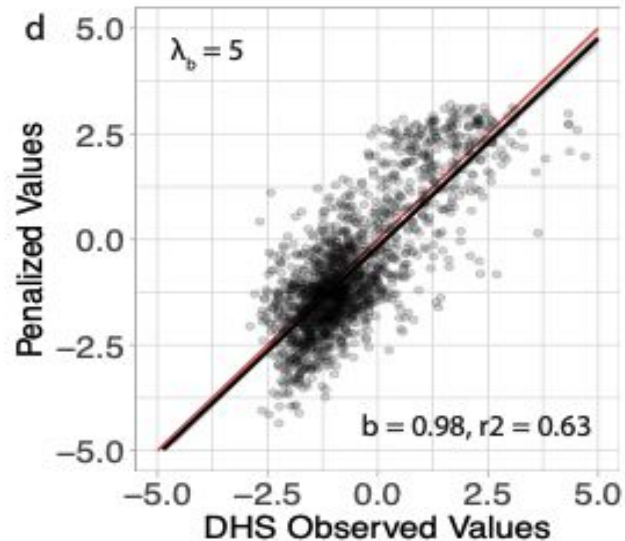
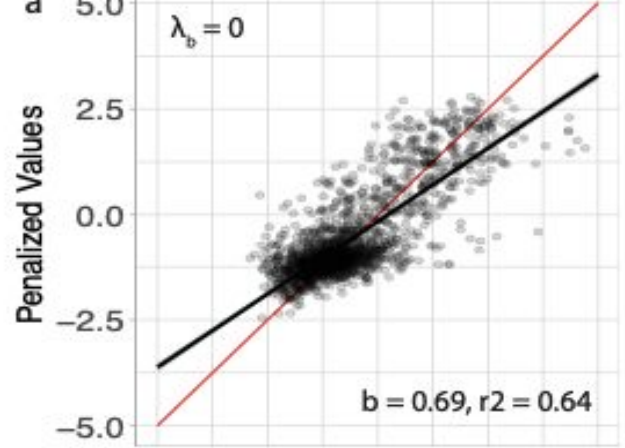
**Satellite resolution and revisit rate, Africa 2019**



Source: Burke et al (2021) Science

# Non-Classical Measurement Error

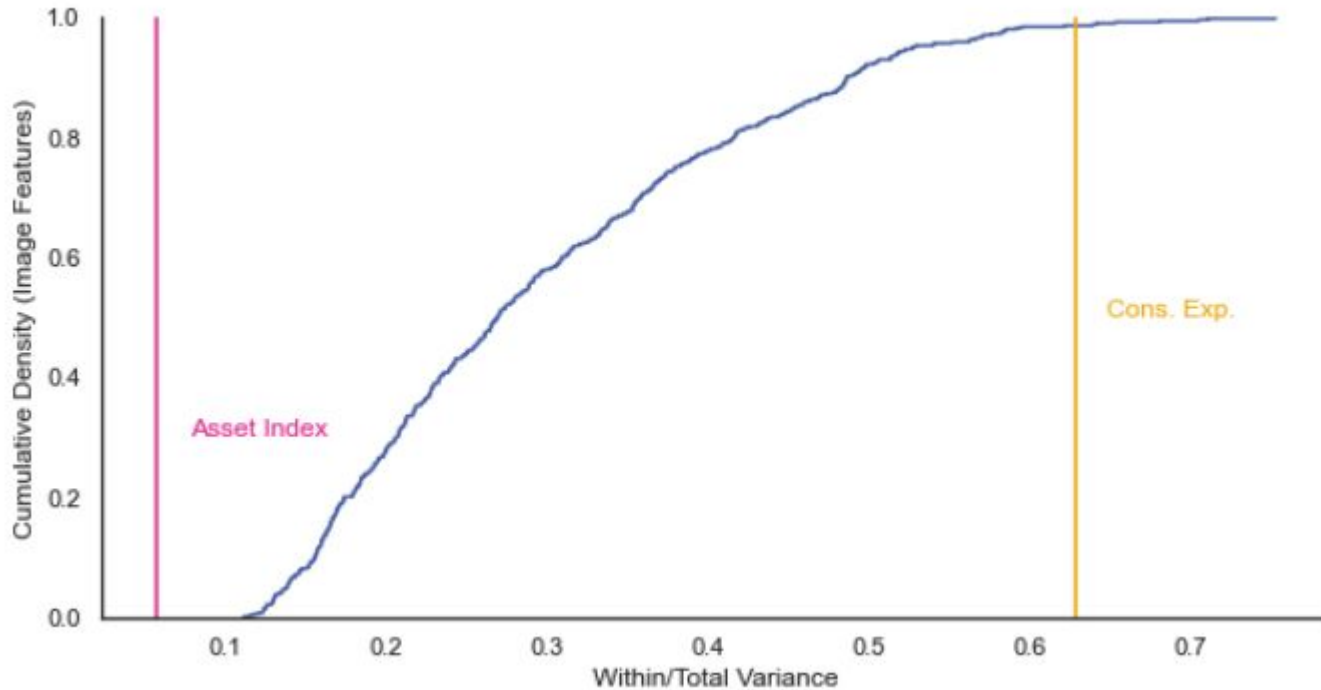
- Often want to use satellite imagery to make a proxy for an outcome of interest
- Recently, there's been a lot of worry that the mismeasurement of outcomes leads to biases
- Typical case for continuous outcomes: Berkson prediction leads to attenuated estimates
- Solutions: Bias-penalizing loss (Ratledge et al 2022), Multiple imputation (Carleton et al 2023)



