Mopti, Mali
(Digital Globe)

HARVEST
EARTH DATA
FOR INFORMED AGRICULTURAL DECISIONS

Monitoring agriculture at the field scale using satellite data and machine learning

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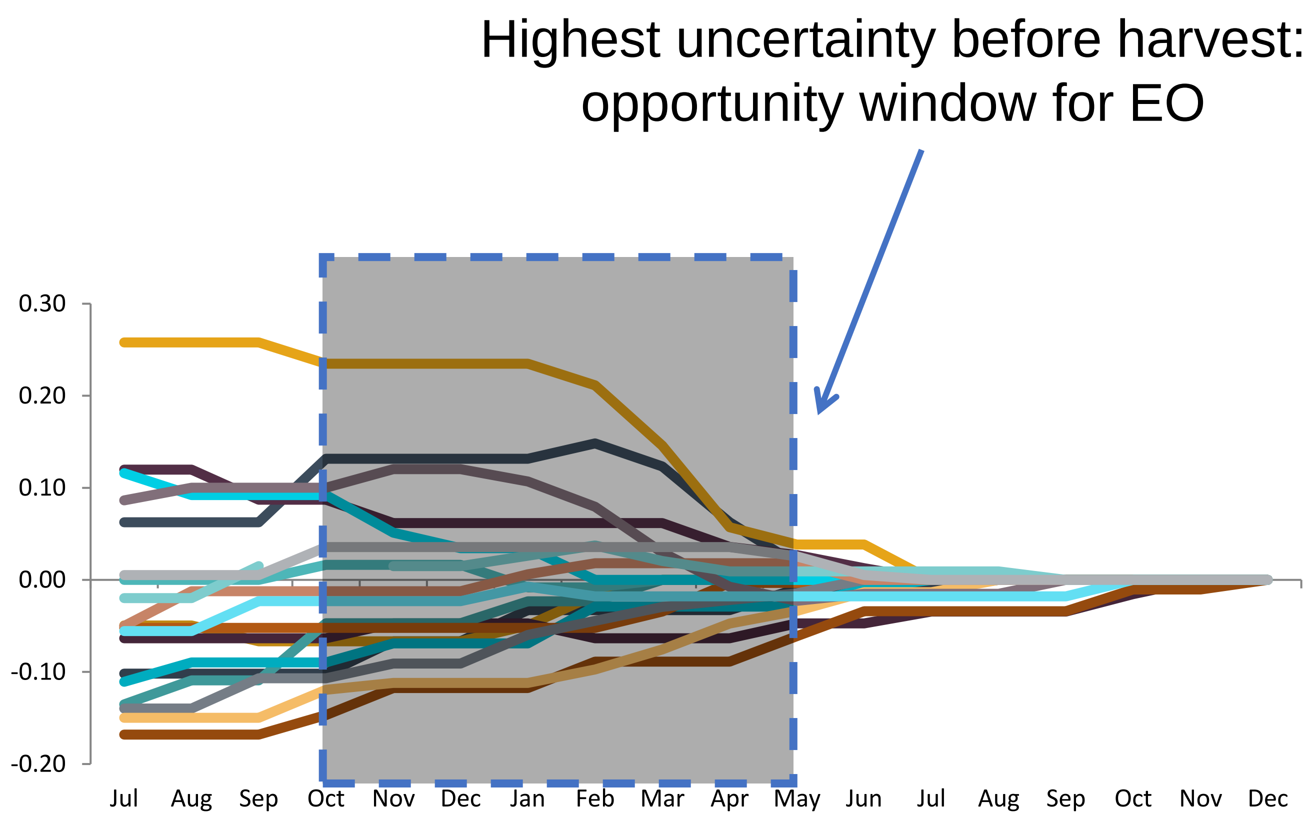
Measuring Development 2020: Data Integration and Data Fusion

Why monitor agriculture?

- Estimate crop production (domestic and international)
- Inform and stabilize markets
- Anticipate crises & deliver aid
- Inform insurance programs
- Monitor and meet sustainable development goals



