Pathogens Without Borders
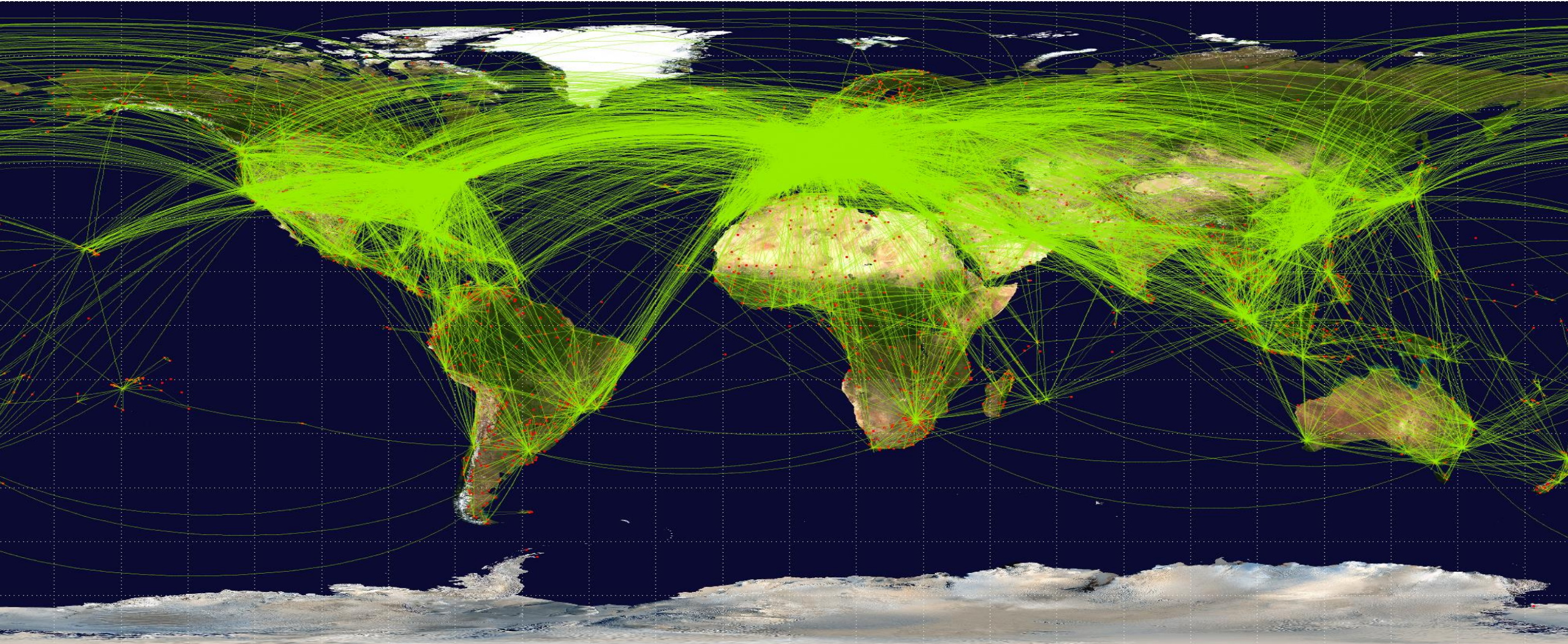## - Keeping Ahead of the Wheat Rust Menace

Dave Hodson

CIMMYT-Ethiopia

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Grand Challenges Meeting, Berlin 16-18 Nov 2018