Source: Ratledge et al (2022) Nature

Examples



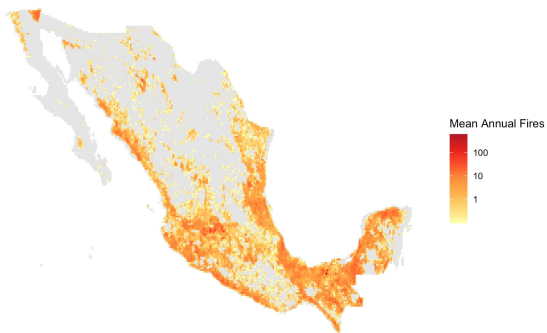


**Christensen, Ferguson, and Ramírez Amaya (2021) *NeurIPS ML4D***

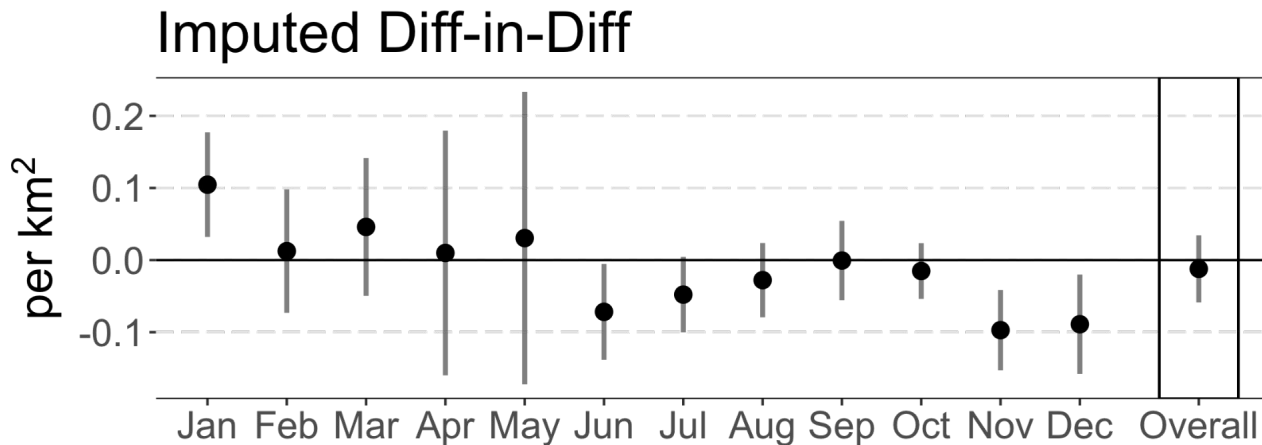
Features of Multispectral imagery that are useful for predicting asset wealth have limited within-location variation, making it hard to track changes in welfare over time

