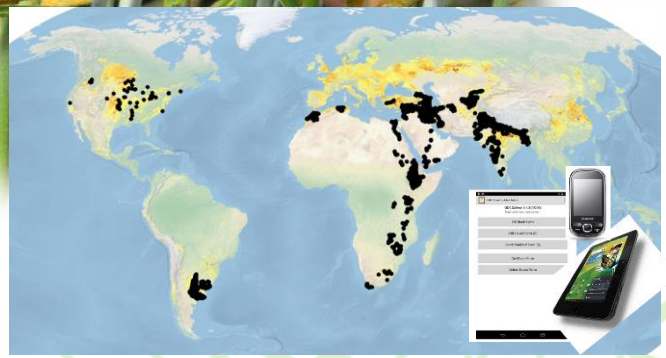

Global Rust Monitoring

Dave Hodson (CIMMYT)
d.Hodson@cgiar.org

Training workshop in cereal rust surveillance, race analysis, and management of wheat rust diseases in Central Asia and Caucasus

Izmir, Turkey 9th May 2022

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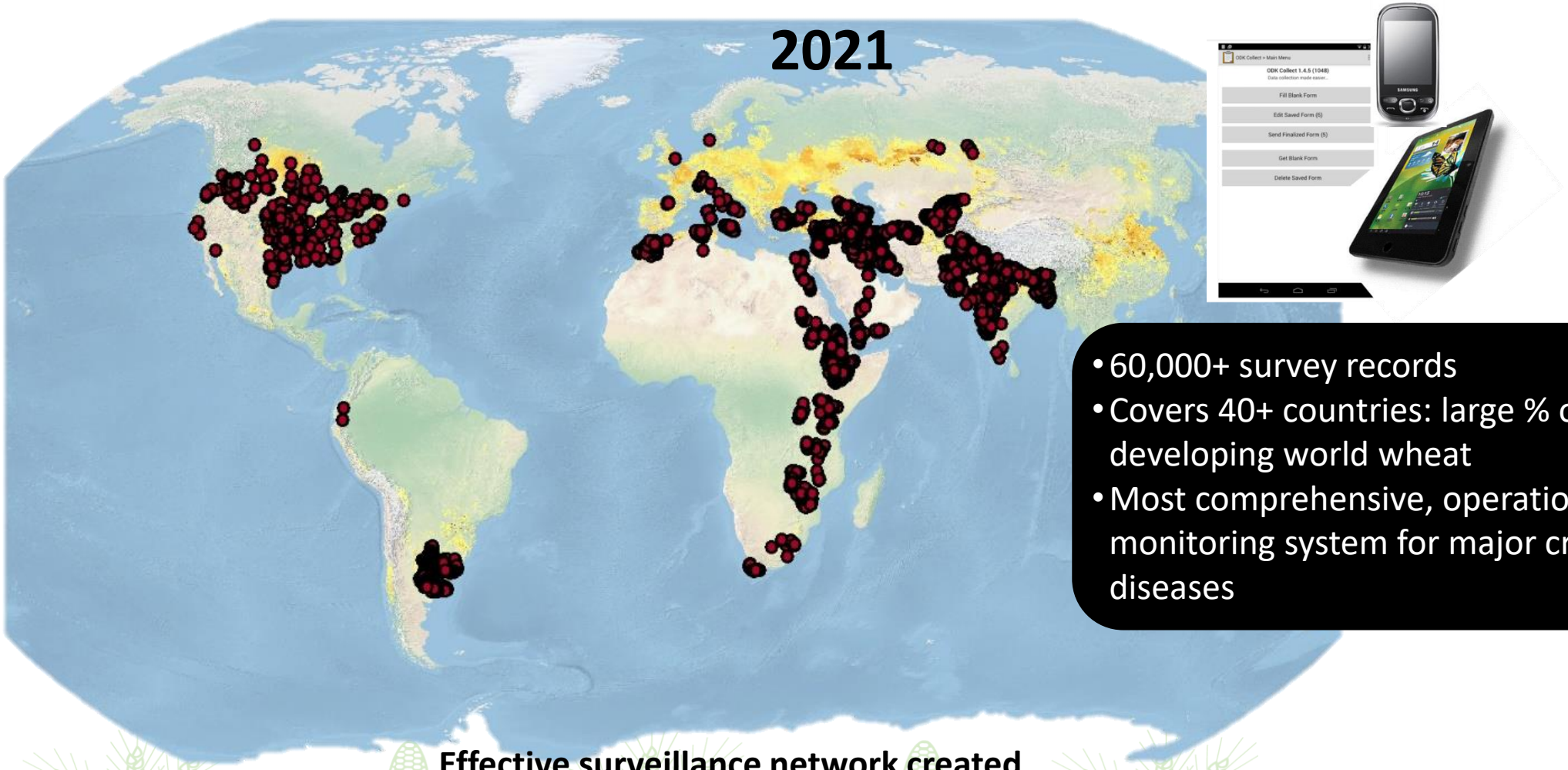
Global Wheat Rust Monitoring



- 60,000+ survey records
- Covers 40+ countries: large % of developing world wheat
- Most comprehensive, operational monitoring system for major crop diseases

Effective surveillance network created

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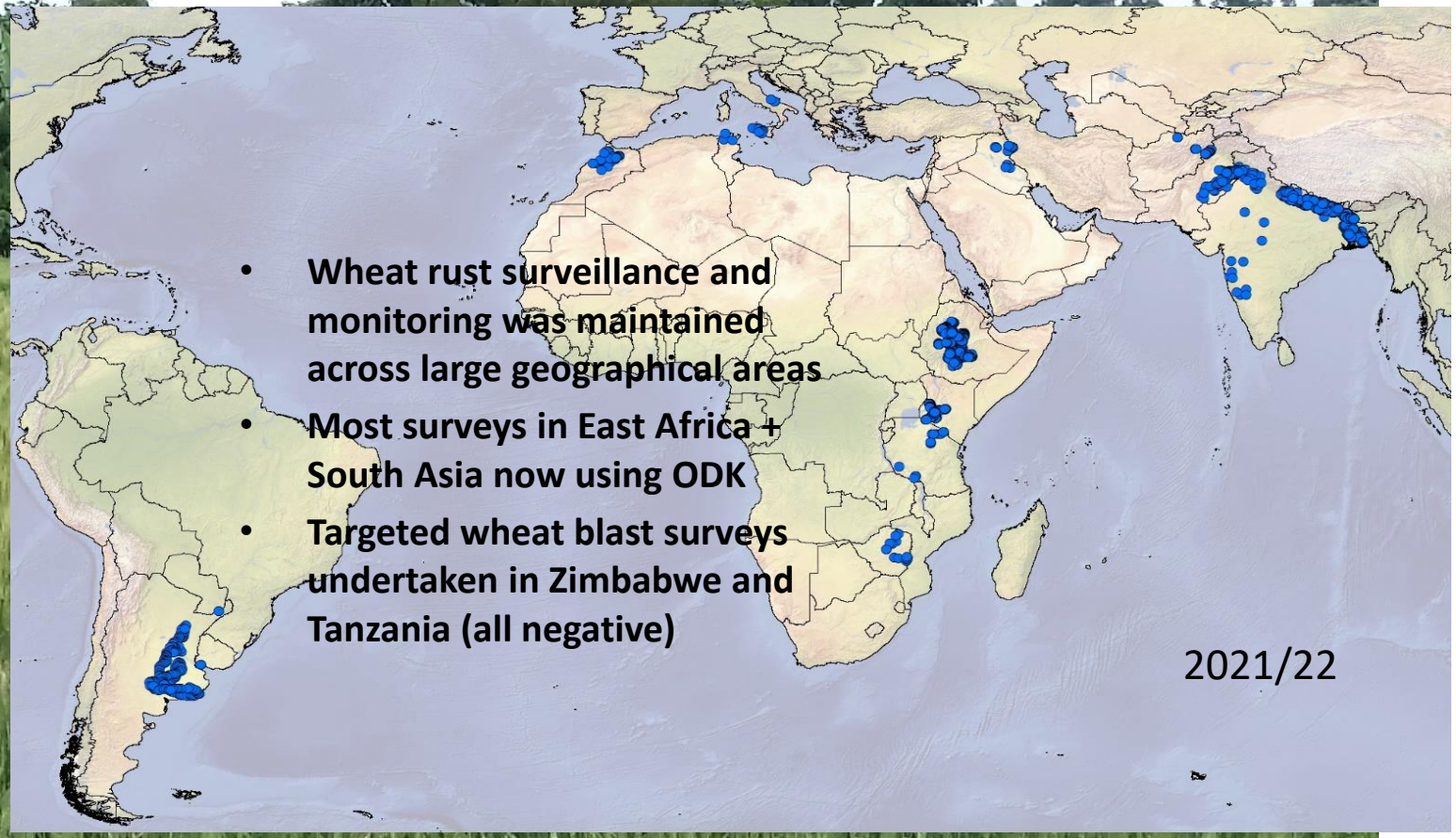
Surveillance



- Wheat rust surveillance and monitoring was maintained across large geographical areas
- Most surveys in East Africa + South Asia now using ODK
- Targeted wheat blast surveys undertaken in Zimbabwe and Tanzania (all negative)

