



Global Wheat Rust Monitoring Systems

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(on behalf of many partners)
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Food System Impacts of Pests & Pathogens in a
Changing Climate, August 19-23, 2019, Aspen, CO



An Increasing Threat

– Transboundary Pathogens & Pests

- **Rate of spread, appearance in new areas, detection of new races (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

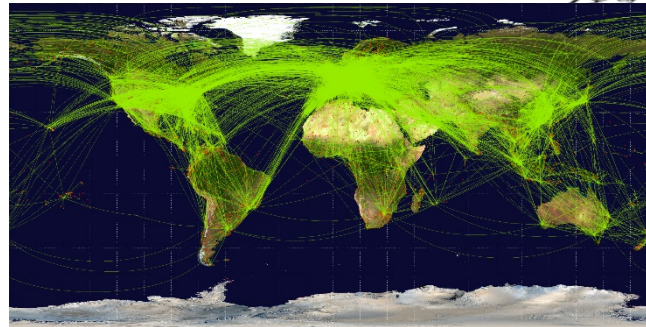
Pathogen Surveillance & Monitoring Systems increasingly needed.

Pathogens without Borders

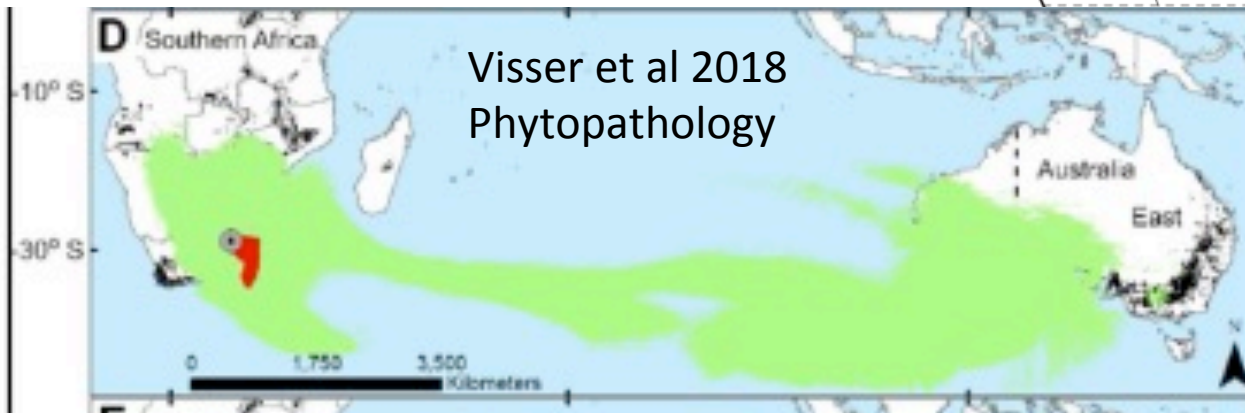
- Wind-borne dispersal of fungal spores (e.g., wheat rusts) across or even between continents [Wheat Stem Rust: Southern Africa – Australia]
- Accidental travel/trade-borne transmission – **increasing with globalization** [Wheat Stripe Rust: Western Europe – Australia]



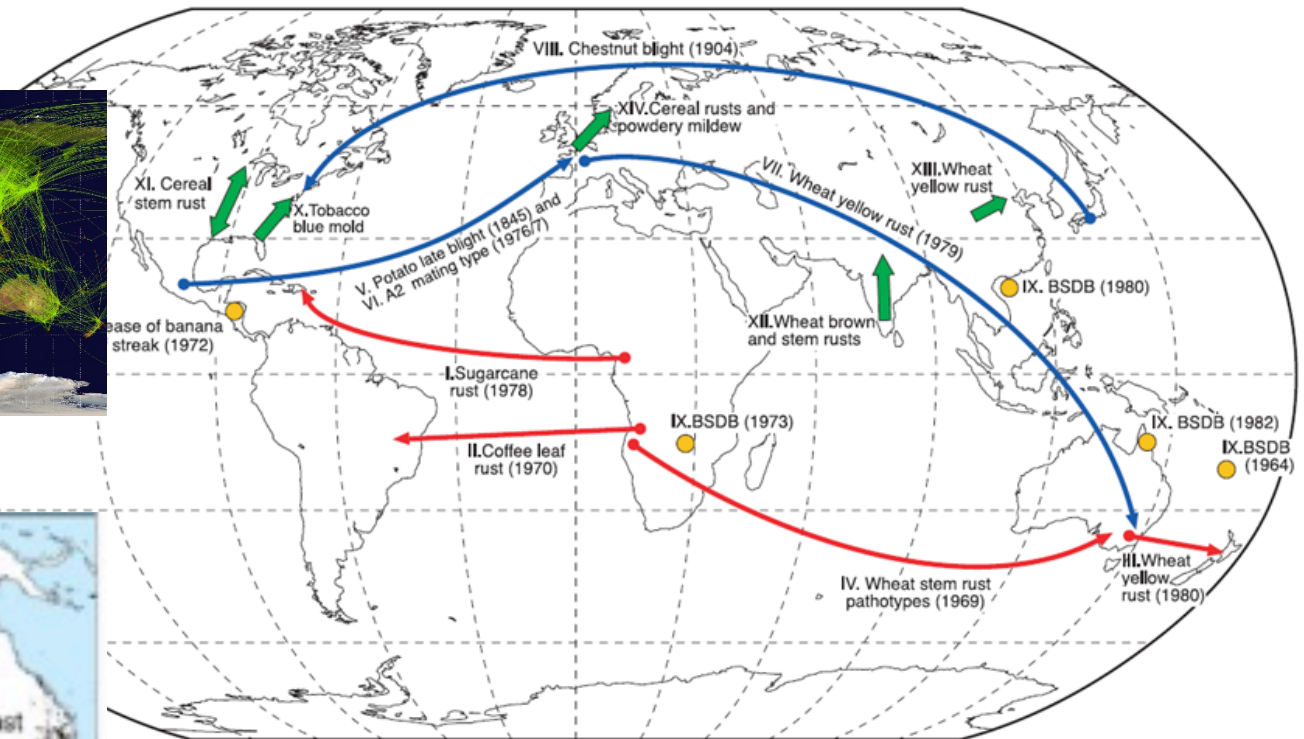
Courtesy of: Prof. Z.A. Pretorius
Uni. Free State, South Africa