# Ferguson & Govaerts (2023) Working Paper

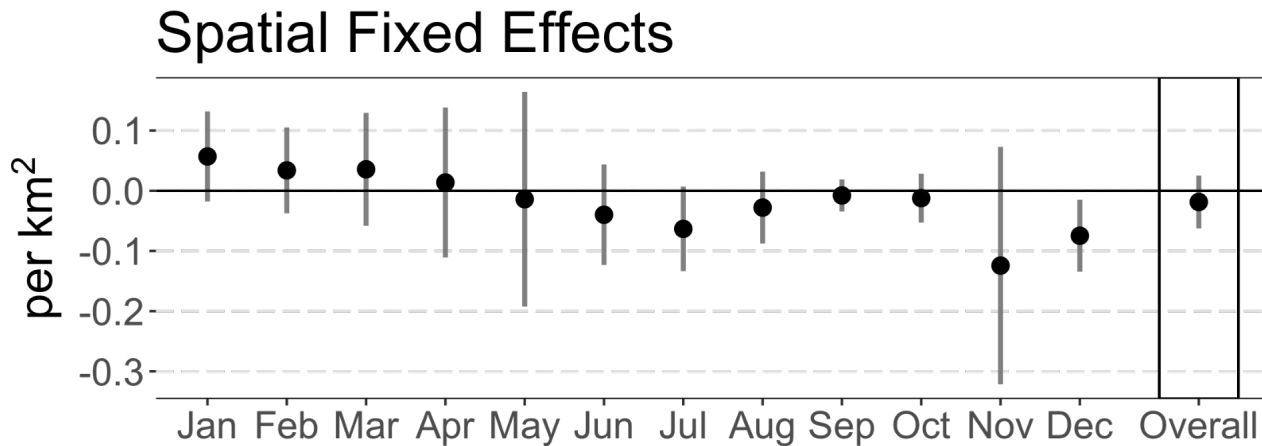
Conservation Agriculture  
adoption in Mexico leads  
to reductions in  
agricultural burning