BGRI
Borlaug Global Rust Initiative

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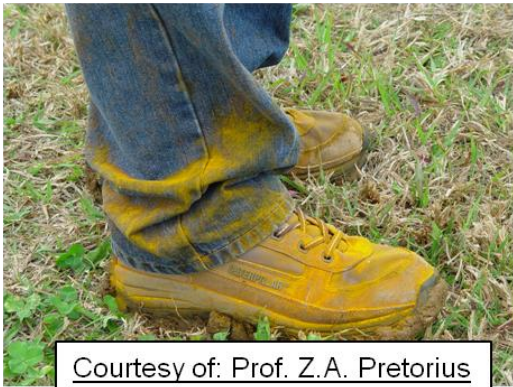
An Increasing Threat – Transboundary Pathogens & Pests
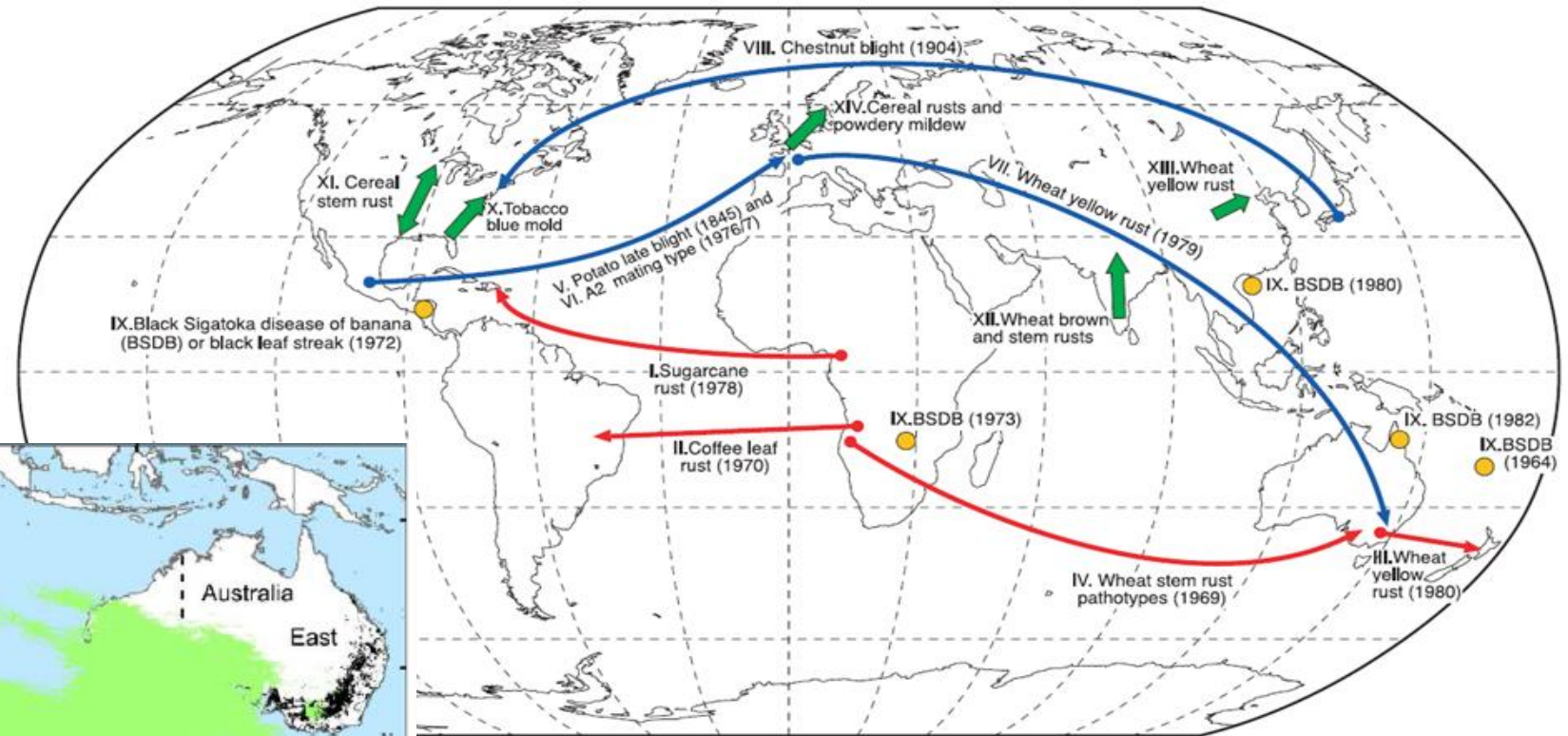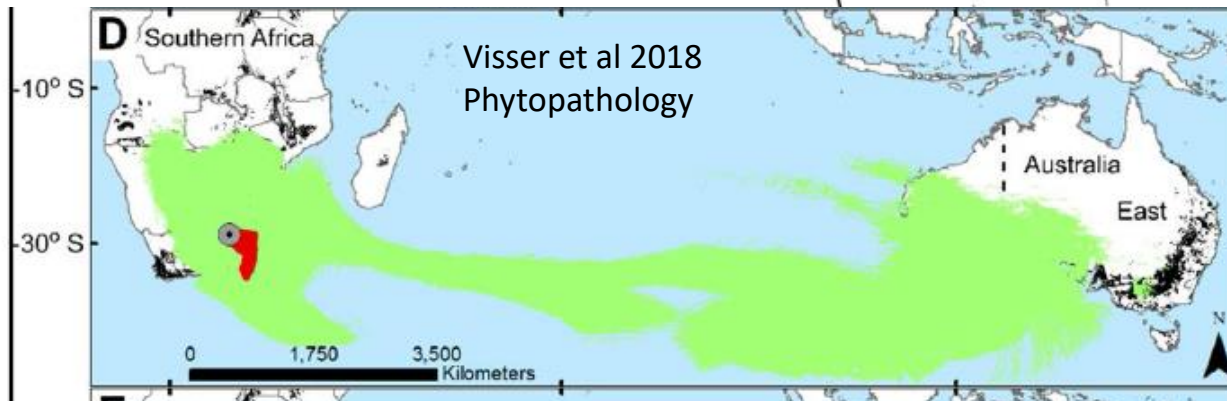

Source: openflights.org

Pathogens without Borders:
Long distance dispersal of plant pathogens

- 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

D Southern Africa

Visser et al 2018
Phytopathology

-10° S

-30° S

Australia
East

0   1,750   3,500
Kilometers

VIII. Chestnut blight (1904)

XIV. Cereal rusts and powdery mildew

XIII. Wheat yellow rust

XI. Cereal stem rust

X. Tobacco blue mold

VII. Wheat yellow rust (1979)

V. Potato late blight (1845) and VI. A2 mating type (1976/7)

IX. BSDB (1980)

IX. Black Sigatoka disease of banana (BSDB) or black leaf streak (1972)

XII. Wheat brown and stem rusts

I. Sugarcane rust (1978)

IX. BSDB (1973)

IX. BSDB (1982)

II. Coffee leaf rust (1970)

IX. BSDB (1964)

IV. Wheat stem rust pathotypes (1969)

III. Wheat yellow rust (1980)

(Brown & Hovmøller, Science, 2002)

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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

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2005: Post-emergence of Ug99
What did we need to do?

- Build the surveillance network (surveys + sampling)
- Track the important pathogens – inform breeding programs
- Implement control options
- Manage + disseminate information
- Improve impact assessments
- Put some early warning systems in place

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SURVEILLANCE AND MONITORING

DRRW/DGGW partners operate the world's largest
largest international crop disease monitoring system.