WASDE forecast errors over past 20 years

Credit: J. Glauber

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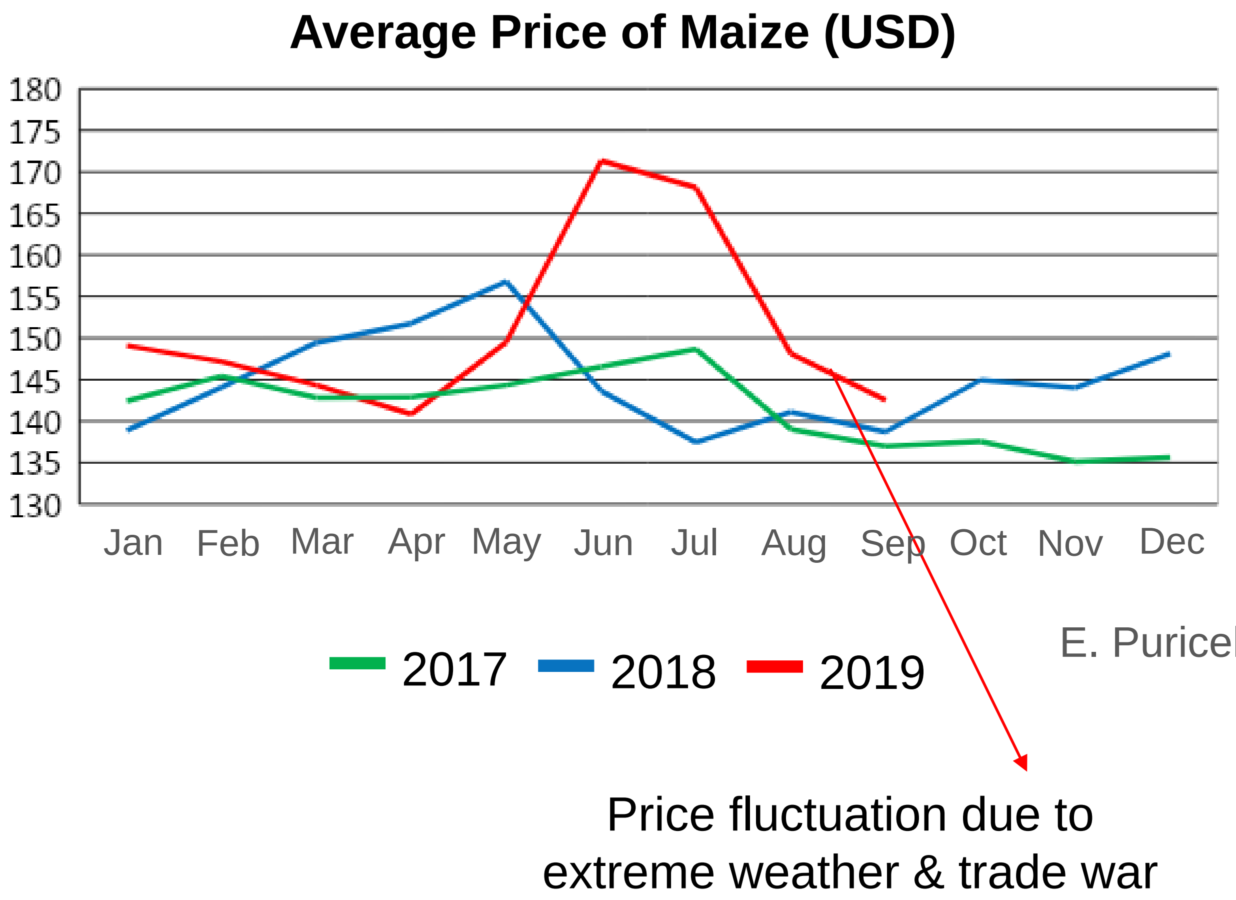

E. Puricelli

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"In the past we always reacted to crop failure, spending billions of shillings to provide food aid in the region.

2017 was the first time we acted proactively because we had **clear evidence from satellite data** very early in the season."

Martin Owor, Commissioner
Office of the Prime Minister (OPM) – Uganda

> $2.6 million saved,
> 150k people helped

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Flooded croplands in Iowa, spring 2019
J. Schaaf

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☆ SDG directly related to agriculture

NASA's commitment to agricultural monitoring

NASA *agro*-nauts?

- Satellite data used for agricultural monitoring since 1970s
  - NASA AgRISTARS program
- Despite 40+ years, huge potential of remote sensing yet to be fully realized
- Today we are enabled by ML and modern compute to realize this potential

ML: unlocking potential of satellite data

- Huge data volumes
  - 11 TB/day from Planet Labs alone

San Francisco, February 11, 2017. Planet, Inc.