Source: openflights.org



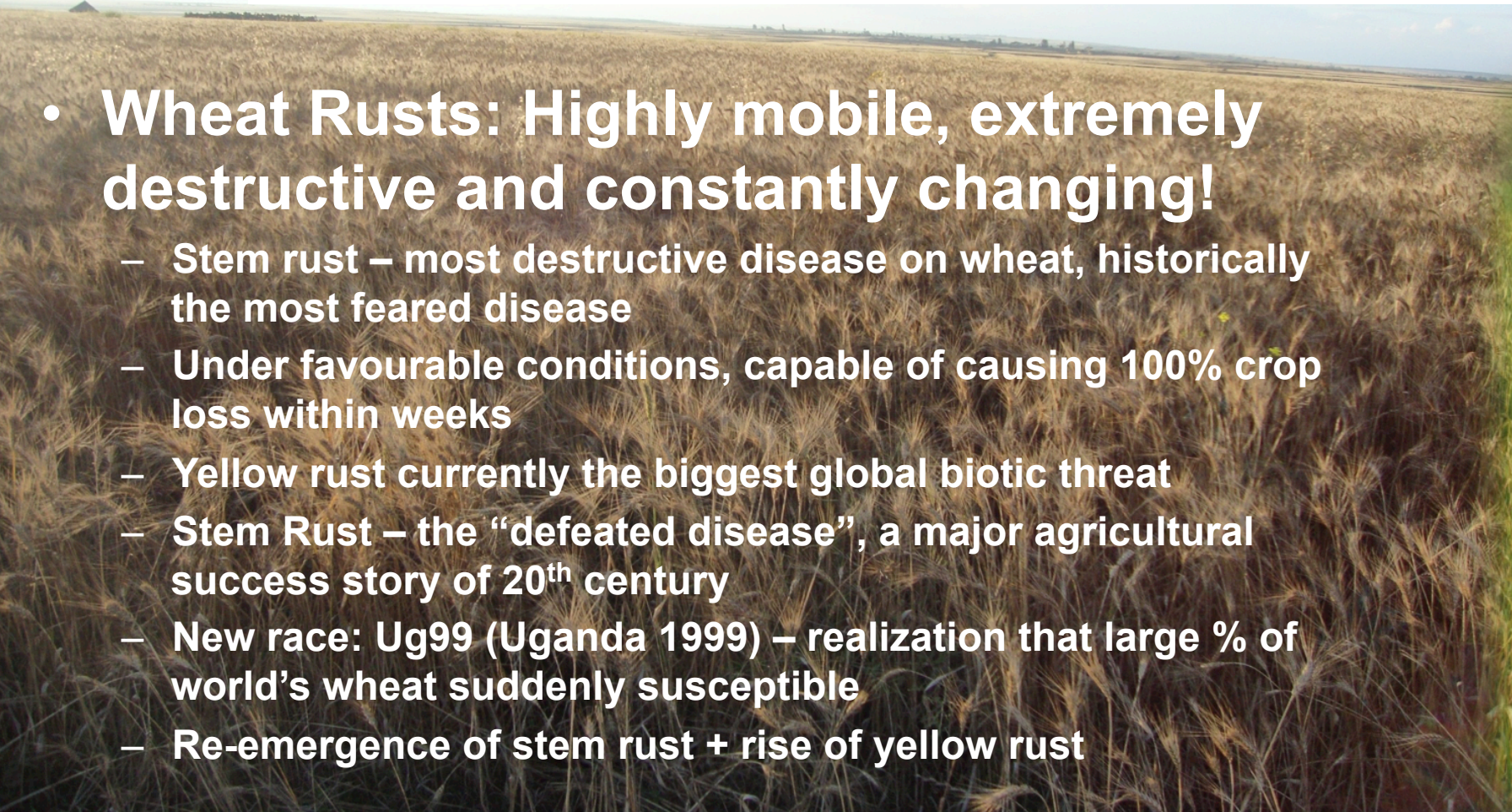
Visser et al 2018
Phytopathology



(Brown & Hovmøller, Science, 2002)