2021/22

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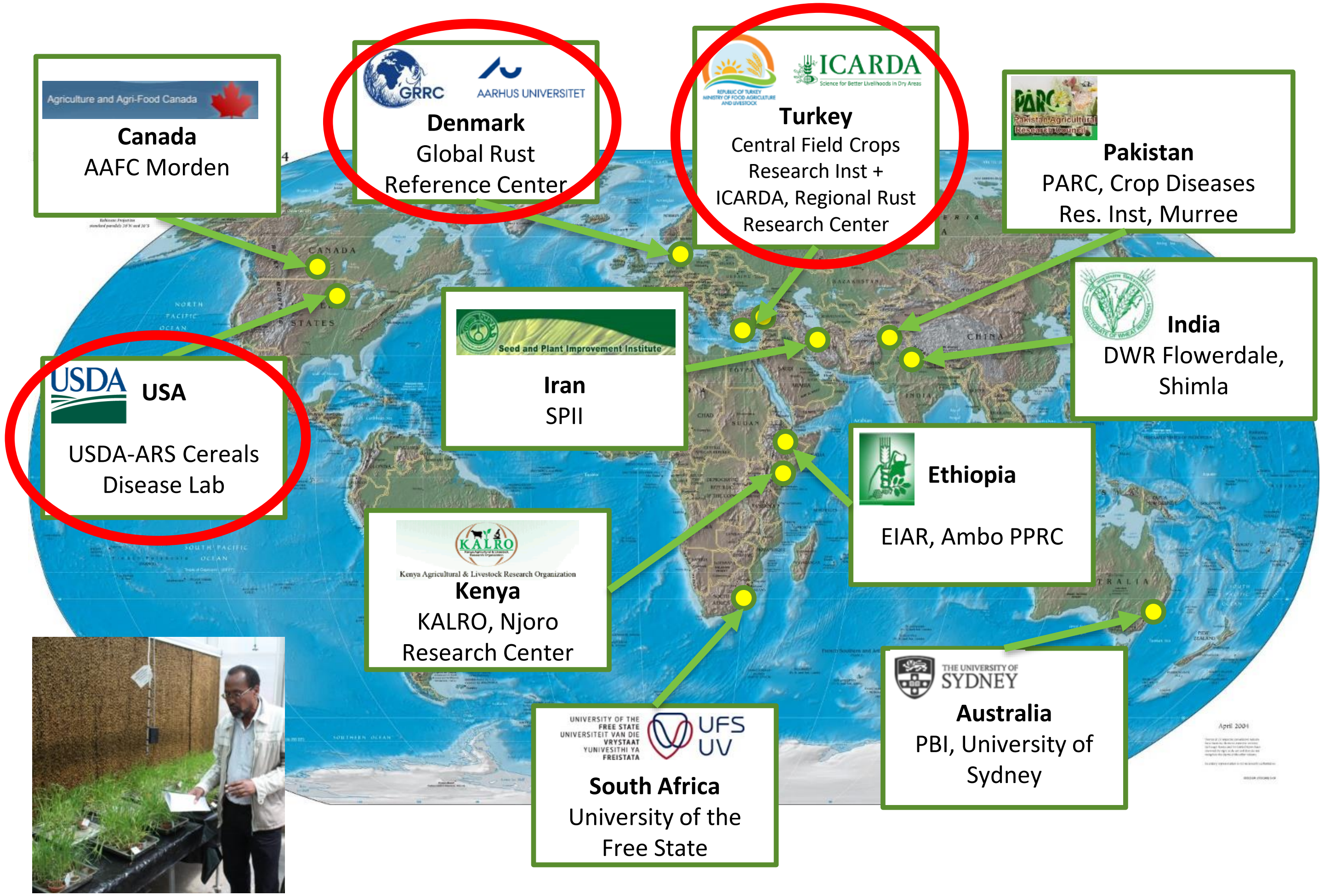
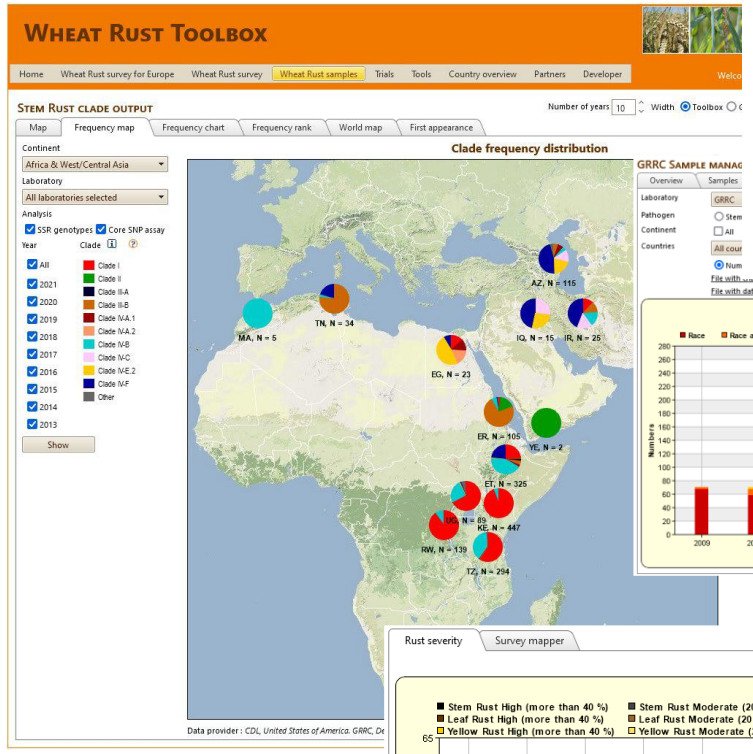
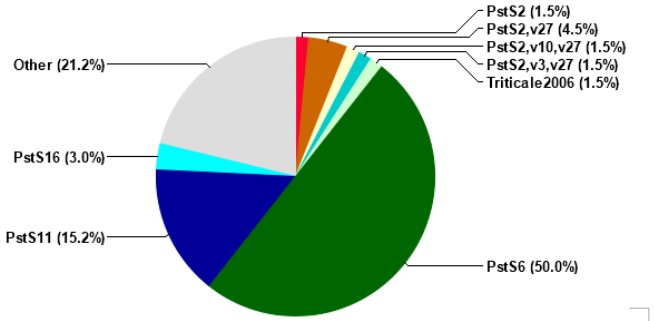
Rust Pathotyping Lab Network

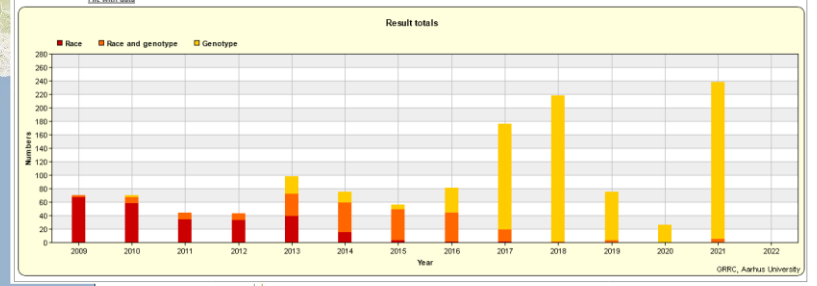


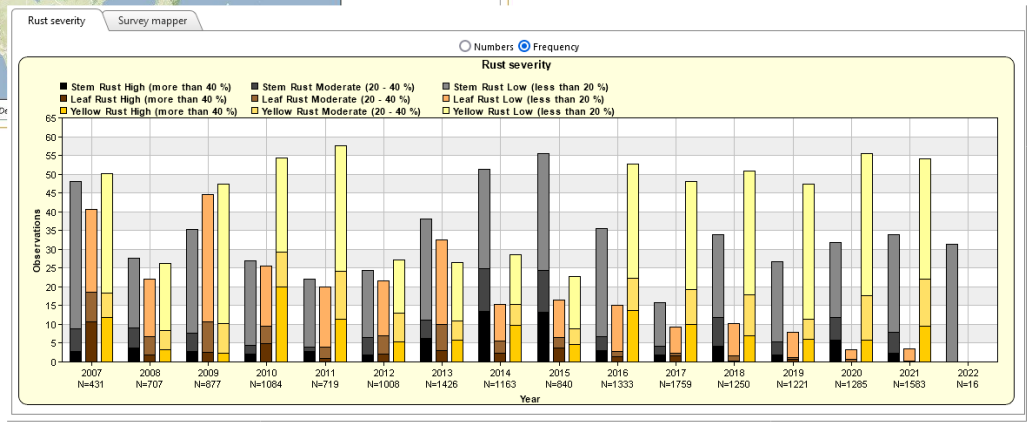
Wheat Rust Toolbox

- The wheat rust toolbox has been maintained and expanded.
- **One of the most comprehensive crop disease data resources**
- **60,000+ geo ref survey records from 43 countries**
- **10,000+ sample records (6700 YR, 3600 SR)**
- New display tools have been added:
  - frequency of races and genotypes
  - cultivar ranking on which races occur.
- A new module for the vulnerability mapping tool
- Automated ODK data feed to toolbox









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Pathotyping YR

- Sampling resuming after covid
- X4 fold increase in samples in 2021
- Rapid genotyping – increasing speed of results
- Izmir lab resuming operation – Yr samples from Ethiopia in process

Number of samples received per February 2nd 2022 (GRRC)

Yellow rust

Pathogen	YR				
Count of Running_number			Crop_seaso		
Geographic group	Country	Site	2020	2021	Grand Total
Africa, C&W Asia	Afghanistan	Farmer		81	81
		Trial		42	42
	Ethiopia	Farmer		125	125
		Trial	20	58	78
		(blank)	6	11	17
	Iraq	Farmer		26	26
		Trial		7	7
	Kenya	Farmer	7	25	32
		Trial	57	27	84
		(blank)		1	1
	Tanzania	Farmer		3	3
		Trial		2	2
Africa, C&W Asia Total			90	408	498
South America	Paraguay	Trial		9	9
	Uruguay	Farmer		9	9
		Trial		11	11
South America Total				29	29
South Asia	Nepal	Farmer		18	18
		Trial		19	19
South Asia Total				37	37
Grand Total			90	474	564