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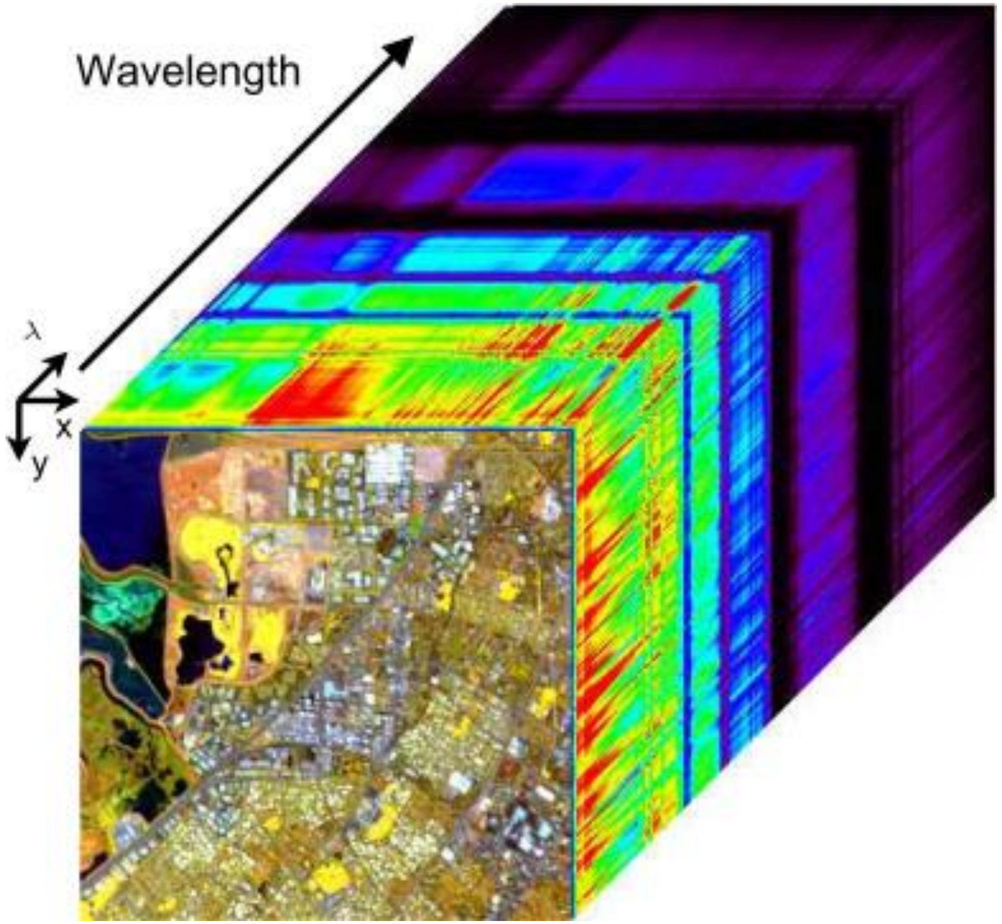
  - Multispectral, hyperspectral



Credit: Christophe et al., 2008

ML: unlocking potential of satellite data

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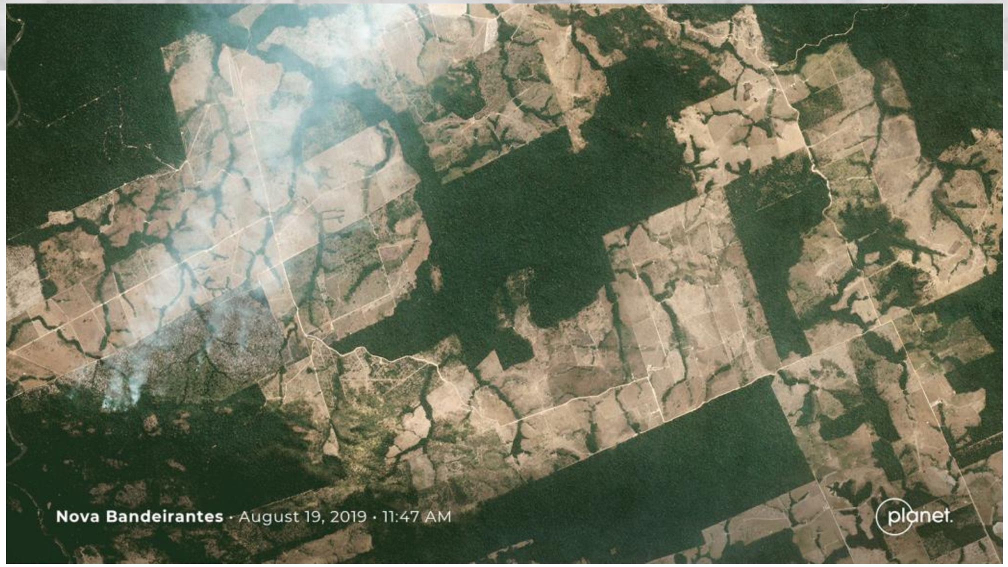
- High-dimensional data
  - Multispectral, hyperspectral
  - Frequent revisit times
    - Landsat: 16 days
    - Sentinel-2: 5 days
    - Planet Labs: daily or sub-daily



3-day timelapse of fires burning in Brazilian Amazon. Credit: Planet, Inc.

