Global Rust Surveillance
- *DGGW Update and Future plans*

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(on behalf of many partners)
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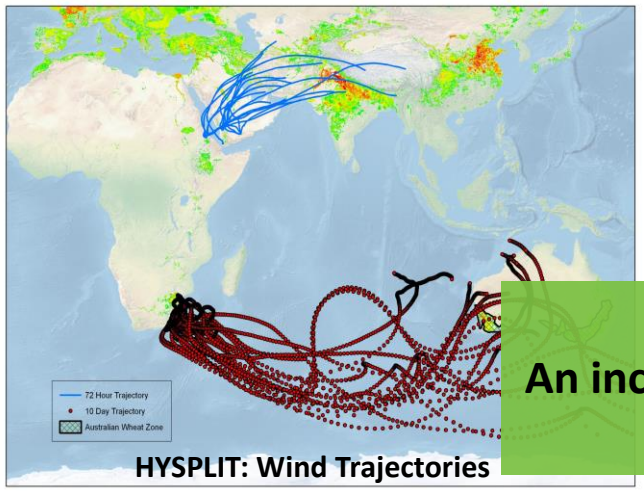
Wheat Rust Surveillance and Contingency Planning Workshop,
Regional Cereal Rust Research Center, Izmir, Turkey 10-20 April 2016.
Supported by ICARDA FAO TAGEM

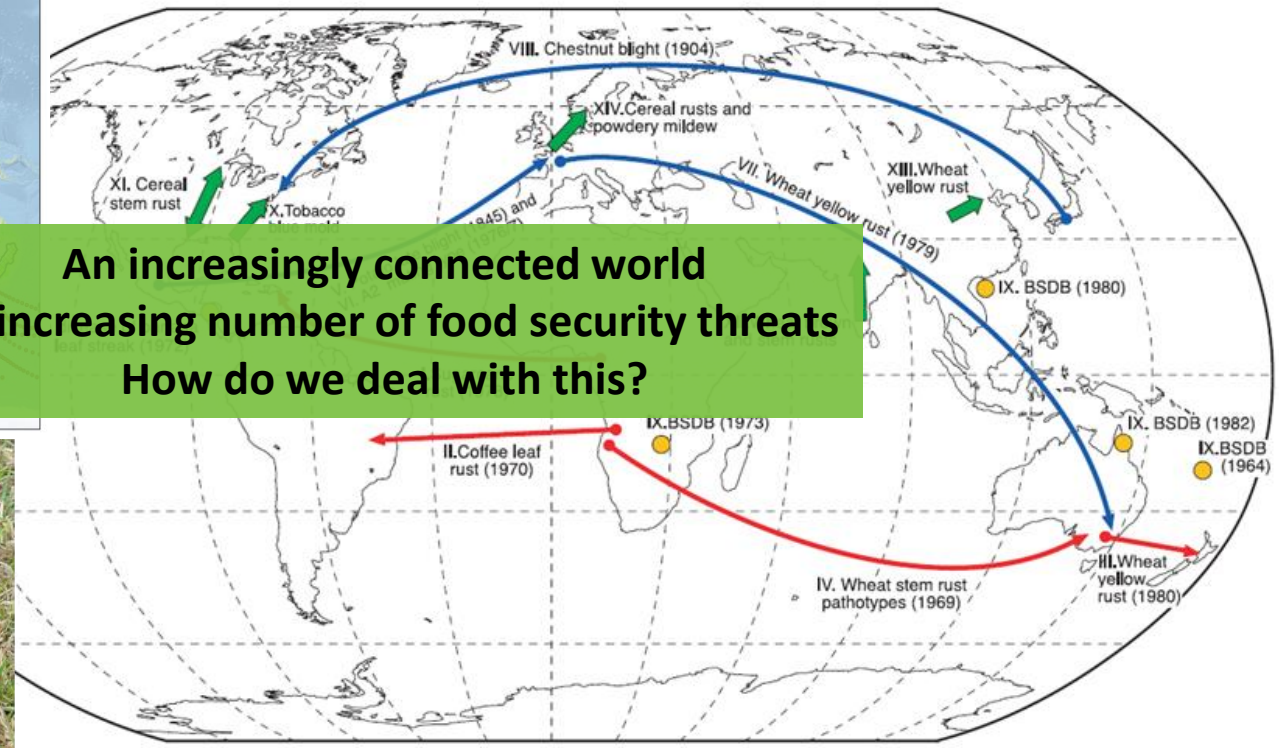
Pathogens without Borders: Long distance dispersal of plant pathogens

- 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 – **<u>increasing with globalization</u>** [Wheat Stripe Rust: Western Europe – Australia]



HYSPLIT: Wind Trajectories

An increasingly connected world
An increasing number of food security threats
How do we deal with this?



(Brown & Hovmøller, Science, 2002)

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

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Wheat Rusts: Long Distance Dispersal + Pathogen Evolution!

Credit; UMN

“a shifty, changing, constantly evolving enemy”

E.C. Stakman

“Rust Never Sleeps”

N.E. Borlaug

Credit: CIMMYT

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Current Races of Concern

Stripe Rust

- Aggressive Strains: PstS1/S2
  - Putative origin: East Africa [2000?]
    - "may be the most rapid spread of an important crop pathogen on the global scale" (Hovmøller et al 2008)
- "Warrior" race group
  - Putative origin: Himalayan region [2010?]
  - Western Europe + spreading (Mert et al 2016)

Stem Rust

- Ug99 race group
  - Putative Origin: East Africa [1998?]
  - Migrating + mutating: Currently 13 races, 13 countries
- "Digelu" race (TKTTF)
  - Putative origin: Middle East [2005?]
  - Causal race of epidemics in Ethiopia since 2013

- **Future??**

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Stem Rust: Global Rust Monitoring Why so important?

- Stem rust – historically the most feared disease of wheat.
- Under favourable conditions, capable of causing 100% crop loss within weeks.
- 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
- Need for global monitoring – where Ug99 is moving + plus detection of the next threats (new variants, other races etc)