326 of these are genotyped
286 with validated results uploaded on WRT

Training: Venancio Riella (Uruguay); Min Lin (Norway): April-July

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REPUBLIC OF TURKEY MINISTRY OF FOOD AGRICULTURE AND LIVESTOCK

ICARDA Science for Better Livelihoods in Dry Areas

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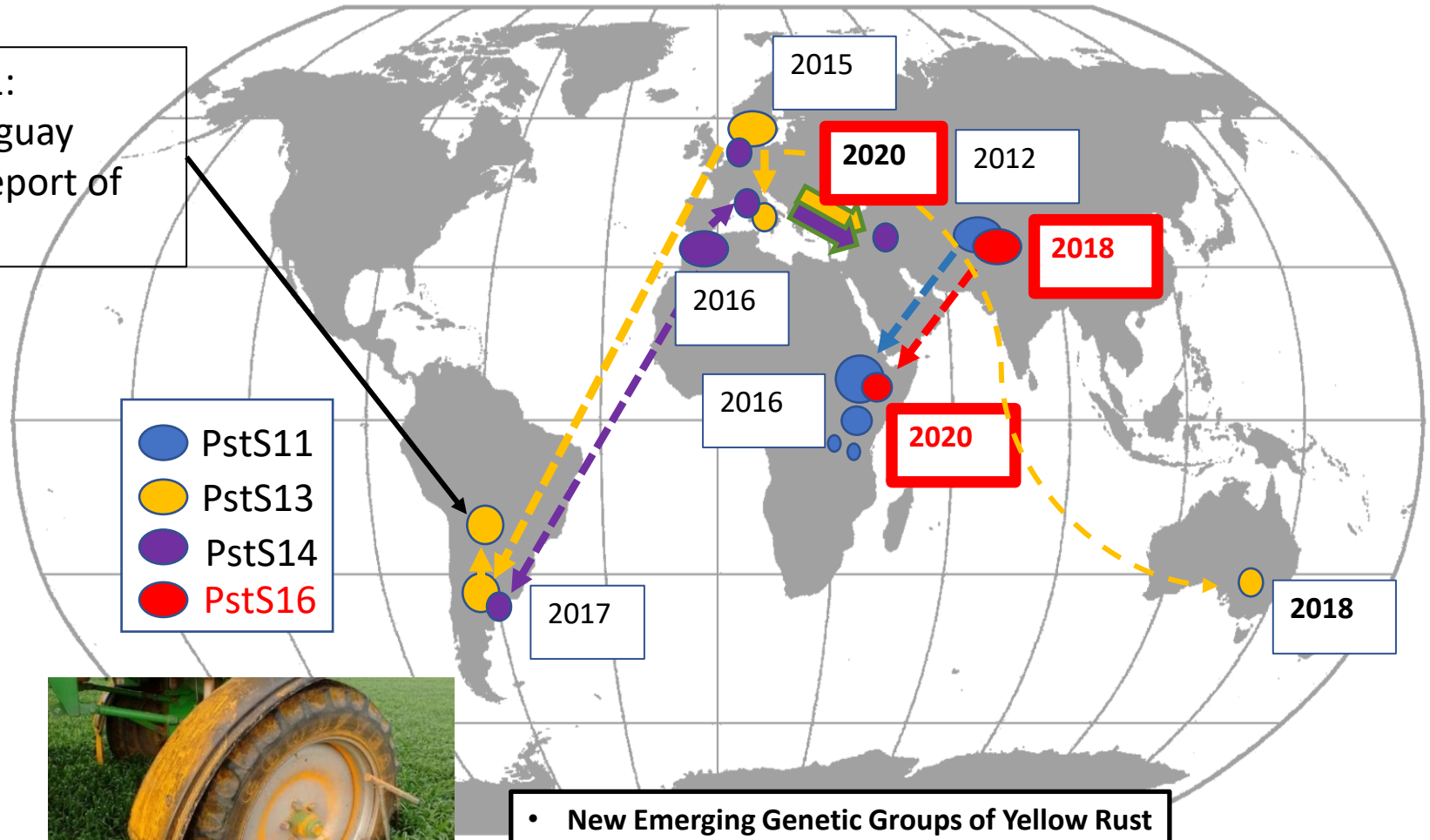
Recent Yellow Rust - Global

- **Tracking important races globally**
- **New race (PstS16) – Afghanistan/Pakistan (2018) – Ethiopia (2020)**
- **No confirmation in Kenya 2021 (samples under test now!)**
- PstS13 confirmed in Australia (2018)
- PstS14 Iraq (2020)
- 2021 First reports of YR Paraguay
- 2021 Nepal – high diversity (sexual population?)



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Pathotyping SR

- Sampling increasing after covid
- X2 fold increase of samples at GRRC
- 3 new variants of Ug99 detected in 2020
- Ug99 race group becoming dominant again in East Africa
- Izmir lab resuming operation – Sr samples from Ethiopia in process

Number of samples received per February 2nd 2022 (GRRC)

Stem rust

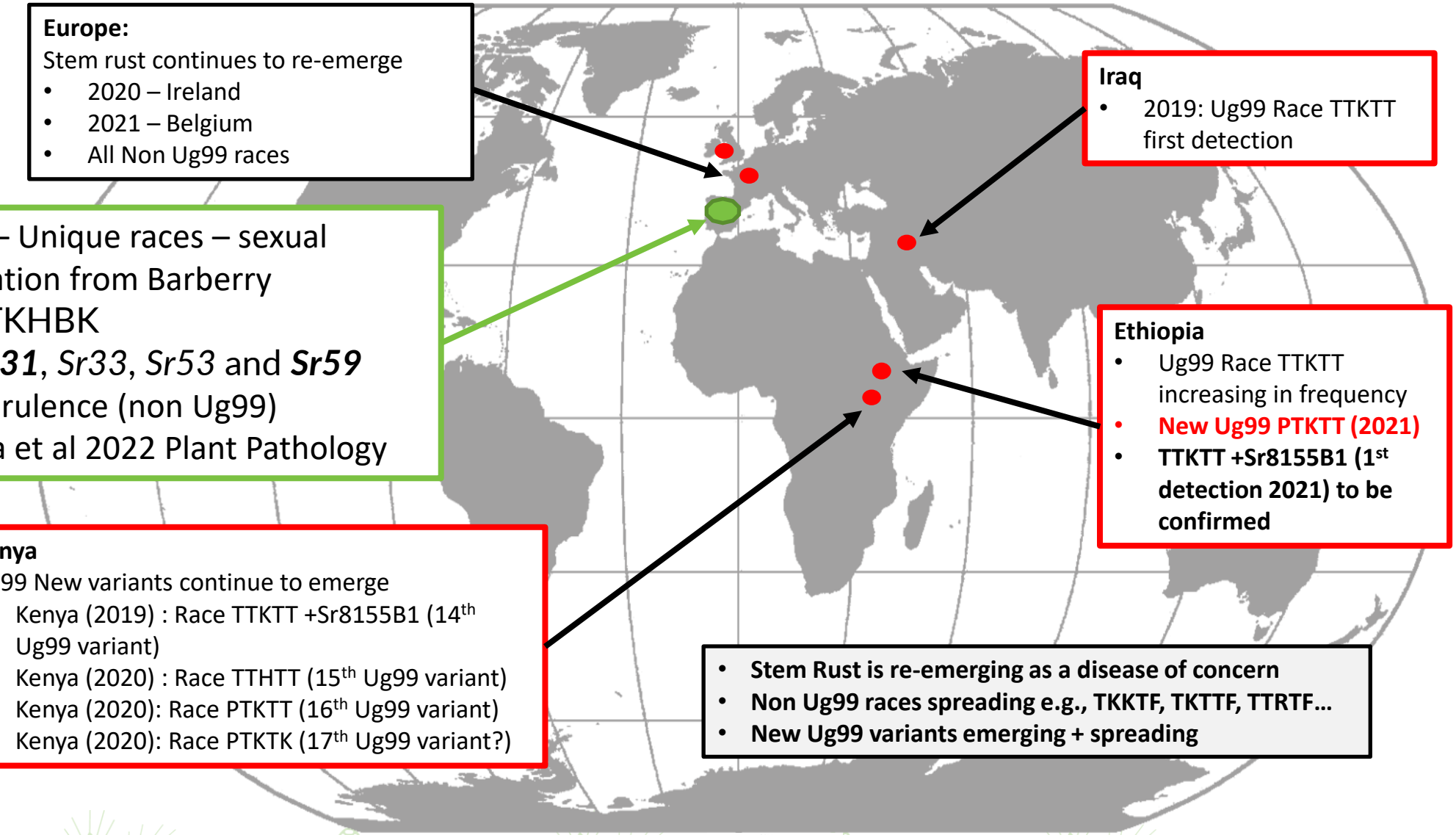
Number of isolates			Crop_season _year		
Geographic group	Country	site	2020	2021	Grand Total
Africa, CW Asia	Ethiopia	Trial		4	4
		-		1	1
	Kenya	Farmer	17	58	75
		Trial	54	31	85
	Tanzania	Farmer		35	35
	Tunisia	Farmer		15	15
		Trial		15	15
Africa, CW Asia Total			71	159	230
C & N America	Mexico	-	11		11
C & N America Total			11		11
Grand Total			82	159	241

140 of these are genotyped
134 with validated results uploaded on WRT

CDL / UMN	Samples	Viable samples	Isolates	Number of Races
Ethiopia	49	49	100	7
Kenya	34	6	10	2 (TTKTT+, TTKSK)

USDA University of Minnesota GRRC GLOBAL RUST REFERENCE CENTER ICARDA EIAR CIMMYT

Stem Rust: Recent Developments



Europe:
Stem rust continues to re-emerge
- 2020 – Ireland
- 2021 – Belgium
- All Non Ug99 races

Spain – Unique races – sexual population from Barberry
Race TKHBK
Vir: ***Sr31***, *Sr33*, *Sr53* and ***Sr59***
Sr31 virulence (non Ug99)
Olivera et al 2022 Plant Pathology

Iraq
- 2019: Ug99 Race TTKTT first detection

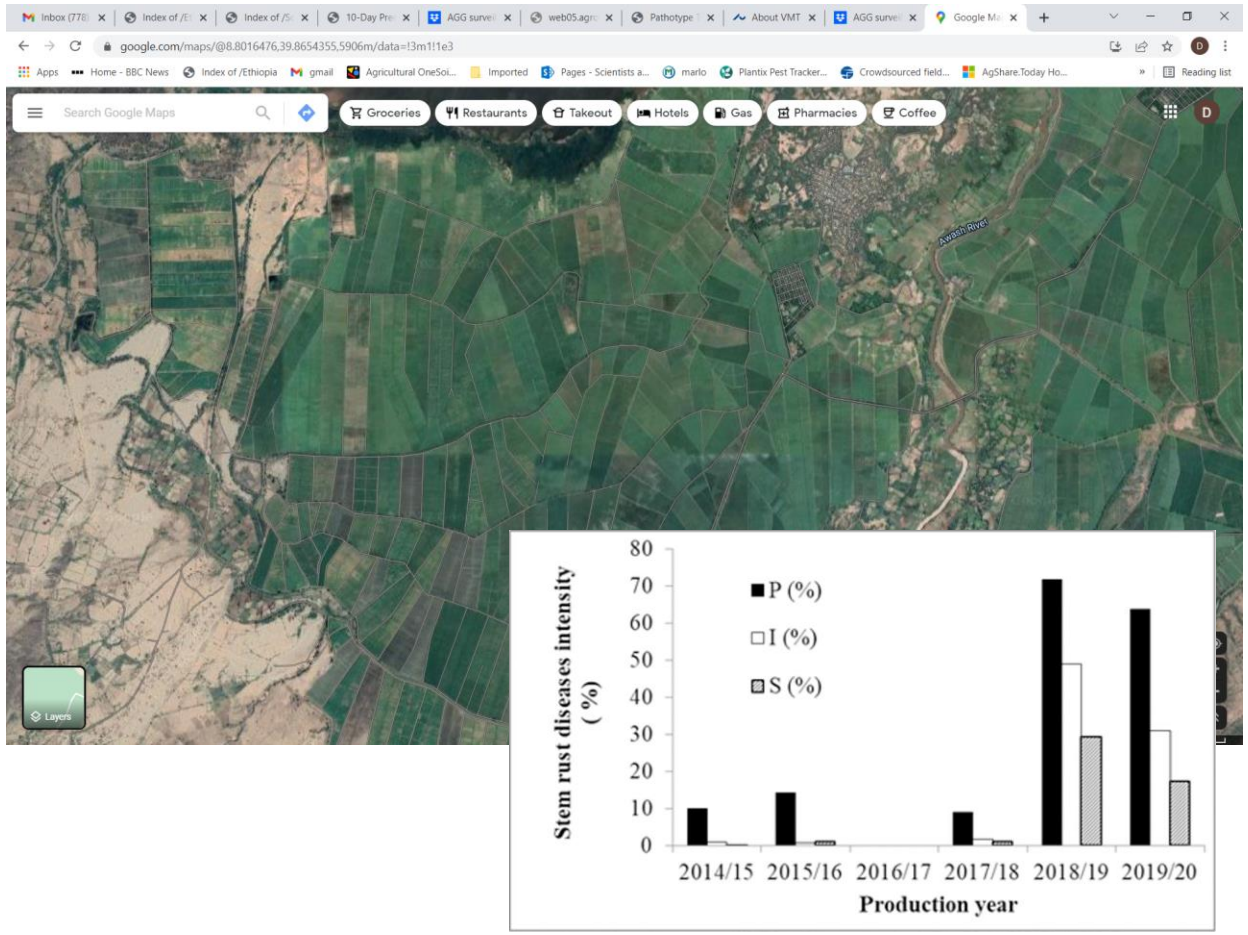
Ethiopia
- Ug99 Race TTKTT increasing in frequency
- **New Ug99 PTKTT (2021)**
- **TTKTT +Sr8155B1 (1st detection 2021) to be confirmed**