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

As of 2017, over 32,000 geo-referenced survey records and 7000+ rust isolates records have been collected in 39 countries.
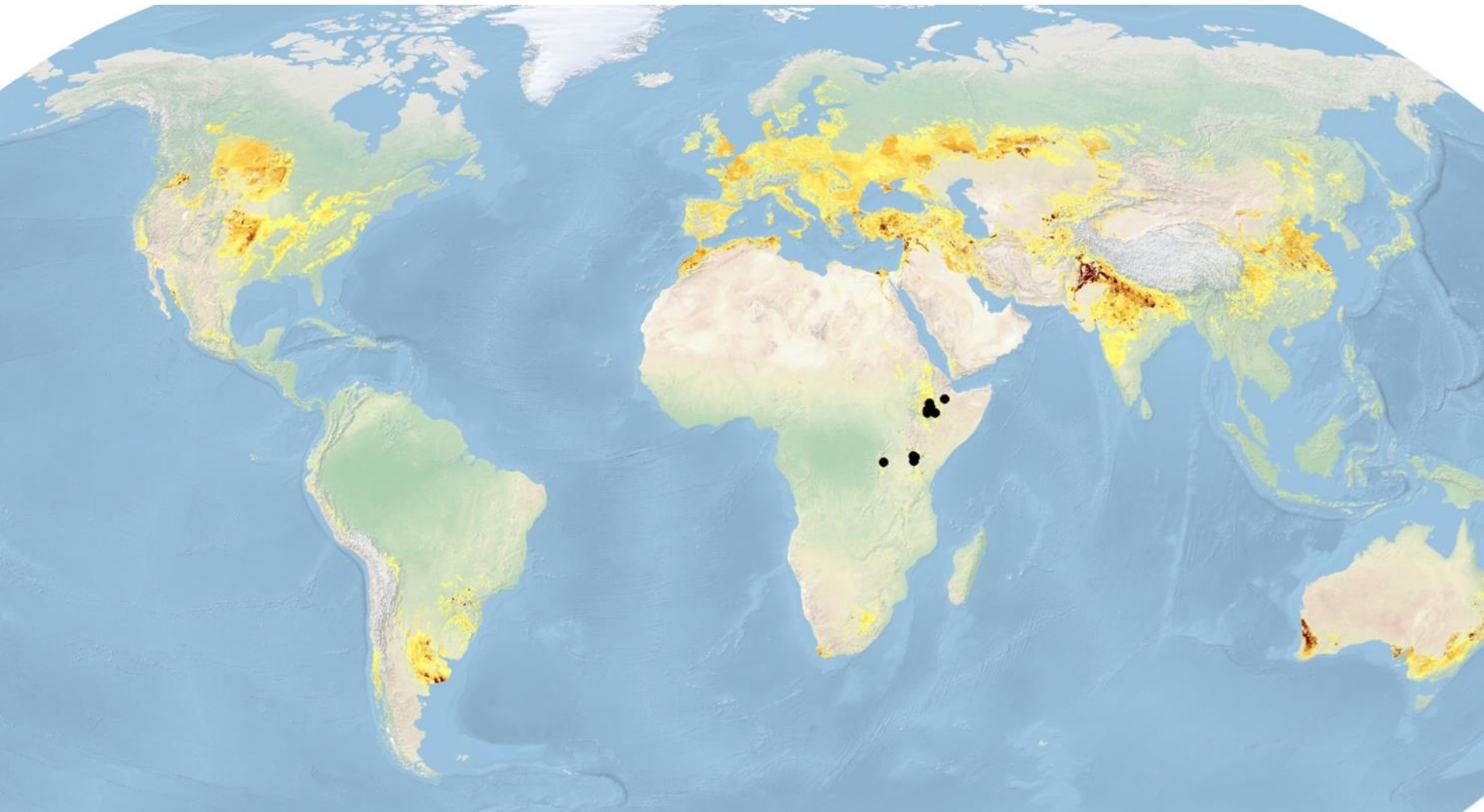
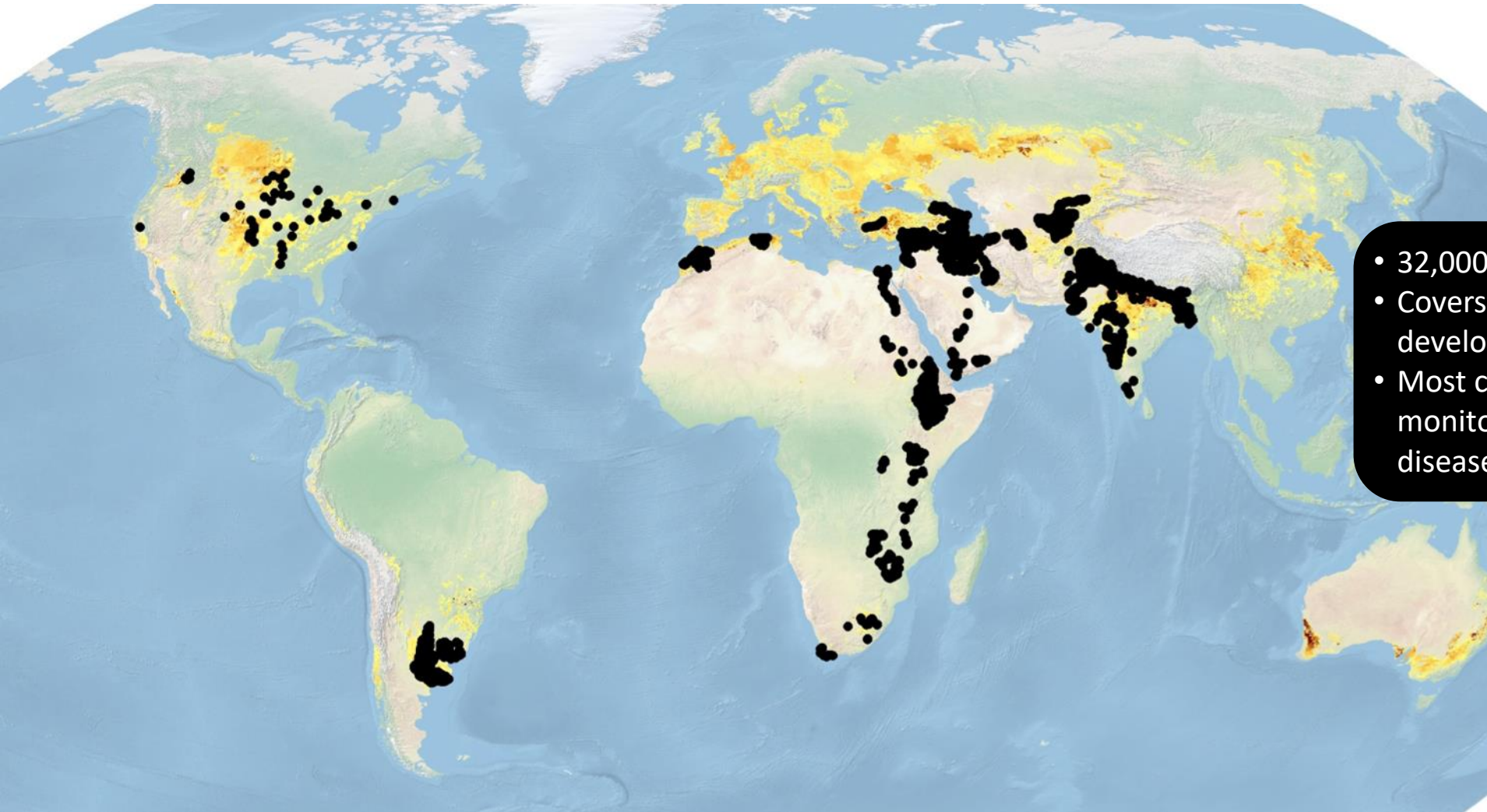CIMMYT senior scientist Dave Hodson teaches field survey protocols to SAARC trainees.