The Problem: Combating Cereal Killers

- **Wheat Rusts: Highly mobile, extremely destructive and constantly changing!**
 - Stem rust – most destructive disease on wheat, historically the most feared disease
 - Under favourable conditions, capable of causing 100% crop loss within weeks
 - Yellow rust currently the biggest global biotic threat
 - Stem Rust – the “defeated disease”, a major agricultural success story of 20th century
 - New race: Ug99 (Uganda 1999) – realization that large % of world’s wheat suddenly susceptible
 - Re-emergence of stem rust + rise of yellow rust



Wheat crop killed by stem rust, Ethiopia Nov 2013



Yellow Rust Epidemic, Ethiopia 2010



SURVEILLANCE AND MONITORING

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

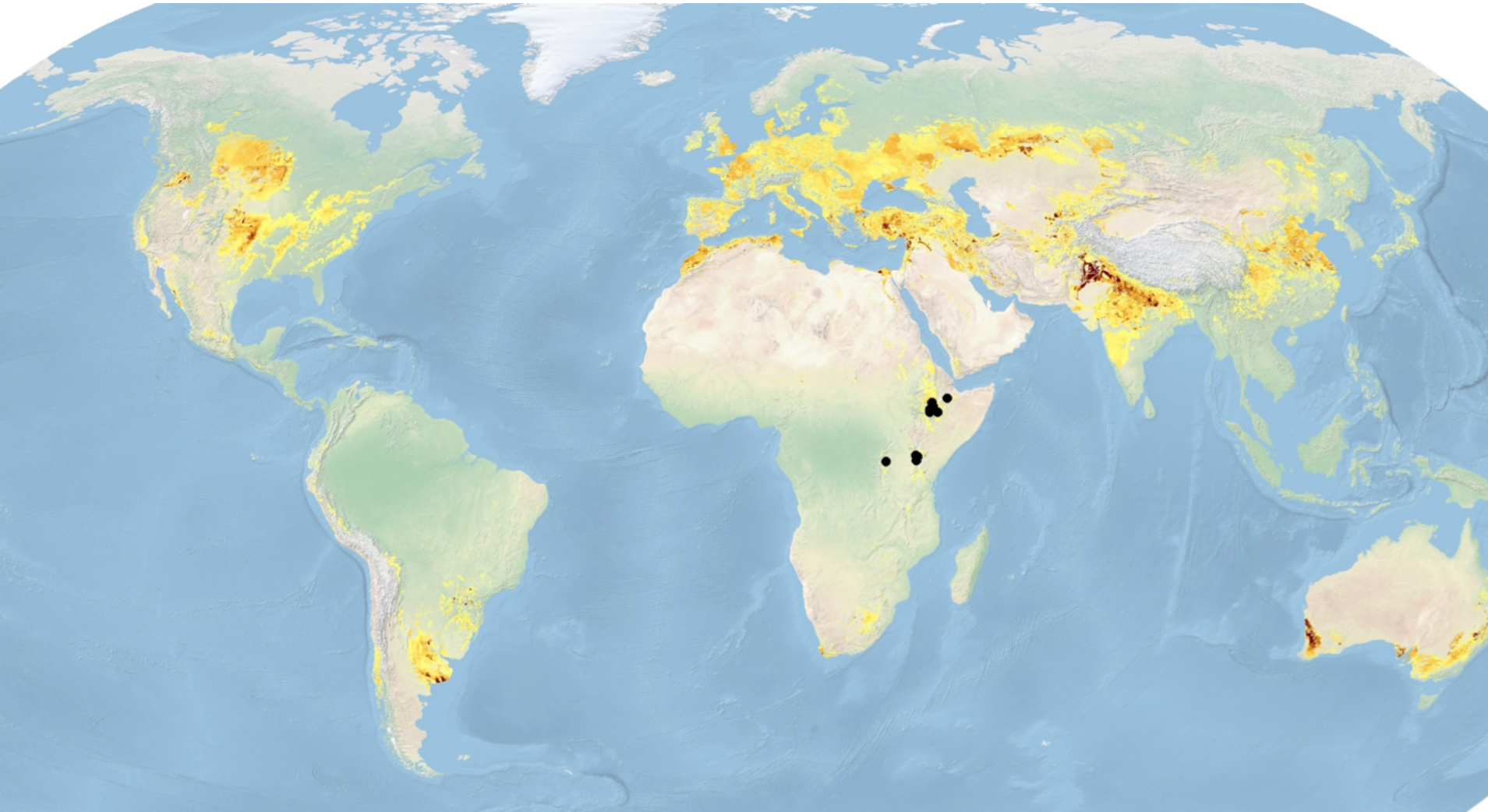


The surveillance system provides early warning of potential rust epidemics to scientists and farmers.

