



# Wheat Rust Early Warning Systems in Ethiopia

## – Using New Technologies to Combat Crop Disease

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(on behalf of many partners)  
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# Overview

- What are wheat rusts and why are they a problem?
- Why do we need early warning?
- How can new technologies play a role – now and in the future?



# An Increasing Threat

## – Transboundary Pathogens & Pests

- **Rate of spread, appearance in new areas, detection of new races (new diseases) is increasing**
  - Drivers: Globalization (trade, travel), Selection pressure (uniform cropping systems), climate change



Stem Rust



Yellow Rust



Wheat Blast



Maize Lethal Necrosis



Fall army Worm

Pathogen Surveillance & Monitoring Systems increasingly needed.

# Wheat Rusts: Combating Cereal Killers

*Highly mobile pathogens, extremely destructive and constantly changing!*

## Stem (Black) Rust

- Most destructive disease on wheat, historically the most feared disease
- Under favourable conditions, capable of causing 100% crop loss within weeks
- Re-emerging as a disease of concern



Wheat crop killed by stem rust, Ethiopia Nov 2013

## Stripe (Yellow) Rust

- Significant increase in spread since 1960
- Est. 5.47 million tonnes loss/yr (US\$979 million / yr)

Source: Beddow et al 2015 *Nature Plants*



Yellow Rust Epidemic, Ethiopia



# Ethiopia



- Largest wheat producer in sub-Saharan Africa
  - Major staple & strategic food security crop
  - About 5 million households dependent on wheat
- 
- A hotspot for rusts (stem & yellow rust)
  - Recurrent epidemics due to new races
  - Wheat rusts the major biotic constraint for wheat farmers
  - A gateway for new rust races in and out of Africa



# Controlling Rust Outbreaks

- Surveillance and monitoring are essential
- Early detection and control are critical in preventing outbreaks
- Control Options:

## 1. Resistant Varieties

- Ideal option
- Long-term control
- Ideally durable resistance, but resistance often breaks down (new races)



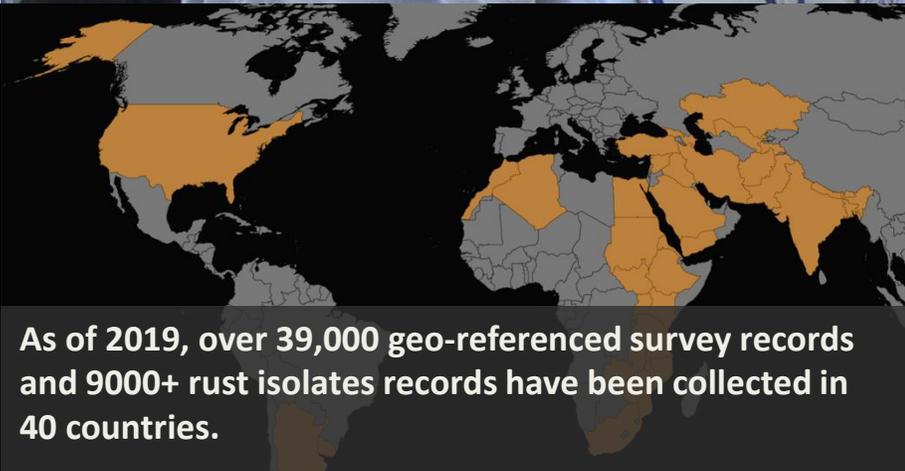
## 2. Fungicide Control

- Only option if resistance breaks down
- Short-term control
- Ideally want limited and optimal use



# SURVEILLANCE AND MONITORING

DRRW/DGGW partners operate one of the world's largest international crop disease monitoring systems.



The surveillance system provides early warning of potential rust epidemics to scientists and farmers.

As of 2019, over 39,000 geo-referenced survey records and 9000+ rust isolates records have been collected in 40 countries.

CIMMYT senior scientist Dave Hodson teaches field survey protocols to SAARC trainees.



