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The Expanding Role of Remote Sensing Technology in Agricultural Production and Trade Decisions

Estefania Puricelli and Brian Barker

Selected Paper prepared for presentation at the International Agricultural Trade Research Consortium's (IATRC's) 2019 Annual Meeting: Recent Advances in Applied General Equilibrium Modeling: Relevance and Application to Agricultural Trade Analysis, December 8-10, 2019, Washington, DC.

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The expanding role of Remote Sensing Technology in Agricultural production and trade decisions

Estefania Puricelli - Brian Barker

NASA Harvest UMD Hub – GEOGLAM Crop Monitor



www.nasaharvest.org

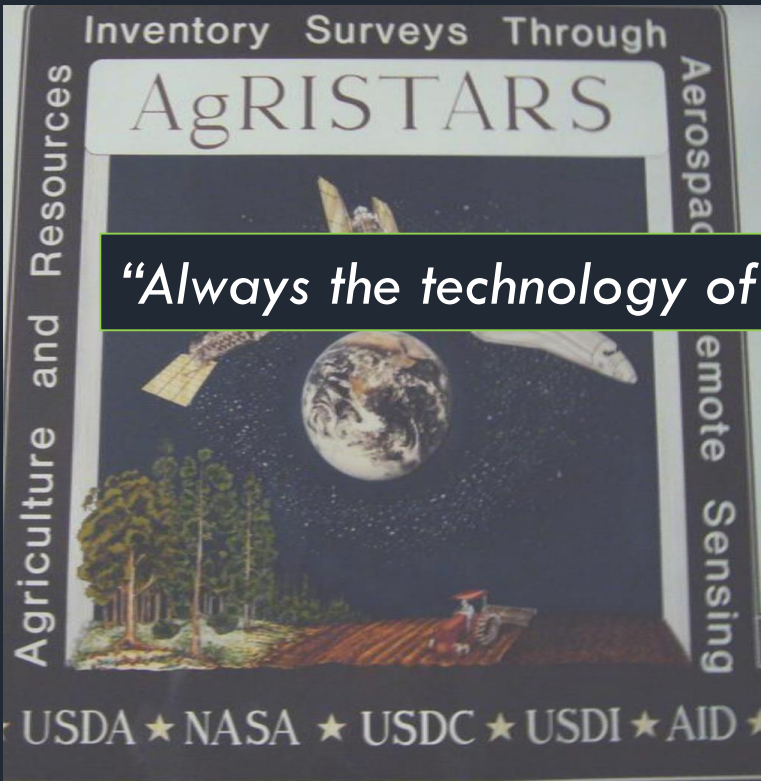
<https://cropmonitor.org/>



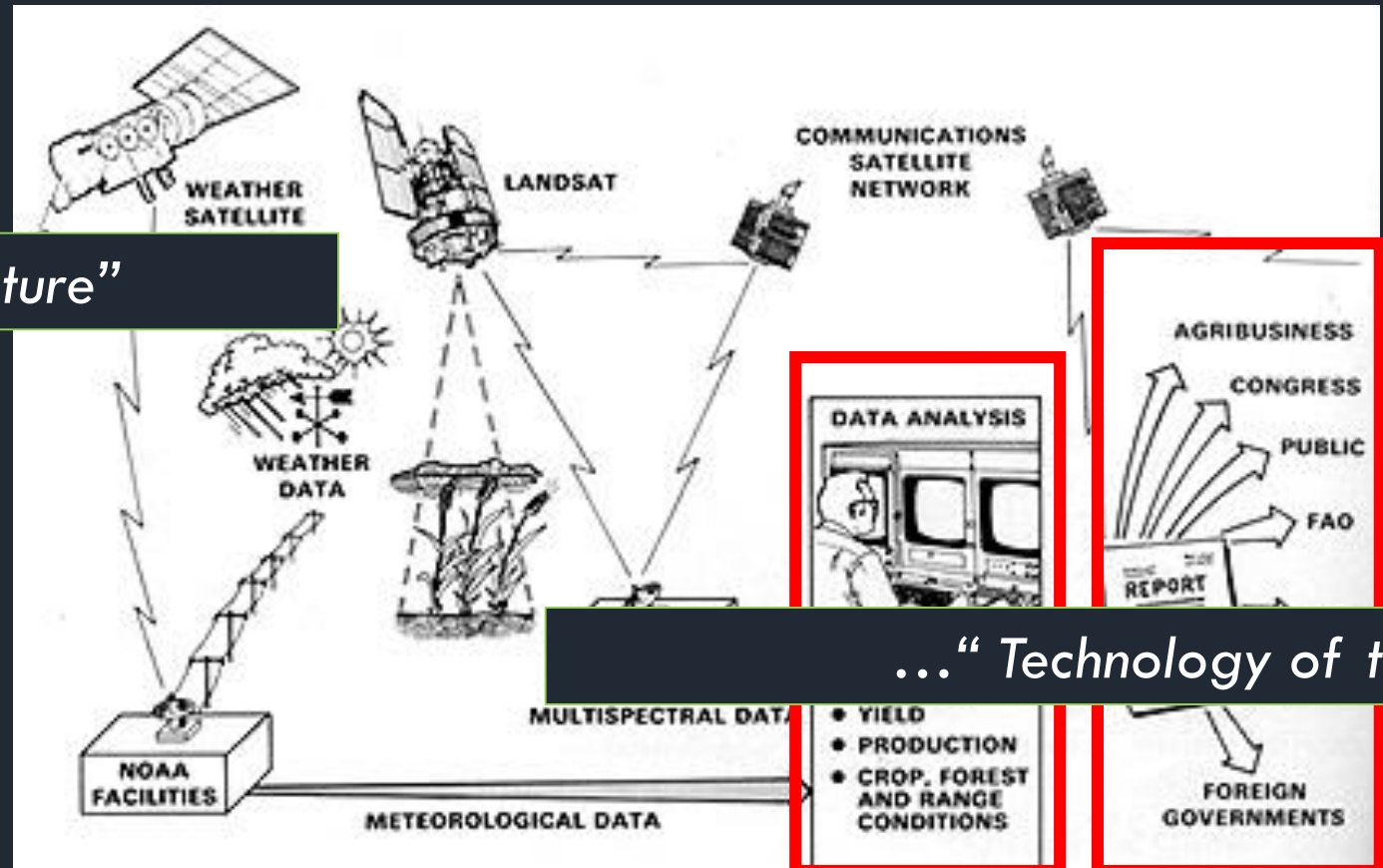
IATRC December 2019, Washington DC

The Vision for Agricultural Remote Sensing 1970s & 80s

Implementation was limited by availability of data and compute



"Always the technology of the future"



... "Technology of today!"

Overselling of capabilities – should be avoided with current push



Climate change compounds Ethiopia's food crisis
MATT CA...
AFP - Standing amidst a group of scrawny fellow Ethiopian farmers, Tuke Shika points to the scorching sun when asked why his food reserves have dwindled this year.



NORTH KOREA
Huge Gap Predicted In Supply
guardian.co.uk TheObserver

Food aid to poor...
price of grain so...
UN warns of drastic crisis as re...
beat shortages by switching to...

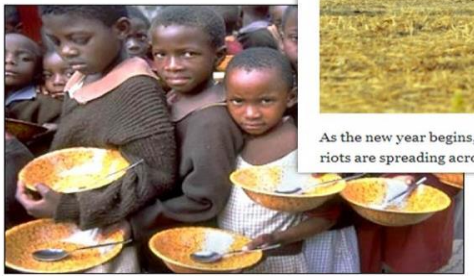
Drought is key fa...
Matt Brown, Foreign Correspondent
Last Updated: March 27, 2009 9:30AM

TARU, Kenya // Rose Mwembe has not had a corn harvest in six months. Last year's late season rains never came and the current rainy season is already a month late, meaning she cannot plant for at least another month.

The arid red earth in front of...
Poverty/World Hunger
More than 1 billion hu...
By Tom Eley
WISN'S
Thursday, Oct 15, 2009

15 October 2009
More than 1 billion people, one sixth of humanity, are undernourished by the end of 2009, two UN agencies reported on Wednesday. The ranks of the hungry are expected to rise to 1.1 billion people in one year, a result of the economic crisis since the Great Depression.

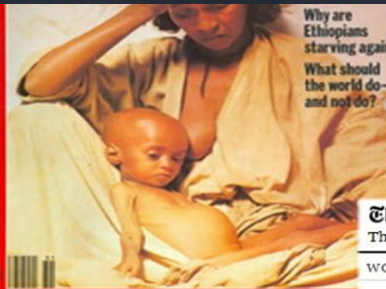
"The State of Food Insecurity," produced by the High Level Panel of Experts (HLPE) for the Commission on World Food Security (CWSF) and the World Food Program (WFP), shows that the sharp increase in global hunger is not the result of natural disasters, but the man-made causes of unemployment, and declining incomes.



As the new year begins, the price of wheat is setting an all-time high in the United Kingdom. The price of wheat is setting an all-time high in the United Kingdom. The price of wheat is setting an all-time high in the United Kingdom.



BBC NEWS AFRICA
Somalia famine: UN warns of 750,000 deaths
As many as 750,000 people could die as Somalia's drought worsens in the coming months, the UN has warned, declaring a famine in a new area.
The UN says tens of thousands of people have...



The New York Times
Thursday, November 10, 2011
WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE
TIMES TOPICS > SUBJECTS > F > FLOODS > 2010 PAKISTAN FLOODS
2010 Pakistan Floods

BBC NEWS
ONE-MINUTE WORLD NEWS
Bangladesh bans most rice exports

Bangladesh has banned exports of nearly all the rice it produces to prevent shortages and keep food costs down.
The government said the ban began on Tuesday and will last six months.



Global Food Crisis
The new world of soaring food prices



FOOD INSECURITY
Little Keeps Nigeria From Crisis
TIME IN PARTNERSHIP WITH CNN
The World's Growing Food
By VIVIENNE WALT

The World's Growing Food
By VIVIENNE WALT



U.N. Food Agency Issues Warning on China Drought



Food security for 7 billion



Following international market crop price Spikes (2008, 2011)
International recognition of need for improved real time, reliable, open information on global agricultural production prospects
Critical for agricultural policies, stabilizing markets, averting food crises

GEOGLAM launched as part of G20 Action Plan on Food Price Volatility and AGRICULTURE

- Launched in 2011 alongside Agriculture Market Information System (AMIS)
- Focus on stabilizing markets & enhancing food security through the use of Earth Observation
- Provides the international forum for the

Harvest is NASA's contribution to the G20 GEOGLAM Program

100 ministers from 92 organizations in 20 countries and 16 inter-governmental organizations

- Forged many of the partnerships that led to creation of Harvest



GEOGLAM & AMIS & NASA Harvest at a Glance

- GEOGLAM & AMIS launched by G20 Ministers of Agriculture in 2011 under Action Plan on Food Security and Agriculture
- GEOGLAM focused on the use of Earth Observations & provides the international forum for the agricultural monitoring community
 - Members from 62 organizations in 28 countries and 16 inter-governmental organizations
- AMIS focused on market information and transparency
 - Members from G20 ministries of agriculture + 7 invited countries
 - Secretariat made up of 11 international organizations
- NASA Harvest is NASA's Program on Food Security and Agriculture, launched in 2017
- Focus on increased uptake of satellite data by public and private sector for agricultural applications
- NASA's contribution to the GEOGLAM Program
- Over 45 partners from public & private sector





What is NASA Harvest?

Launched December 2017

- A new innovative NASA Applied Sciences program on Food Security and Agriculture
 - domestic & international focus
- Developing & implementing agricultural applications with a wide range of stakeholders
- Carried out through coordinated multi-sectoral consortium led by University of Maryland
- Connecting across NASA Applied Sciences & research program
 - e.g. SERVIR, Water Resources, LCLUC
- Providing inputs back to NASA on requirements and priorities
- Demonstrate socioeconomic benefits of earth observations for agriculture

For NASA the consortium approach is an experiment that is so far proving to be effective



Harvest OBJECTIVE

Empower decisions that support food security, stable markets, economic progress, and sustainable, resilient crop production, through:

- Advancing awareness & operational uptake of Earth observations
- Focusing on small holder and large-scale agriculture, from field to global scales
- Working at the intersection of Earth observation, land science, social science, & policy





Harvest Approach

- End user/stakeholder driven
- Forge strategic partnerships across sectors and geographies
 - Full data to decision chain
 - Innovate in linking stakeholder networks
- Leverage ongoing activities & enhance them
 - Focus on high impact and transition of research to operations
 - Mix of “application readiness levels” (ARLs)
- Build on the progress and international partnerships forged through GEOGLAM
- Coordinate with complementary initiatives and programs
- Demonstrate value and success & adapt and scale applications
- Articulate community priorities and gaps
 - Through thematic working groups





Why Use Earth Observations To Monitor Agriculture?