Digelu crop killed by stem rust, Ethiopia Nov 2013

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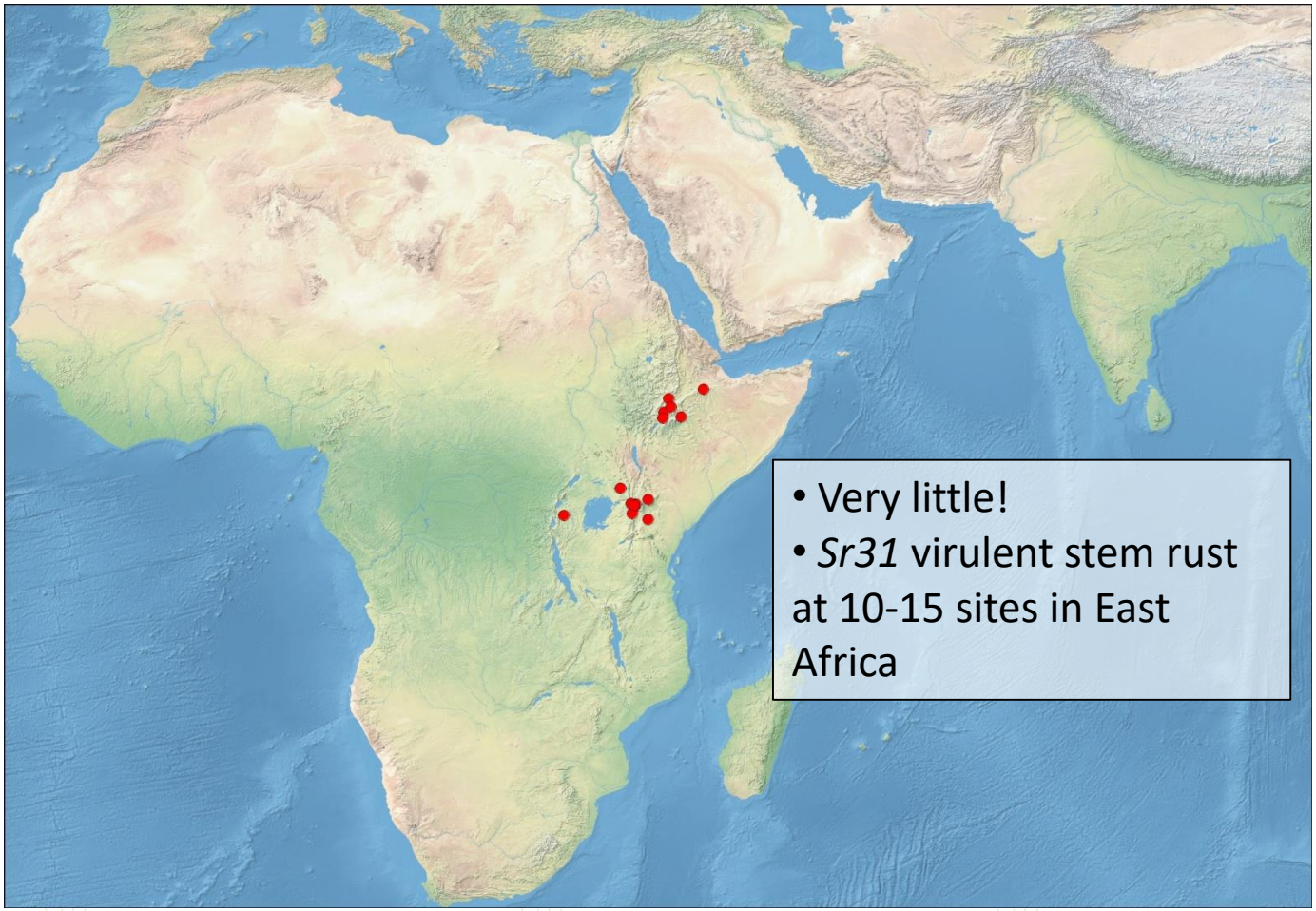
Stem Rust Ug99:
In 2005 What did we know?



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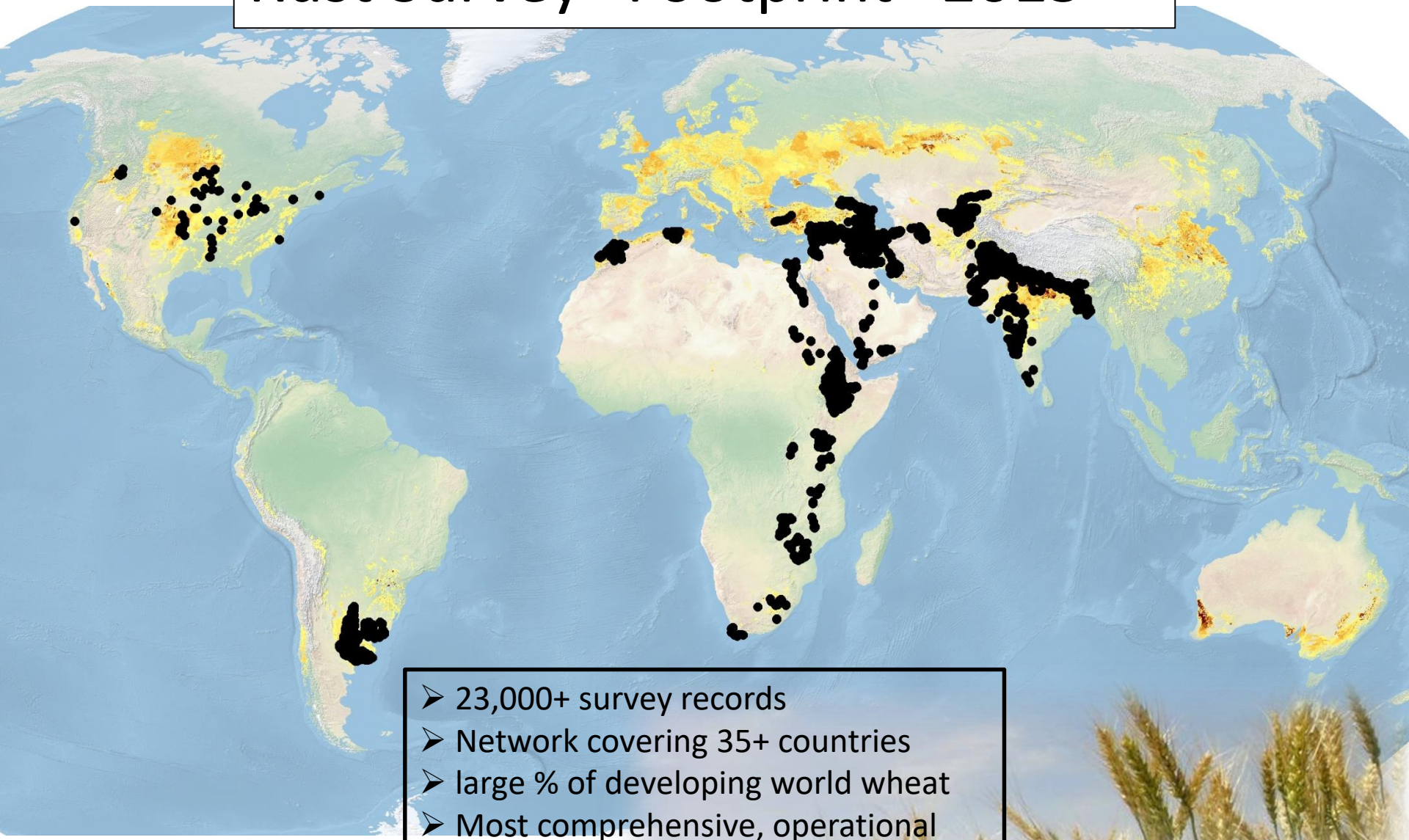
2005: What did we need to do?