Cornell University

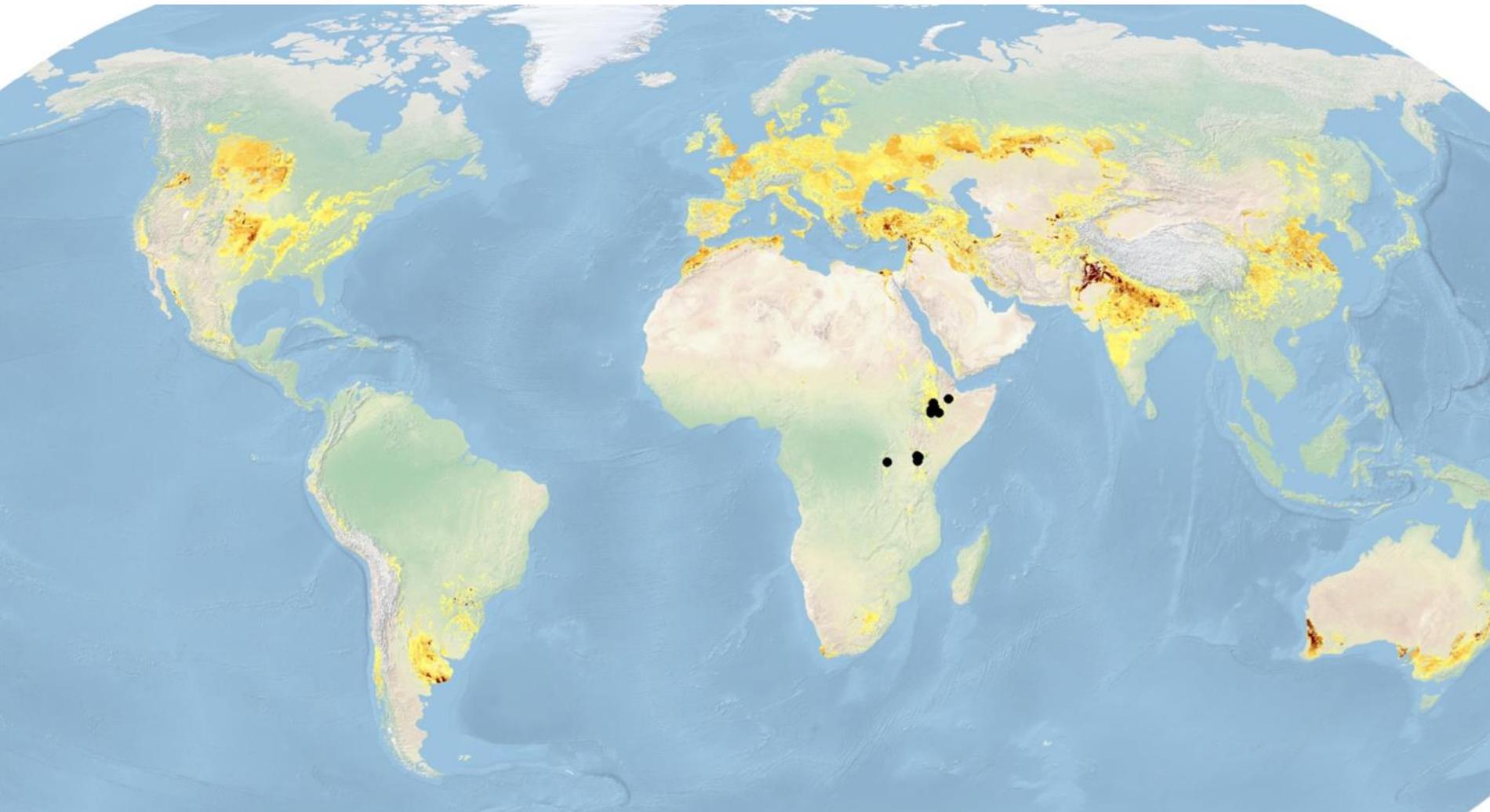
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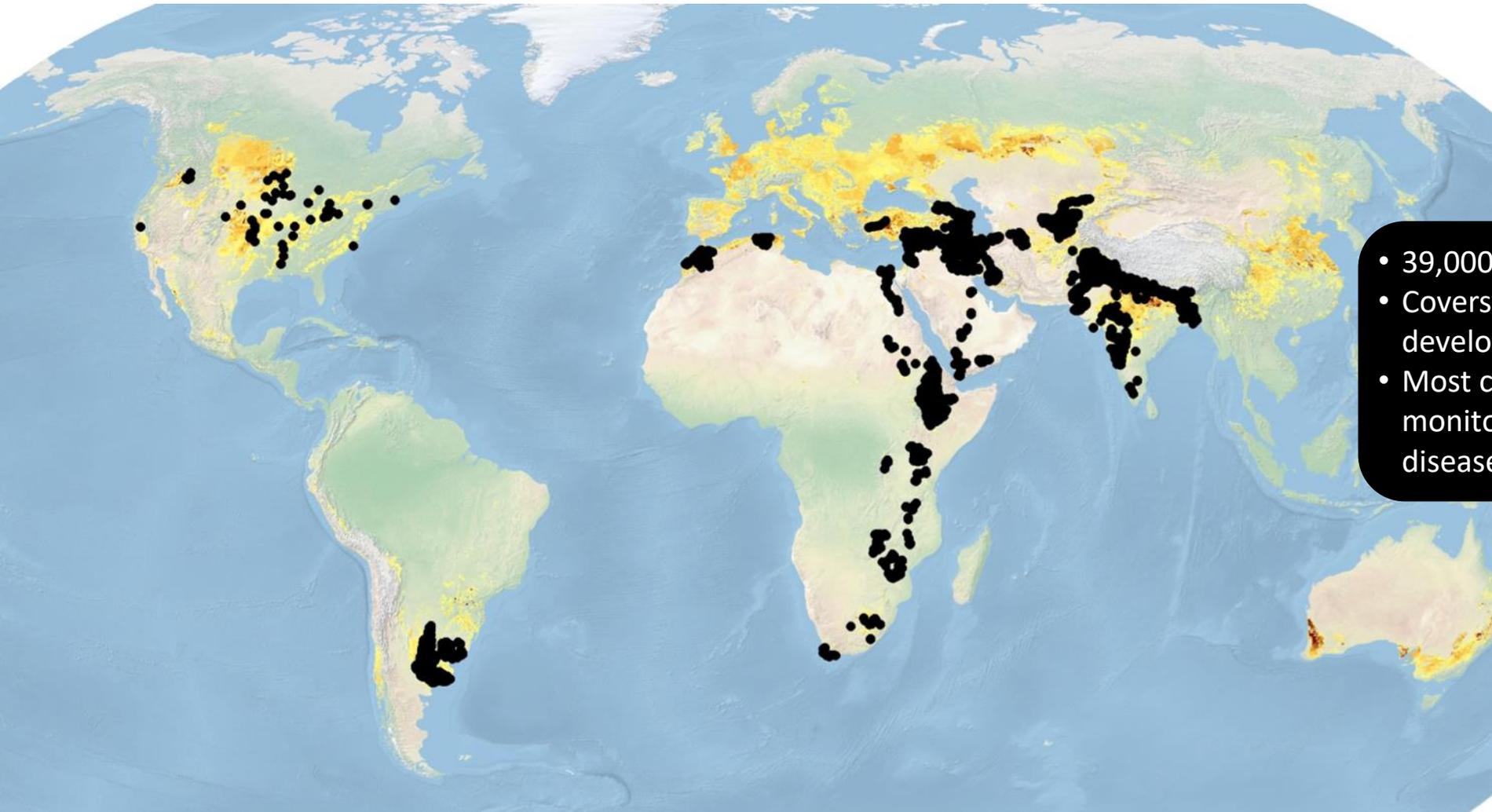
CIMMYT<sup>MR</sup>