A New Era for Satellite Data for Agricultural Monitoring

- Satellite data offers cost-effective, timely, transparent, information on crop type, plant health, stress, productivity, all at the field to global scales, on a daily basis
- Major recent advances in data, cloud & super compute, and big data analytics are revolutionizing our capabilities and enabling realization of long-held promise for agricultural applications in support of decisions and policy



TIMELY

Landsat-7

GRACE-1
GRACE-2

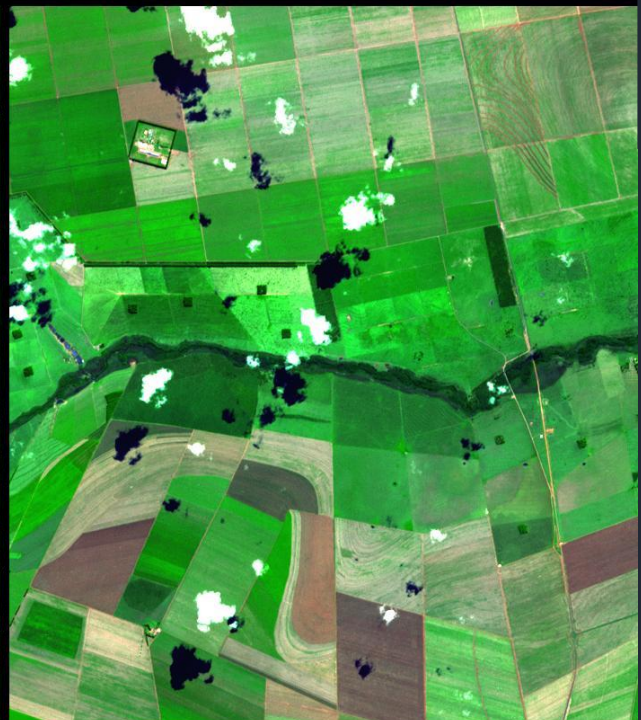
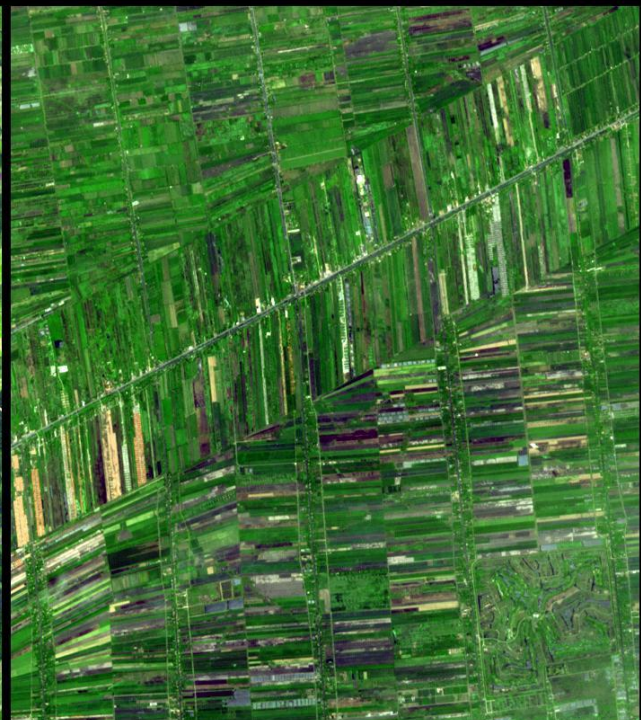
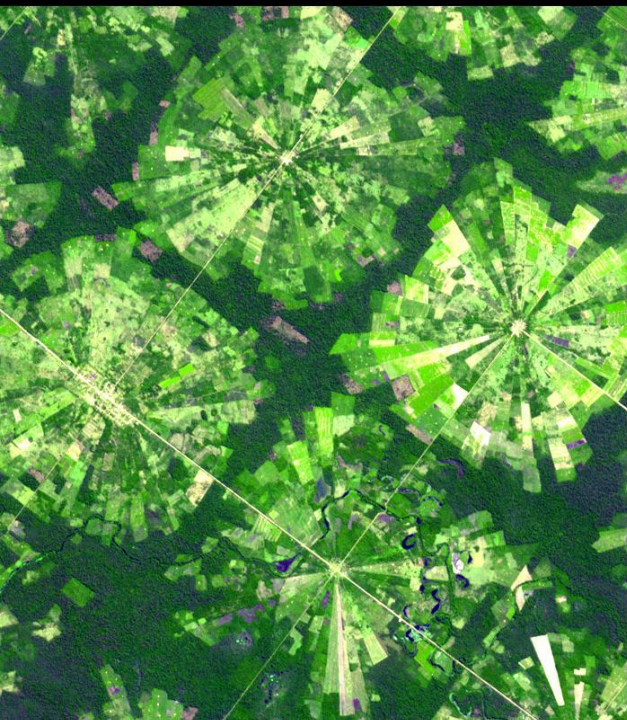
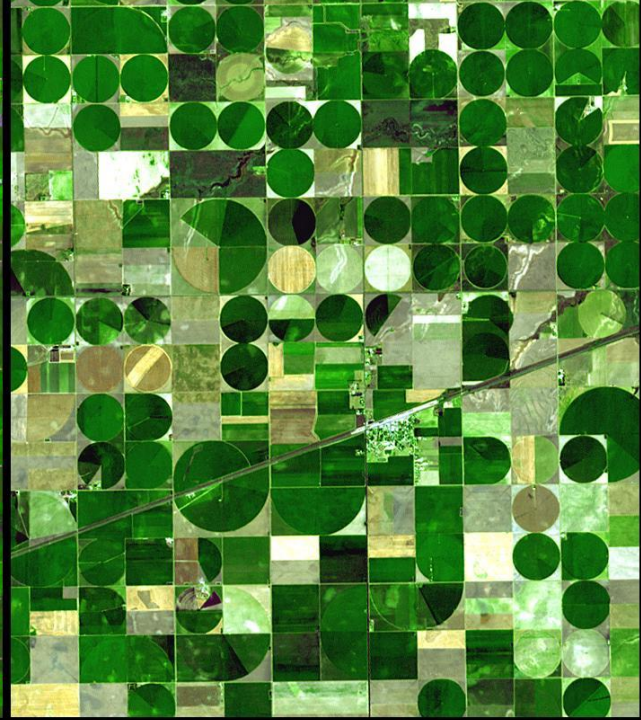
The Whole World Yesterday...



Cheap, systematic, transparent information at scale

Timely and accurate information is fundamental for increasing market transparency

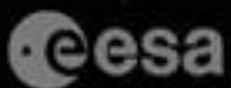




Challenge:
ROBUST
METHODS

for monitoring

DIVERSE
LANDSCAPES



A New Era for Satellite Data for Agricultural Monitoring

New satellite constellations revolutionizing use for agriculture, enabling global monitoring at field level on a near daily basis

250 Meter Resolution

30 meter resolution

3 meter resolution

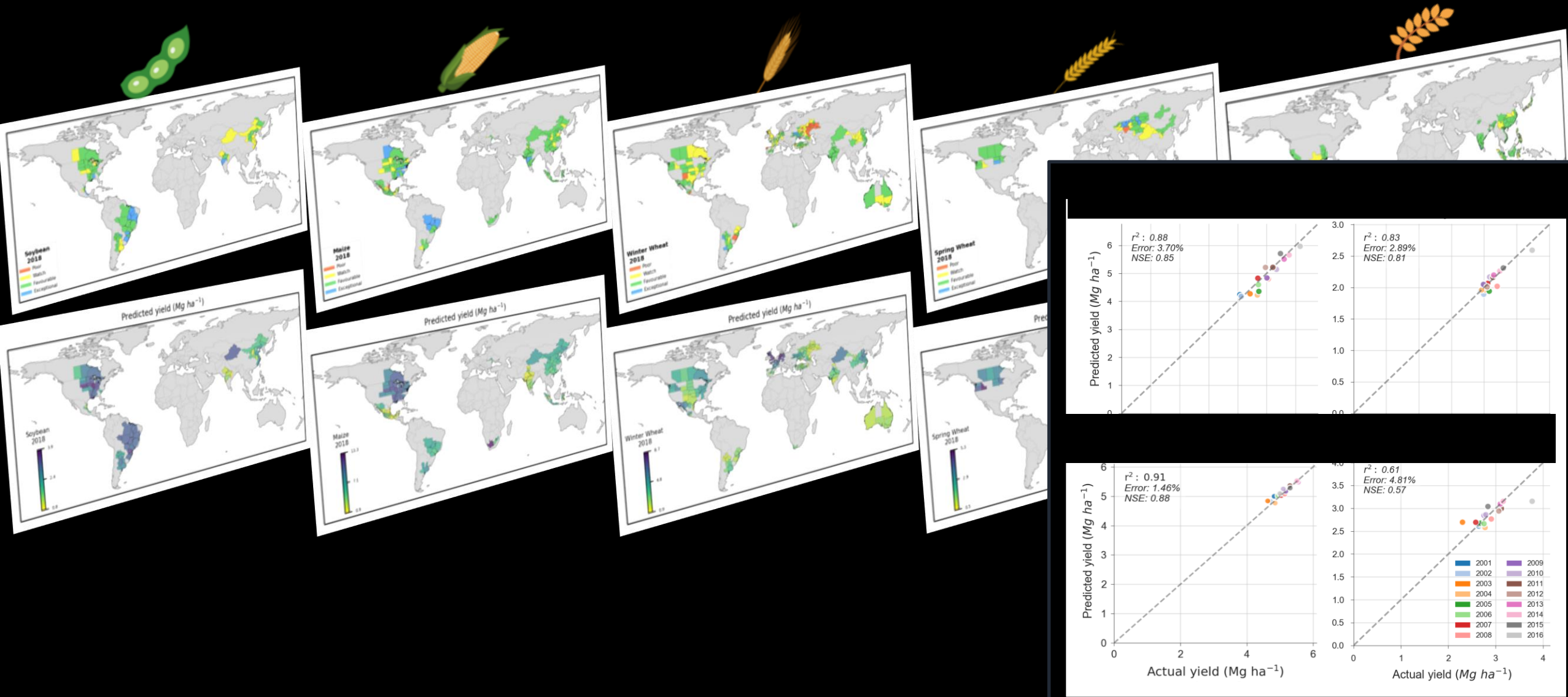
Traditionally relied on 1km-250m daily observations. Today we have 30m-10m every 2-5 days, and 3m daily are becoming routine!

MODIS

Landsat

Planet

Quantitative Yield Indicators for Major Producers: Global Scale



National to Sub-national Yield Forecasts

Major producers/exporters

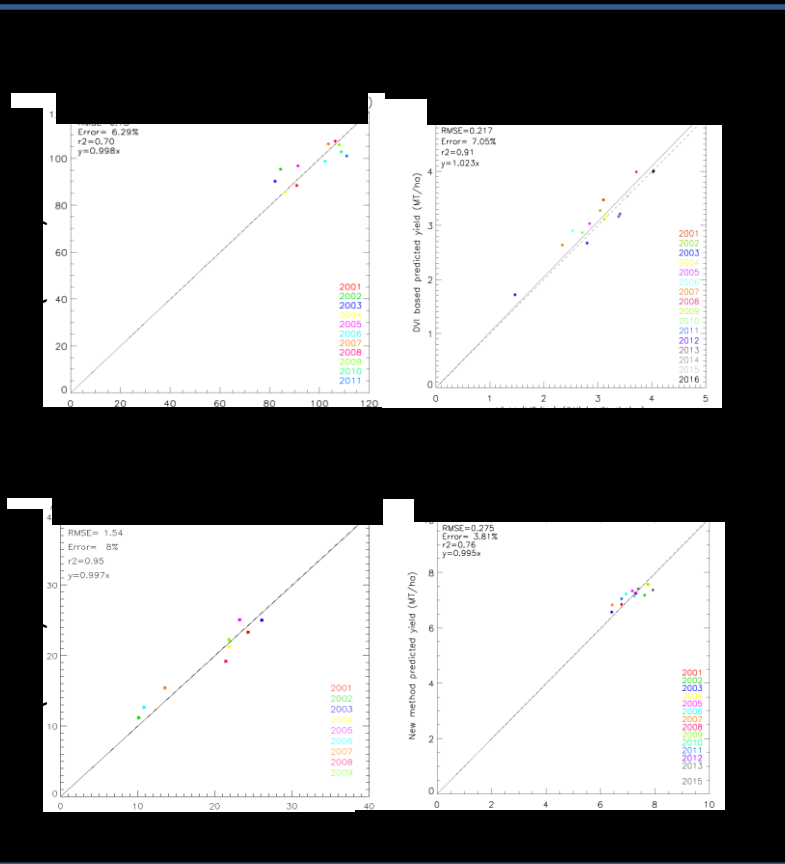
National Scale

3-8% error 1.5- 2 months prior to harvest

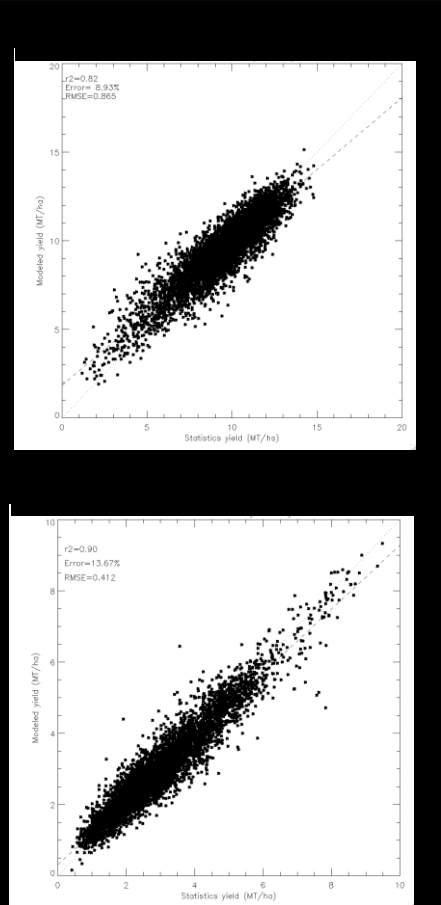
Sub-National Scale

8-14% error 1.5- 2 months prior to harvest

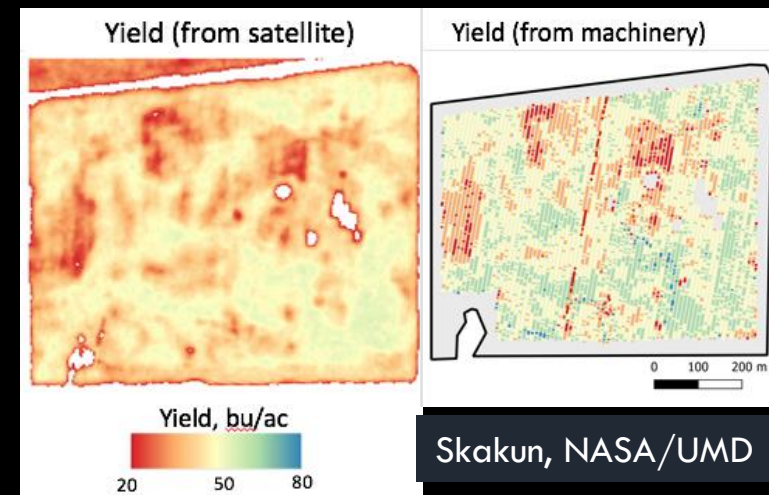
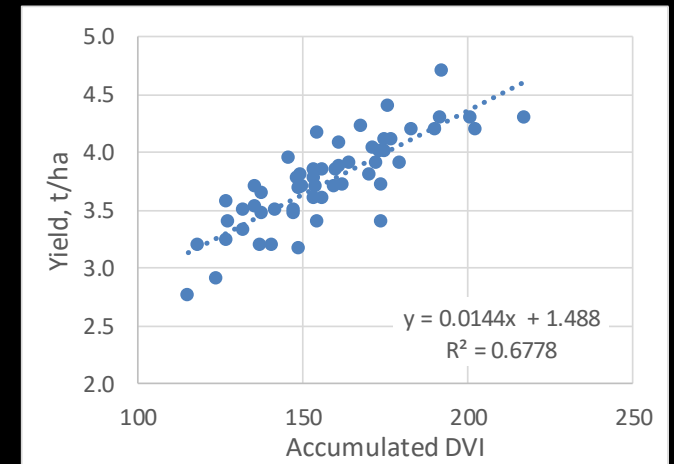
Field Scale Iowa