Before and after Sentinel-2 images of Palu earthquake in Indonesia, 2018.
Credit: ESA/CESBIO

ML: unlocking potential of satellite data

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    - Landsat: 16 days
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    - Planet Labs: daily or sub-daily
- Non-trivial interaction and pre-processing
  - Cloud removal
  - Orbital track
  - Interpolation/smoothing
  - Co-registration

Blank pixels = no data (satellite track) or clouds

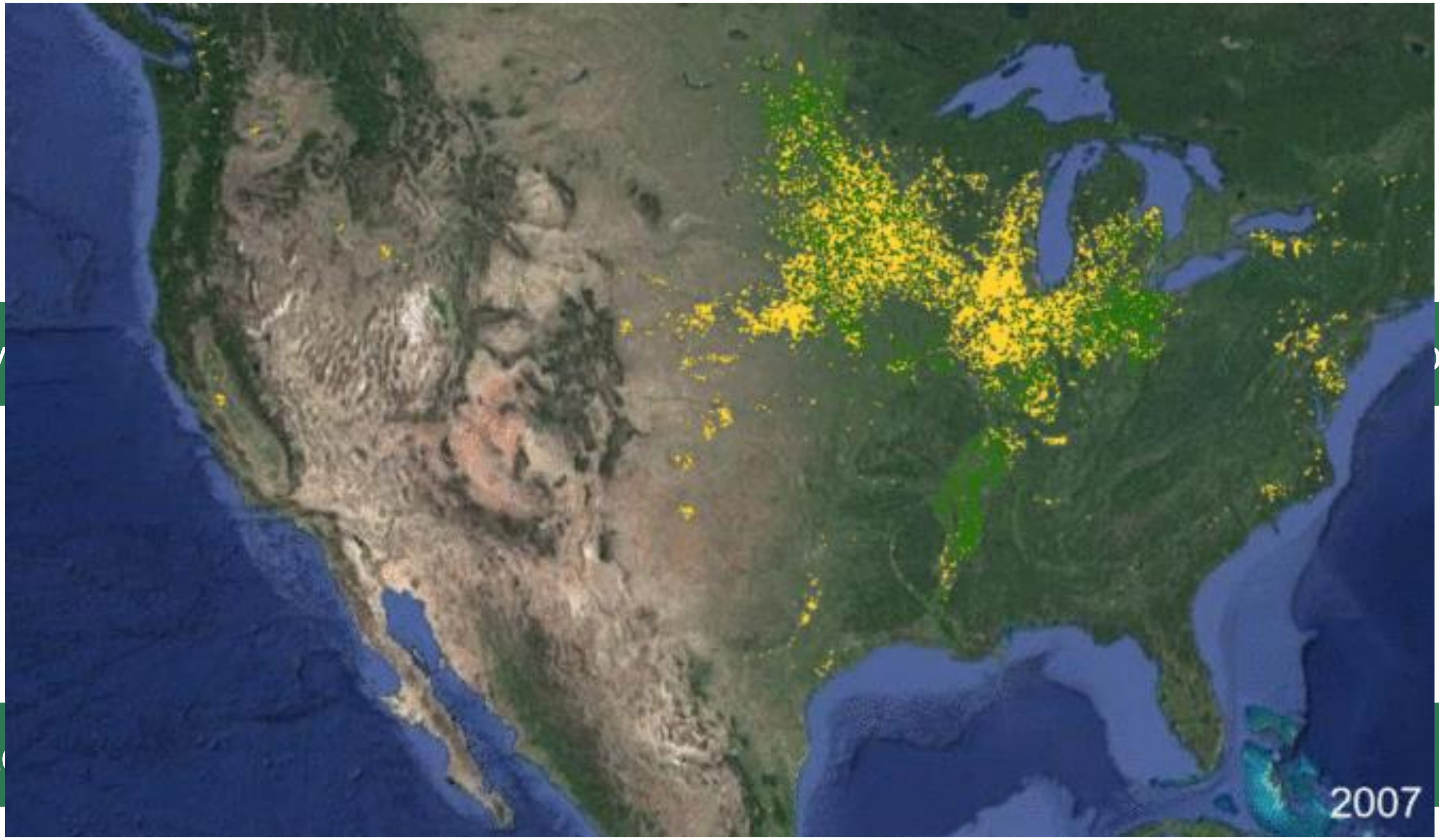
Sentinel-2 Time Lapse (Cropped)
Harmonized Landsat and Sentinel-2 (HLS)
Credit: USGS/NASA