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

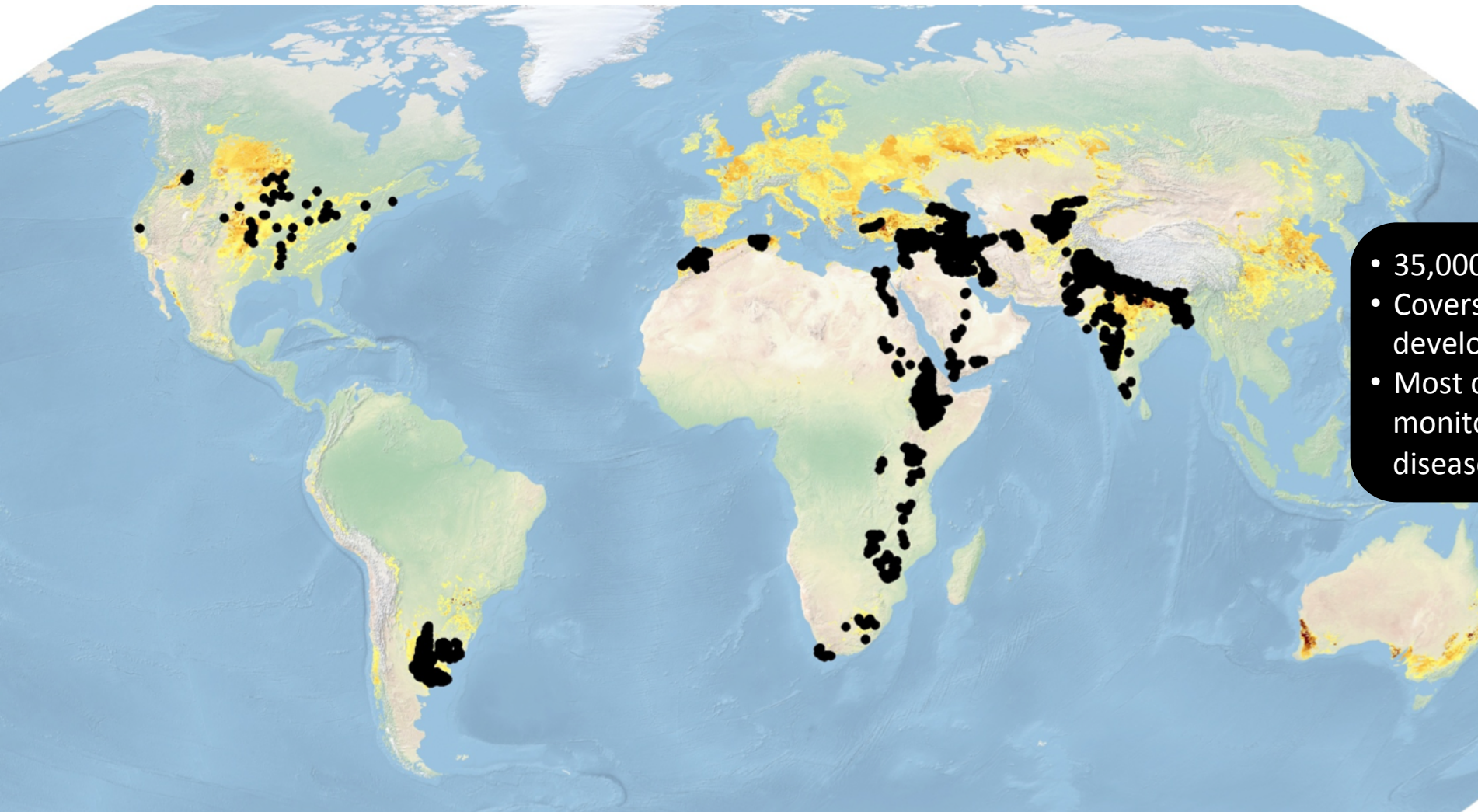
Global Wheat Rust Monitoring

2005



Global Wheat Rust Monitoring

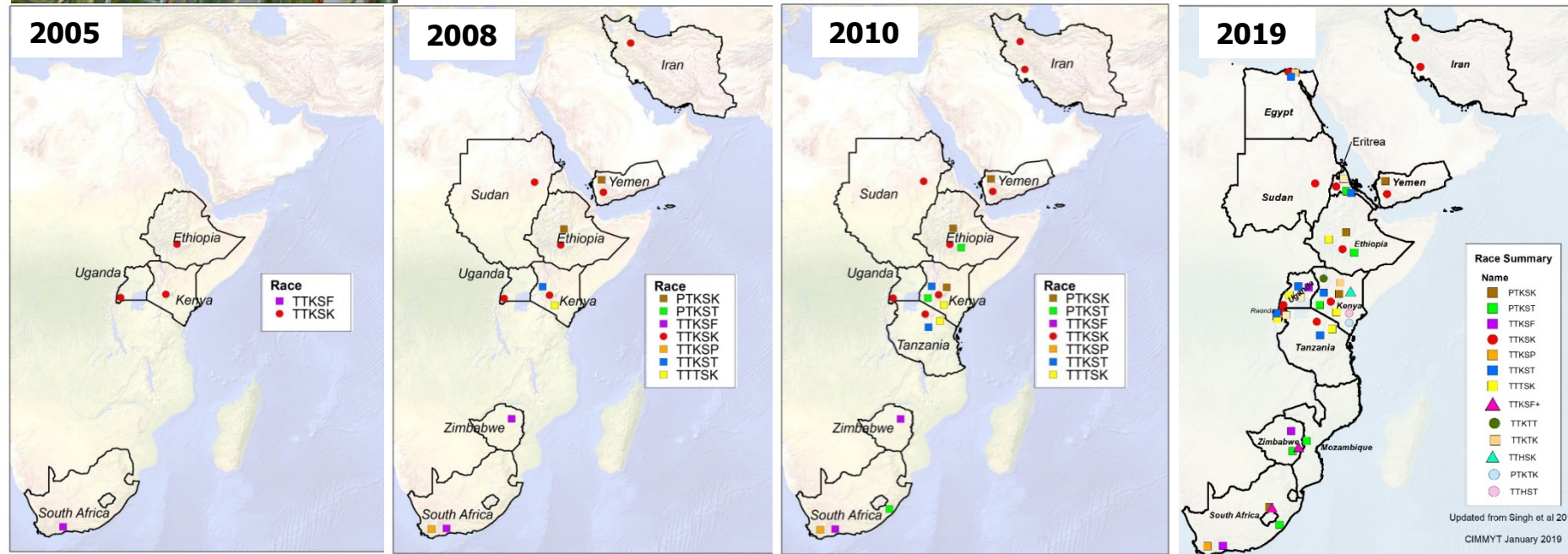
2018



- 35,000+ survey records
- Covers 40+ countries: large % of developing world wheat
- Most comprehensive, operational monitoring system for major crop diseases



Evolution and spread of races belonging to Ug99 lineage of stem (black) rust fungus



- Ug99 is mutating and migrating