Franch et al, NASA/UMD

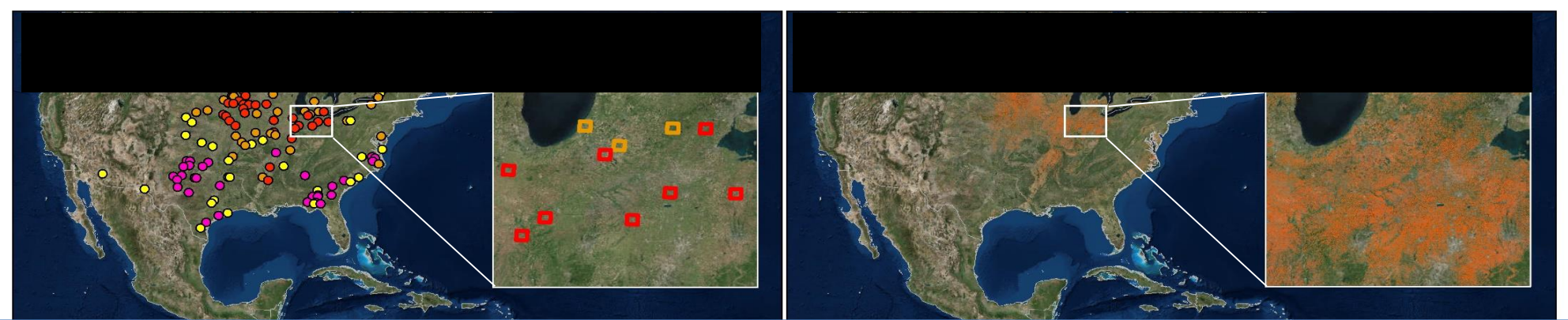


Franch et al, NASA/UMD

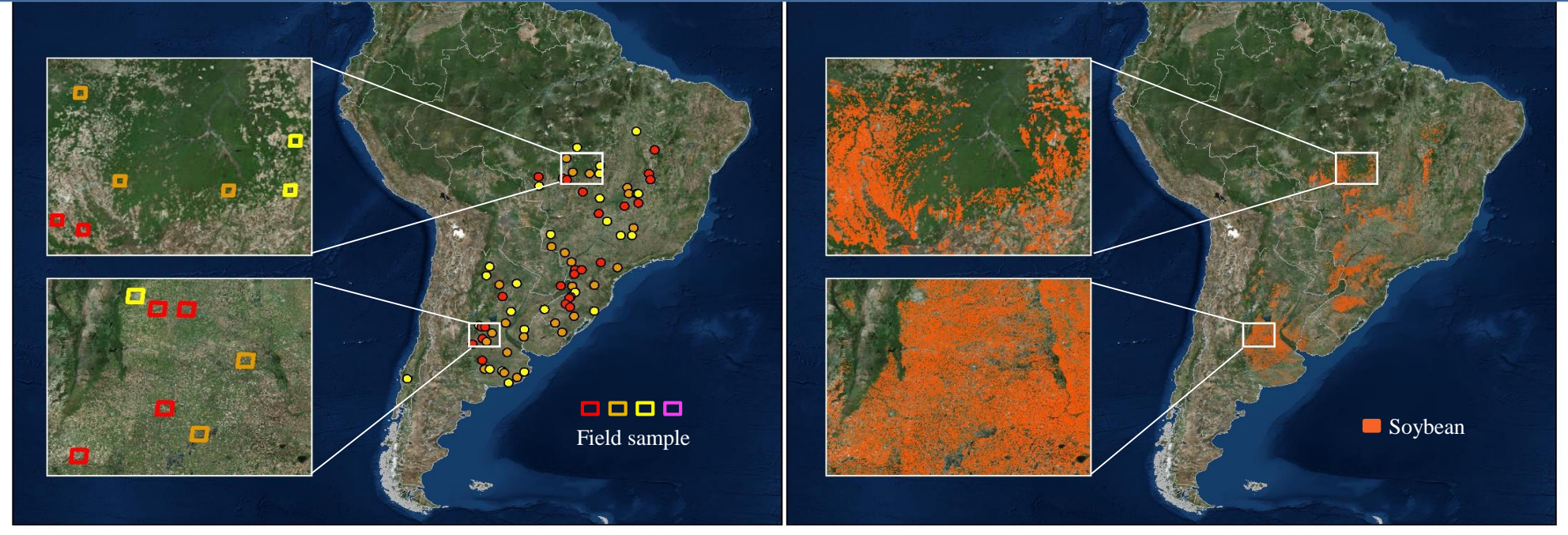


Skakun, NASA/UMD

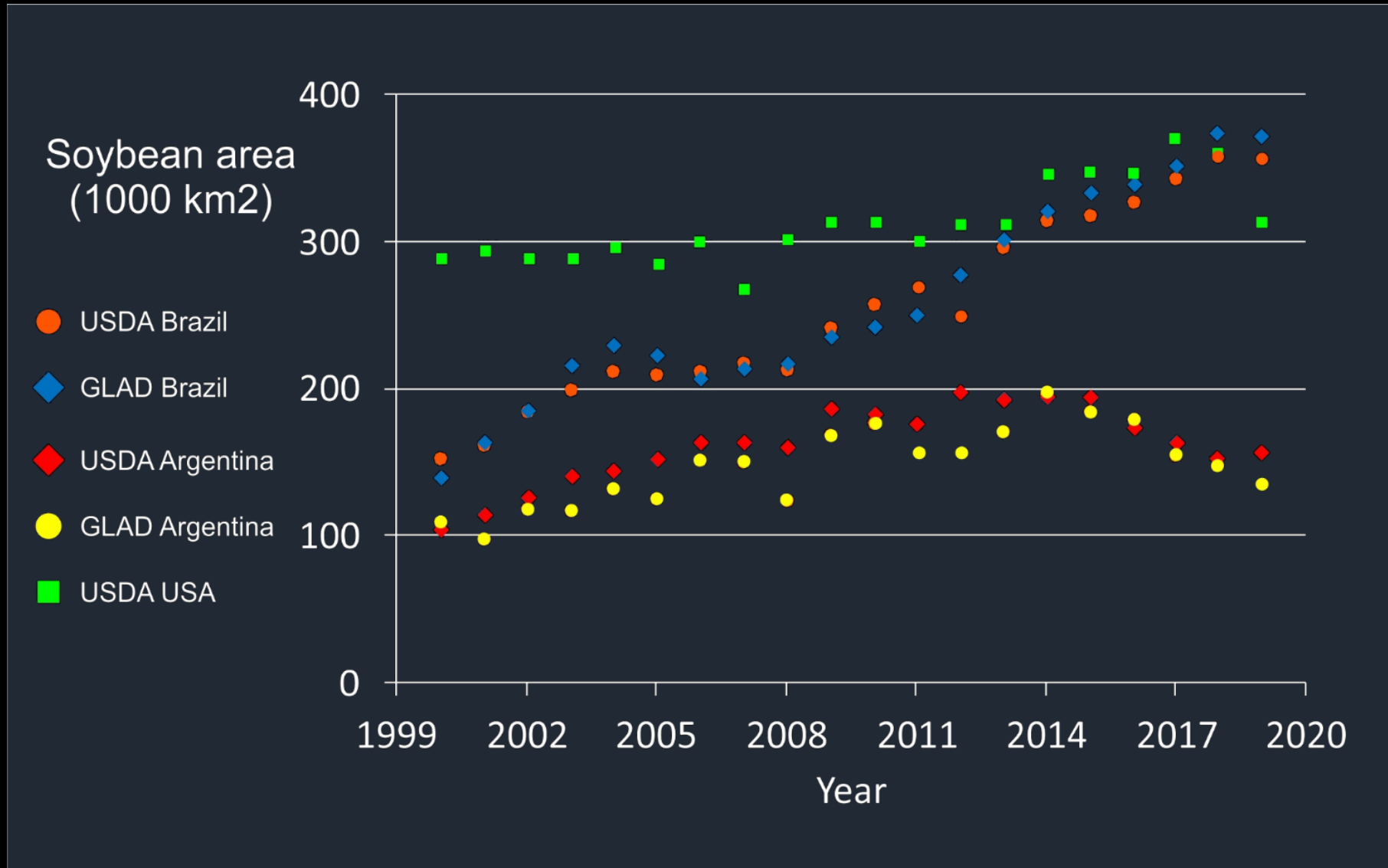
National-to-Continental Scale, In-season Crop Area Estimation & Mapping



Timely, cost effective, scalable, comparable across countries



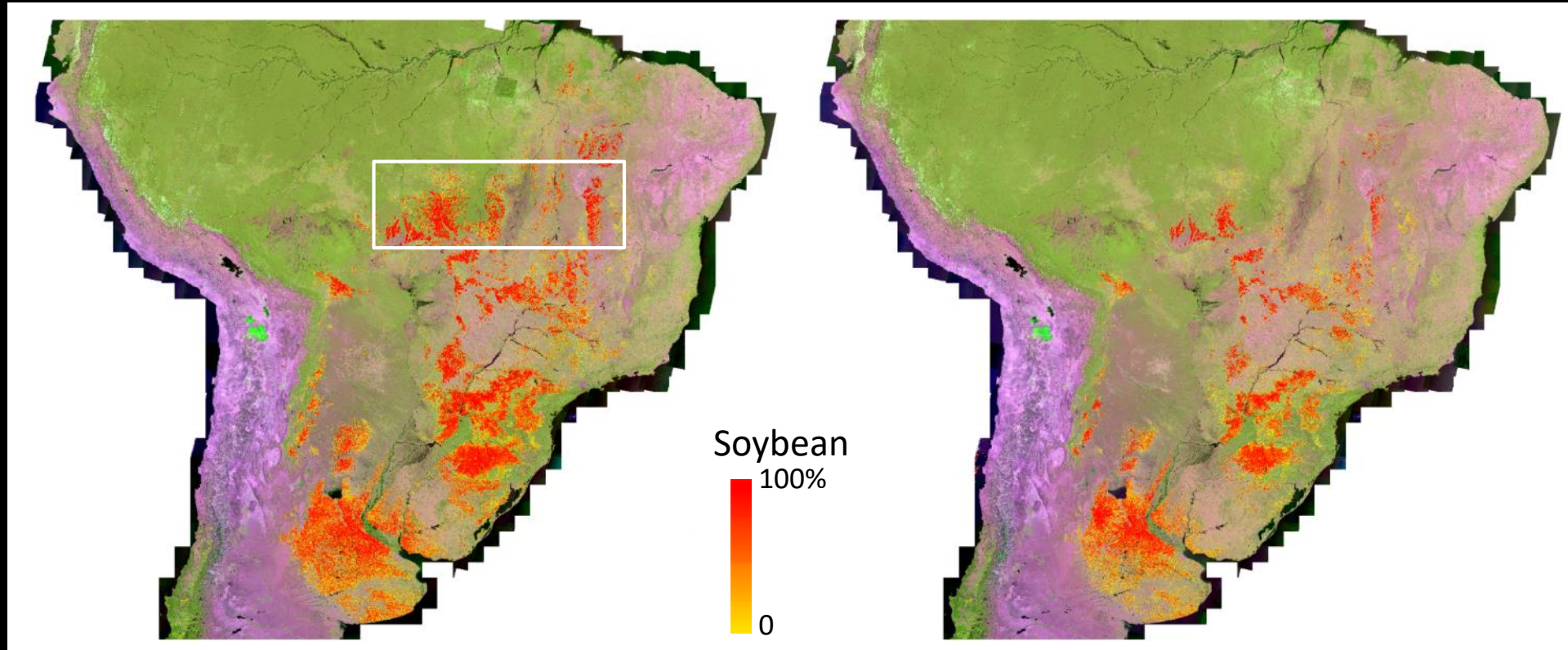
Comparison of GLAD (Satellite Driven) Soy Estimates vs. Official 2000 - 2019