Monitoring agriculture in satellite data

Forecast y

nditions

Det



Corn Soybeans

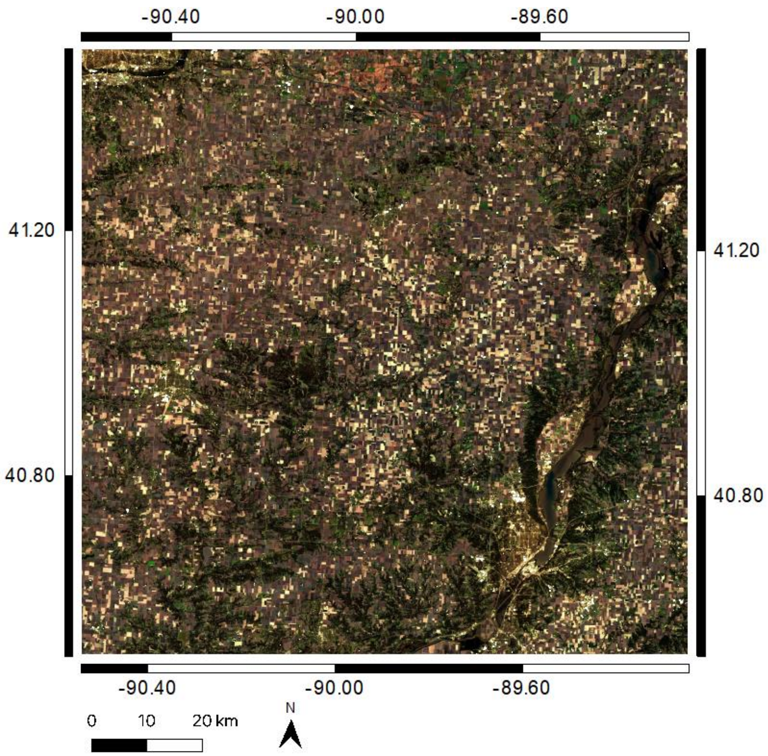
In-season crop type mapping

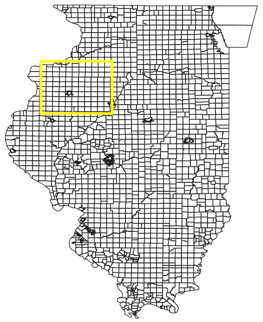
- Highest uncertainty during growing season, especially anomalous years
  - 2019: planting delays due to flooding in spring
  - 2020: delayed surveys due to COVID-19 travel restrictions
- Goal: map crop types and planting timelines using satellite data

Flooded croplands in Iowa, spring 2019
J. Schaaf

In-season crop type mapping in US Corn Belt

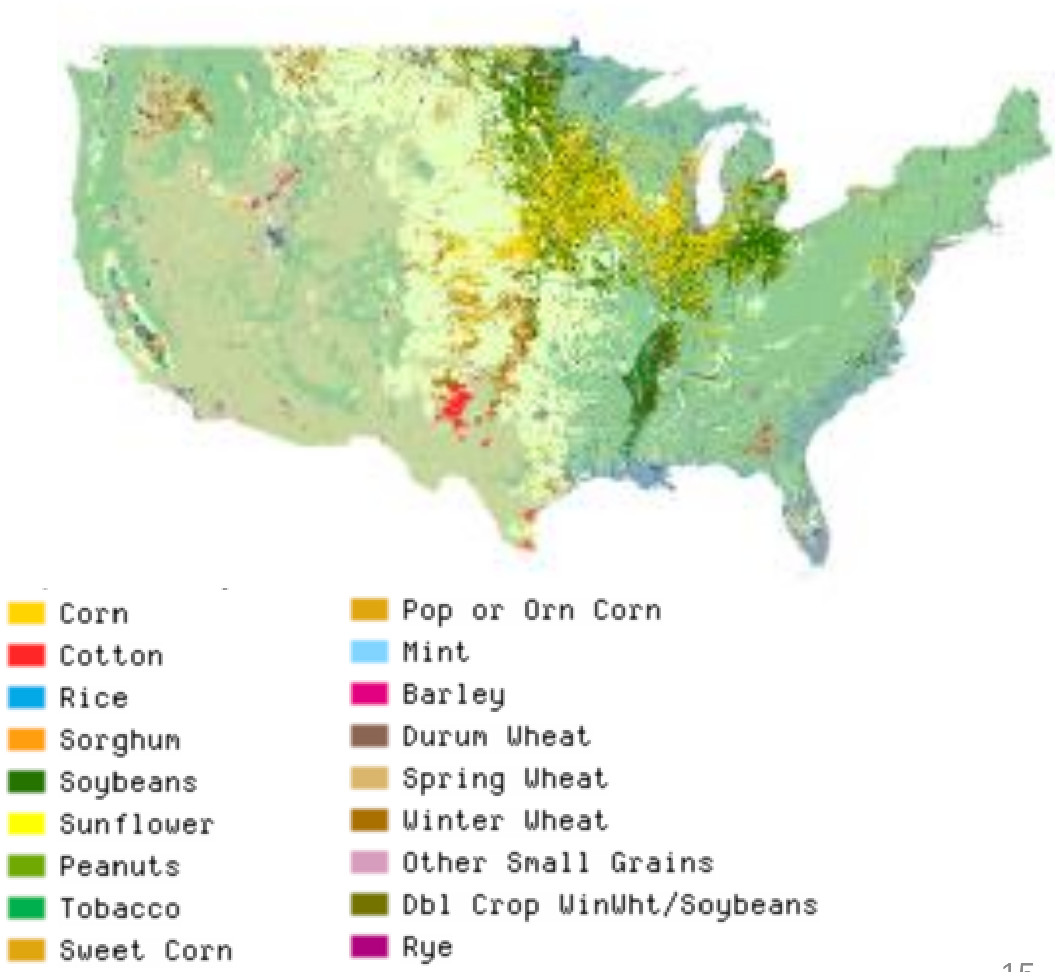
- Satellite data: Harmonized Landsat and Sentinel-2 (HLS) dataset
  - 30m/pixel resolution
  - 3-5 day revisit time
  - Multispectral (visible to shortwave IR)
  - Publicly available