- **TL X 14** races now known. Presence in 13 countries confirmed
- 80-90% wheat varieties/germplasm susceptible or with inadequate resistance in 2006
- Launch of Borlaug Global Rust Initiative in 2005 (DRRW project in 2008)
- Global stem rust threats now extend beyond Ug99

Re-emerging Stem Rust (Non Ug99)

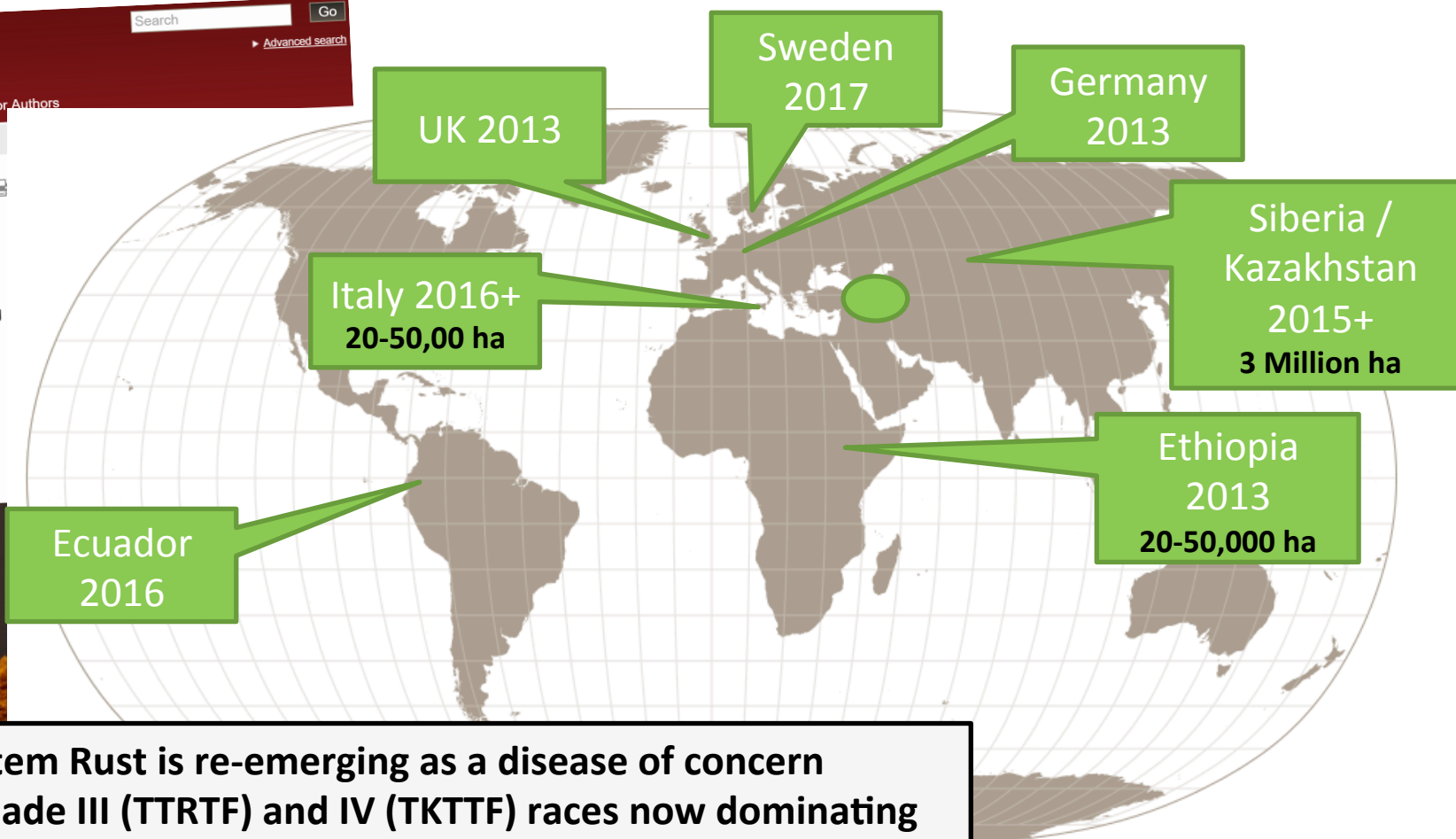


Deadly new wheat disease threatens Europe's crops
Researchers caution that stem rust may have returned to world's largest wheat-producing region.