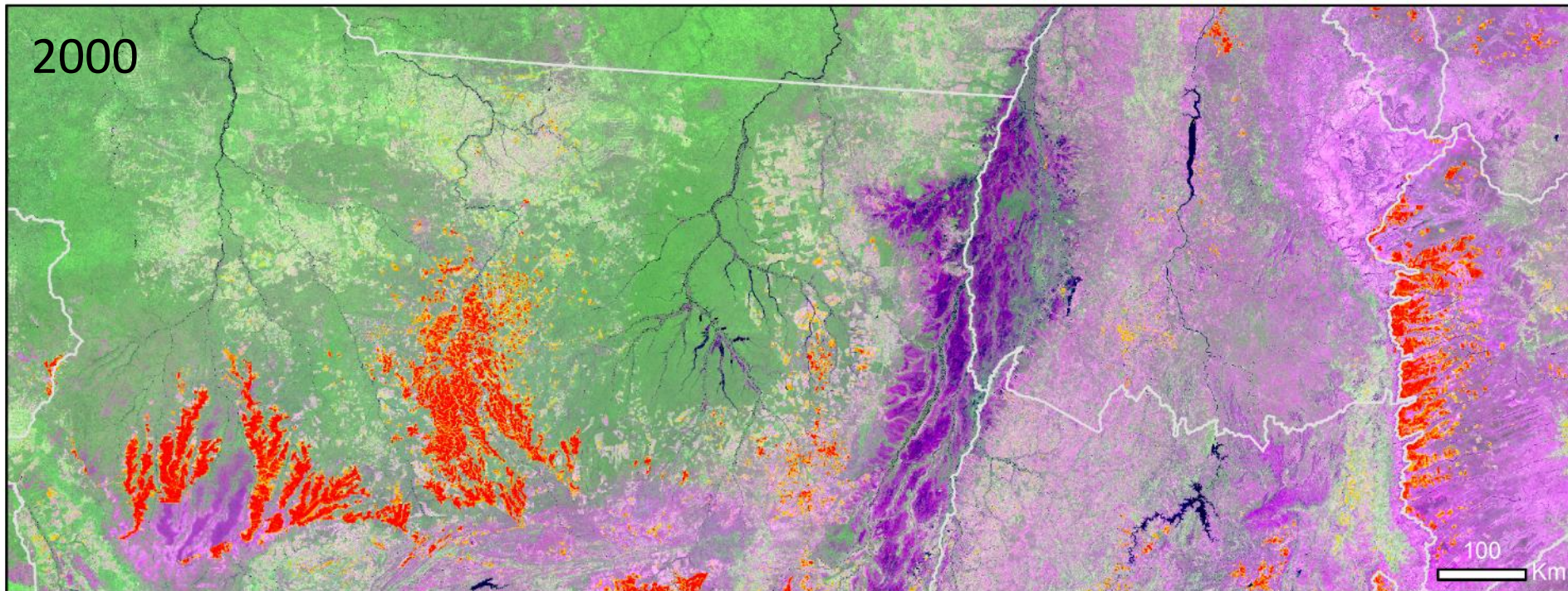
Soybean expansion 2000 vs. 2019

2019

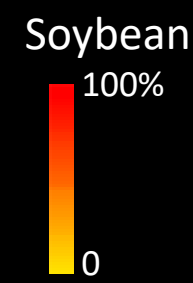
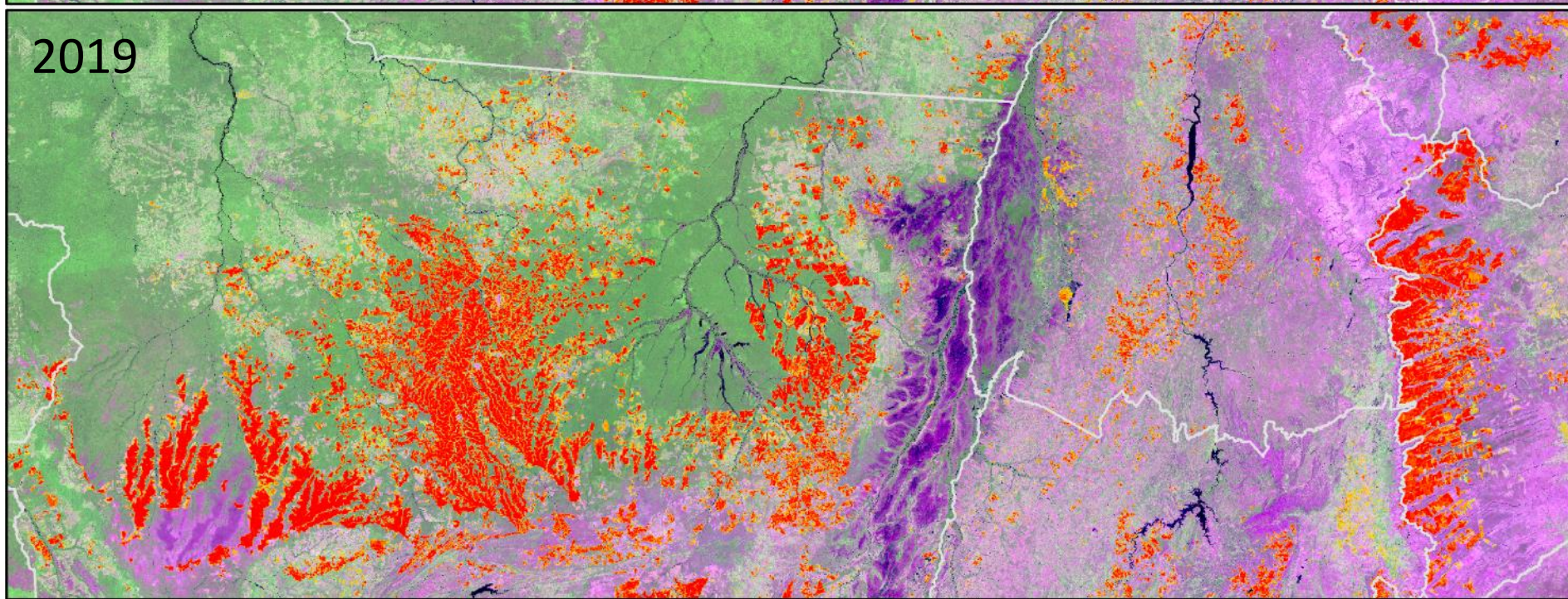
2000



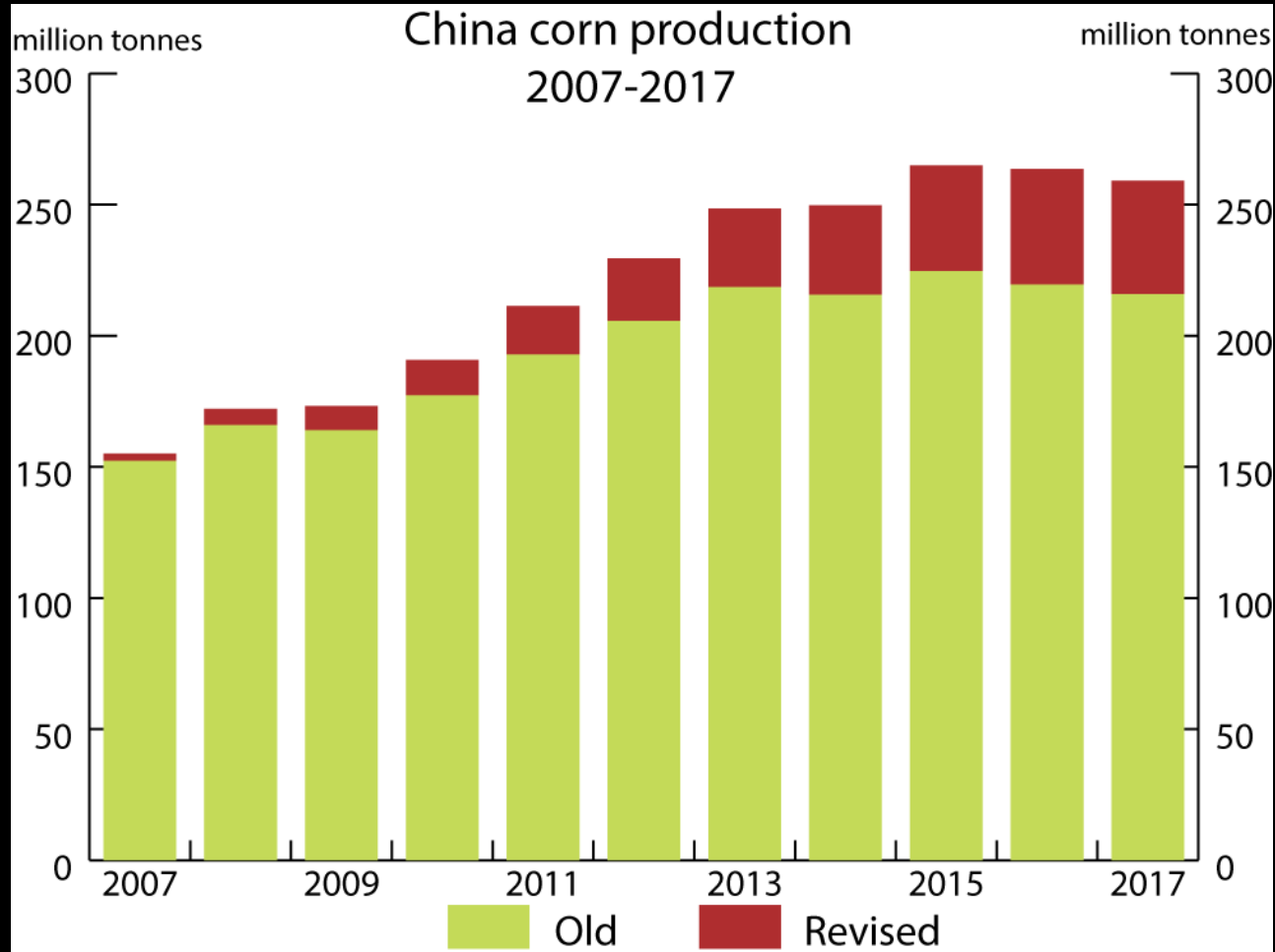
2000



2019

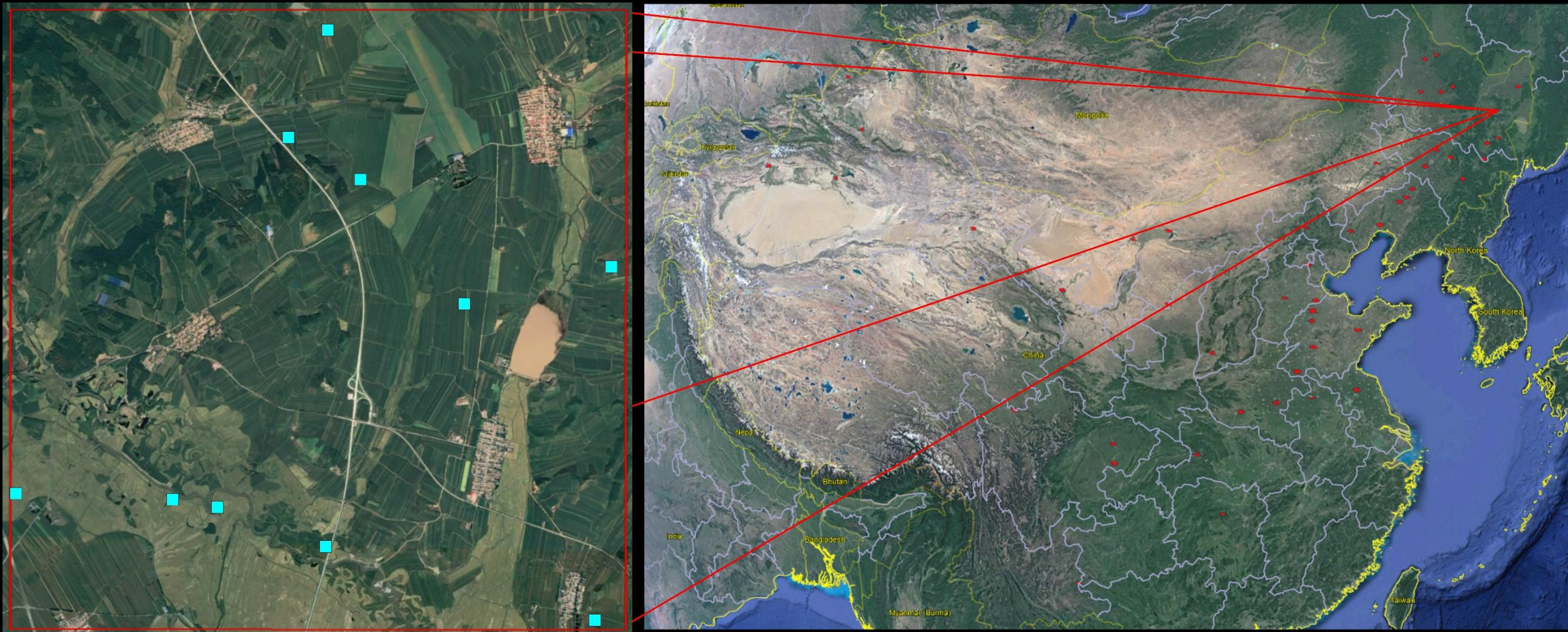


Application of same approach to the China maize area question



- In its 2017 Census, China sharply revised a decade of its agricultural statistics
- Given the uncertainty this sparked, AMIS asked GEOGLAM to look at the satellite data evidence to understand the current crop area in China and its distribution
 - Is the additional area concentrated primarily in the northern growing areas?
- Applying methodology implemented for continental scale soy area estimation in South America to estimate maize area in China using satellite data

Application of Approach to Cultivated corn area estimation of China



Example field site from Heilongjiang province



Example Harvest Activities

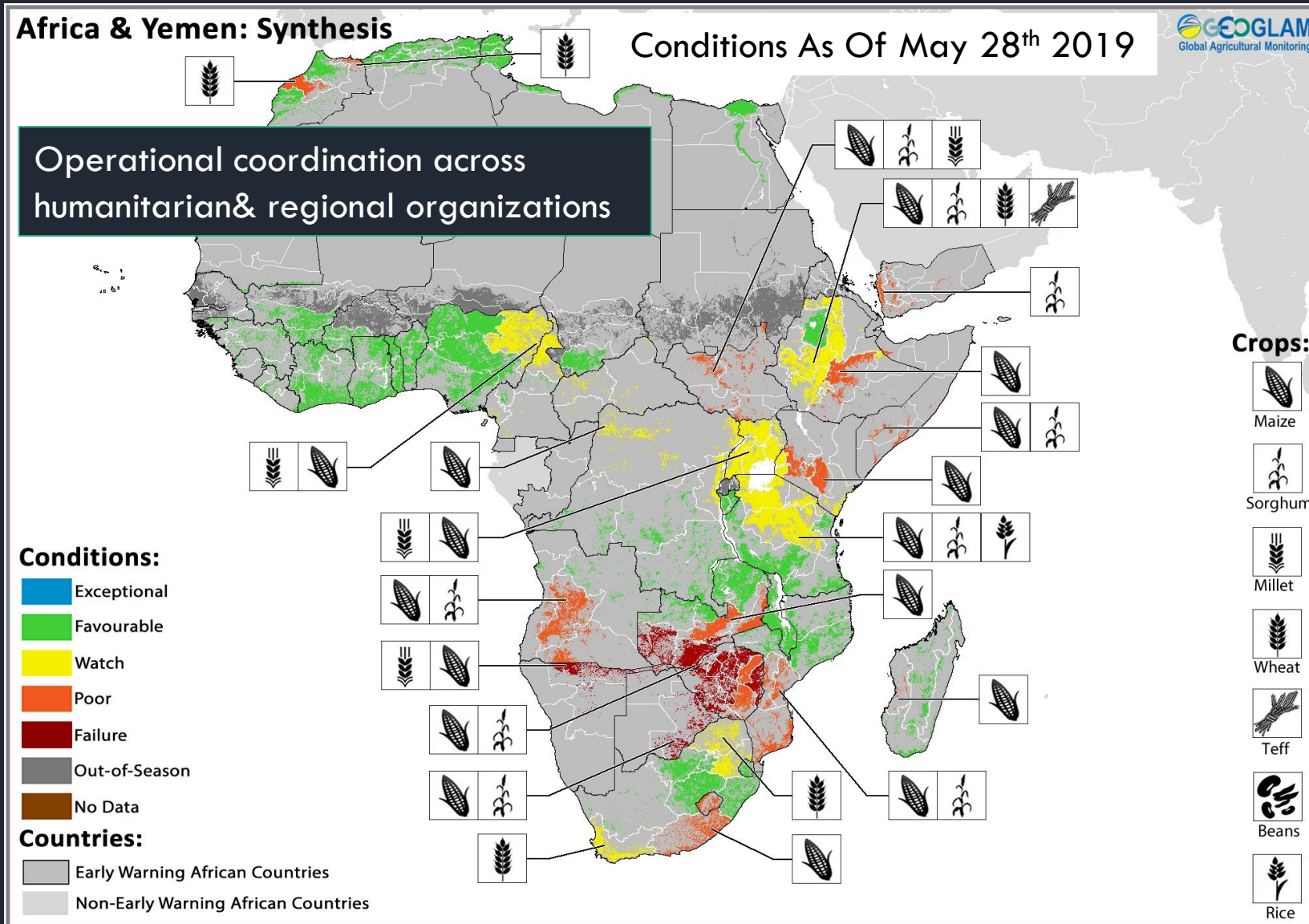
Food Security & Early Warning

Enhancing data and building capacity in support of food security decisions



GEOGLAM CROP MONITOR FOR EARLY WARNING

Timely, reliable, information on crop conditions, reducing uncertainty in support of food security decisions



No. 21 – October 2017 www.croponitor.org

Crop Monitor EARLY WARNING

Overview:
 In **East Africa** conditions are under watch due to dry conditions and impacts of fall armyworm infestation, while in **West Africa**, conditions are generally favourable despite some concerns due to ongoing conflict and dry conditions. There is some concern over winter wheat in **Southern Africa** due to dry conditions that are affecting the main producing areas. Crops are out of season across the **Middle East** and **North Africa** except in Egypt, where harvests have started and production prospects are favourable. In **Central and South Asia**, spring wheat harvest is complete and conditions are favourable with good yields received. In **Southeast Asia**, wet season rice harvest is ongoing with concerns from heavy rains and flooding during August and September. In **Central America** and the **Caribbean**, end of *primera* season conditions are favourable, with exceptional yields in eastern areas of El Salvador and Guatemala.