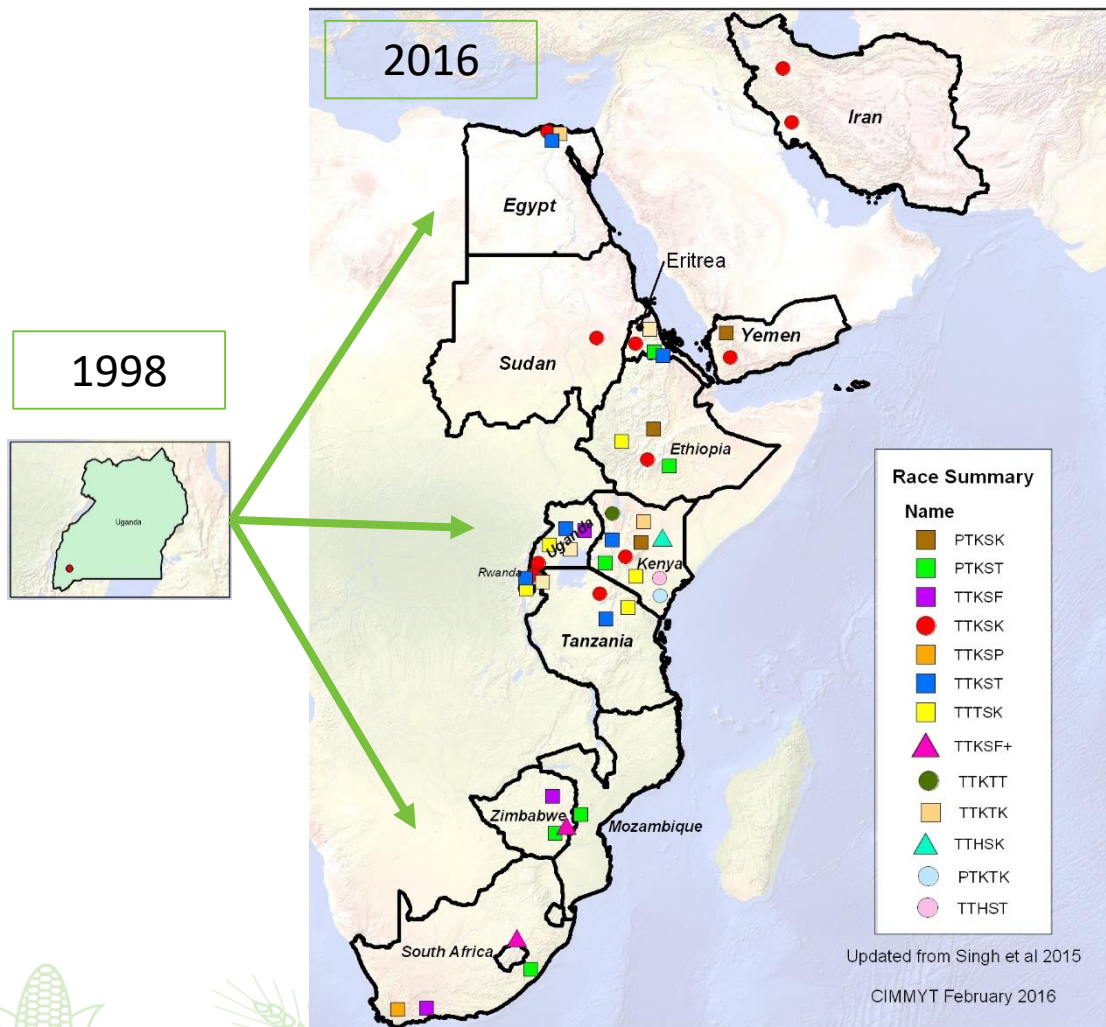# Global Wheat Rust Monitoring

2005

Global Wheat Rust Monitoring

2016

- 32,000+ survey records
- Covers 39+ countries: large % of developing world wheat
- Most comprehensive, operational monitoring system for major crop diseases