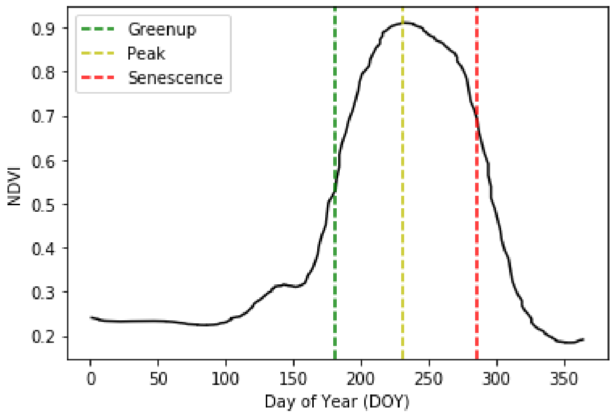


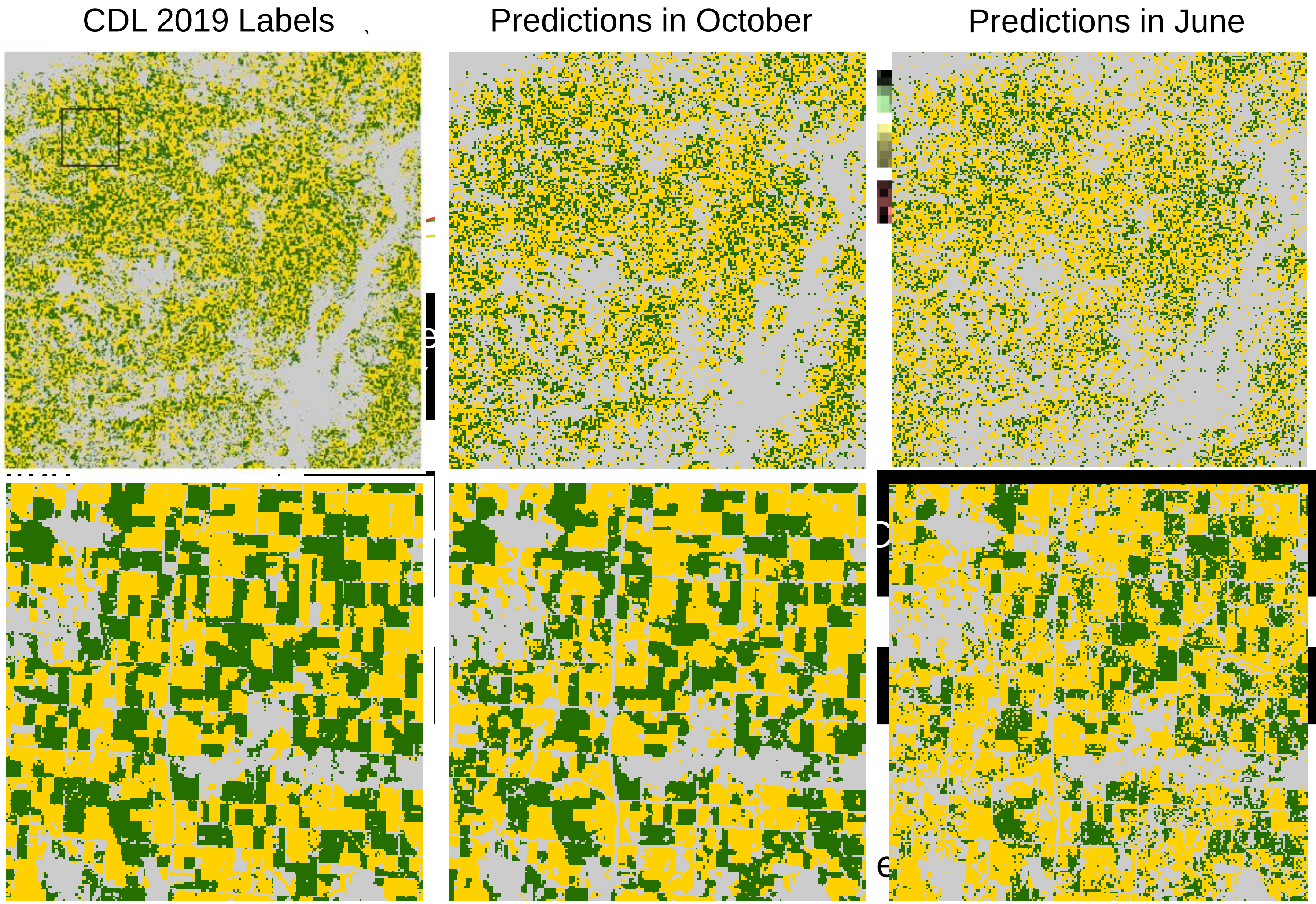
In-season crop type mapping in US Corn Belt