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

2016: What have we managed to do?

Rust Survey “Footprint” 2015



- 23,000+ survey records
- Network covering 35+ countries
- large % of developing world wheat
- Most comprehensive, operational monitoring system for major crop diseases

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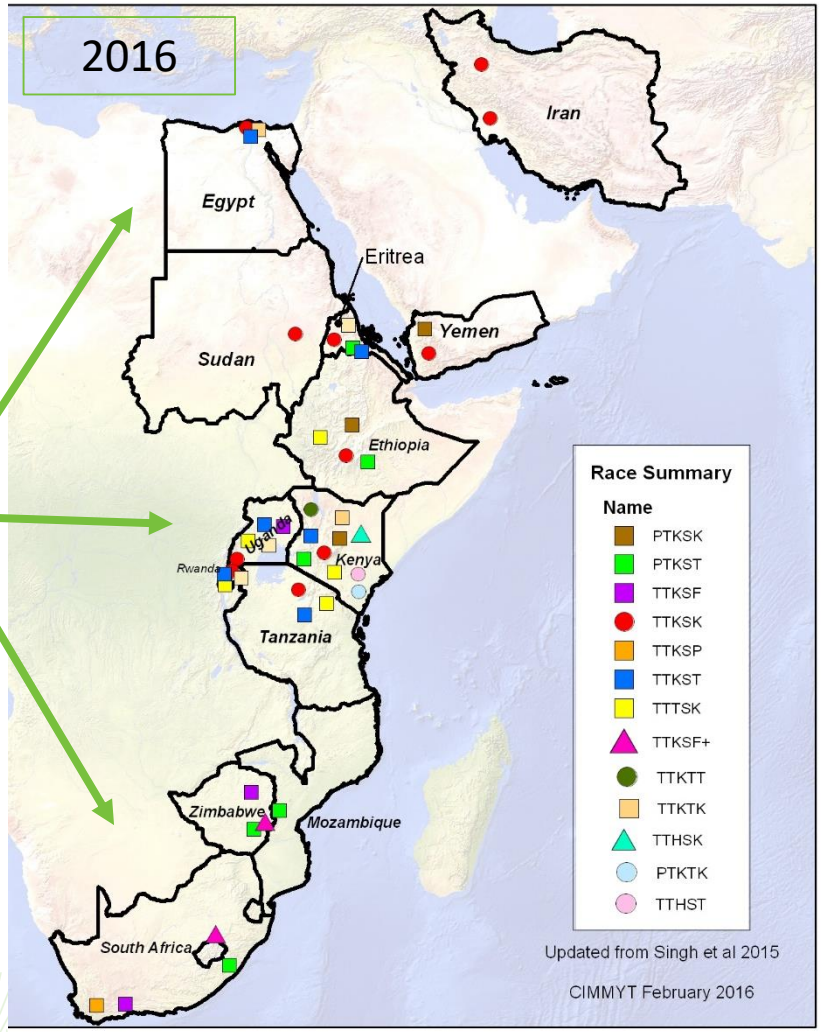
Successful Pathogen Tracking: Spread of Ug99 Race Group 1998-2016

1998



- 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
- In 2014: 1 new variant (TTKTK – Ug99 + *SrTmp* vir) detected in Kenya, Uganda, Rwanda, Eritrea and Egypt
- **Ug99 races getting more virulent over time – serious implications for other regions**

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Barberry in East Africa – New discoveries

Aecia – North Shewa, Ethiopia Dec

Huge credit to the East African teams – for just finding the barberry sites!!

United States Department of Agriculture
Agricultural Research Service

EIAR

Kenya Agricultural & Livestock Research Organization

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Linking Surveillance with Breeding Programs

- Detect important pathogen changes
- Select most relevant races for germplasm screening
- Established world-class screening facilities in East Africa [>470,000 lines screened]
- CIMMYT Focus: Breeding minor, slow-rusting genes based adult-plant resistance (APR)

Table: Ug99 stem rust resistance in CIMMYT wheat entries identified for international distribution in 2015
(Based on three seasons of field data at Njoro, Kenya and seedling test)

Resistance Category	% of Entries
High-Adequate APR	44.8% (n=294)
Adequate APR depending on location of deployment	15.9% (n=104)
Race-specific (9+ Sr genes)	28.8% (n=189)
Inadequate-Susceptible	10.5% (n=69)

Kingbird - one of the best sources of APR

Kenya Agricultural & Livestock Research Organization

EIAR

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Enabling Factors for Success

- Critical focus (Ug99)
- **Partners (lots of them!) – whole spectrum from advanced to basic research**
- Enabling tools and technologies
- Continual engagement / community building
- Investments in capacity building – human and infrastructure
- Strong champions – Dr Borlaug + many others in partner countries

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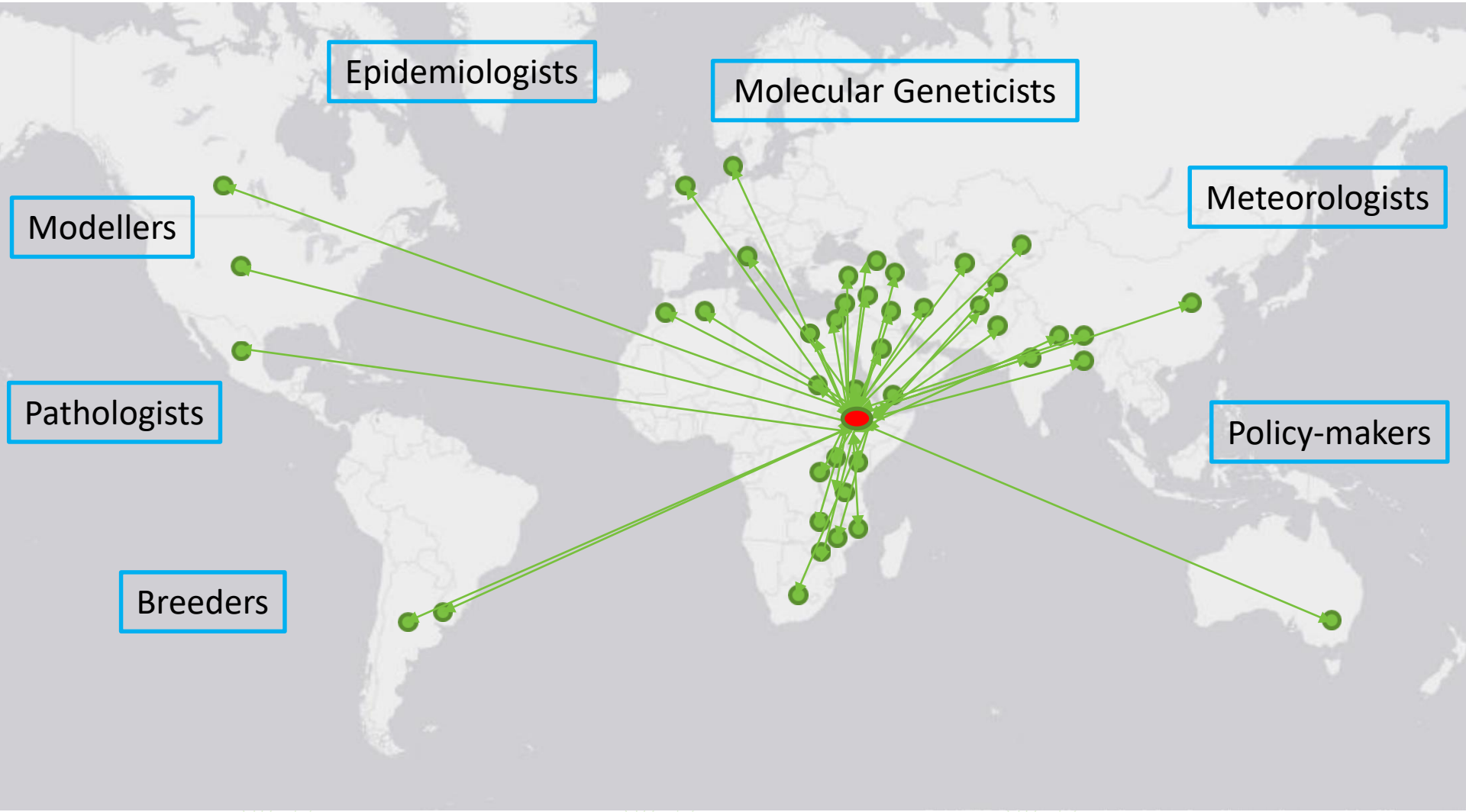
Rust Surveillance Partnership Networks