Successful Pathogen Tracking:
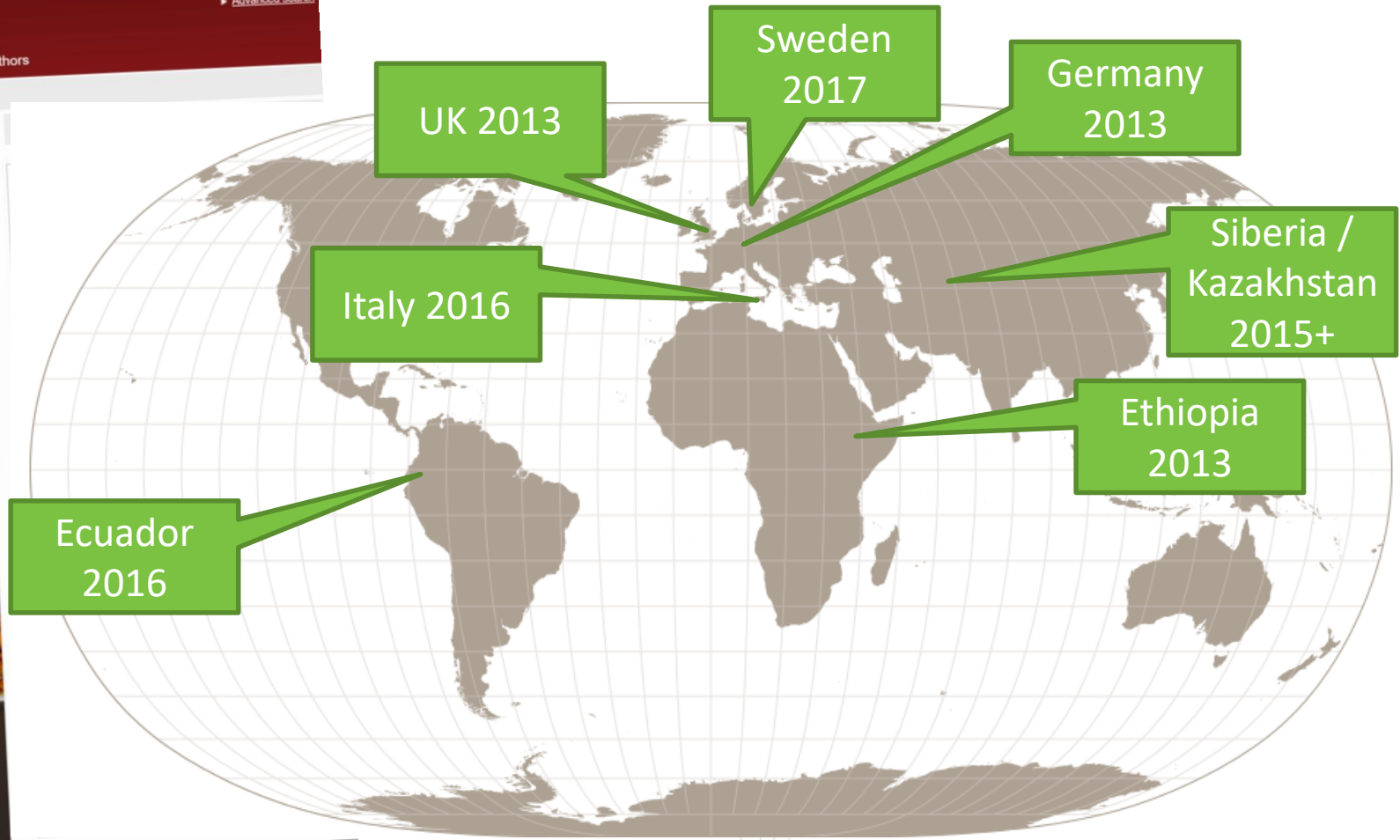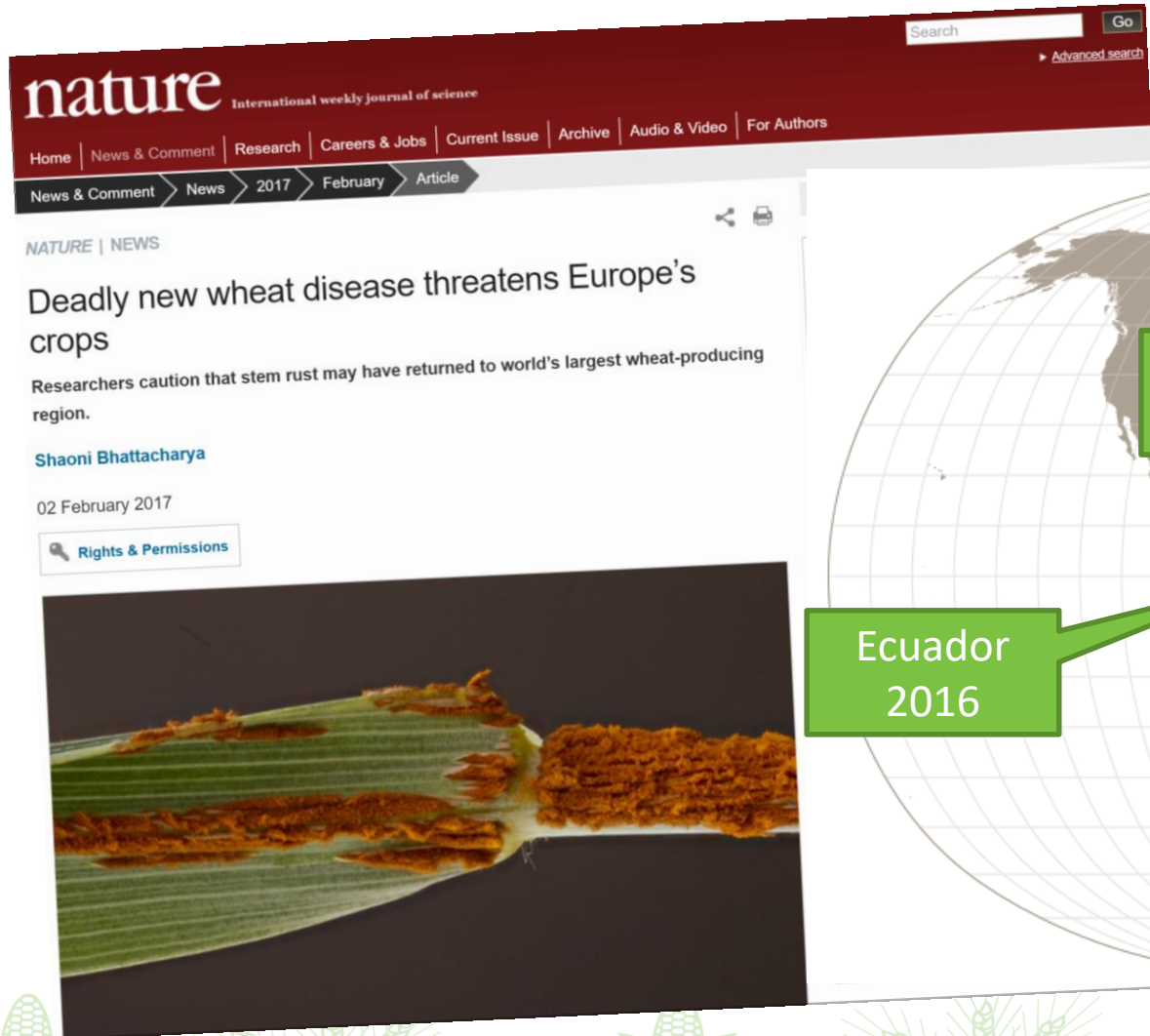# Spread of Ug99 Race Group 1998-2016