- Satellite data: Harmonized Landsat and Sentinel-2 (HLS) dataset
  - 30m/pixel resolution
  - 3-5 day revisit time
  - Multispectral (visible to shortwave IR)
  - Publicly available
- Crop type labels: USDA Cropland Data Layer
  - Released in February after harvest
  - 30 m/pixel resolution



In-season crop type mapping in US Corn Belt





To accurately predict crop type in f
(including anomalous) years,
need to **compare inputs at sa**
phenological stage,
not necessarily at the same tim

Corn Soybean Other

Satellites going where people cannot

- Mali: low food security due to conflict/instability

Remains of homes destroyed during the March 23, 2019 attack on Ogossagou village that killed >150 civilians. © 2019 UNICEF/Keita

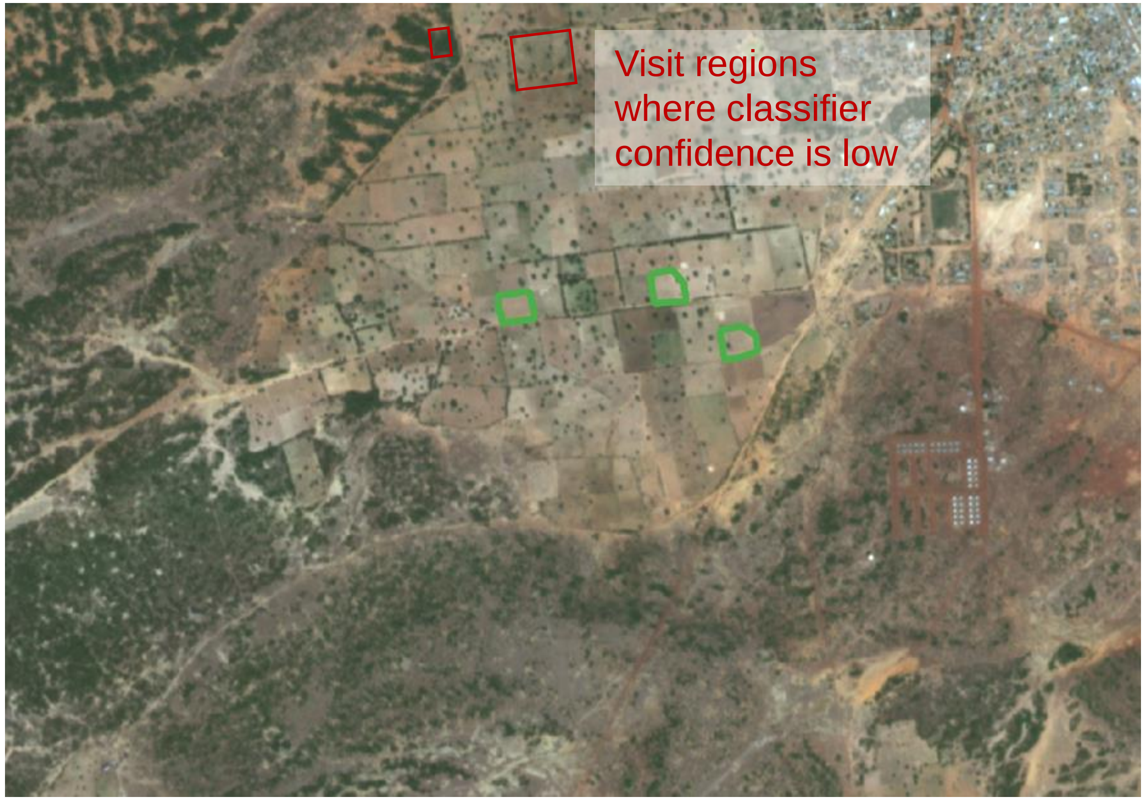
Satellites going where people cannot

- Mali: low food security due to conflict/instability
- USAID Bureau for Food Security implementing ag-focused development programs in Mali
  - Evaluating program effectiveness via household surveys too dangerous
- Goal: infer agricultural monitoring information from satellite data