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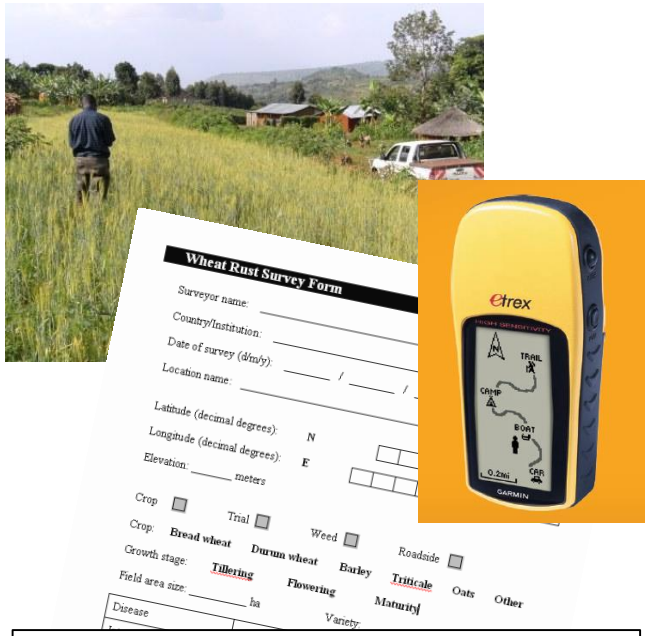
Enabling Tools & Technologies: survey + sampling

Traditional



- GPS + Paper forms
- Manual data entry

New Options

- Smartphone / tablets (GPS, Camera, Electronic Form)
- Rust Survey App developed
- Automatic data transfer

Survey teams using standardized methods in 30+ countries
Field to database now possible in near real-time

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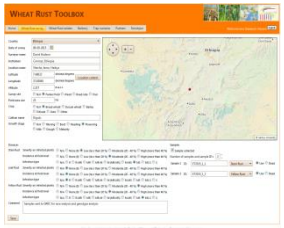
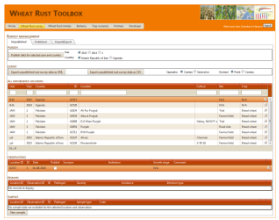
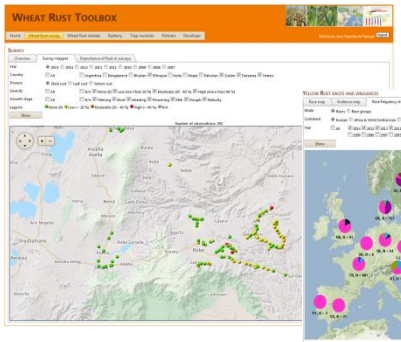
Data Management: Wheat Rust Toolbox

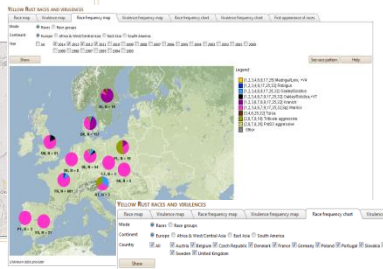
NB: Generic – Applicable to all rusts

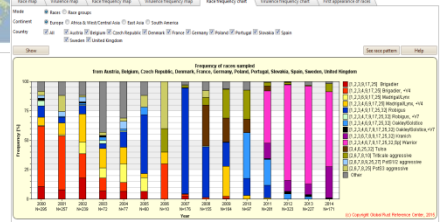
On-line Data Entry & control











Tablet / Smartphone survey tool

Quality control/publish

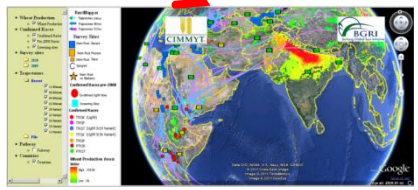
Outputs:
- Survey Mapping
- Pathotypes, +...

User Management

Data Export / Exchange

Wheat Rust Toolbox

Host Pathogen Dbase
(Survey data, Pathotypes & Genotypes, Trap nursery, Rust on barberry)