Contents:

- Conditions at a Glance..... 2
- East Africa & Yemen..... 3
- West Africa..... 5
- Southern Africa..... 6
- Central & South Asia..... 7
- Southeast Asia..... 8
- Central America & Caribbean..... 9
- Appendix – Terminology & Definitions..... 10

Assessment based on information as of September 28th

The Crop Monitor is a part of GEOGLAM, a GEO global initiative.

GROUP ON EARTH OBSERVATIONS

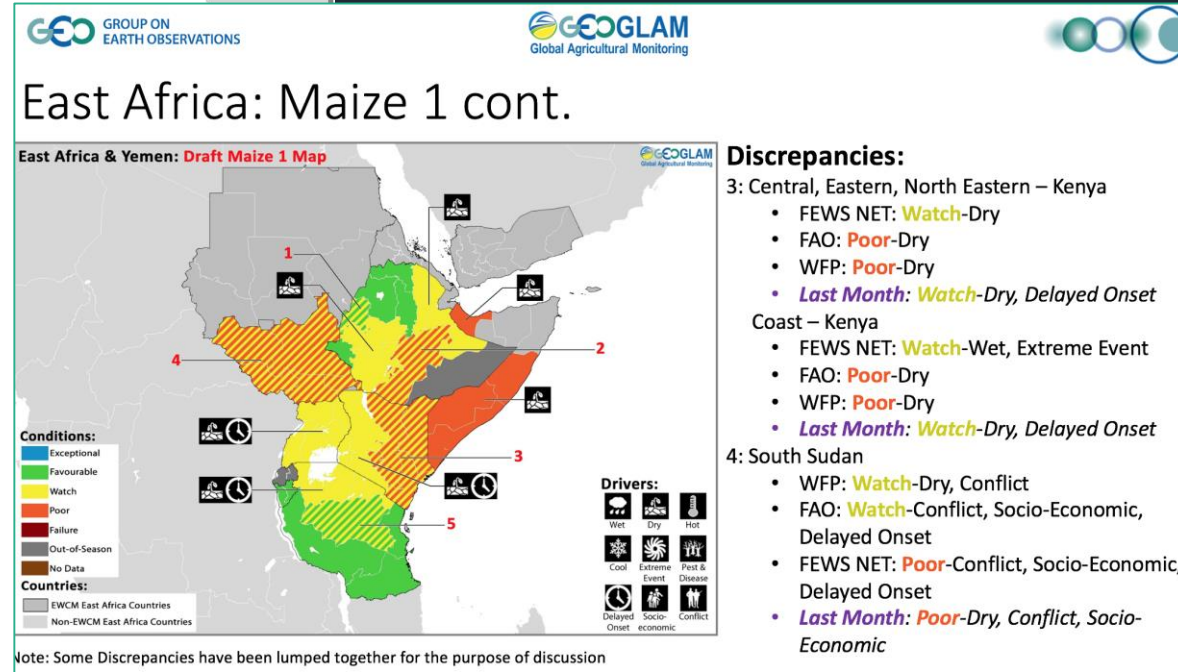
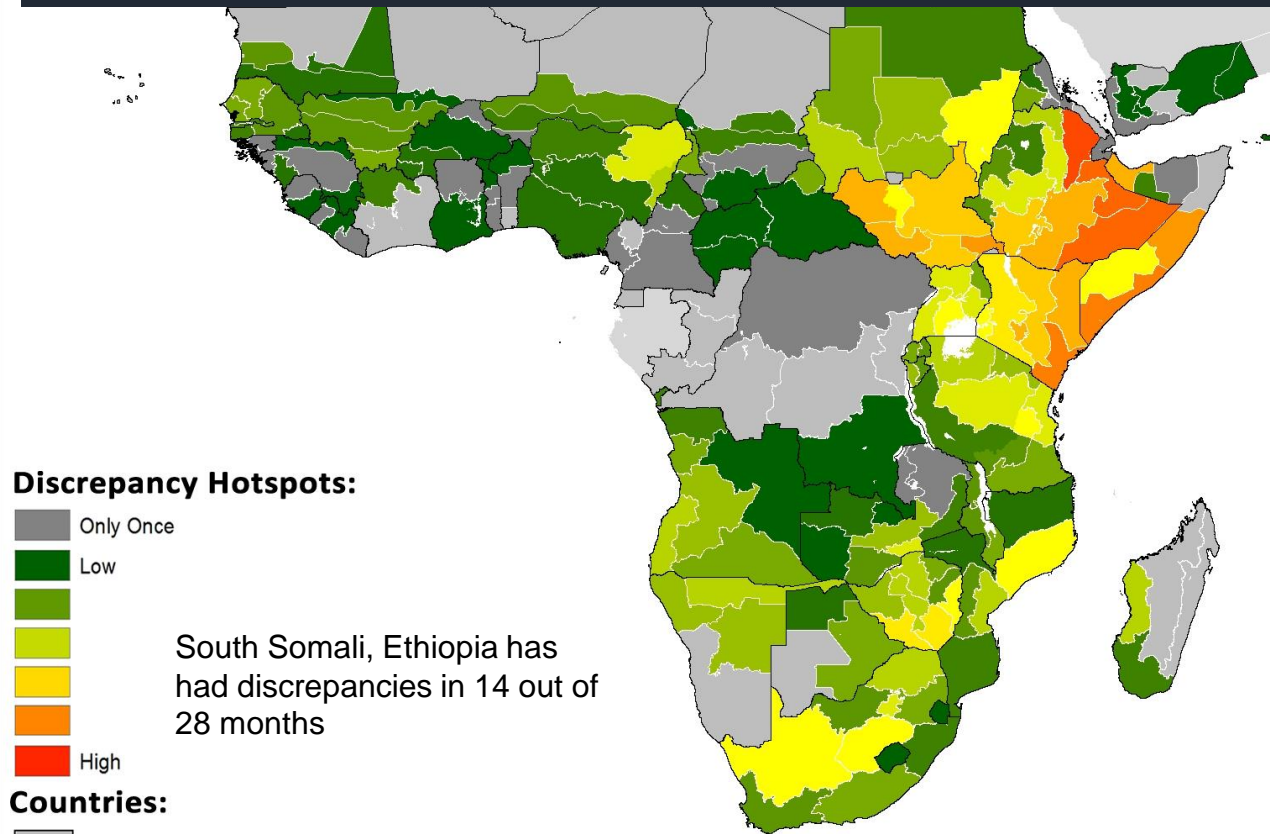
Inter-Agency Discrepancy Hotspots: April 2016- Sept 2018

Discrepancies Across Africa & Yemen: February 2016 - May 2019



Reducing uncertainty is critical for informing humanitarian and national food security decisions

Interagency Discrepancy example

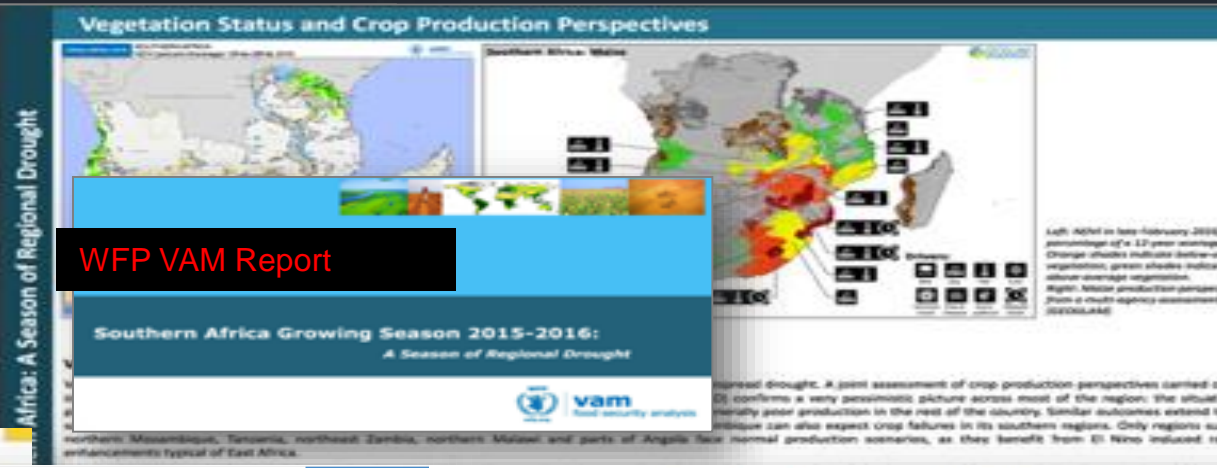


B. Barker & C. Justice



Business / Land & Agriculture
 Dry and brown Southern Africa will need food aid
 BY EMIKO TERAZONO AND ANDREW ENGLAND, FEBRUARY 15 2016, 05:52

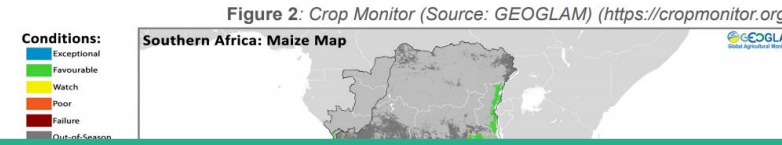
allAfrica
 Countries Topics Development BioTech
 Get Free NYC
 THE HERALD
 Zimbabwe: WFP Extends Food
 Tagged: Food and Agriculture • Aid and Assistance • International Organisations • Southern Africa • Z



FEWS NET
 SOUTHERN AFRICA Special Report
 Monitoring the globe
 A severe drought, related to El Niño, is ongoing in the current lean season. While April/May harvest is expected to be average, this report presents a pessimistic outlook for crop and livestock conditions.

United Nations Office for the Coordination of Humanitarian Affairs
 OCHA

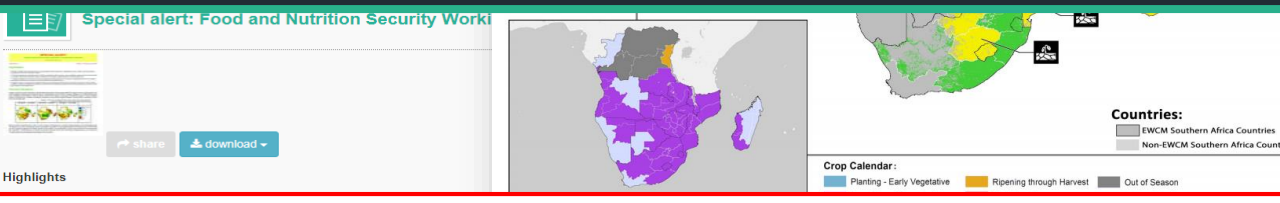
United Nations Office for the Coordination of Humanitarian Affairs
 OCHA



USED TO INFORM DECISIONS ABOUT ALLOCATION OF SPECIFIC RESOURCES BY NATIONAL GOVERNMENTS & HUMANITARIAN ORGANIZATIONS

Food Security
 Drought
 Trump Other Perceptions Of The Migrant Caravan

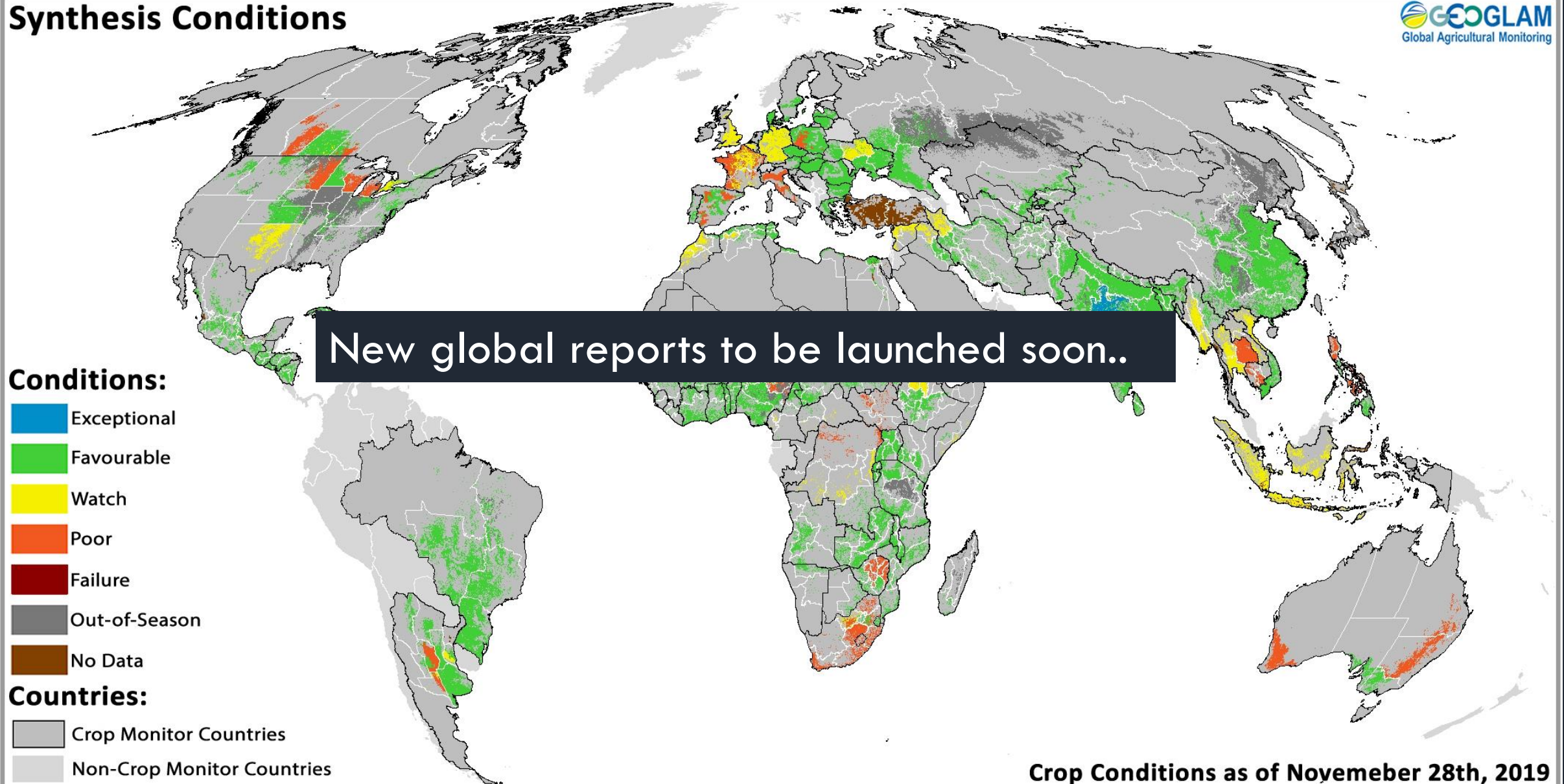
Financial Times
 Corn withers as record weather on food prices