# Global Wheat Rust Monitoring

2005



# Global Wheat Rust Monitoring 2019



- 39,000+ survey records
- Covers 40+ countries: large % of developing world wheat
- Most comprehensive, operational monitoring system for major crop diseases

# Building a Framework for Early Warning in Ethiopia

- *“The EWS encompasses a sophisticated framework that integrates **field and mobile phone surveillance data, spore dispersal and disease environmental suitability forecasting, as well as communication to policy-makers, advisors and smallholder farmers.**”*
- *“The framework represents one of the first advanced crop disease EWSs implemented in a developing country.”*

Environmental Research Letters

LETTER • OPEN ACCESS

An early warning system to predict and mitigate wheat rust diseases in Ethiopia

Clare Allen-Sader<sup>1,7</sup>, William Thurston<sup>2</sup>, Marcel Meyer<sup>1</sup>, Elias Nure<sup>3</sup>, Netsanet Bacha<sup>4</sup>, Yoseph Alemayehu<sup>5</sup>, Richard O J H Stutt<sup>1</sup>, Daniel Safka<sup>8</sup>, Andrew P Craig<sup>7</sup>, Eshetu Derso<sup>4</sup> [+ Show full author list](#)

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[Environmental Research Letters, Volume 14, Number 11](#)

[Focus on Environmental Research Infrastructures: New Scientific Capabilities to Address Global Challenges](#)