External Applications e.g., RustMapper

GRRC

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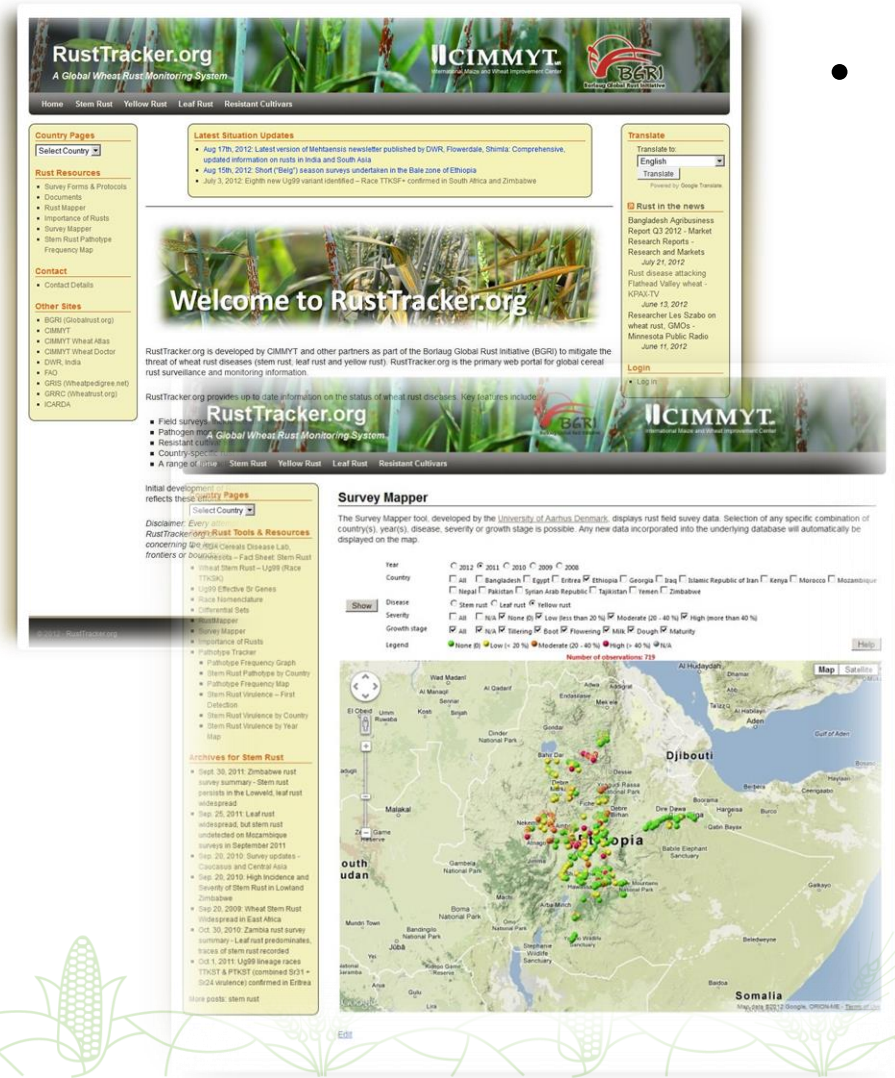
Public Information Systems: WWW Rust Tracker.org



- **Aim:** Single source of up-to-date information for all global wheat rust monitoring activities
  - Linked directly to Wheat Rust Toolbox
  - Dynamic tools – Wheat Rust Toolbox driven
  - Integration of pathogen + host information
  - **www.rusttracker.cimmyt.org**

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Rust Pathotyping Lab Network

Canada
AAFC Morden

Denmark
Global Rust Reference Center

Turkey
Central Field Crops Research Inst + ICARDA, Regional Rust Research Center

Pakistan
PARC, Crop Diseases Res. Inst, Murree

India
DWR Flowerdale, Shimla

USA
USDA-ARS Cereals Disease Lab

Iran
SPII

Ethiopia
EIAR, Ambo PPRC

Kenya
KALRO, Njoro Research Center

South Africa
University of the Free State

Australia
PBI, University of Sydney

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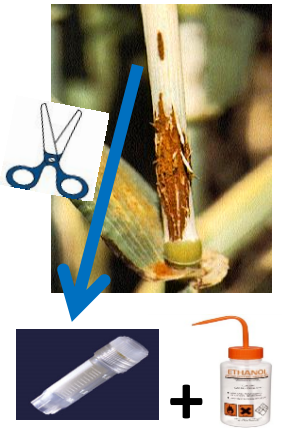
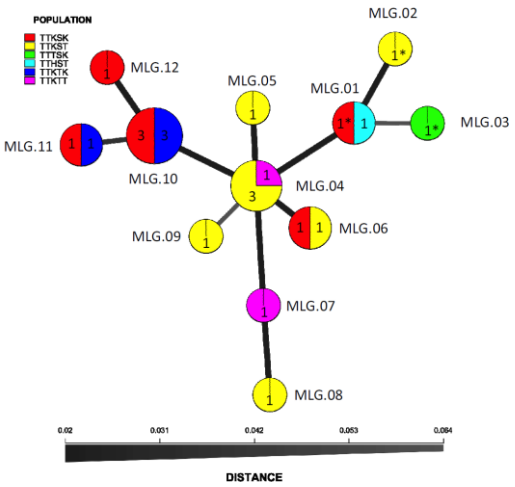
New Technologies: Molecular diagnostics and population genetics

- **Molecular diagnostics:** Rapid + robust diagnostic SNP assay for wheat stem rust Ug99 race group (field collected single pustules).
  - Stage 1: Ug99 Race Group Yes / No.
  - Stage 2: Diagnostic for key races
- **Population genetics:** Developed two high-throughput genotyping SNP chips for studying population genetics and diagnostics of wheat stem rust
  - 1. PgtSNP 1.5k (Illumina GoldenGate)
    - - 50% genome coverage
  - 2. PgtSNP 3.0k (Illumina Infinium)
    - - 98% genome coverage





Newcomb et al. 2016 Phytopathology

Ethiopia 2013: Digelu race (TKTTF) Failure and Success?

- Race TKTTF – Not in Ug99 race group. Virulent on *SrTmp.* Likely an incursion into Ethiopia from Middle East region
- **Failure:** We missed seeing the threat – lack of damage in other regions, imperfect knowledge of R genes in predominant Ethiopian cultivars, lack of knowledge re: migration pathways into Africa

- **NB: First indication of new race mid Oct 2013, full blown epidemic mid Nov 2013! (a single sample in Aug 2012 was later confirmed as 1st detection)**

Digelu crop killed by stem rust, Ethiopia Nov 2013

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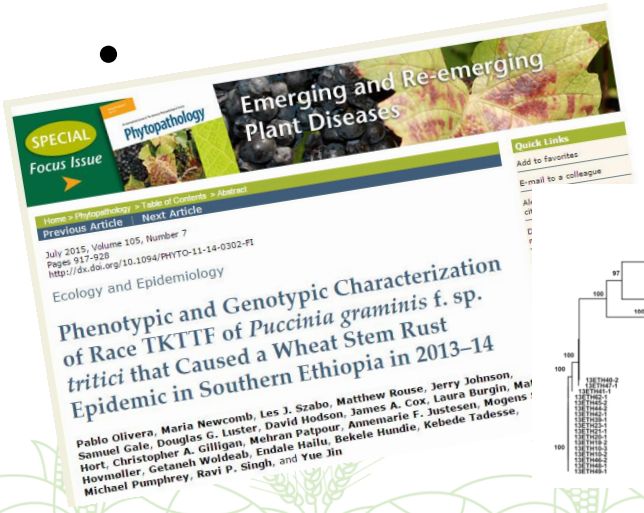
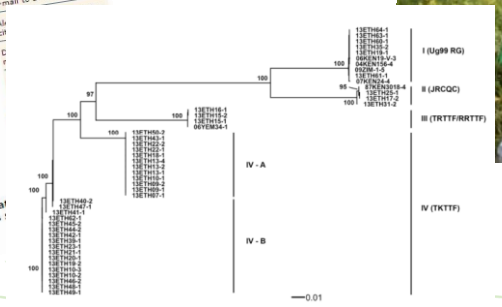
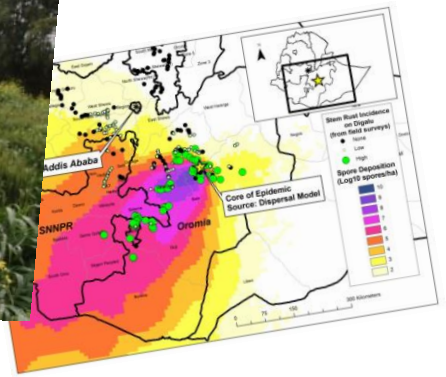
Ethiopia: Digelu race (TKTTF)