Joint Statement
 El Niño Set to Have a Devastating Impact on Southern Africa's Harvests and Food Security
 WFP World Food Programme
 FEWS NET
 European Commission
 Food and Agriculture Organization of the United Nations

Current Global Crop Conditions

Synthesis Conditions



Example Harvest Activities

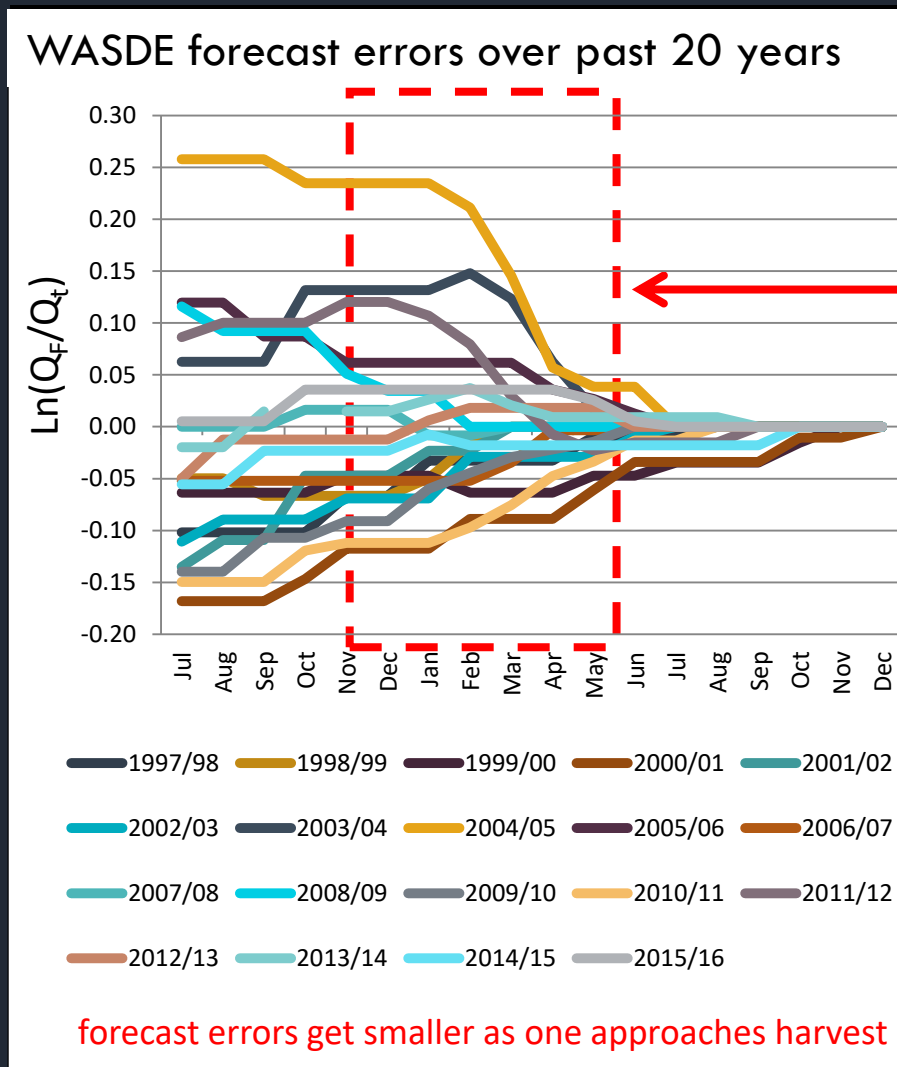
INTERNATIONAL MARKETS & TRADE

Reducing uncertainty & enhancing market transparency



Reducing Uncertainty During The Growing Season

Brazil Soybean Example



Opportunity window for Remote Sensing

Case Study: US Corn Belt, in-season estimations using Machine Learning and Artificial Intelligence



Credit: Julius Schaaf (Iowa farmer)



Importance of the in-season estimations US 2019/20

Table 1. NASS Planted Acreage Estimates (Thousand Acres)

| Commodity | Prospective Planting: | Acreage: | Crop Production (Re-survey of Acreage): |
|-----------|-----------------------|----------|---|
| | Mar-19 | Jun-19 | Aug-19 |
| CORN | 92,792 | 91,700 | 90,005 |
| SOYBEANS | 84,617 | 80,040 | 76,700 |
| WHEAT | 45,754 | 45,609 | - |

Data: United States Department of Agriculture – National Agricultural Statistics Service

I ILLINOIS
farmdocDAILY

Maize Futures Price and Simple Moving Average (Daily)

CBOT - Yellow - Nearby

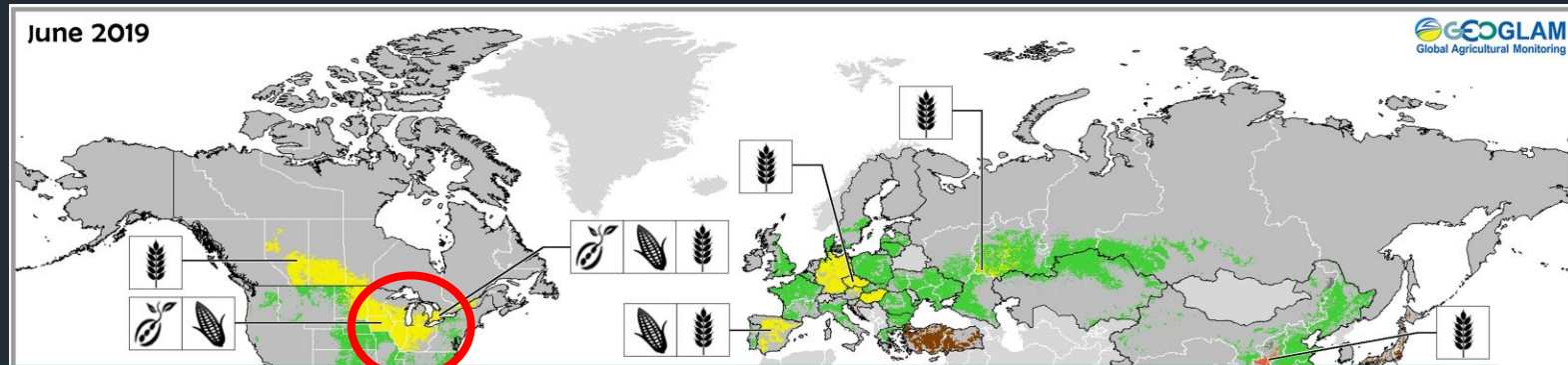


GEOGLAM Crop Monitor for AMIS

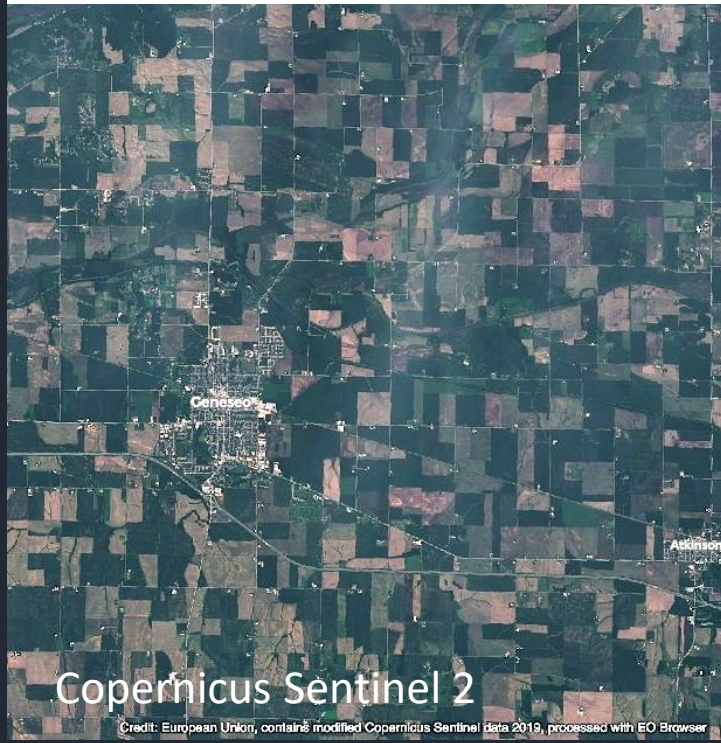


Contents

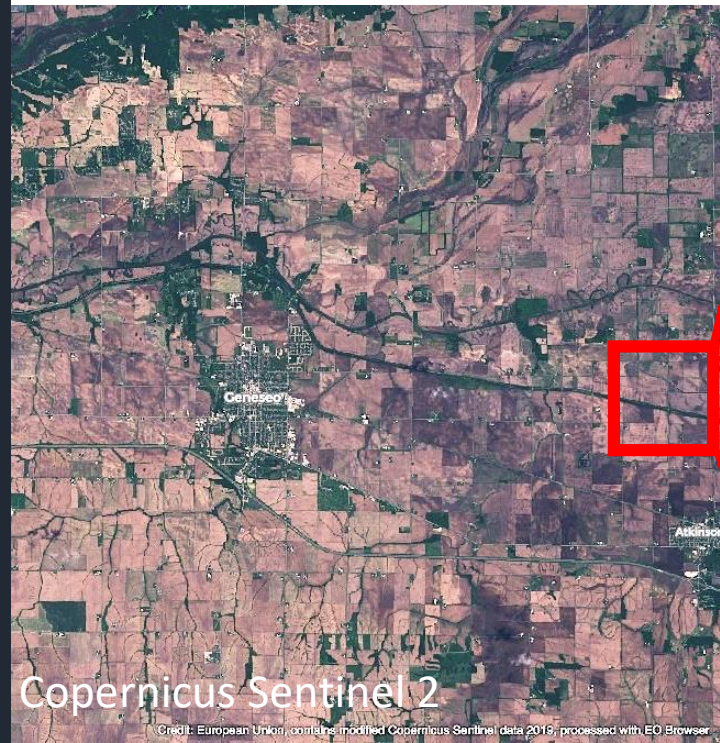
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| Feature article - Earth observations | 1 |
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JUNE 13th 2018
Northern Illinois