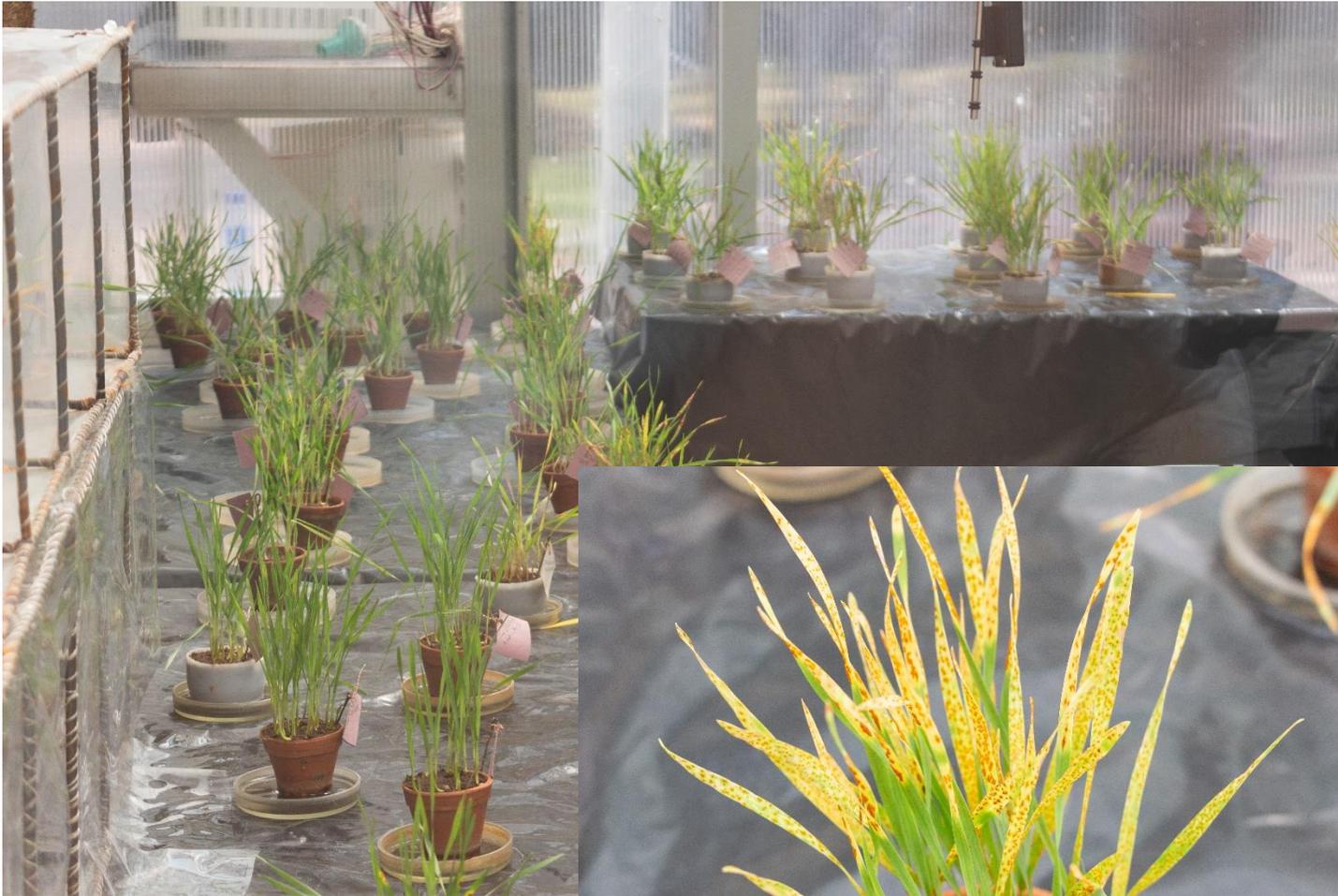
# Ethiopia Field Surveys & Sampling



- Standardized surveys since 2007
- Approx 1200 fields per year
- 95% of surveys now using ODK
- Near real-time data



# In-country Race Analysis



- New rust races are constantly evolving – new races often the cause of epidemics
- Tracking race evolution essential
- Capacity in Ethiopia for all 3 wheat rusts (Stem rust – Ambo; Yellow rust – Kulumsa; Leaf rust – Debre Zeit)



# Phone Crowd Sourcing + Targeted SMS Alerts



Ethiopian  **ATA**  
Agricultural Transformation Agency  
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## 8028 Farmer Hotline

*How a new IVR/SMS service is revolutionizing the way Ethiopia's smallholder farmers access vital agricultural advice and information.*



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**Crowdsourced Phone Surveys**  
4+ million subscribers

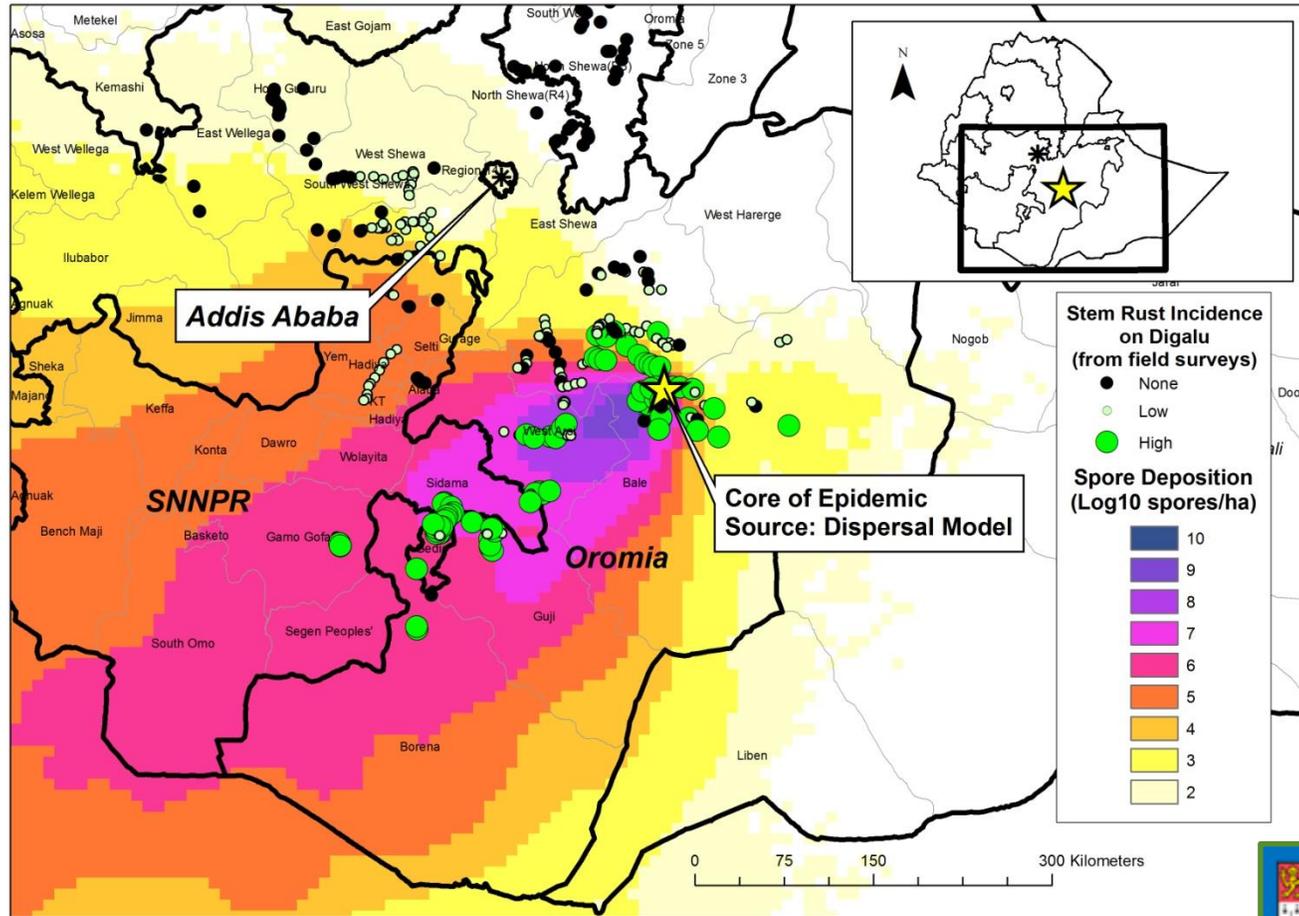


Ethiopian  **ATA**  
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**Targeted SMS alerts**  
4+ million subscribers