- **Success:**
  - Rapid detection and identification within season
  - Outstanding global collaboration (see Olivera et al 2015)
  - **Germplasm screening started immediately in Ethiopia (seedling + adult plant – single race nurseries)**
  - Catalyst for advanced early warning systems
  - Would not have been possible without prior investments around Ug99
-







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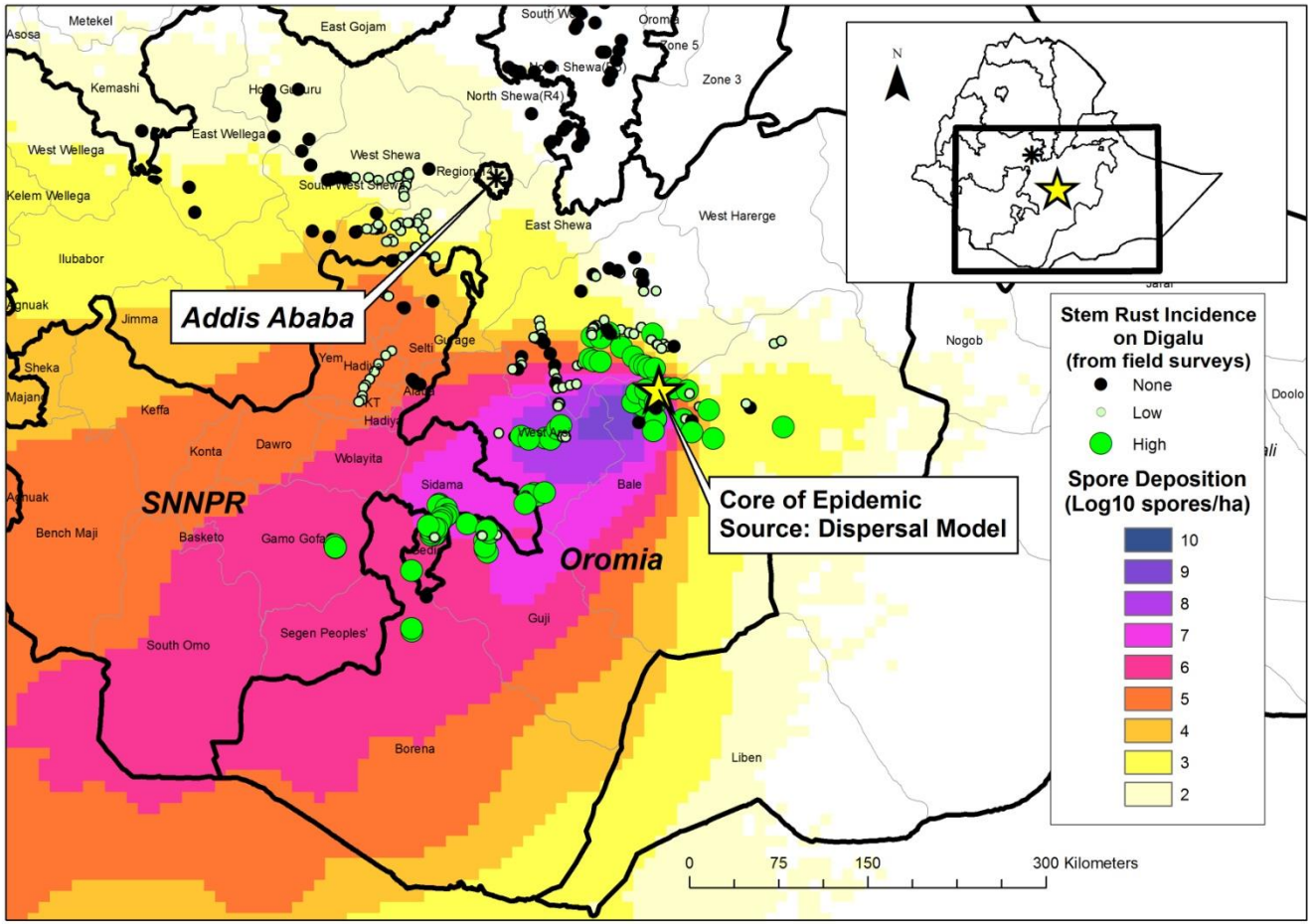
Emerging Early Warning Systems

Ethiopia – Spore dispersal Nov 2013 (Race TKTTF epidemic)



- Spore dispersal / deposition models (close match to observed field data)
- Quantified probability of spore migration pathways at regional scales

Credit: Cambridge University, UK + UK Met Office (see Olivera et al., 2015)

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Met Office

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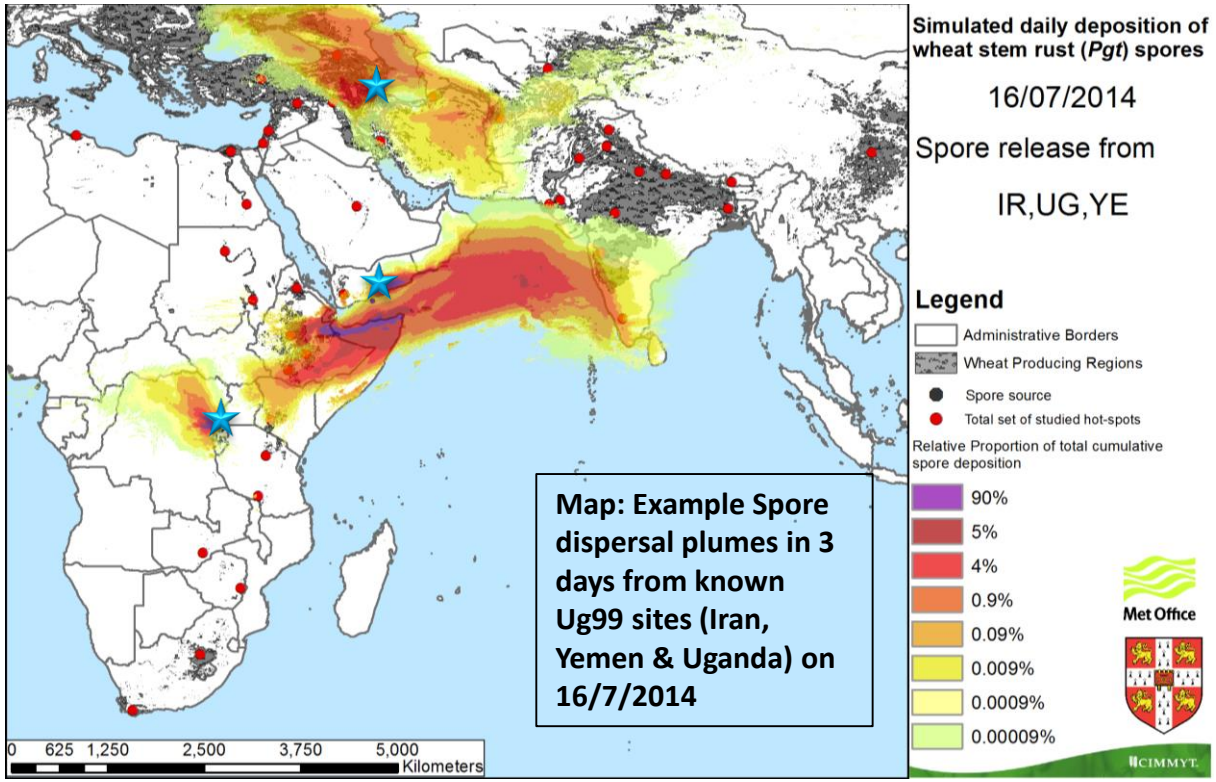
Stem Rust Spore Dispersal Modelling - Emerging early warning systems