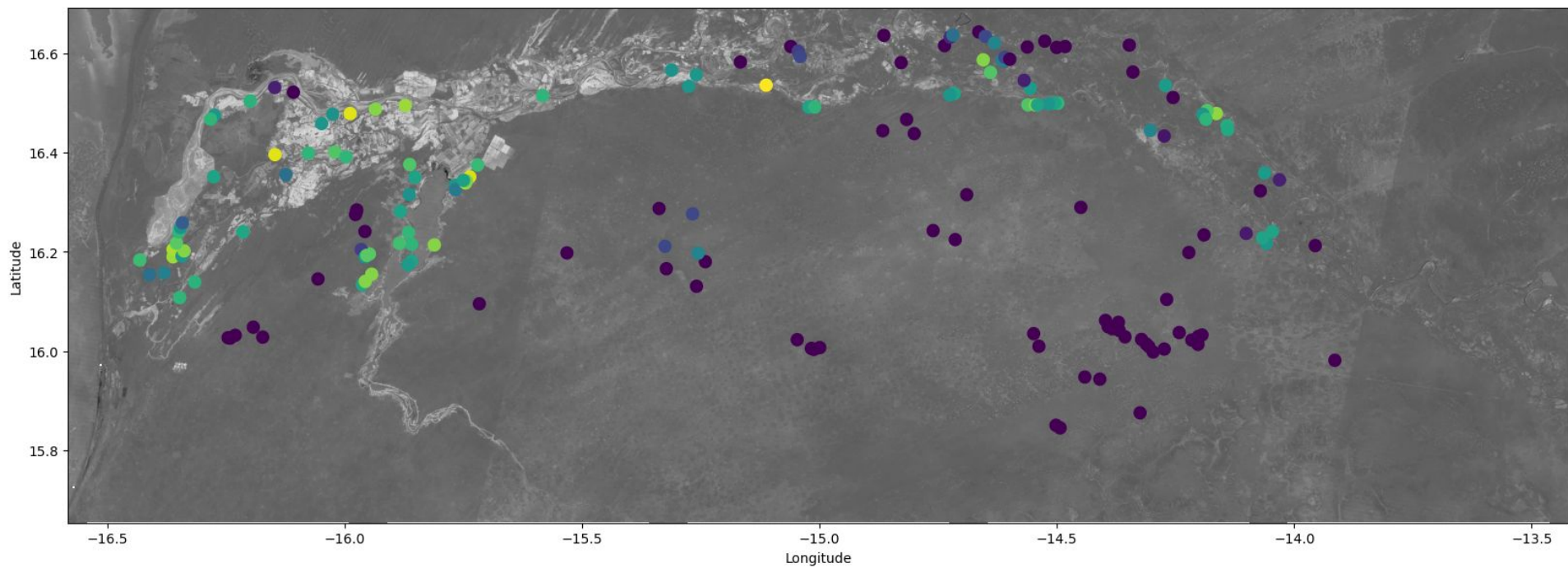


A  
Agricultural Fires



B  
Agricultural Fires

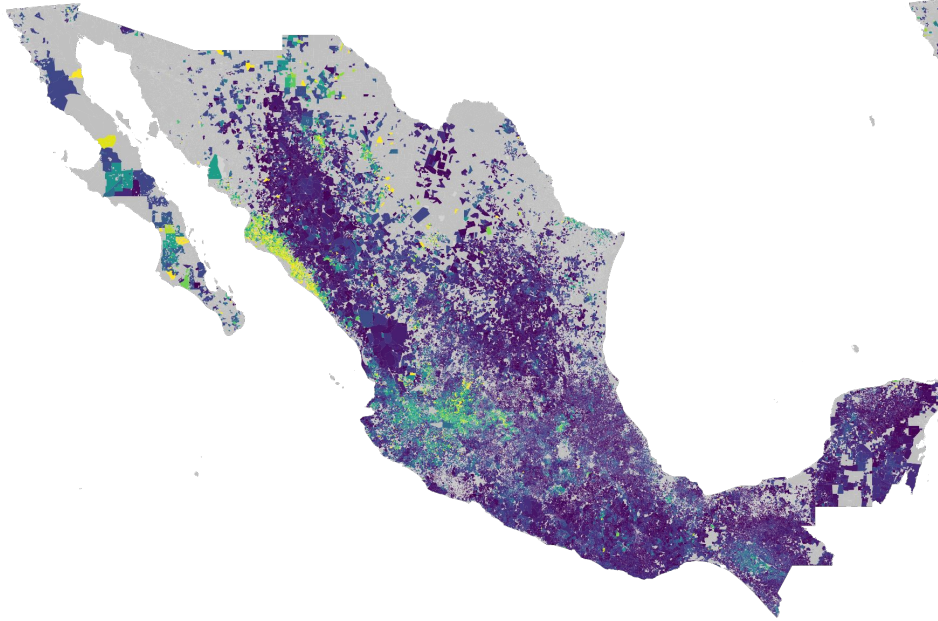




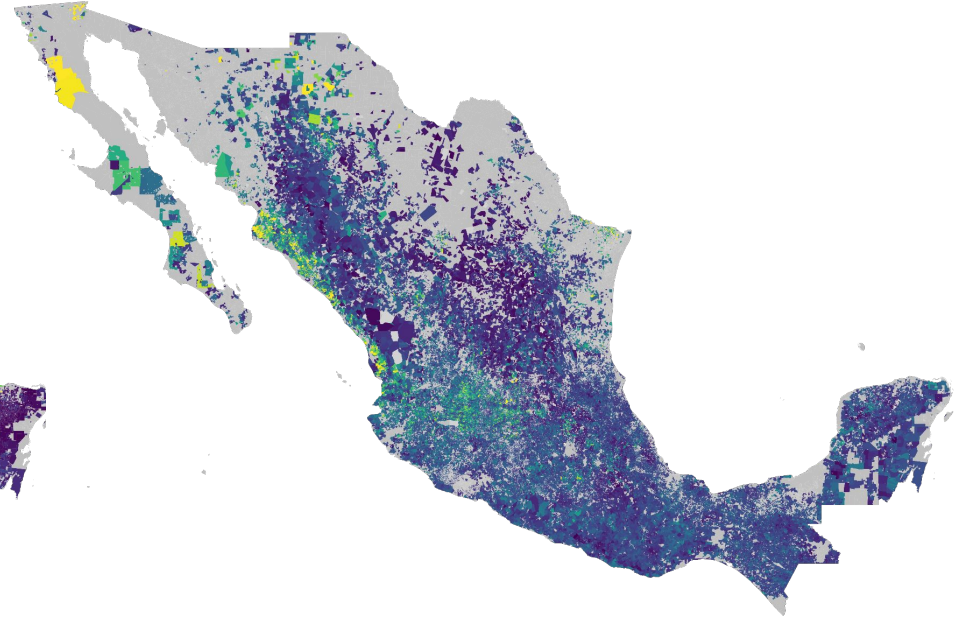
**Cisse, De Janvry, Ferguson, Gonzalez-Navarro, Mbaye, Sadoulet, and Syll (2023) Working Paper**