Kenya
Ug99 New variants continue to emerge
- Kenya (2019) : Race TTKTT +Sr8155B1 (14th Ug99 variant)
- Kenya (2020) : Race TTHTT (15th Ug99 variant)
- Kenya (2020): Race PTKTT (16th Ug99 variant)
- Kenya (2020): Race PTKTK (17th Ug99 variant?)

- **Stem Rust is re-emerging as a disease of concern**
- **Non Ug99 races spreading e.g., TKKTF, TKTTF, TTRTF…**
- **New Ug99 variants emerging + spreading**

Ethiopia Irrigated Wheat

- Rapid expansion of irrigated areas (highlands and lowlands) – 300,000 ha
- Target for 2022/23 – 3 million hectares!
- Likely big influence on disease epidemiology – both stem and yellow rust
- Green bridge between seasons
- Asynchronous planting (wide variation in growth stages)
- Implications for surveillance + migration to other regions
- Strong rust control measures likely to be needed

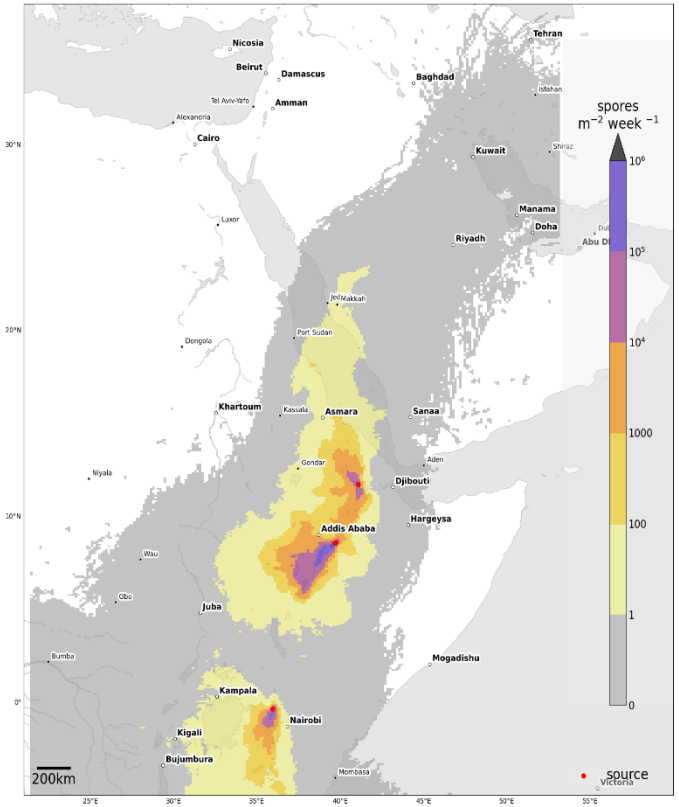


Yesuf et al 2021 PLOSOne

Ethiopia Irrigated Wheat

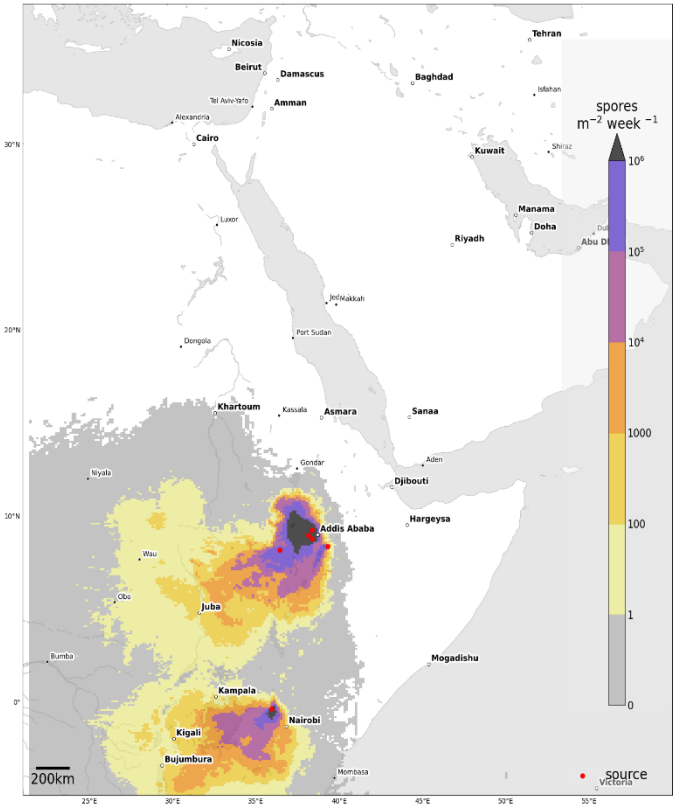
- Increased inoculum – both stem and yellow rust
- Increasing likelihood of migration e.g., middle east
- Increased likelihood new races
- Increased likelihood of infection between seasons

NAME dispersion forecast for the proportion of Wheat **Stem rust** spores
2022-02-20-00:00 - 2022-02-27-00:00 (UTC)



Issued 20 Feb 2022 with Met Office Unified Model meterological input data

NAME dispersion forecast for the proportion of Wheat **Stripe rust** spores
2022-03-04-00:00 - 2022-03-11-00:00 (UTC)



Issued 04 Mar 2022 with Met Office Unified Model meterological input data

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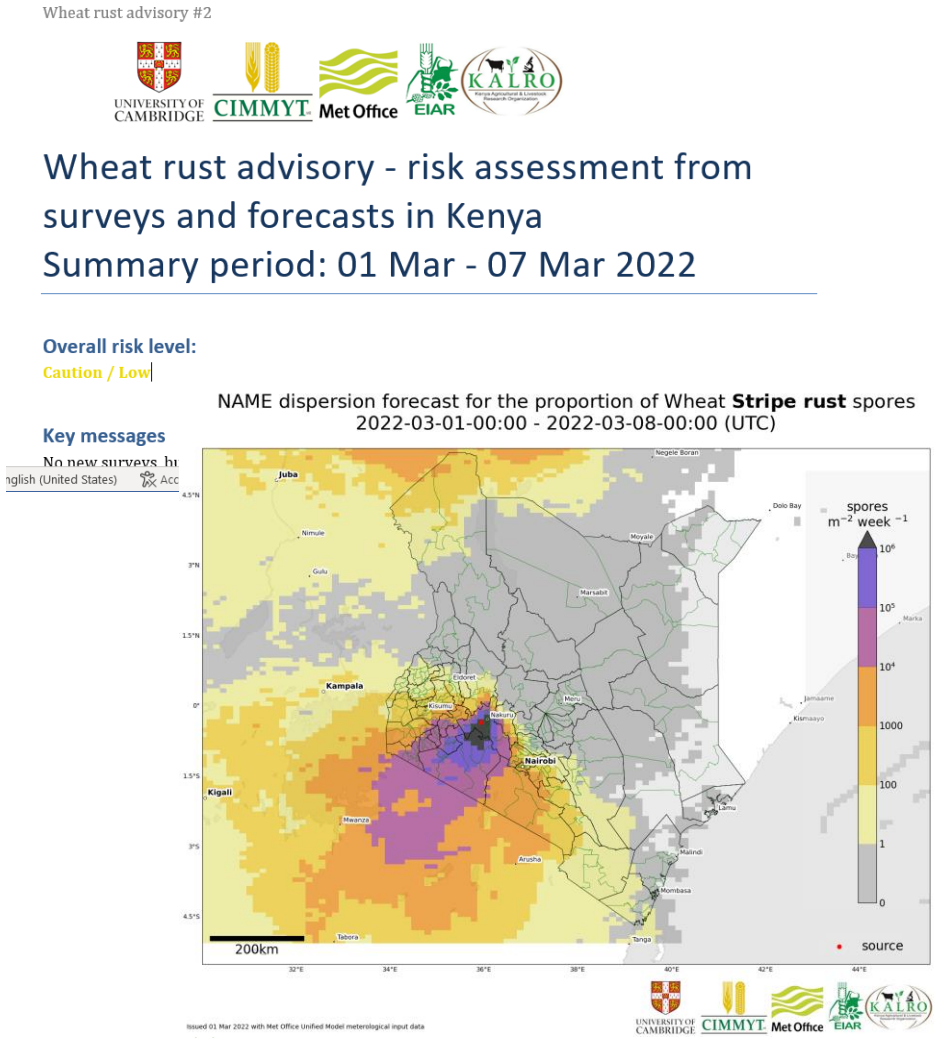
Kenya

- New Greenhouse at Njoro – contractors finalizing. Hand over very soon
- Surveys starting to be implemented
- Feb 2022 surveys. PstS11 & PstS1/2 (no PstS16)
- Vulnerability Mapping Tool in development – Pre-season risk of PstS16 incursion
- Forecasting system expanded to Kenya. Weekly advisories to KALRO
- MARPLE + Nuru (AI) – start in Kenya in 2022