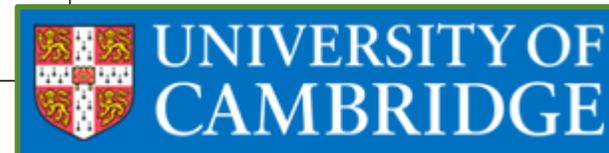
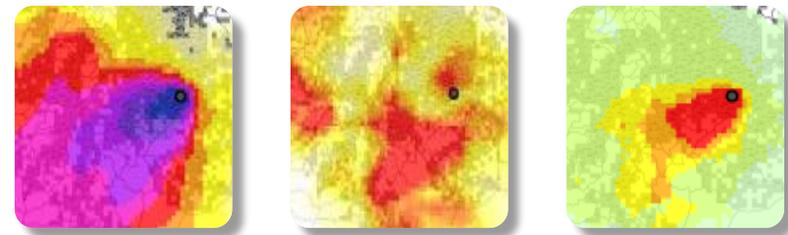


# Spore dispersal and disease environmental suitability forecasting



- Advanced Spore Dispersal Model (NAME model, UK Met Office)
- 7 day forecast models for dispersal and risk (daily, in-season)

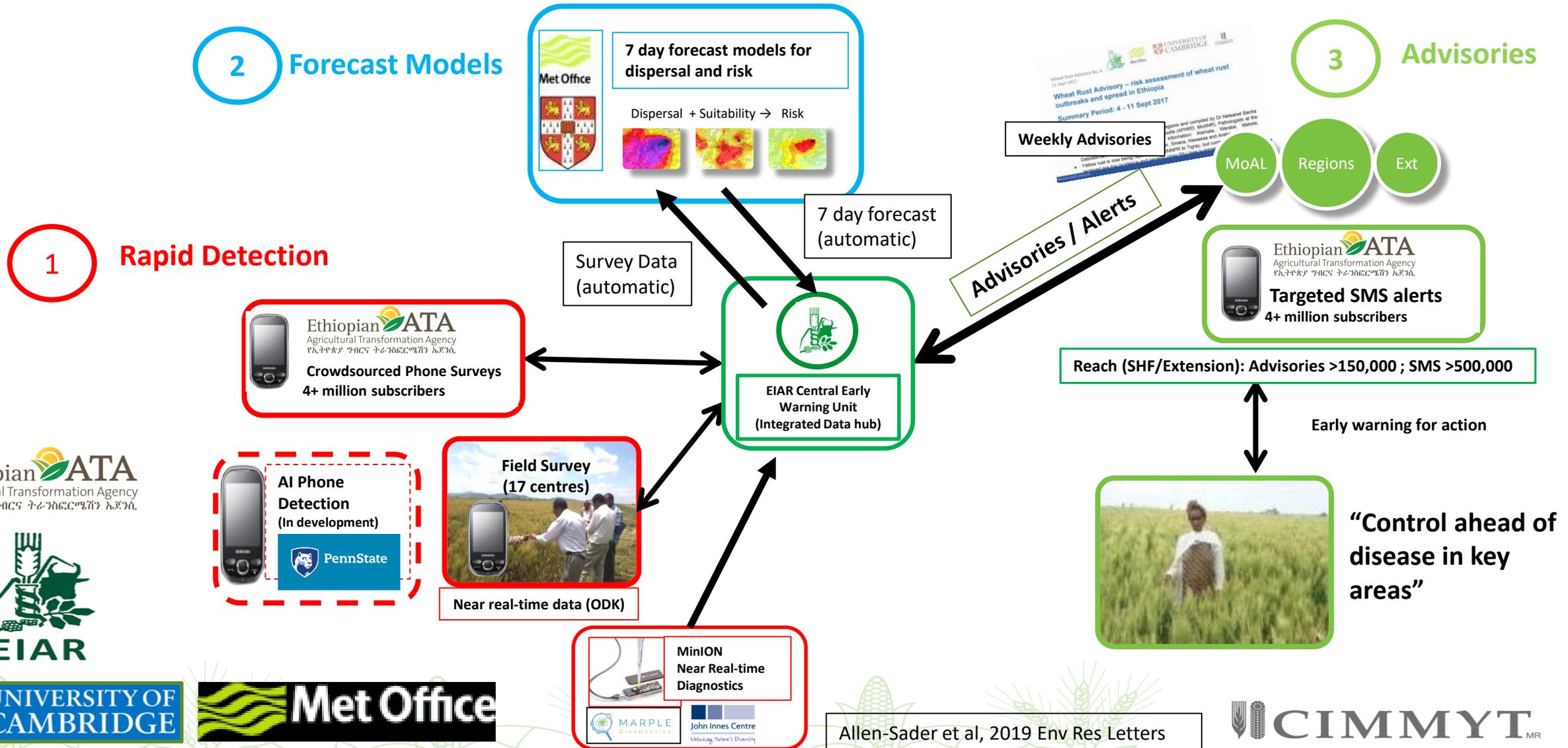
Dispersal + Suitability → Risk



Olivera et al., 2015 Phytopathology  
Meyer et al 2017 Nature Plants

# Ethiopia: Rust Early Warning Framework

Partnerships to create one of the most advanced crop disease forecasting / early warning systems in the world