Ug99 Sites – Simulated spore release



Map: Example Spore dispersal plumes in 3 days from known Ug99 sites (Iran, Yemen & Uganda) on 16/7/2014

Credit: M. Meyer, Cambridge University

Pathogens without Borders

- Rust spores capable of travelling 1000's of Km in a few days
- Using advanced models: Quantified the probability and seasonality of migration between countries and regions
- Developing rust early warning / forecast systems (E.g., In Ethiopia forecast risk mapping)

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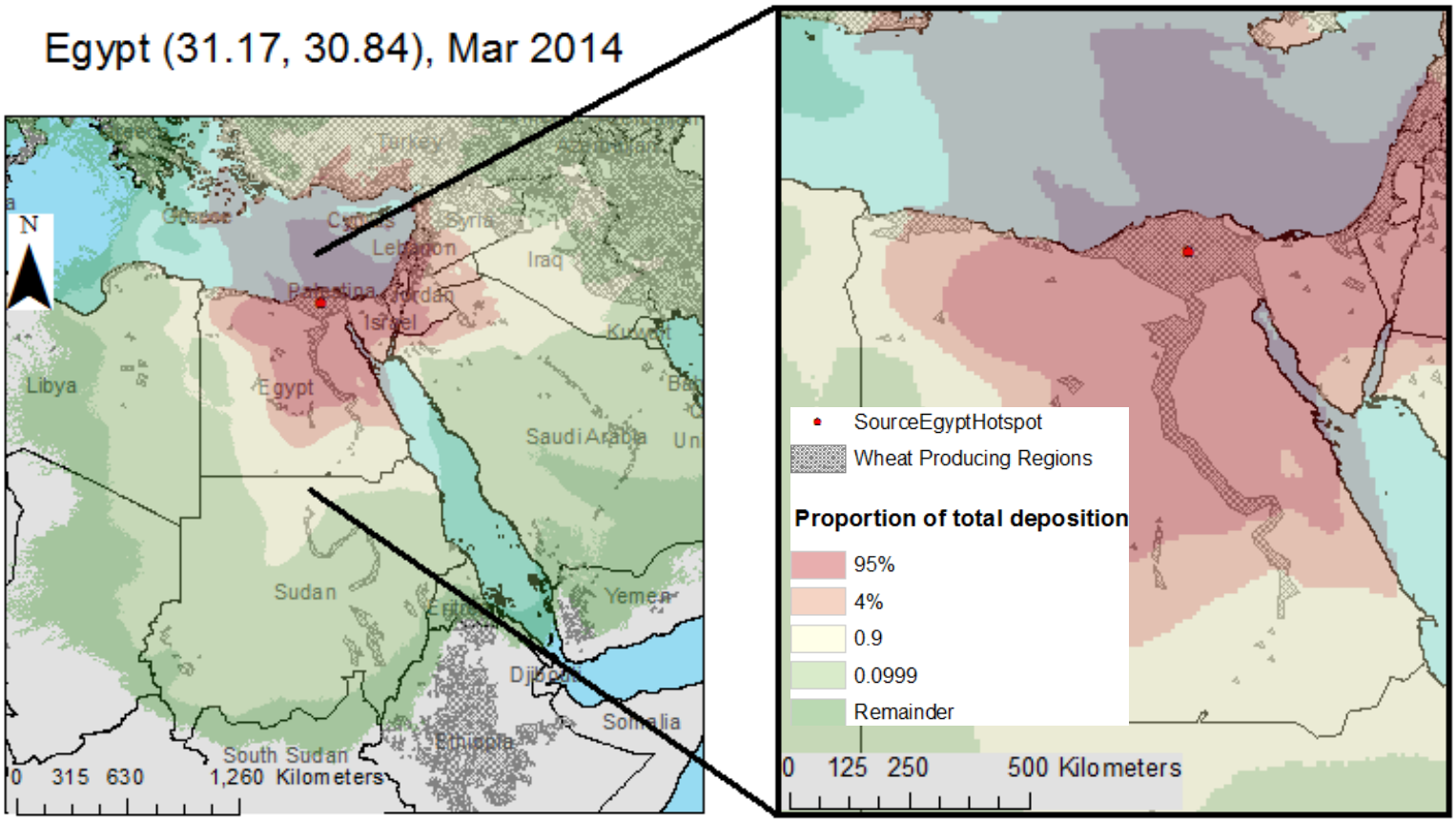
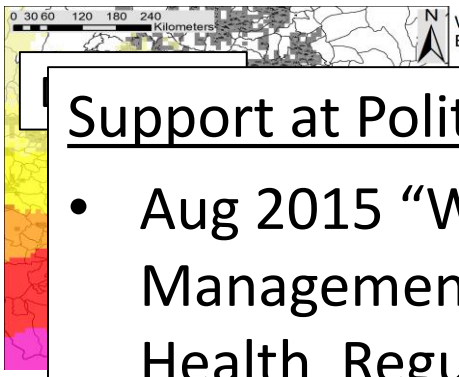
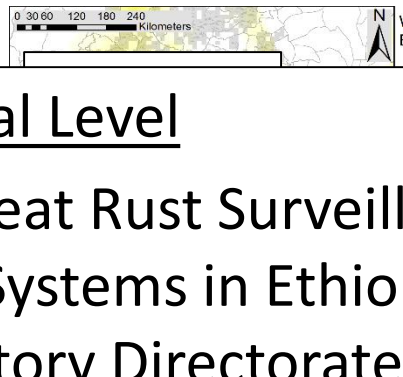
Regional Warning: Example