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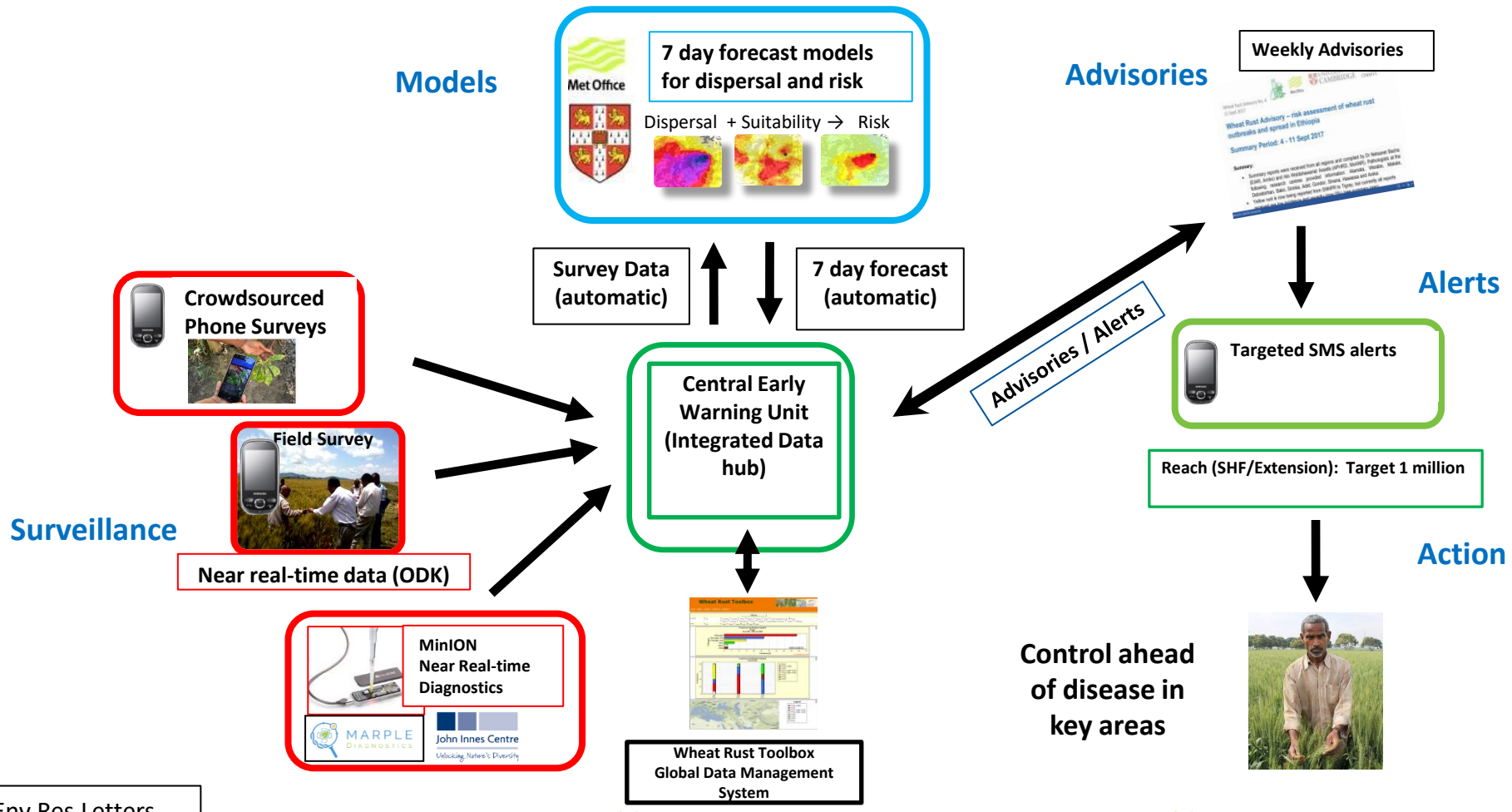
Early Warning Advisory Systems



Allen-Sader et al, 2019 Env Res Letters

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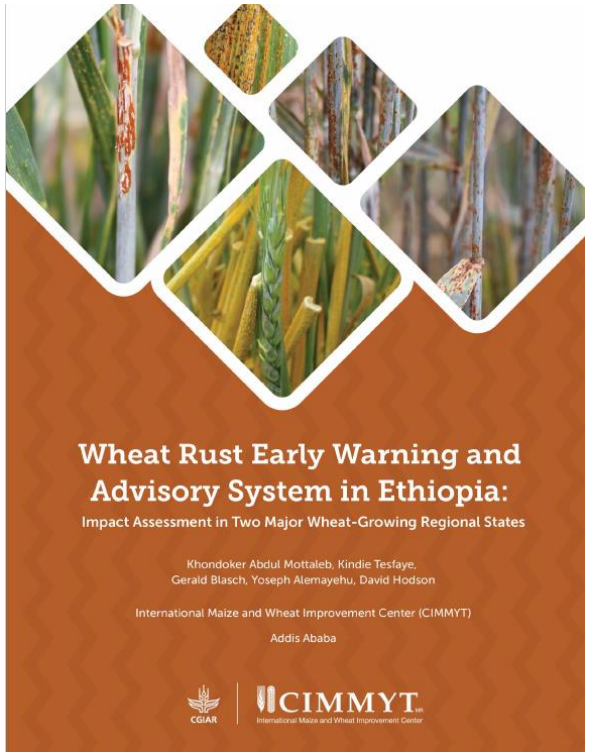
Early Warning East Africa (Ethiopia, Kenya)

- Operational Early Warning Advisory System (EWAS) in Ethiopia – reaching 100,000's farmers
- Impact Assessment (ACES project) (Mottaleb et al 2021) – 1000+ farmers, Oromia & Amhara + repeat study in 2021/22 season
- Positive benefit from the wheat rust early warning system
  - farmer behaviour change in terms of fungicide use
  - increased awareness on rusts + ability to control
  - national policy changes e.g., reserve stocks of fungicides and creation of a dedicated desk in the national bank to facilitate import of fungicides.
- **2021/22 had extremely high risk for a yellow rust epidemic. It is extremely likely that the early warning and response prevented a major yellow rust epidemic in 2021 (Paper in prep)**
- EWAS now being expanded to Kenya – weekly advisories to KALRO



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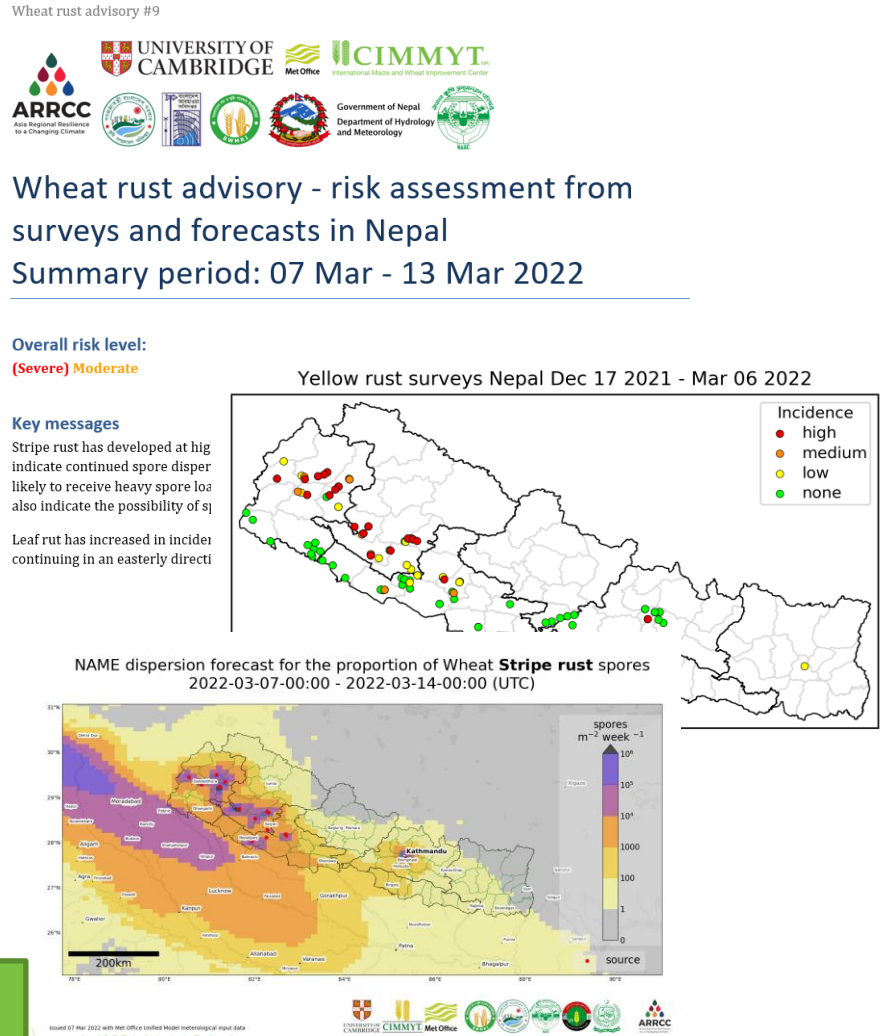
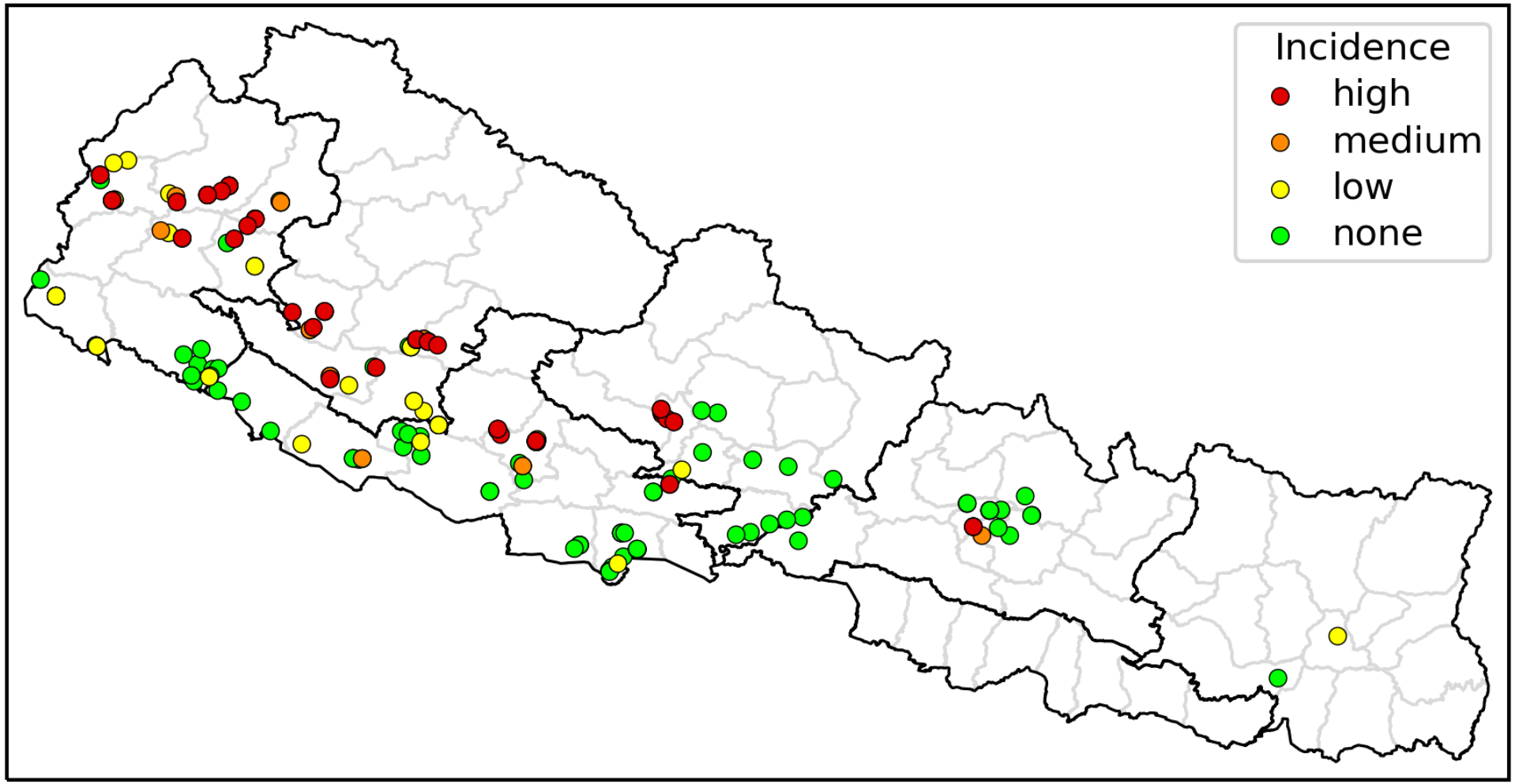
Early Warning South Asia