JUNE 13th 2019
Northern Illinois



July 25, 2018, Northern Illinois



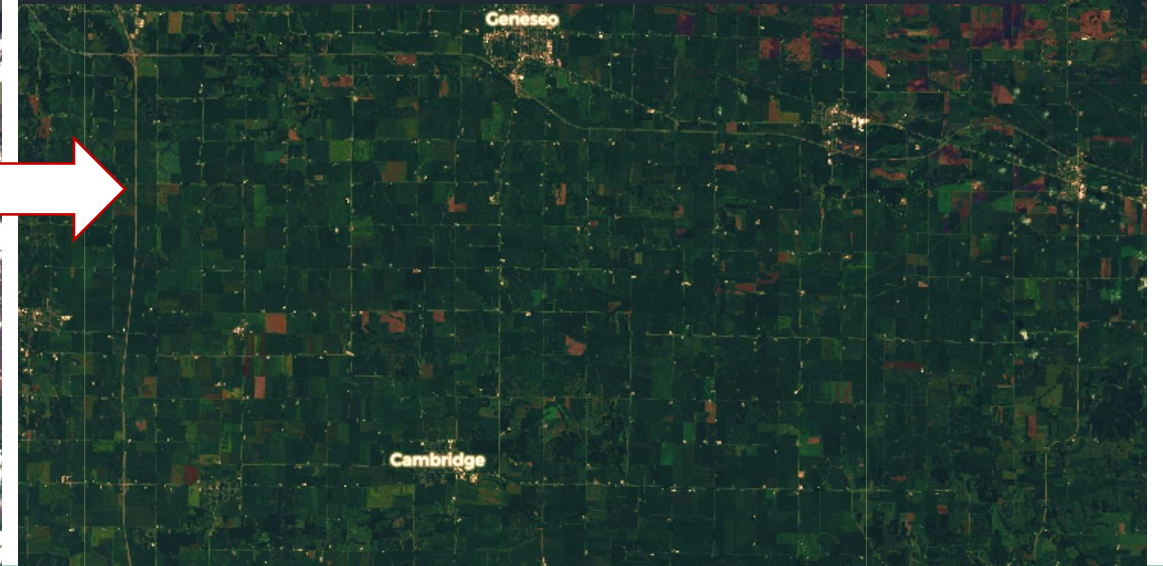
July 25, 2019, Northern Illinois



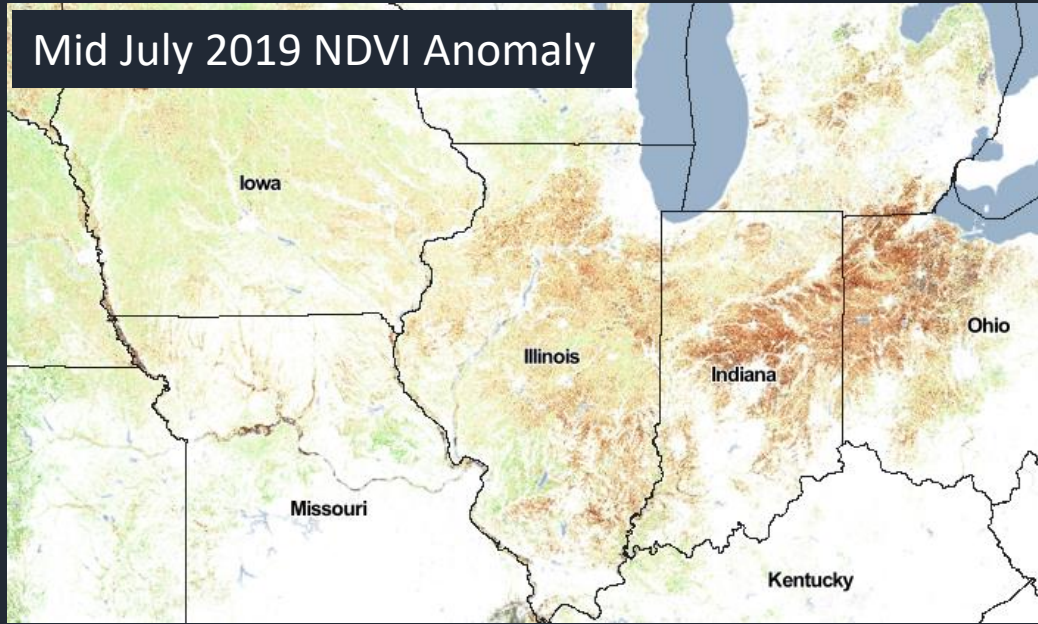
September 26, 2018, Northern Illinois



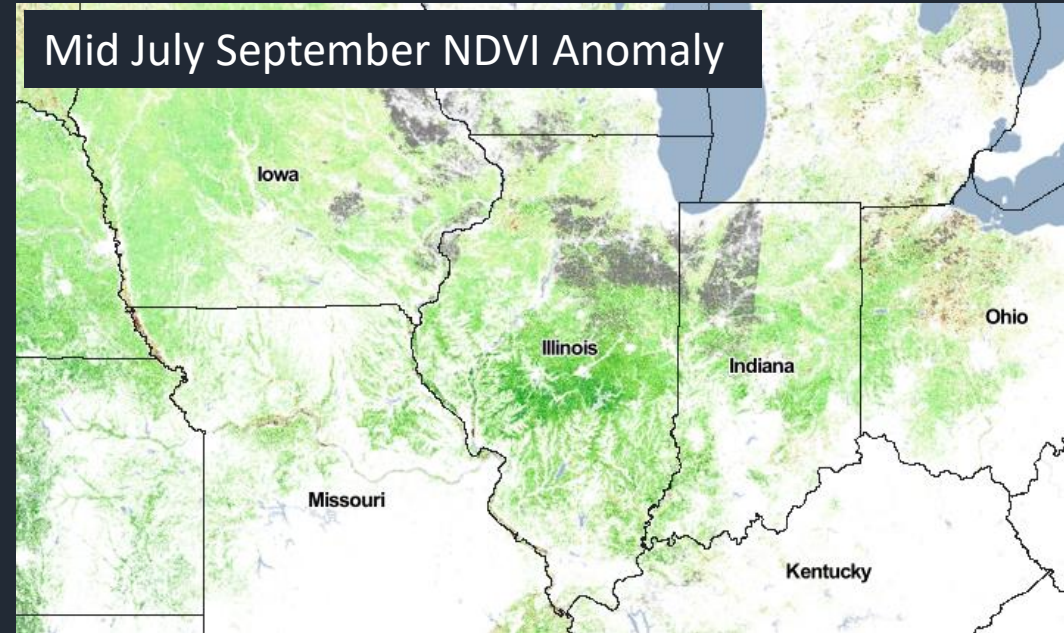
September 26, 2019, Northern Illinois



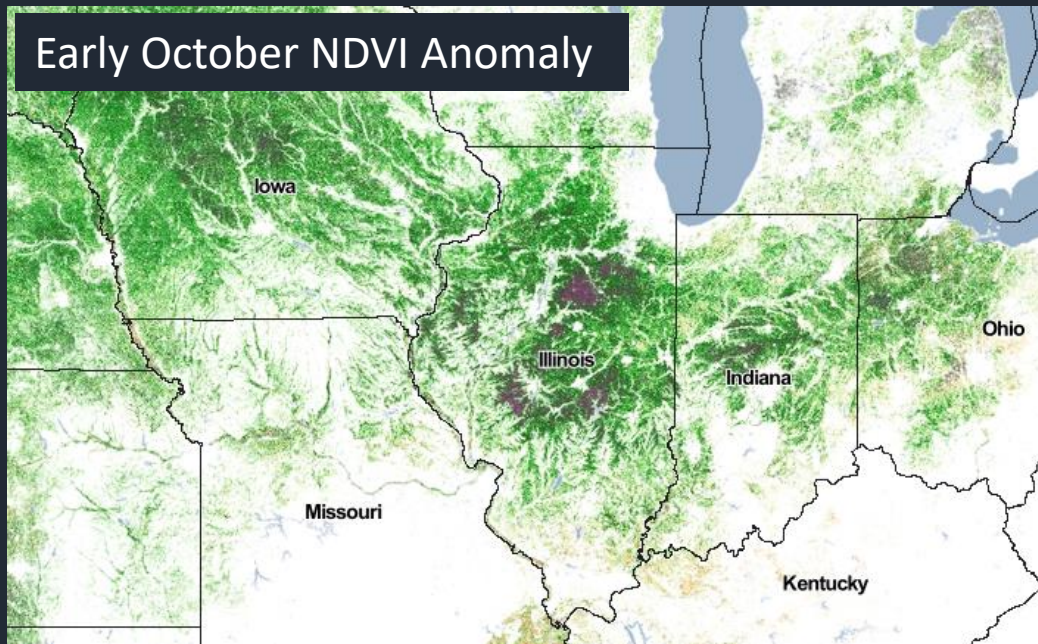
Mid July 2019 NDVI Anomaly



Mid July September NDVI Anomaly



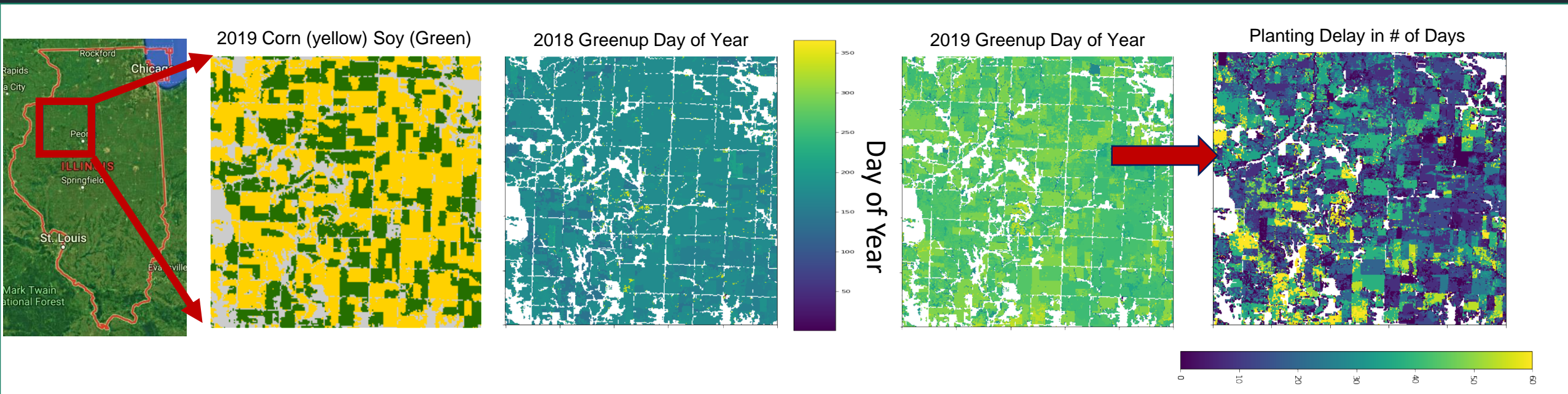
Early October NDVI Anomaly



- Comparison of crop vegetation in mid July, mid September and early October 2019 vs. average conditions over croplands
- Brown indicates crop biomass below average, green & purple are above average

HOW DELAYED WAS THE 2019 US Season?

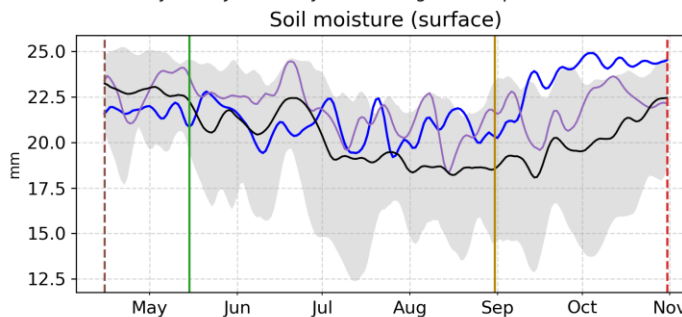
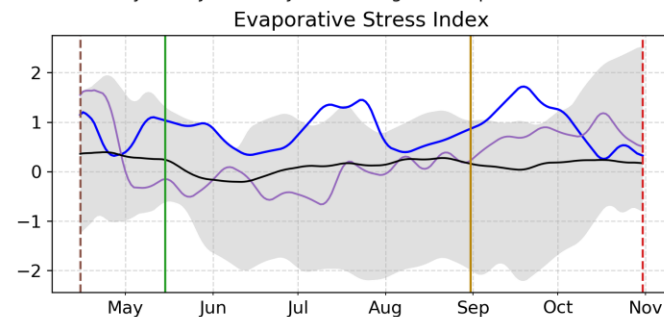
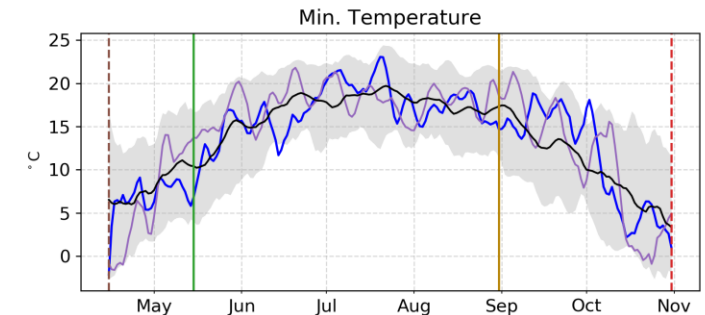
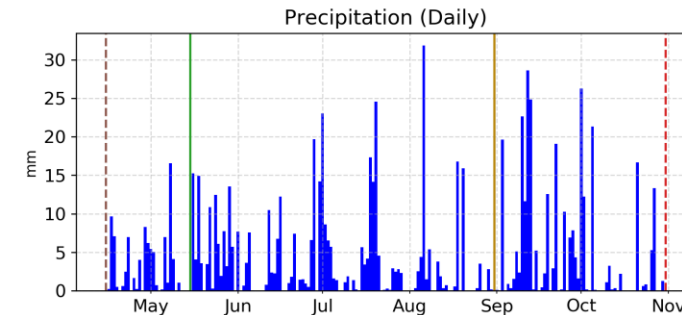
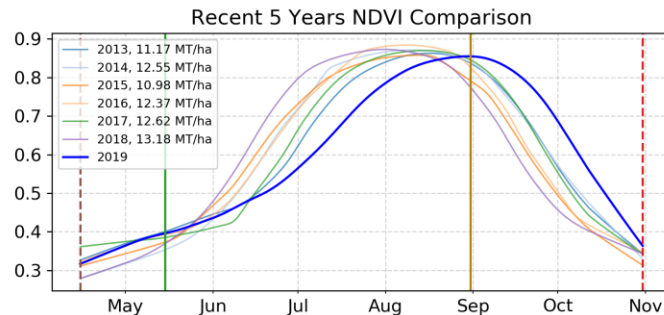
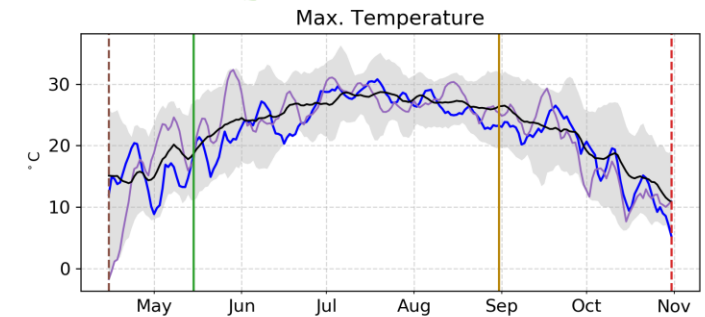
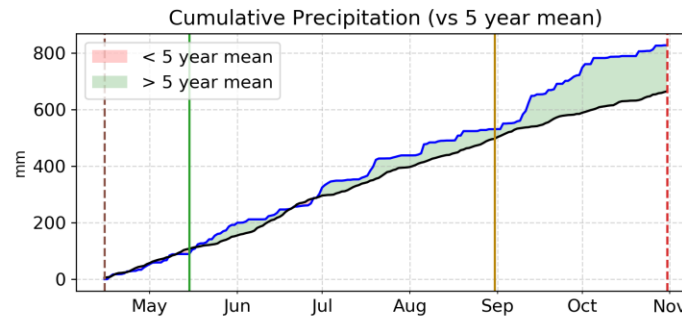
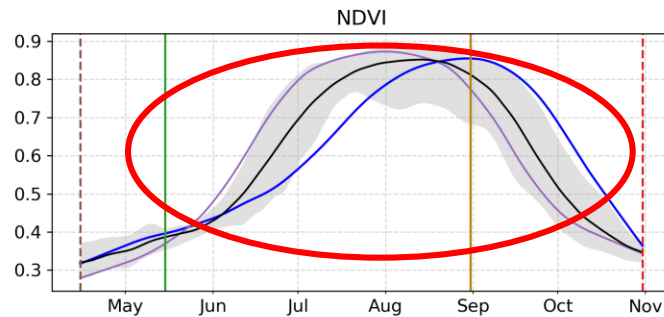
Field scale analysis of emergence dates, crop progress, and harvest dates
2019 Vs. 2018 crop emergence, Northern IL



- 2019 crops were planted much later
- Mean planting delay in 2019:
 - 26 days later than 2018 with some fields up to 60 days later

Development of the 2019 season in Illinois

Illinois (Illinois, United States Of America) Maize 2019



Legend

- 2019
- 2018
- 5 year Mean
- 10 year Min/Max
- - - Planting
- Greenup
- Senescence
- - - Harvest

Data Sources

- NDVI: UMD GLAM system
- Temperature: NOAA CPC
- Precipitation: CHIRPS
- Evaporative Stress Index: NASA ESI
- Soil Moisture: SMAP

▶ Crop growth stage dates are based on the 5 year average GEOGLAM best available crop calendars