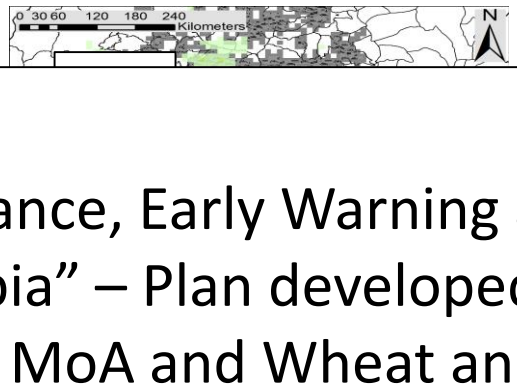
- First Detection Ug99 races Egypt 2014
- Using spore dispersal models – Alert to potential at risk countries



Early Warning – Framework (Ethiopia)







Met Office

Support at Political Level

- Aug 2015 "Wheat Rust Surveillance, Early Warning and Management Systems in Ethiopia" – Plan developed by Plant Health Regulatory Directorate, MoA and Wheat and Barley Value Chain, ATA & EIAR (including consultation with CIMMYT)
- Plan endorsed by H.E. Wondirad Mandefro, State Minister of Agriculture
- Early warning spore dispersal / deposition maps developed by Cambridge University + UK Met Office being tested in Ethiopia

Extension – Crowd source disease information (near real time data)

Field Survey – near real-time data

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Expansion to other crops / diseases

- Similar surveillance system now being developed for Maize Lethal Necrosis (MLN) in Africa

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Delivering Genetic Gains in Wheat (DGGW)

- New project to continue and expand work of BGRI
- New grant announced in Cd Obregon, Mexico 16th March 2016
- 4 years of funding from BMGF US$24M (+ hoped for contribution from DFID, UK?)
- To “mitigate serious threats to wheat brought about by climate change and develop and deploy new strains of wheat that are heat tolerant as well as resistant to wheat rusts and other diseases”.

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DGGW

- Much broader scope than DRRW
- More emphasis on breeding / other traits
- Rusts still an important component
- Rust surveillance and critical rust screening facilities remain priority issues in DGGW

Concluding Remarks

- Made some advances regarding stem 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)
- **Pathogen surveillance at large-scale is challenging, but with partnerships possible and increasingly important!**

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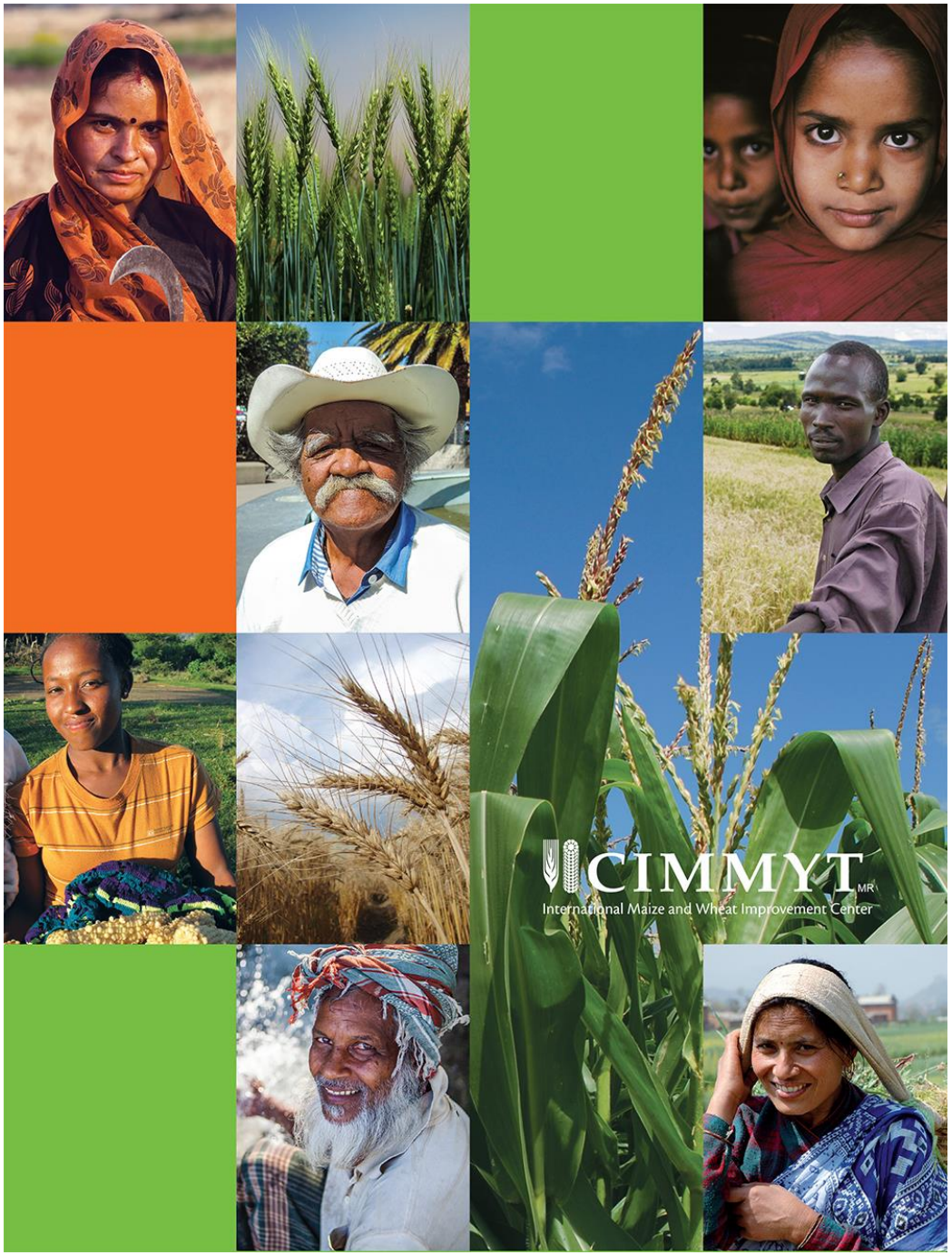
Acknowledgements

- AAFC, Morden, Canada
- ATA, Ethiopia
- **BMGF**
- Cambridge University, UK
- CIMMYT
- CRIFC, Turkey
- **DFID**
- DRRW / Cornell University
- DWR, Shimla, India
- EAAPP
- EIAR, Ethiopia + RARI's
- Ethiopian MoA + Regional BoA's
- FAO
- Global Rust Reference Centre, Denmark
- ICARDA
- John Innes Center, UK
- KALRO, Kenya
- PBI, University of Sydney, Australia
- Sathguru Management Consultants
- UK Met Office
- University of the Free State, South Africa
- University of Minnesota
- USDA-ARS Cereals Disease Laboratory, Minnesota
- **USAID**

Partners in national programs in over 30 countries



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