# New Technologies

## MinIONs, AI, Drones & Remote Sensing



Photo: Matt Heaton, JIC

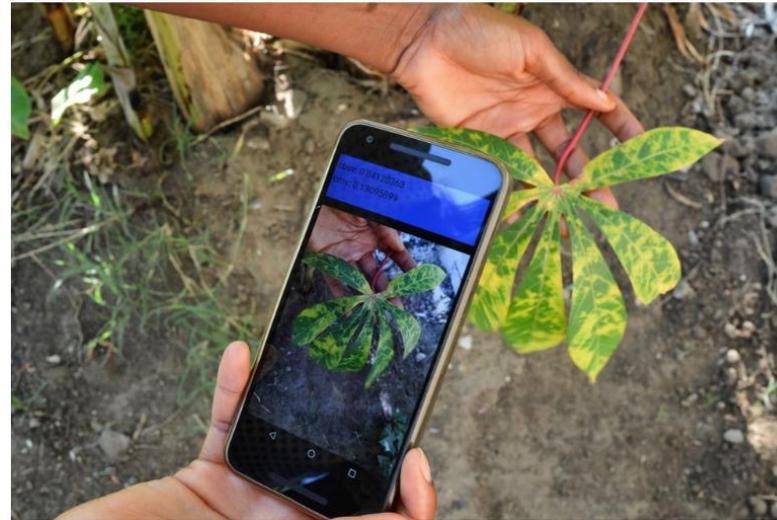


Photo: IITA / Penn State Plant Village



Photo: Matt Heaton, JIC



# Real-time, Mobile Pathogen Diagnostics

New races = highest risk.

Can we detect them quicker? (in-season before establishment + spread)



2019 INNOVATOR OF THE YEAR

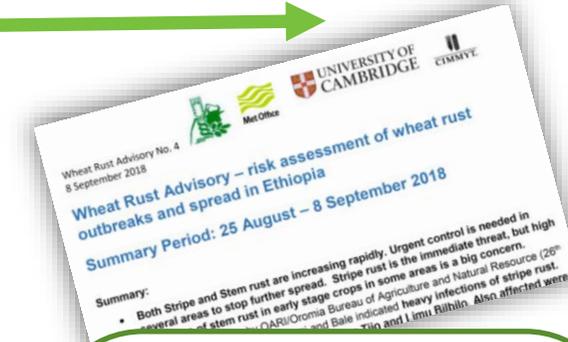
Winner: International Impact



Field Sampling

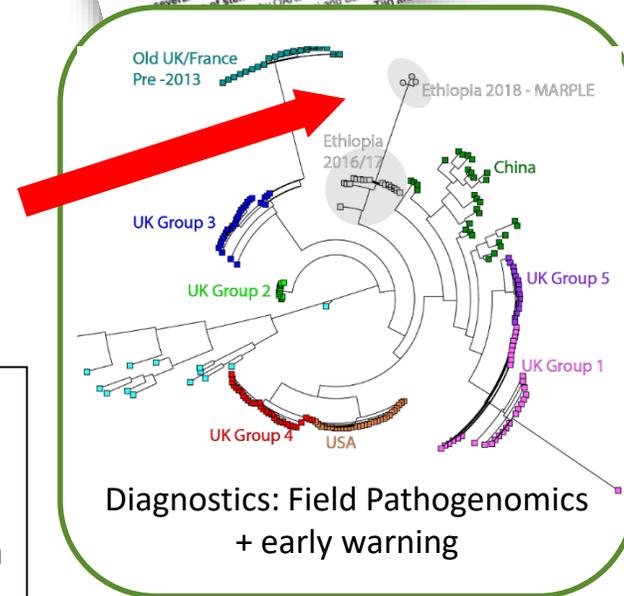


MinION nanopore sequencing (Mobile Lab)



Radhakrishnan et al  
2019 BMC Biology

- First field testing of Nanopore sequencing in Ethiopia –Sept 2018
- **First ever application on a rust fungal pathogen**
- It works! Field samples to diagnostic in 2 days!!
- Results already incorporated into national rust early warning system