Timelapse of PlanetScope images in Segou, Mali

Satellites going where people cannot

- Data labels collected in limited field campaigns by USAID and Lutheran World Relief, e.g.:
  - Field boundary
  - Crop type
  - End of season yield
  - Farming practices
- Semi-supervised ML methods allow learning from unlabeled and labeled examples
- Plan to use active learning to select sites for future ground data collection



Field boundaries in Segou, Mali (LWR/C. Nakalembe, Planet)

Supporting farm insurance

- Challenge: where to collect crop samples (costly, inefficient)?
  - Representative of variability within fields
  - Reduce travel time/complexity
- Solution: optimize crop cuts using ML regression + genetic algorithm

Swiss Re

HARVEST

GreenTriangle

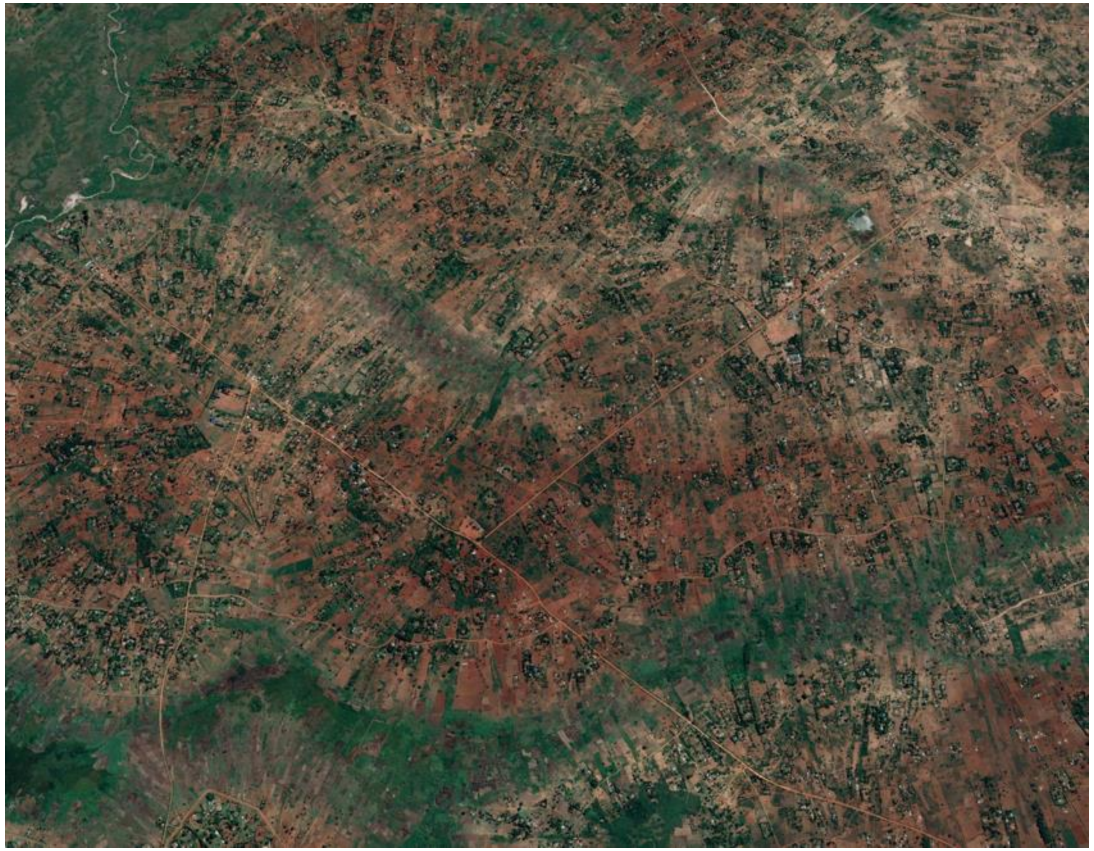
R. Sahajpal et al.

22% reduction in **travel distance**
40% reduction in **crop cuts**

without sacrificing yield estimation performance

Supporting farm insurance

- Challenge: where to collect crop samples (costly, inefficient)?
  - Representative of variability within fields
  - Reduce travel time/complexity
- Solution: optimize crop cuts using ML regression + genetic algorithm
- Working with Ministries of Agriculture to support smallholder insurance programs
  - Focus areas: Kenya and Mexico
  - Providing crop type maps, production, condition, yield from satellite data
  - Supported by SwissRe Foundation



Smallholder agriculture in western Kenya (Maxar)

Key takeaways

- It's an exciting time for satellite-based agricultural monitoring!
- Modern machine learning methods, compute availability, and satellite data providers are revolutionizing our ability to provide accurate, timely, actionable info at scale
- NASA Harvest is building on decades of investments by NASA & international community to advance uptake of satellite data for informing agricultural decisions across the globe
    - In-season crop type classification
    - Crop assessment in inaccessible locations
    - Supporting farm insurance programs

Thank you!

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