Locations exposed to greater agricultural productivity growth as a result of irrigation infrastructure development in the Senegal River Valley experienced greater increases in economic activity

Ground truth



Prediction



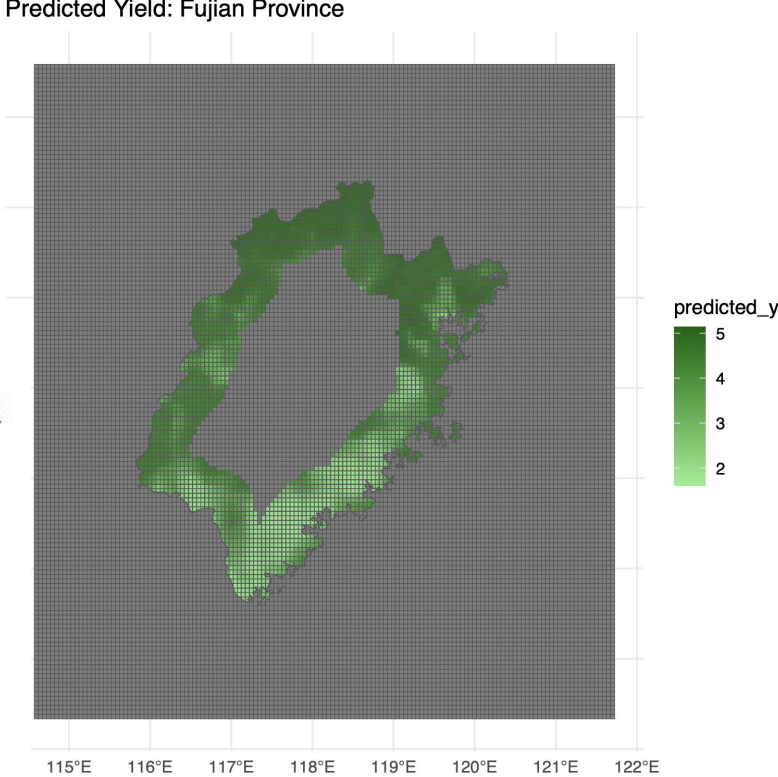
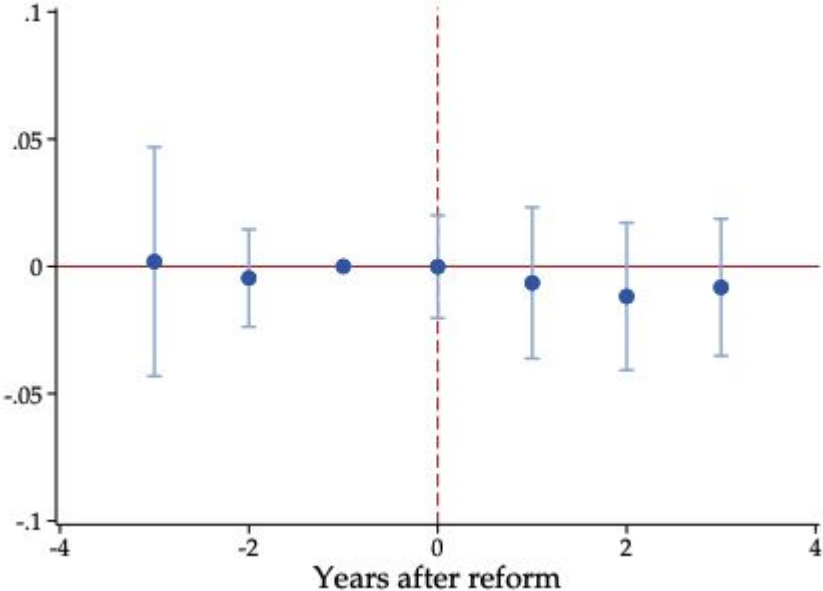
**Ferguson, Sayre, and Sogomo (2023) Working Paper**