ARRCC
Asia Regional Resilience to a Changing Climate

- Successful transfer meteorologically-driven dynamic epidemiological forecasting models for wheat rust from Ethiopia to:
  - Nepal and Bangladesh
- In-season, operational system – daily, 7-day forecasts (spore dispersal, environmental suitability), weekly advisories
- Reaching over 400,000 farmers in 2020/21 season (Nepal & Bangladesh)
- Regional forecasting (South Asia) now operational + weekly regional advisories
- MARPLE + Nuru (AI) – start in Nepal 2022



Yellow rust surveys Nepal Dec 17 2021 - Apr 17 2022

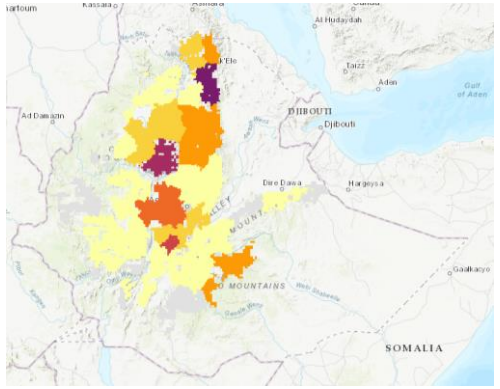


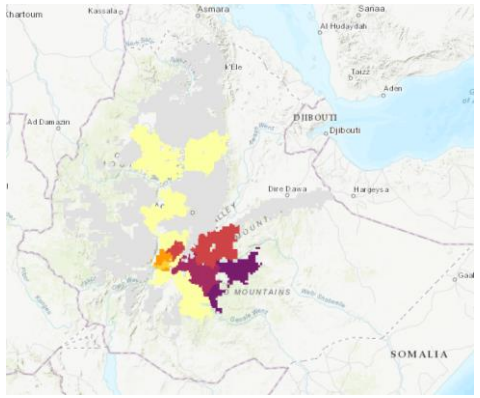
Estimated 20% of Nepal wheat area affected

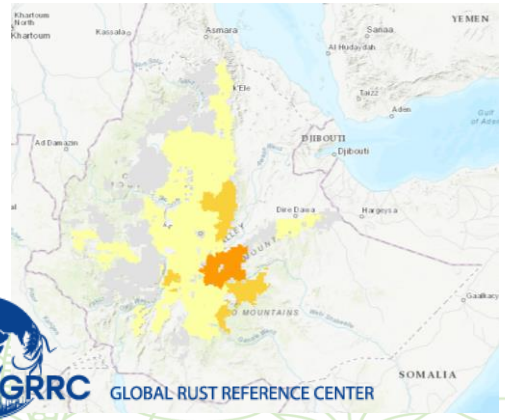
Yellow Rust Western Nepal Period: Feb 27 to March 8, 2022

(All photos Dr. Dhruba Bahadur Thapa)

Variety Distributions







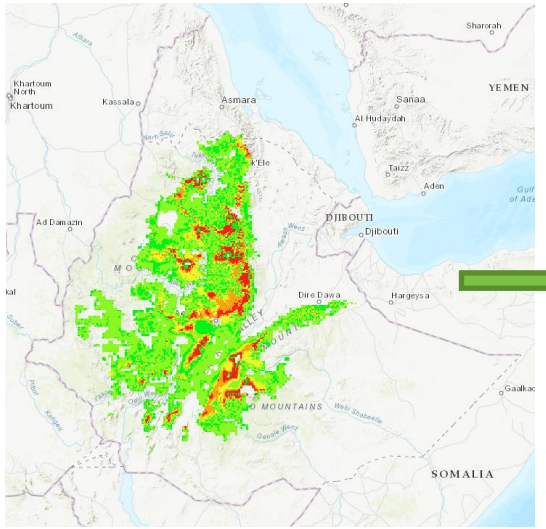
Vulnerability Mapping Tool

- Host x Pathogen x Environment ⟹ Vulnerability / Risk
- Ethiopia – 2021: Pre-season risk information for PstS16
- **Kenya – 2022: Risk for incursion of PstS16**

* Infection Risk

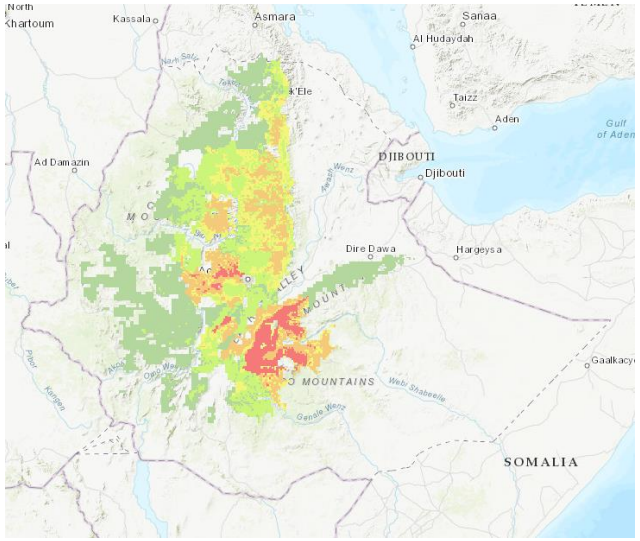
Score	Infection Risk	Reaction	Severity
1	very low	R - RMR	15%
2	low	MR	30%
3	medium	MRMS	40-50%
4	high	S	60-70%
5	Very high	VS	90-100%

Environmental Risk



ELEVATION RANGE (M)	YELLOW RUST RISK
2000 - 2200	Very Low Risk
2200 - 2400	Low Risk
2400 – 2600	Moderate Risk
2600 - 2800	High Risk
2800 - 3300	Very High Risk