- 1998/9: 1 Ug99 race (TTKSK) detected in 1 country (Uganda)

Ug99 is mutating and migrating

- 2015: 13 Ug99 races detected across 13 countries (Africa and Middle East)
- In 2013/14: 5 new Ug99 races detected in Kenya
- **Ug99 races getting more virulent over time – serious implications for other regions**

Re-emerging Stem Rust (Non Ug99)

Stem Rust: Race Groups of Concern (Non Ug99)

A. Berlin, SLU
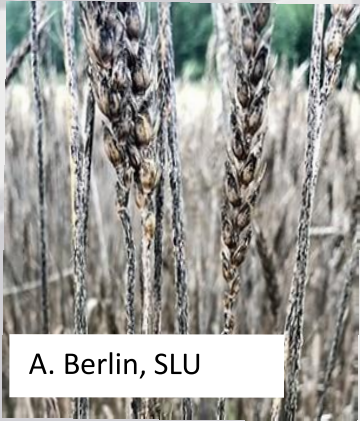
Sweden: 2017
1st outbreak in 60 years
(sexual population)

W. Siberia/ N. Kazakhstan
2015+
51 races from 31 samples
(sexual population) (Incl
TTTTF, TKTTF)
3 Million ha Affected!

Sicily: 2016+
20,000 ha
TTRTF (+Sr13/9e +)

Ecuador: 2016
RRTTF

TKTTF Group: 2007+
(+ vir Sr25, 24 ..)
Ethiopia (2014): 30-50,000ha

Clade III
Clade IV

- **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**

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SCREENING NURSERIES
(Linking surveillance to breeding)

The DRRW established world-class wheat rust screening facilities in Kenya (Njoro) and Ethiopia (Debre Zeit).

The scientists at Njoro + Debre Zeit have evaluated the disease resistance of more than **650,000** wheat, rye, and barley accessions from 25 countries since 2006.

140+ wheat varieties with improved agronomic traits, climate resilience and disease resistance have been released and adopted by the BGRI in 11 at-risk countries in the past 10 years.

Screening data is used to evaluate the resistance of the world's wheat varieties to yellow rust races and the Ug99 family of stem rust races.

The International Stem Rust Screening Nursery at the Kenya Agricultural and Livestock Research Institute (KALRO) Njoro, Kenya.

EIAR

Kenya Agricultural & Livestock Research Organization

Cornell University

BILL & MELINDA GATES foundation

UKaid from the British people

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Ethiopia: Impact in Farmers Fields

- **New, rust resistant varieties have been adopted at scale**
- **2016/17 (on-farm crop cuts + DNA Fingerprinting)**
  - **>61% of area sampled planted to recent varieties**
  - **Giving 12-17% yield gain over old varieties**
  - **Estimated 190,000 tonnes increased production**
  - **Estimated US$40 million in benefit to farmers**

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New Technologies

Models to MinIONs
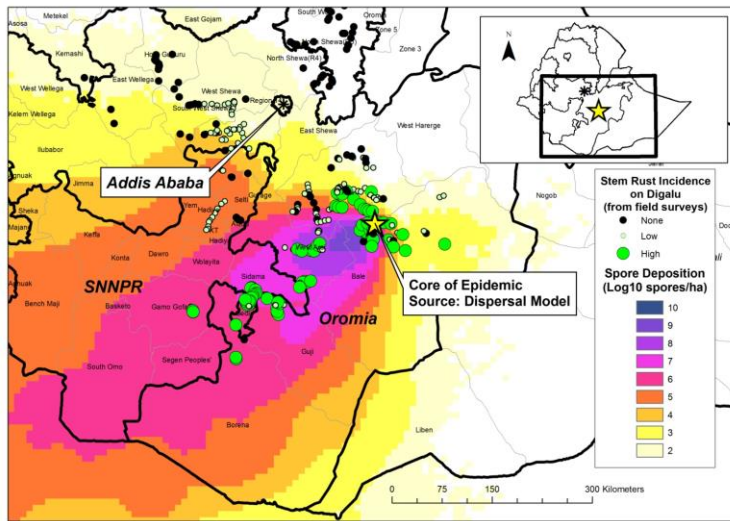
Advanced Stem Rust Spore Dispersal Modeling - Rust Early Warning Systems

- 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

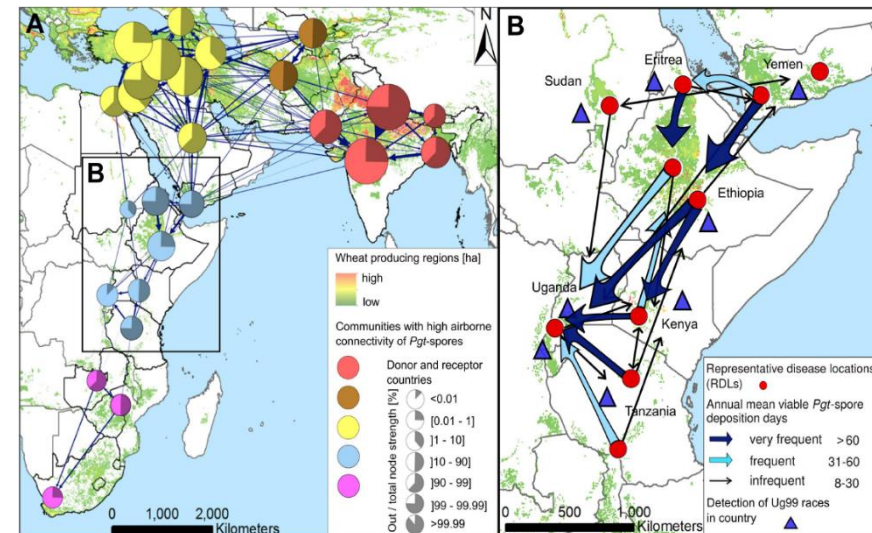- **Predicting many of movements we now seeing globally**