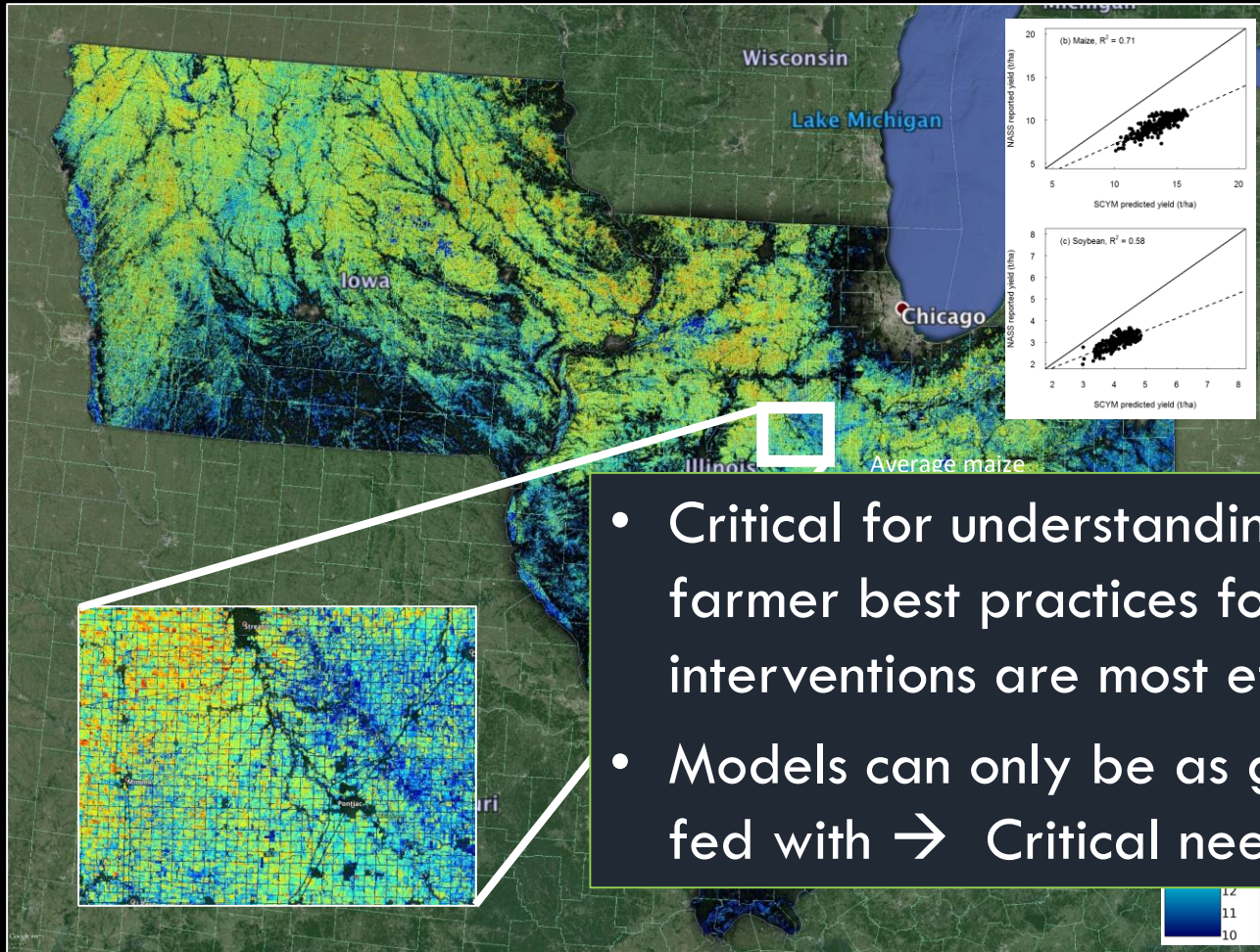
NASA Harvest GEOCIF forecast for US Corn: 166.1 bu/ac vs. USDA 167 bu/ac

Sahajpal et al. UMD

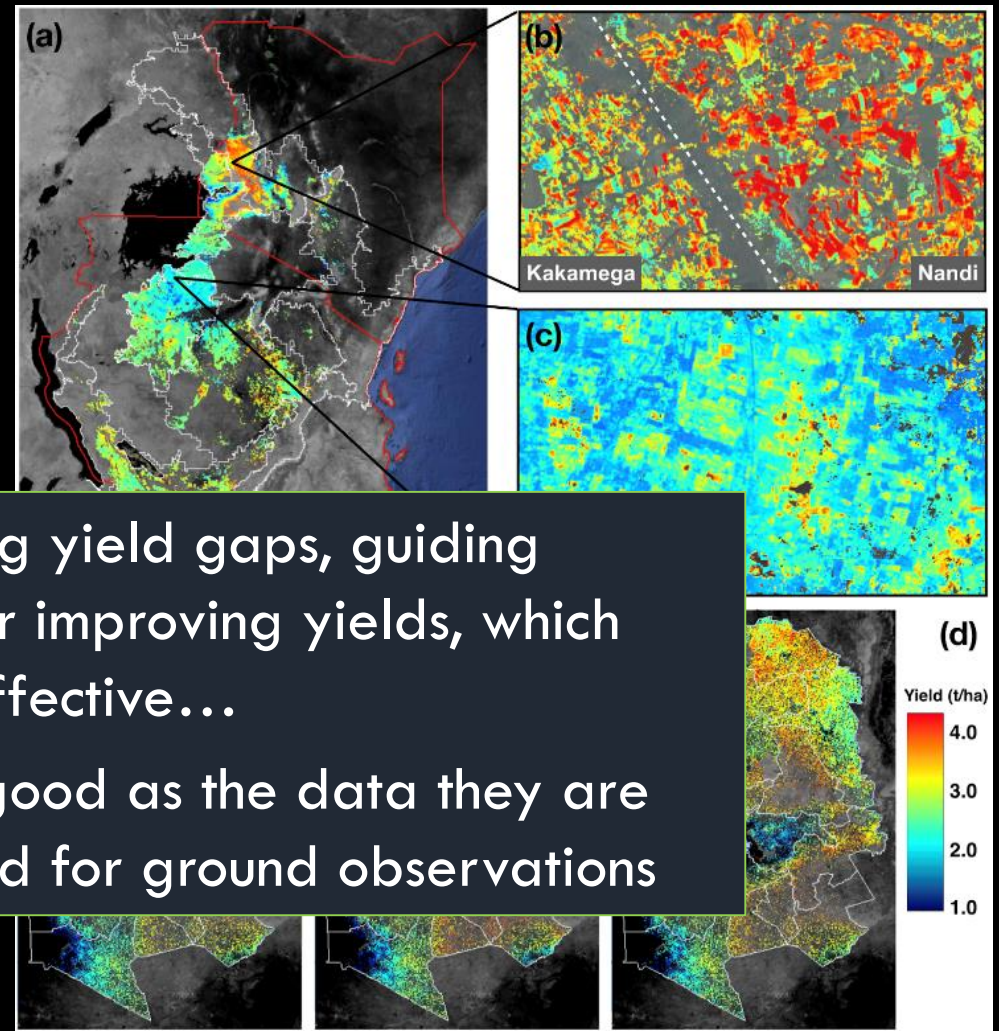


End of season Field Yield Indicators at Scale

US Corn Belt



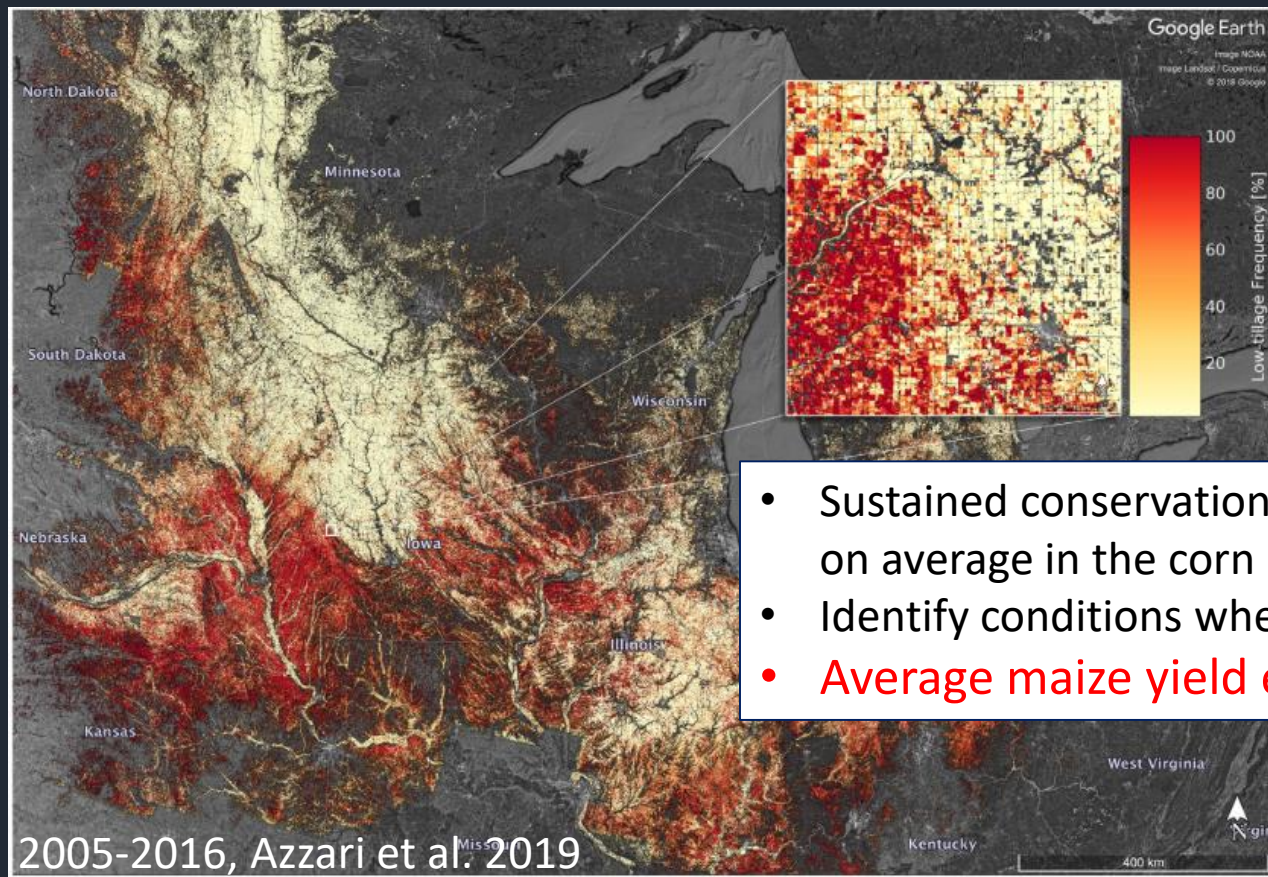
Tanzania and Kenya



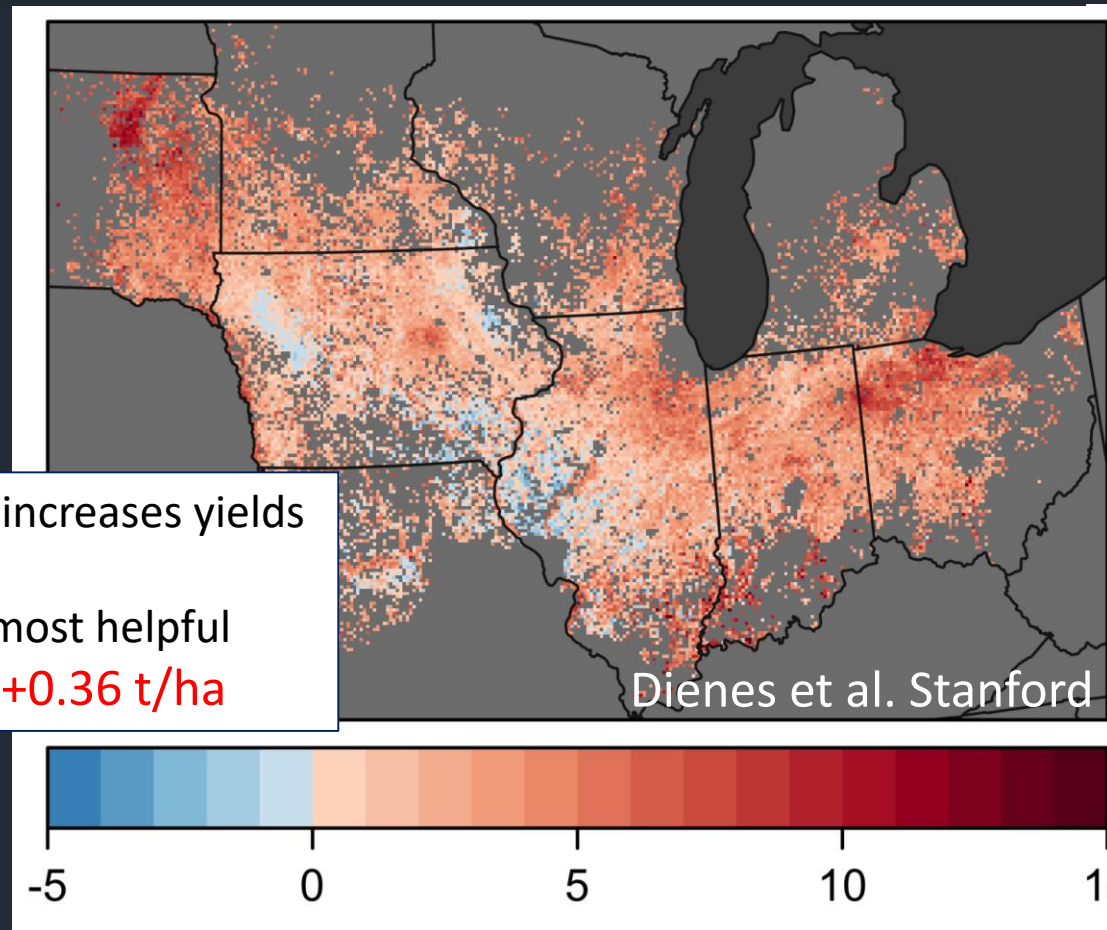
- Critical for understanding yield gaps, guiding farmer best practices for improving yields, which interventions are most effective...
- Models can only be as good as the data they are fed with → Critical need for ground observations

Assessing Conservation Tillage Impacts on Yields


Annual Field Scale Tillage Intensity Maps



Impact of Conservation Tillage on Yields



- Sustained conservation tillage increases yields on average in the corn belt
- Identify conditions where it's most helpful
- **Average maize yield effect: +0.36 t/ha**

Mean Maize Yield Impacts (%) 

Summary & Key Takeaways

- It's an exciting time for satellite-based agricultural monitoring
 - New era revolutionizing ability to provide accurate, timely, actionable info at scale
- Satellite data is playing an increasingly critical role across the agricultural sector, with a tangible impact on markets and trade.
- Realizing full potential & promise of satellite data requires:
 - Open sharing of data, information, methods and experiences
 - Stakeholder communities to drive the research and development
 - Innovation in science and technology
 - International collaboration and partnerships across countries, organizations, sectors, & disciplines
- NASA Harvest building on decades of investments by NASA & international community to radically advance uptake of satellite data for informing agricultural decisions across the globe

New data & technologies enable huge potential for progress, realizing it, requires close partnerships across research, policy and stakeholder communities



THANK YOU!

For More Information

Website: www.nasaharvest.org

Twitter: [@NASAHarvest](https://twitter.com/NASAHarvest)



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