# AI – Automated disease detection



Photo: IITA / Penn State F

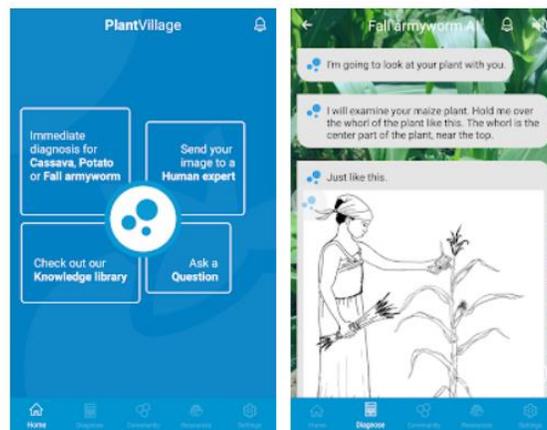


PlantVillage Nuru

PlantVillage Education

PEGI 3

Add to Wishlist

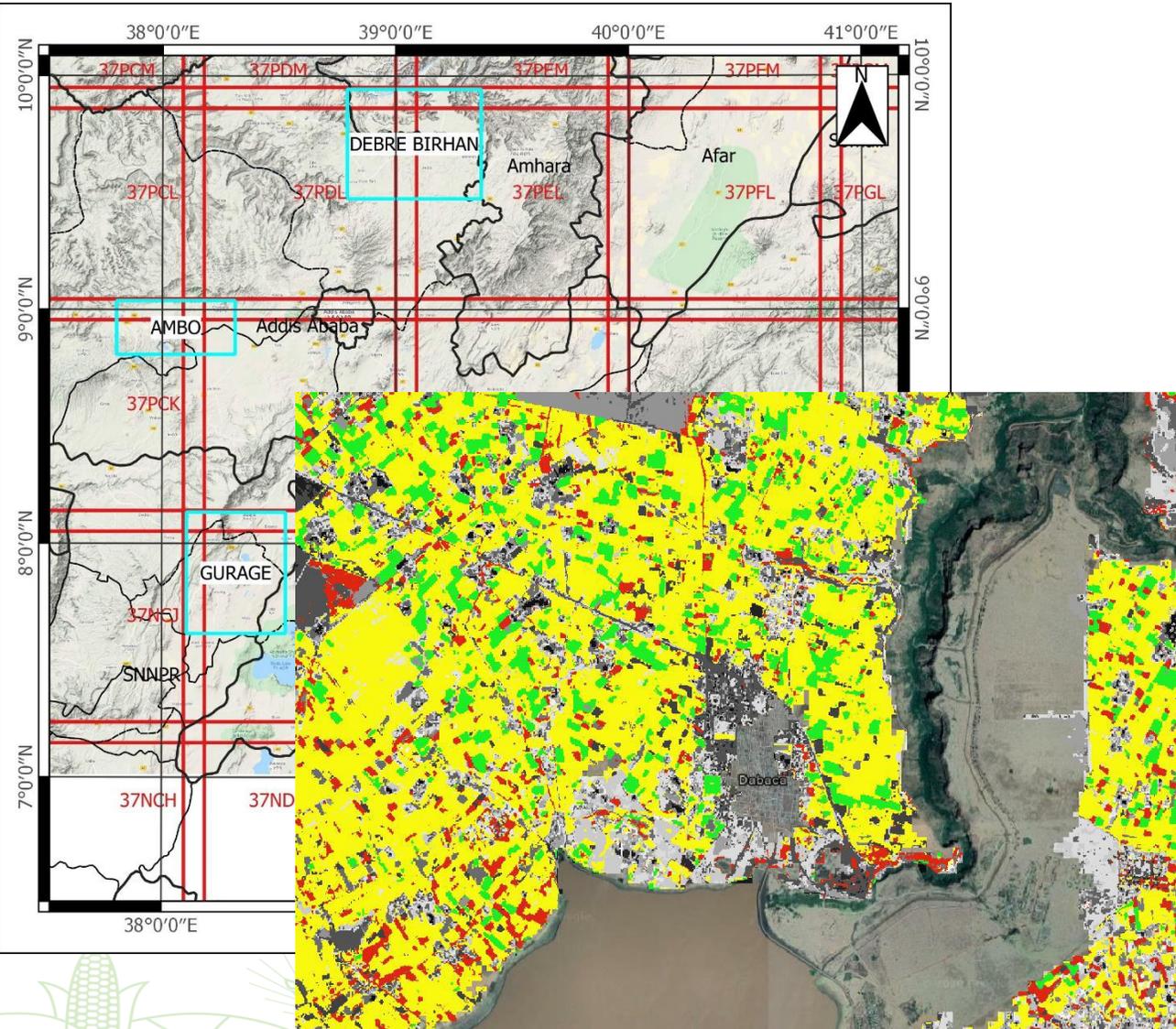


- Pilot project with Penn State (Prof. David Hughes)
- Beta version for wheat rust detection using smartphones – based on Google Tensor Flow
- Initial tests with Facebook group