Shaoni Bhattacharya

02 February 2017

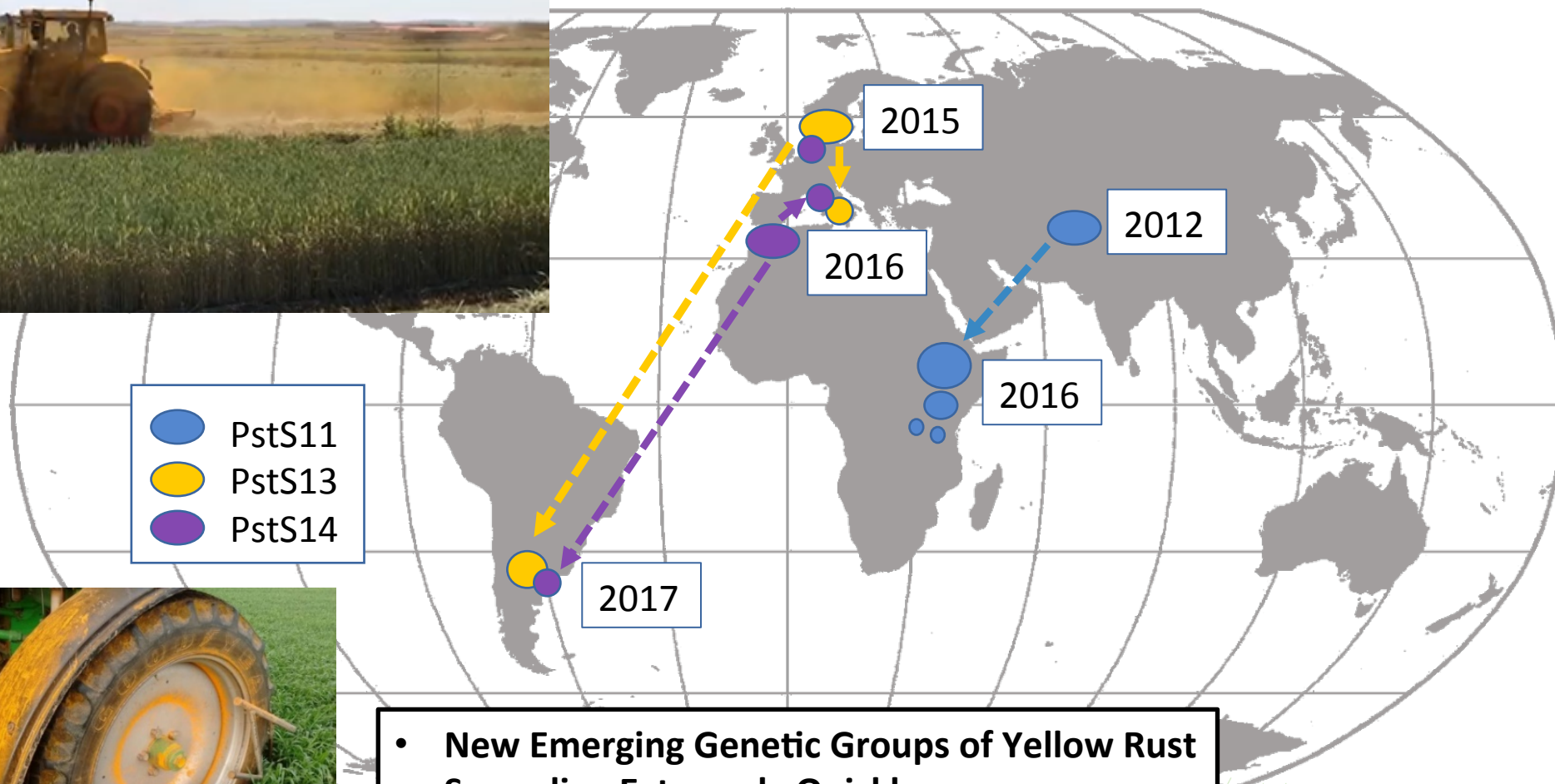
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- Stem Rust is re-emerging as a disease of concern
- Clade III (TTRTF) and IV (TKTTF) races now dominating over Ug99 races in East Africa
- High Race Diversity (Sexual populations): Georgia, Siberia/ Kazakhstan, Sweden
- Caucus region – important role?