Risk of Infection – PstS16



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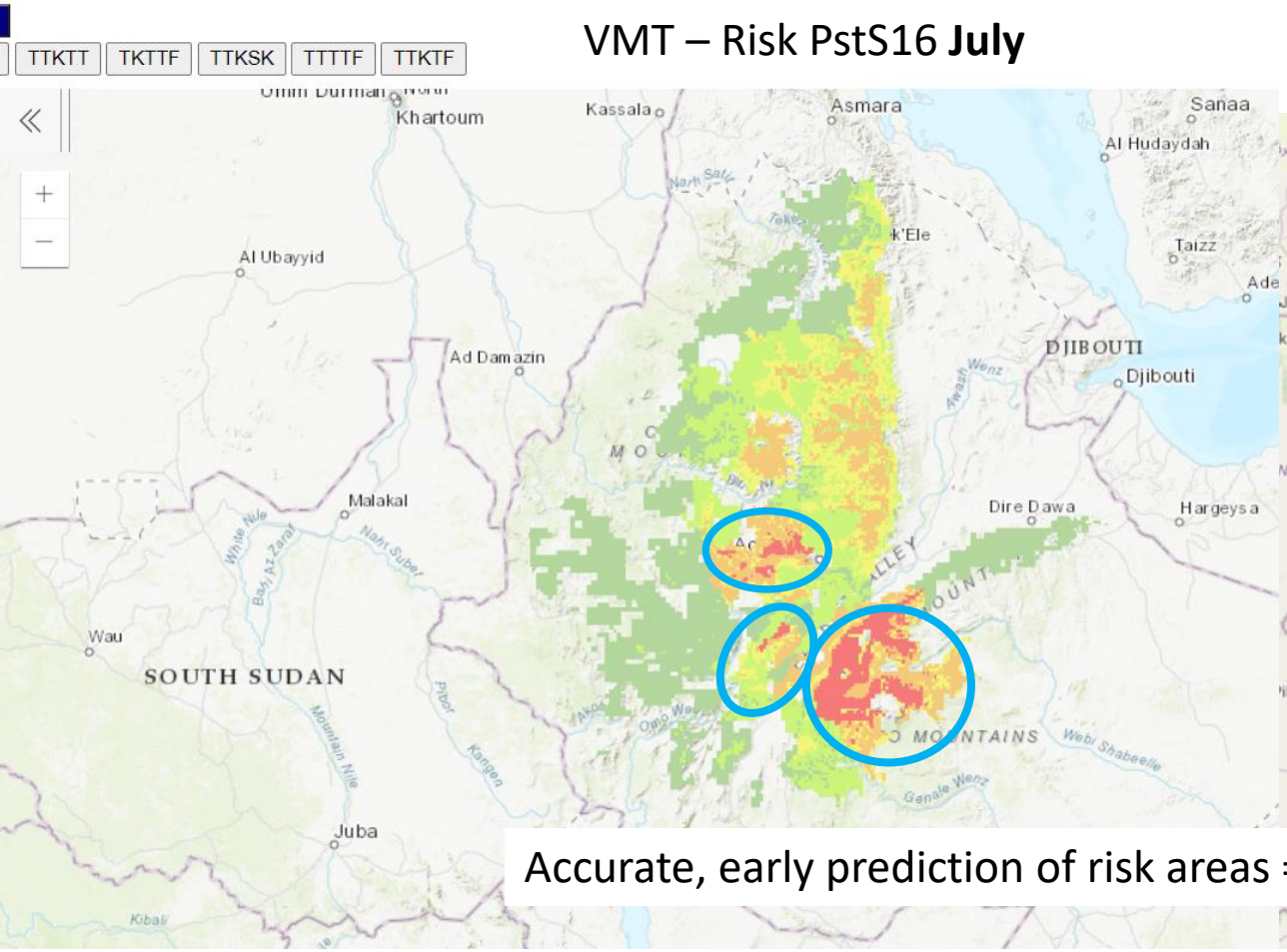
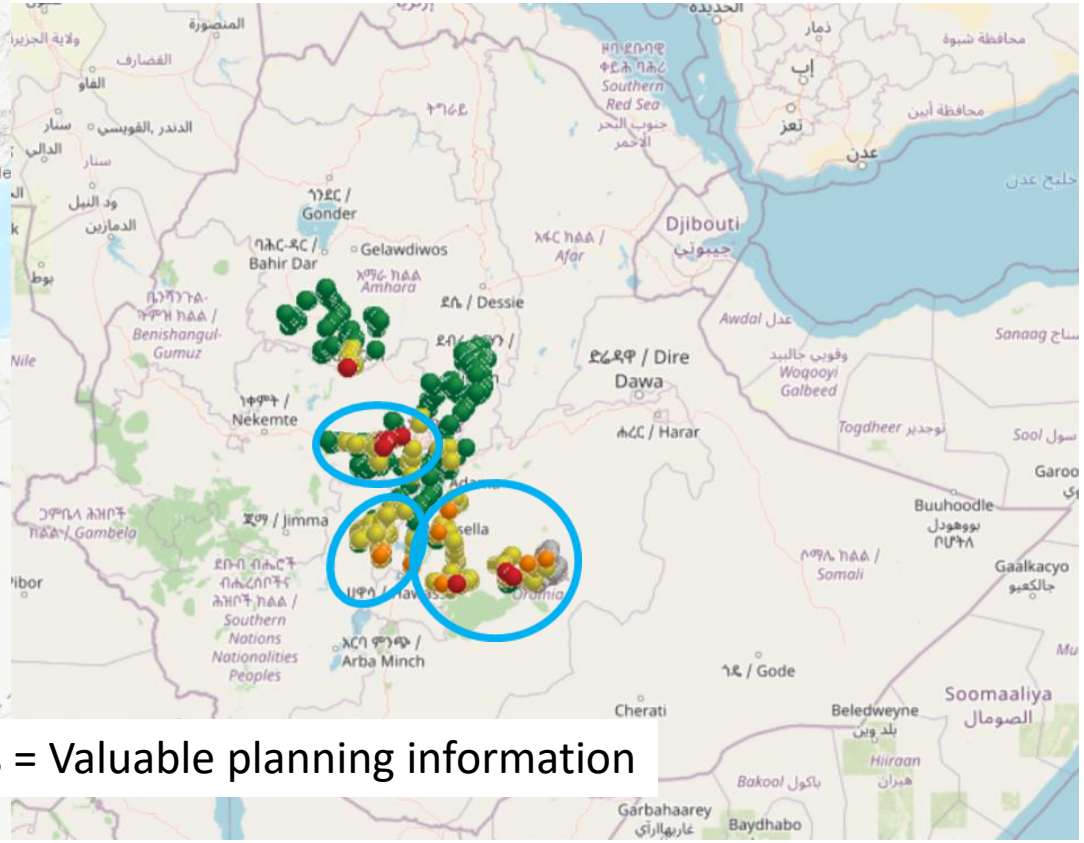
Yellow Rust PstS16 – Where is the likely risk?

VMT – Risk PstS16 **July**



2021 YR Severity **September**



Accurate, early prediction of risk areas = Valuable planning information

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New Technologies

MinIONs, AI, Drones & Remote Sensing

Photo: Matt Heaton, JIC

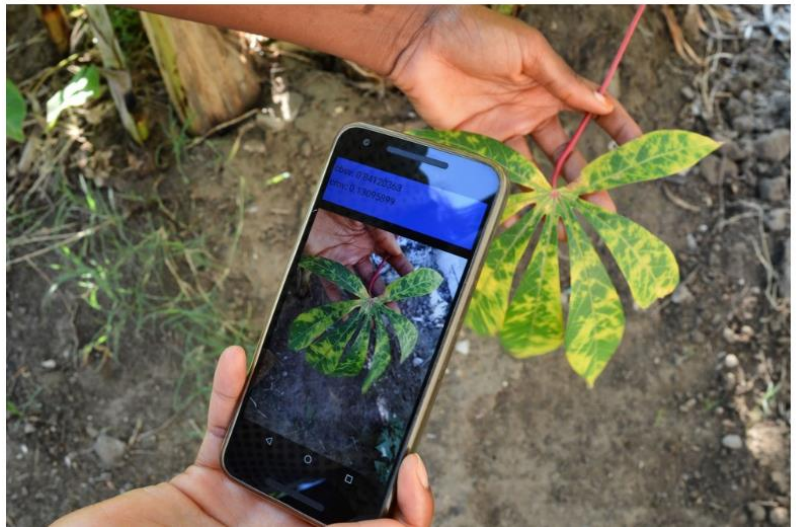

Photo: IITA / Penn State Plant Village

Photo: Matt Heaton, JIC

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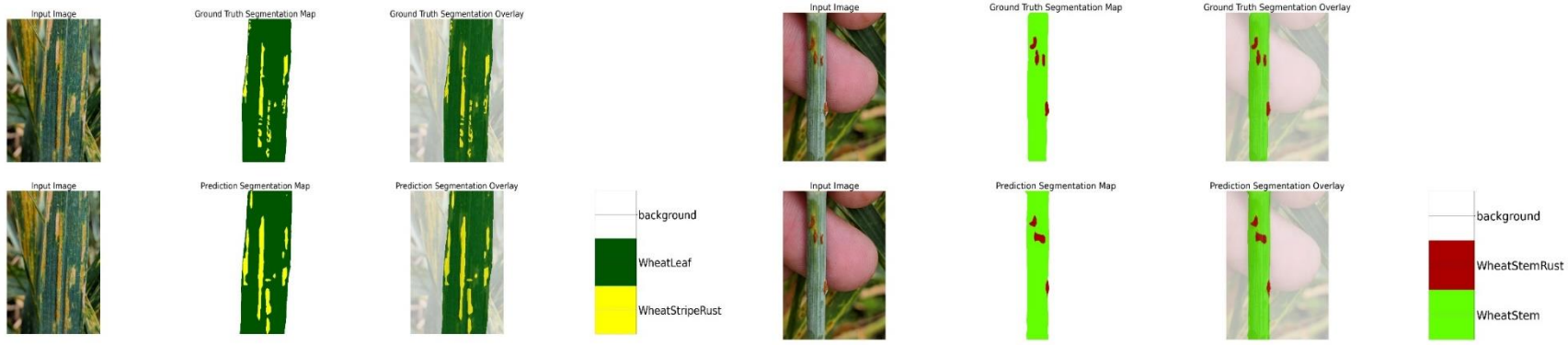
New Tools – Automated Rust Detection

- New advances in AI/ML technology – Nuru app
- Advanced image segmentation and tiling techniques promises to be a major leap forward.
- With tools like *Nuru*, extension agents and farmers can all contribute to field surveys.

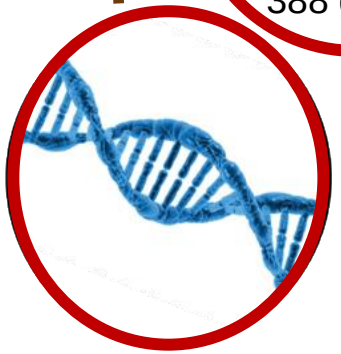


PlantVillage PennState CIMMYT

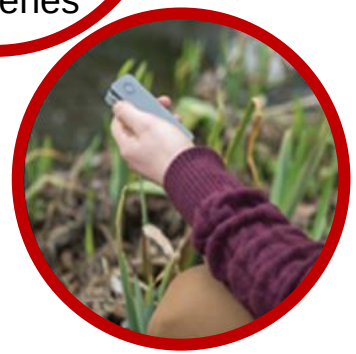
Mobile And Real-time PLant disEase (MARPLE) diagnostics

MARPLE DIAGNOSTICS

INNOVATOR OF THE YEAR
BBSRC | UK Research and Innovation



PCR
388 genes



Risk Forecasting

Identify disease → Extract DNA → Mobile sequencing → Data analysis → Diagnostics define strain → Data Integration **IN SEASON** > Early Warning System

2 days from sample prep to results!!