Meyer et al 2017 Nature Plants

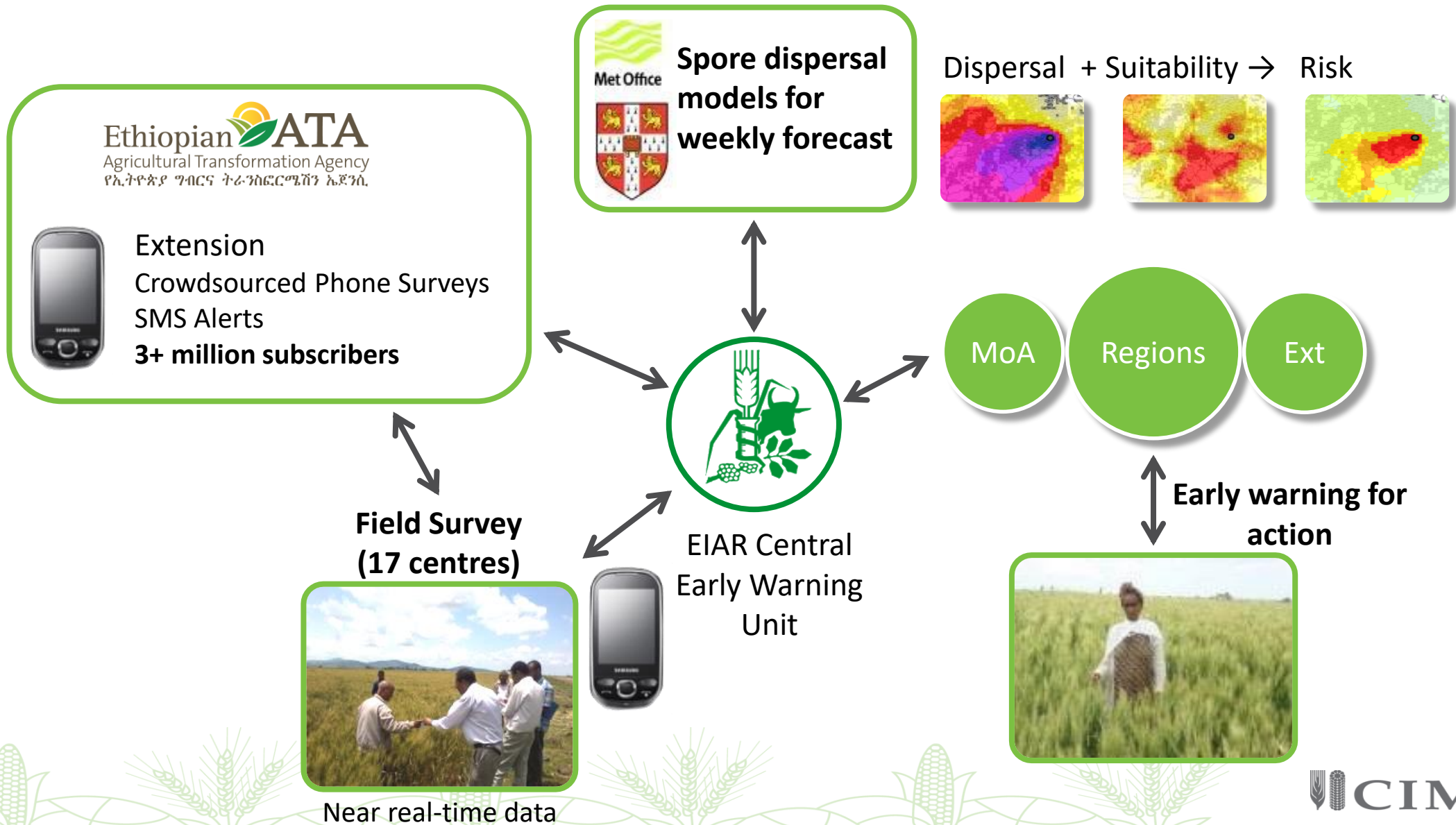# Early Warning Framework - Ethiopia

Spore dispersal models for weekly forecast

Dispersal + Suitability → Risk

Extension
Crowdsourced Phone Surveys
SMS Alerts
3+ million subscribers

Field Survey (17 centres)