Recent Stripe Rust Races Spreading Across Globe

Yellow rust spores released when harvesting triticale for forage in the Huesca province, Spain. Source: Lluís Xanxo / Dolors Villegas, IRTA, Spain May 2019

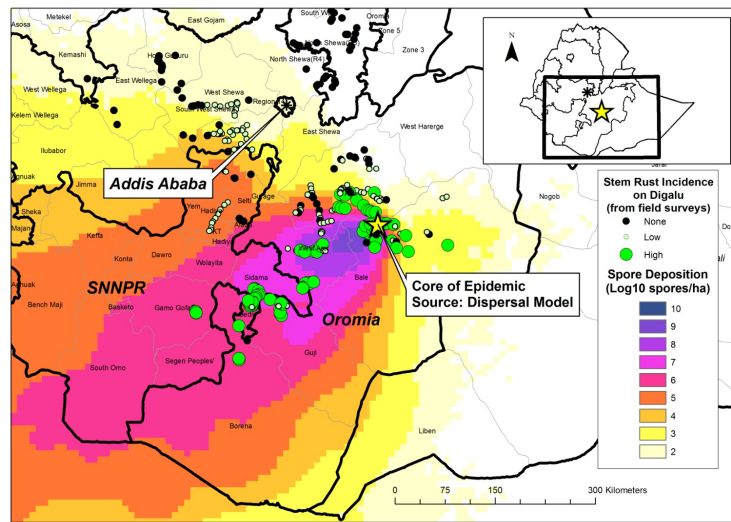


Argentina 2017

- New Emerging Genetic Groups of Yellow Rust
- Spreading Extremely Quickly
- Large Scale Epidemics

New Technologies

Models to MinIONs



Advanced Stem Rust Spore Dispersal Modeling - Rust Early Warning Systems

- Advanced Spore Dispersal Model (NAME model, UK Met Office)
- **Big Data Approach** (20TB Data + UK Met Office supercomputer)
- **First quantitative estimates** of spore dispersal to different regions and continents
- Models give a **risk assessment framework** e.g., how likely stem rust to move into South Asia?
- **Real-time forecasting** part of an early warning system – Ethiopia
- **Predicting many of movements we now seeing globally**

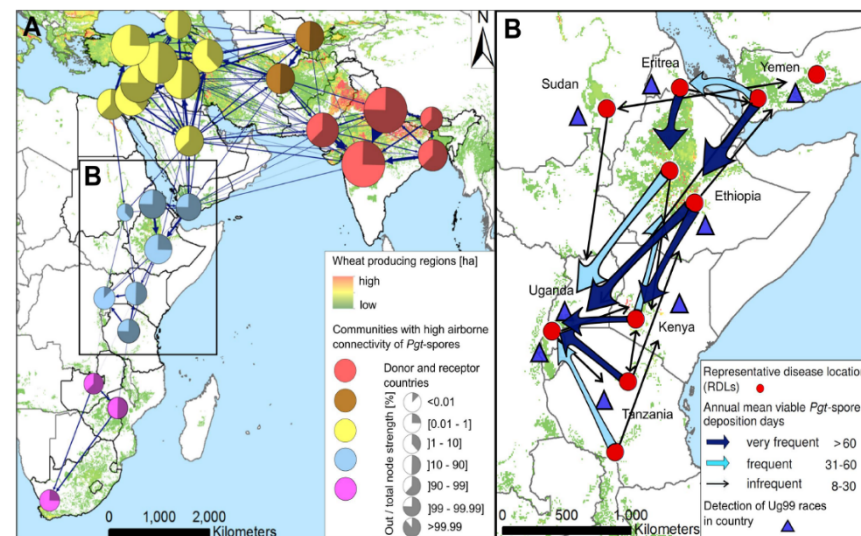
LETTERS

DOI: 10.1038/s41477-017-0017-5

nature
plants

Quantifying airborne dispersal routes of pathogens over continents to safeguard global wheat supply

M. Meyer^{1*}, J. A. Cox¹, M. D. T. Hitchens¹, L. Burgin², M. C. Hort², D. P. Hodson³ and C. A. Gilligan^{1*}



Meyer et al 2017 Nature Plants

Real-time, Mobile Pathogen Diagnostics



2019 INNOVATOR OF THE YEAR
Winner: International Impact

← 2 Days →



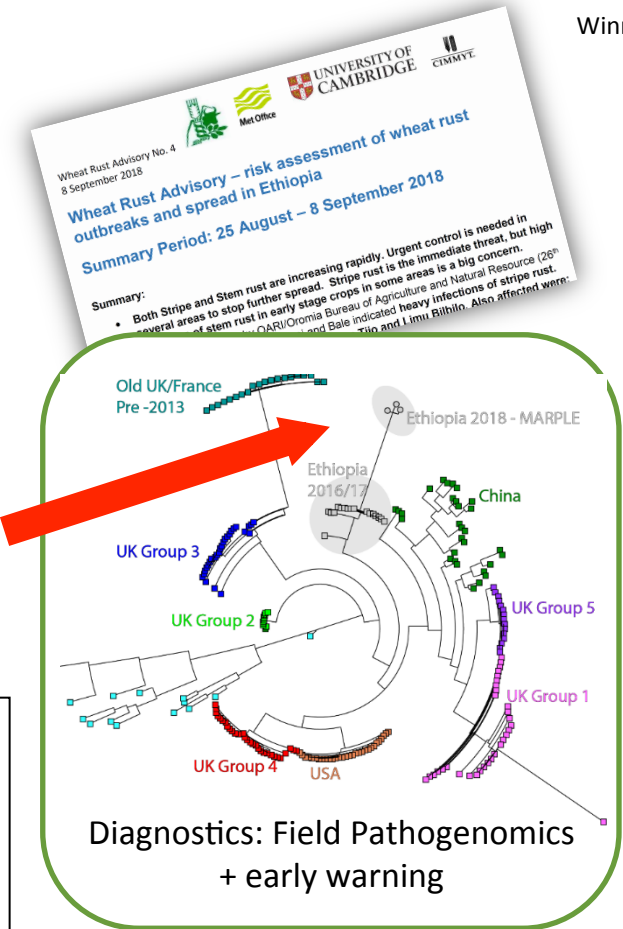
Field Sampling



MinION nanopore sequencing (Mobile Lab)