Slide: Dr. Diane Saunders, JIC

John Innes Centre

Radhakrishnan et al & **Saunders** (2019) BMC Biology

EXCELLENCE WITH IMPACT WINNER 2016

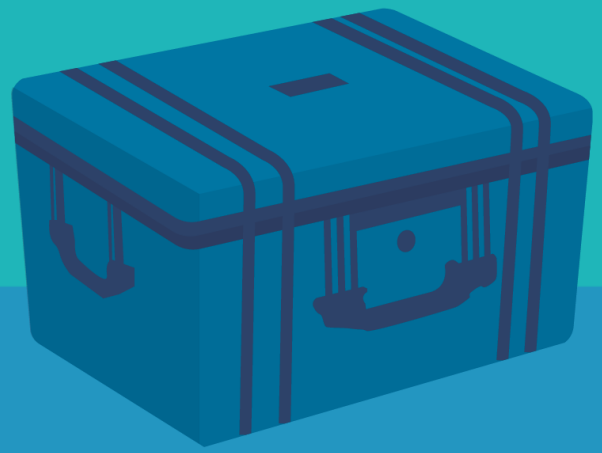
UKaid from the British people

CGIAR Platform for Big Data in Agriculture

BILL & MELINDA GATES foundation

UKRI Biotechnology and Biological Sciences Research Council

MARPLE
DIAGNOSTICS



A truly mobile, rapid response lab

MARPLE Roll Out

- Ethiopia – 4 hubs
- Nepal – Workshop April 2022
- Kenya – Workshop July 2022

NARC, Khumaltar, Nepal 26-29 April 2022
https://www.jic.ac.uk/news/marple-diagnostics-reaches-south-asia/

John Innes Centre

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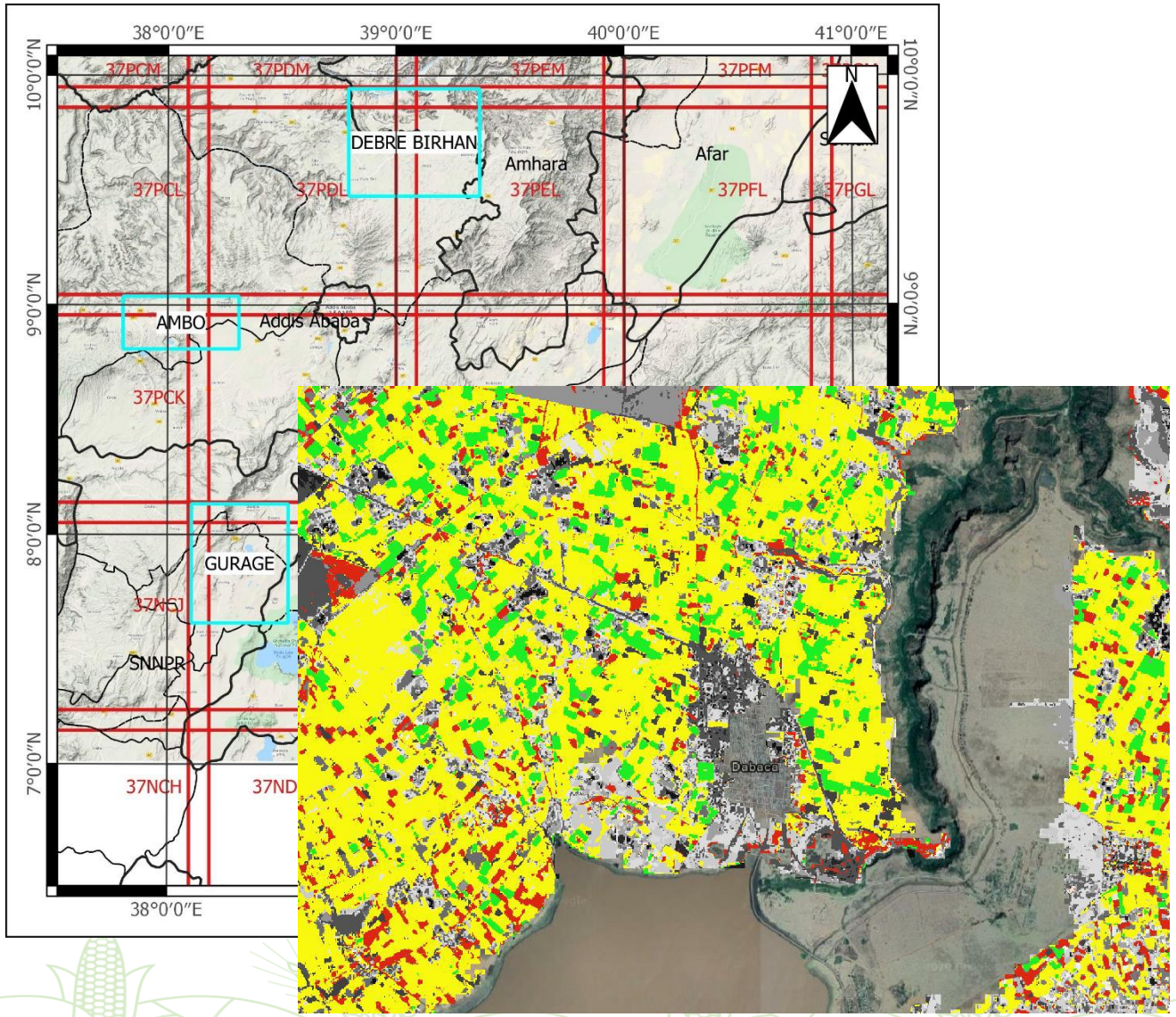
Remote Sensing

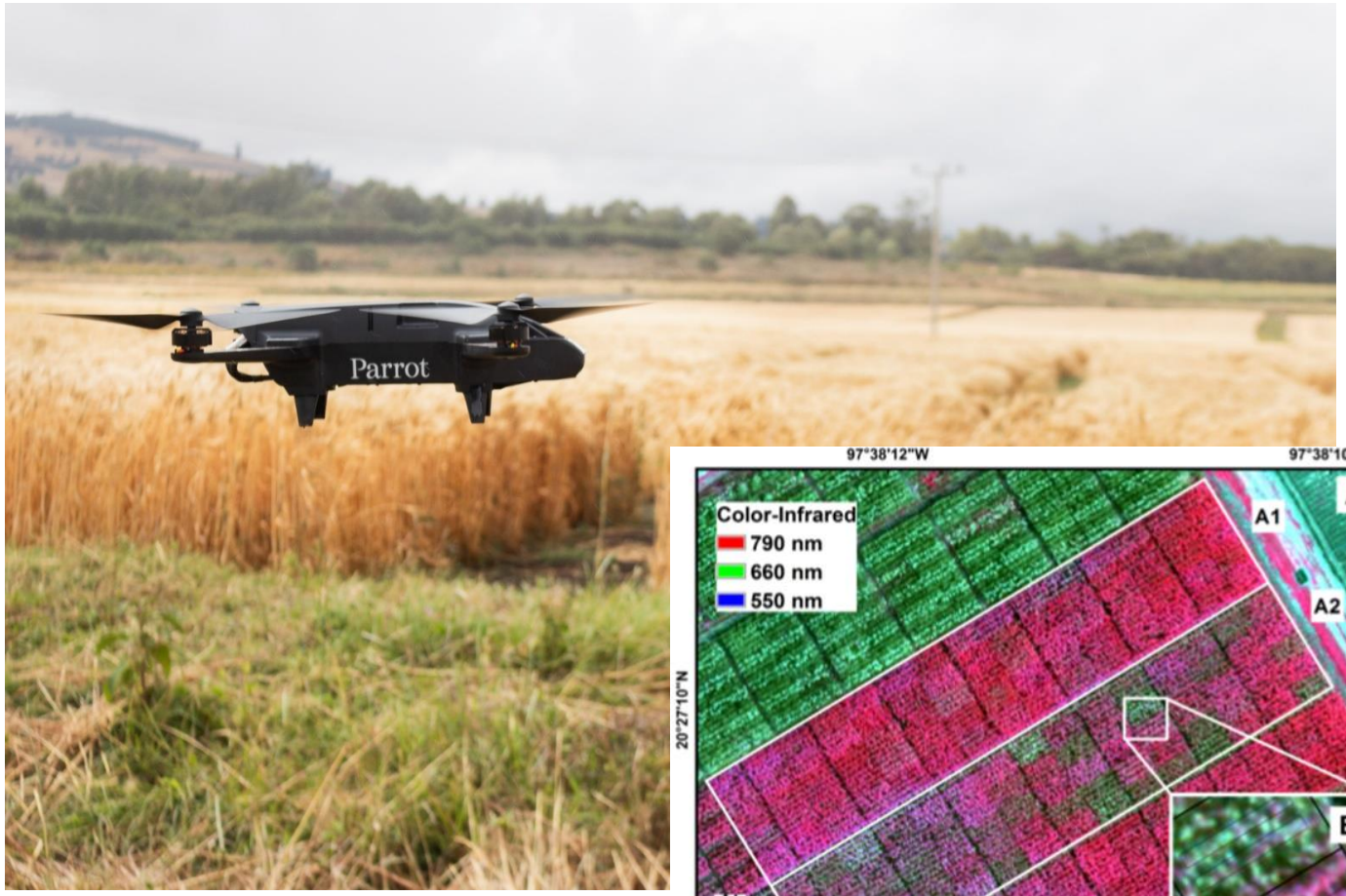


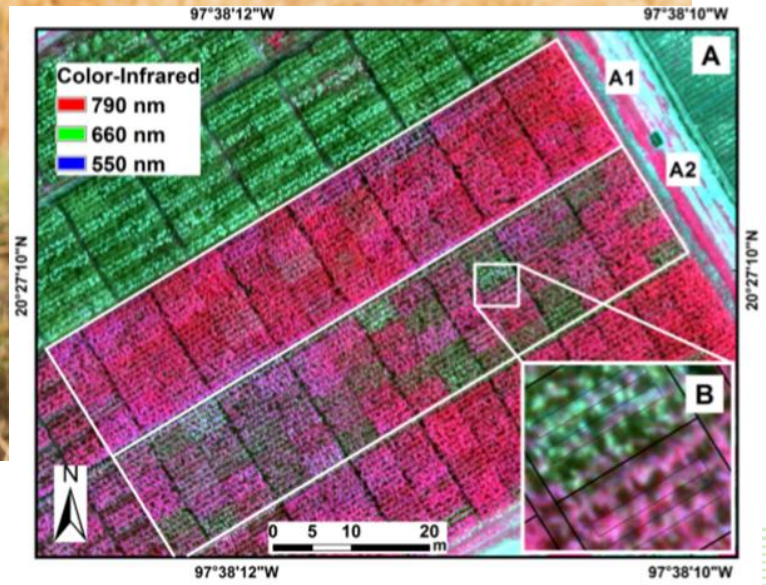
- Link with UCL, Belgium (Prof. Pierre Defourny)
- Host landscape + crop growth stage (Sentinel)
- Improved inputs for epidemiological models
- Crop stress

UCLouvain

CIMMYT

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)

Loladze et al. 2019

EIAR

UCLouvain

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Summary

- Large-scale and long-term surveillance maintained
- Toolbox represents one of most comprehensive crop disease data resources
- Pathotyping returning to scale pre-covid
- Important races being detected quickly and tracked. Many new variants!!
- NARS rust capacity in East Africa increasing
- Advanced, in-season early warning and advisory systems operational in Ethiopia, Nepal, Bangladesh + starting in Kenya.
- Early warning systems showing impact e.g., Ethiopia 2021
- Vulnerability tool providing advance warning of risk from new races
- Irrigated areas in Ethiopia – need close monitoring and robust control strategies
- New tools (MARPLE, AI, Drones) being applied

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Acknowledgements

- AAFC, Winnipeg, Canada
- ATA, Ethiopia
- Cambridge University, UK
- CIMMYT
- CRIFC, Turkey
- 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
- Penn Sate University / PLant Village
- 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

Partners in national programs in over 35 countries