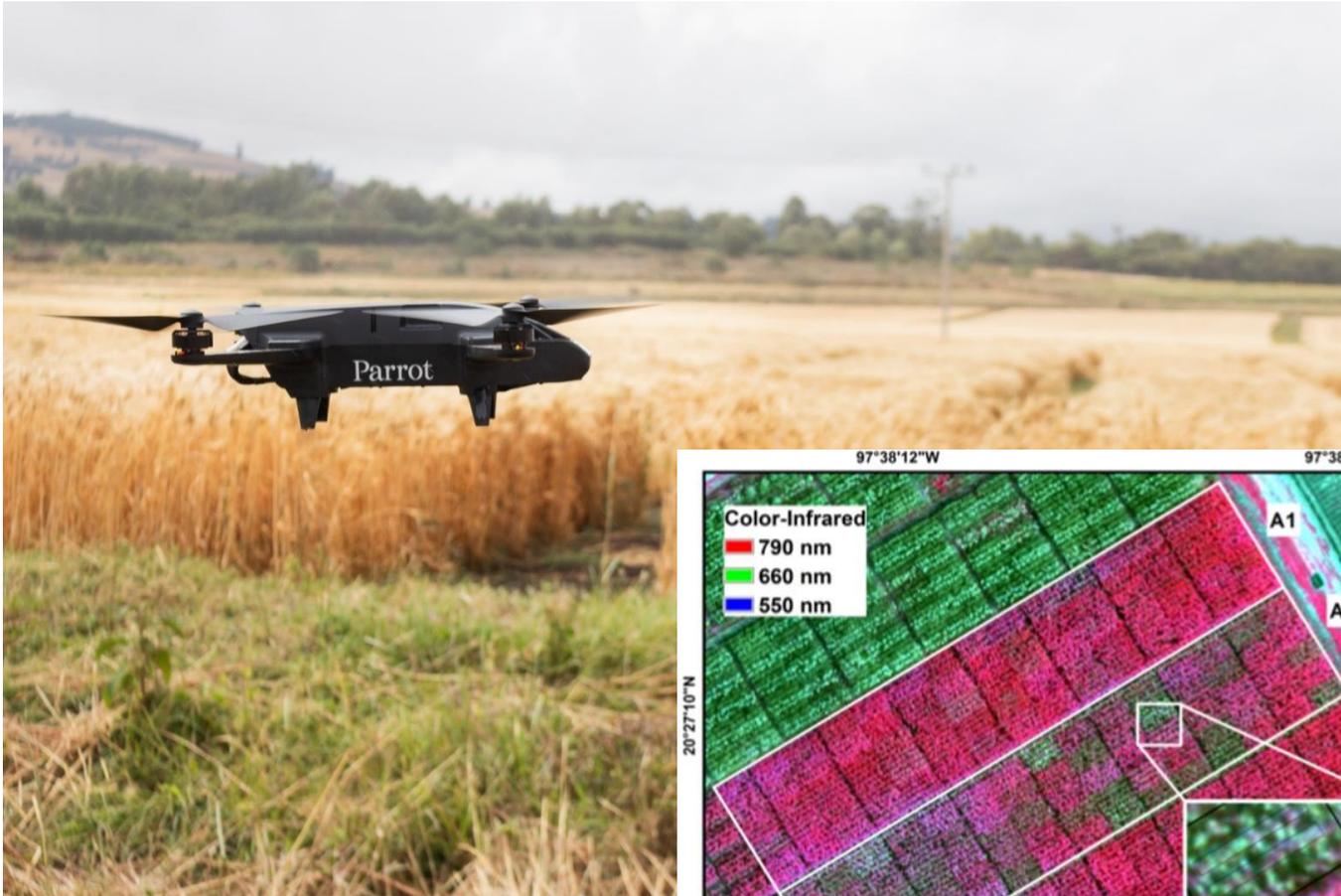


# Remote Sensing

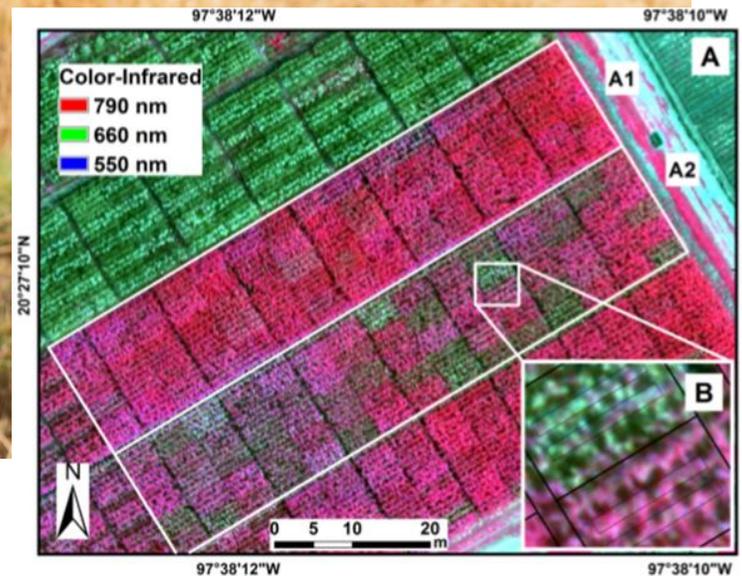
- Link with UCL, Belgium (Prof. Pierre Defourny)
- Host landscape + crop growth stage (Sentinel)
- Improved inputs for epidemiological models
- Crop stress



# Drones – Crop Disease Detection



- Starting to test methods for rust detection in Ethiopia
- Builds on existing work on Tar Spot complex (Maize)
- Linkage to satellite images? (Planet, Pleiades, Sentinel)



# Concluding Remarks

- Wheat rusts are amongst the most damaging and important crop diseases
- Made advances regarding rust surveillance globally. Probably most comprehensive, operational monitoring system for major crop diseases
- Developed an operational early warning and response system in Ethiopia
- One of the first advanced crop disease EWSs implemented in a developing country
- New technologies already playing a key role – Molecular diagnostics, dispersal / epidemiology models, extension phone systems + testing others (AI, RS) that are likely to be increasingly important
- Multi-disciplinary approaches increasingly needed to combat the increasing threats from transboundary diseases



# Acknowledgements

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- EAAPP
- EIAR, Ethiopia + RARI's
- Ethiopian MoA + Regional BoA's
- FAO
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- ICARDA
- John Innes Center, UK
- KALRO, Kenya
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- Penn Sate University
- Sathguru Management Consultants
- UCL, Louvain, Belgium
- UK Met Office
- University of the Free State, South Africa
- University of Minnesota
- USDA-ARS Cereals Disease Laboratory, MN

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