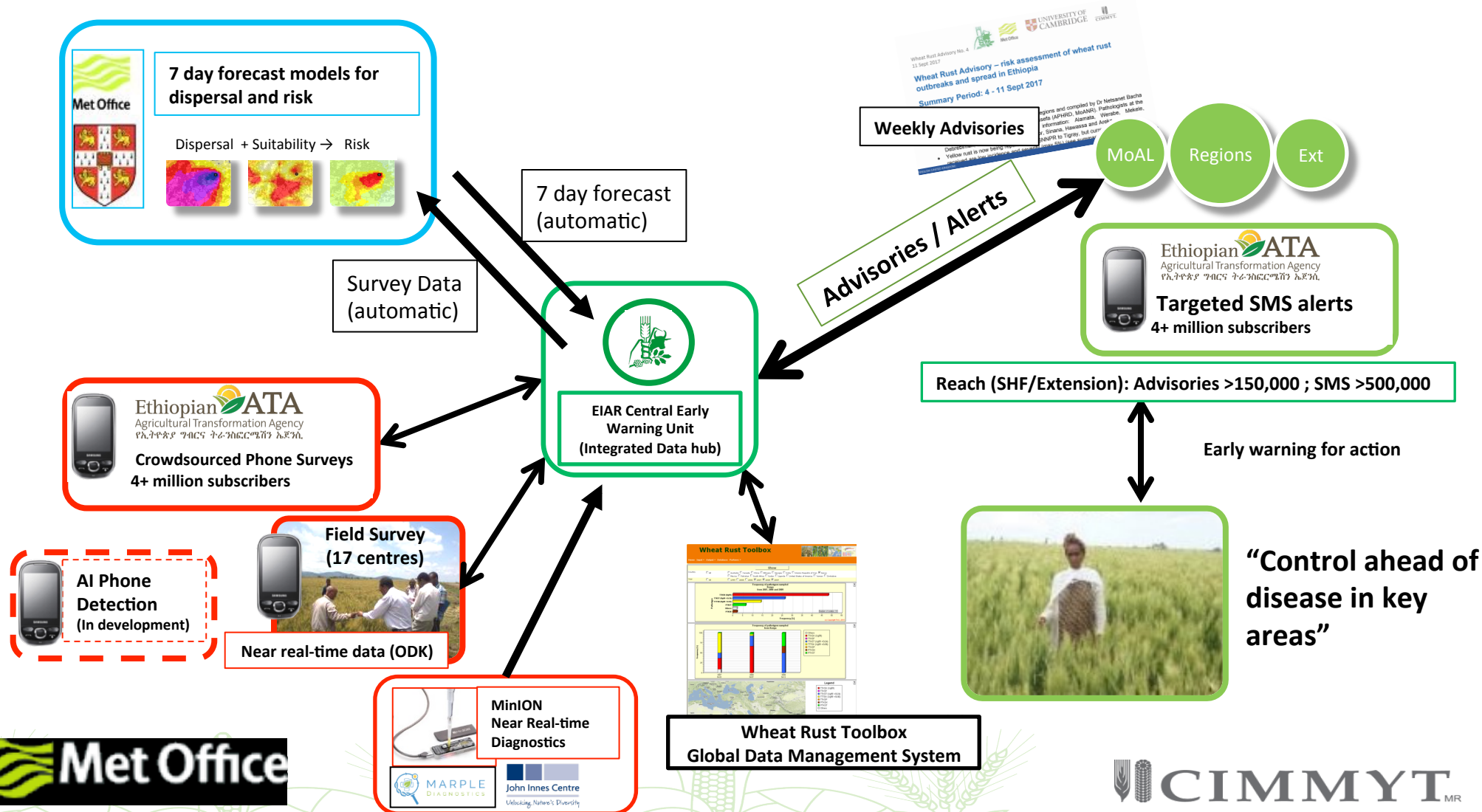
*Radhakrishnan et al
2019 BMC Biology*

- 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



Ethiopia: Rust Early Warning Framework

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



Concluding Remarks

- Made advances regarding rust surveillance. Probably most comprehensive, operational monitoring system for major crop diseases
- Ug99 race group investments / learning now being applied to other important races (and other rusts)
- New races continuing to evolve / future incursions likely – **we must have long-term effective monitoring, sharing of information + strong connections to breeding programs** (role of durable resistant cultivars critical)
- New technologies playing a key role – Molecular diagnostics, dispersal / epidemiology models
- Advanced disease forecasting / early warning



Acknowledgements

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- University of the Free State, South Africa
- University of Minnesota
- USDA-ARS Cereals Disease Laboratory, Minnesota

Partners in national programs in over 35 countries