MoA   Regions   Ext

EIAR Central Early Warning Unit

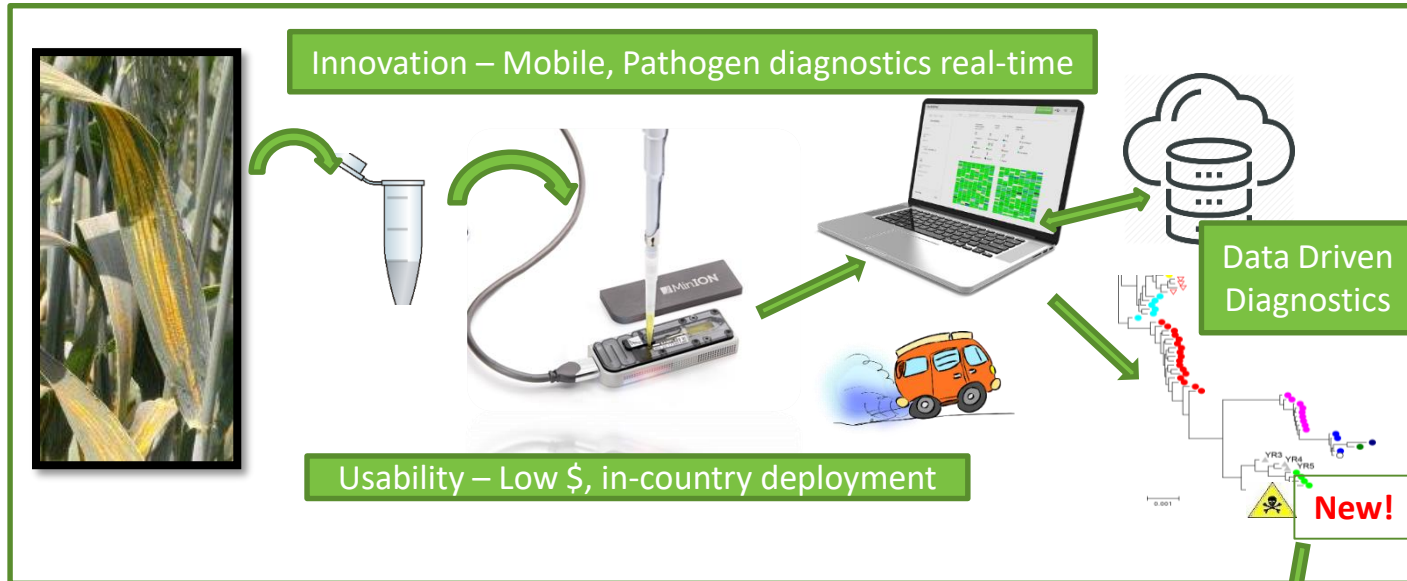**Early warning for action**

Near real-time data

Real-time, Mobile Diagnostics (MinION): Yellow Rust

Exotic incursions = highest risk

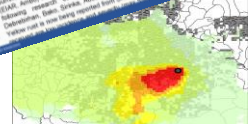**Can we detect them quicker? (in-season before establishment + spread)**

MARPLE DIAGNOSTICS

Innovation – Mobile, Pathogen diagnostics real-time

Data Driven Diagnostics

Usability – Low $, in-country deployment

New!

- **Identify New genetic group Incursions – Fast!**
- **Early Warning + Early Control**

Early Warning Alert + Control

Data Integration - Early Warning System

Risk Forecast

Impact

Future: Other pathogens, countries, crops

John Innes Centre
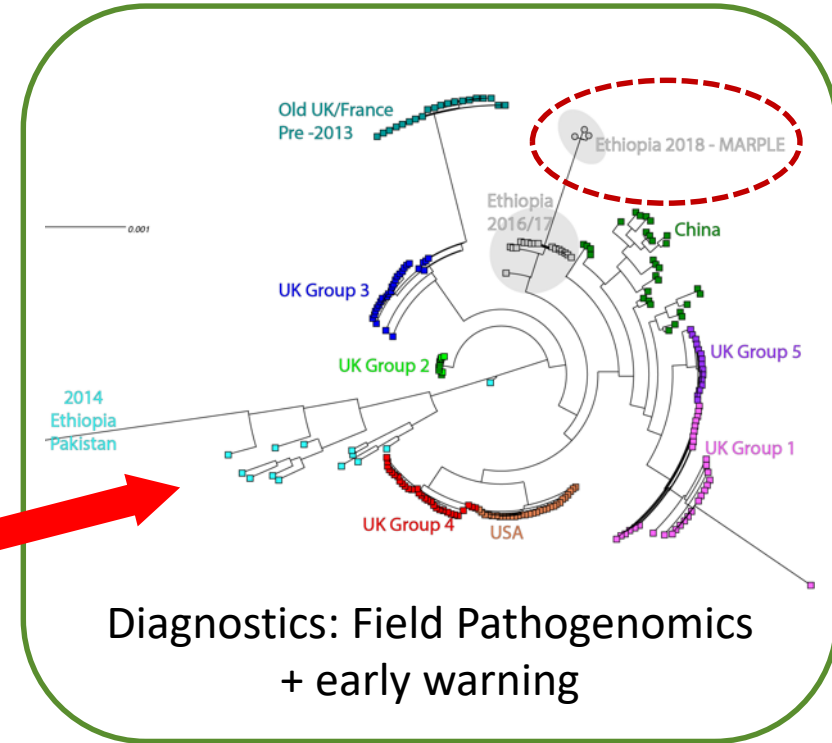Unlocking Nature's Diversity

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Real-time, Mobile Pathogen Diagnostics – A reality

3 Days

Field Sampling

MinION nanopore sequencing (Mobile Lab)

Diagnostics: Field Pathogenomics + early warning

- 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 3 days!!
- Results already incorporated into national rust early warning system

Concluding Remarks

- Made some advances regarding rust surveillance. Probably most comprehensive, operational monitoring system for major crop diseases

- Multi-disciplinary partnerships are critical to success (and also community building)

- Ug99 investments / learning now being applied to other important races (and other rusts and other diseases e.g., MLN)

- New pathogen threats continuing to evolve / future incursions likely – **we must have sustained, long-term effective monitoring, sharing of information + strong connections to breeding programs** (role of durable resistant cultivars critical)

- New technologies playing important roles

- **Pathogen surveillance at large-scale is challenging, but with partnerships possible and increasingly important!**

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Acknowledgements

- AAFC, Winnipeg, Canada
- ATA, Ethiopia
- Cambridge University, UK
- CIMMYT
- DRRW / DGGW Cornell University
- EAAPP
- EIAR, Ethiopia + RARI's
- Ethiopia MoAL + Regional BoA's
- FAO

- Global Rust Reference Centre, Denmark
- ICARDA
- John Innes Center, UK
- PBI, University of Sydney, Australia
- UK Met Office
- University of the Free State, South Africa
- University of Minnesota
- USDA-ARS Cereals Disease Laboratory, Minnesota

National Partners in 35+ Countries