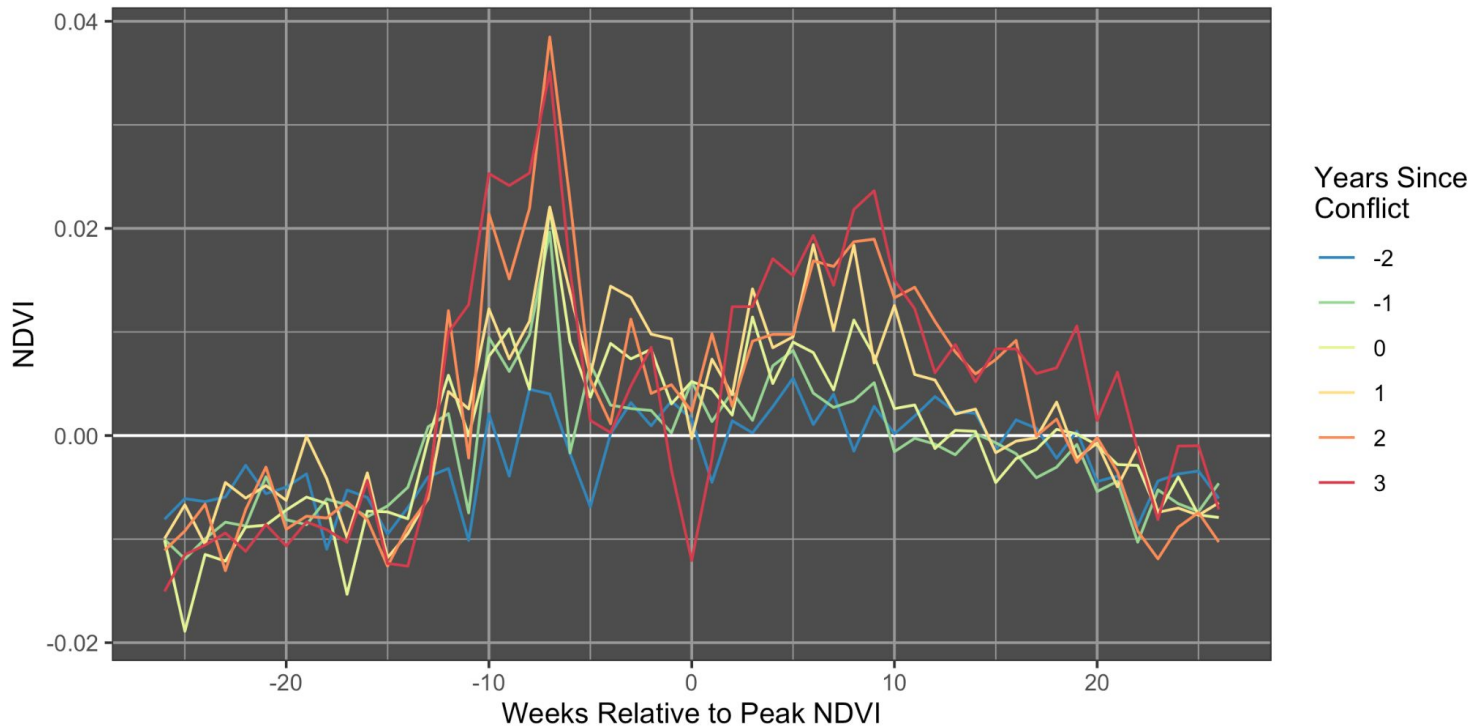
Multispectral imagery can be used to accurately downscale aggregated yield measures

# Ferguson & Kim (2023) Working Paper

## Chinese Household Responsibility System had no discernible effect on agricultural productivity

Figure 7: Differences-in-discontinuities effect of HRS adoption on estimated log yield





## Ferguson (2023) Working Paper

Conflict leads to land abandonment in sub-Saharan Africa

Thanks!

[joel\\_ferg@berkeley.edu](mailto:joel_ferg@berkeley.edu)

[joelferg.github.io](https://joelferg.github.io)