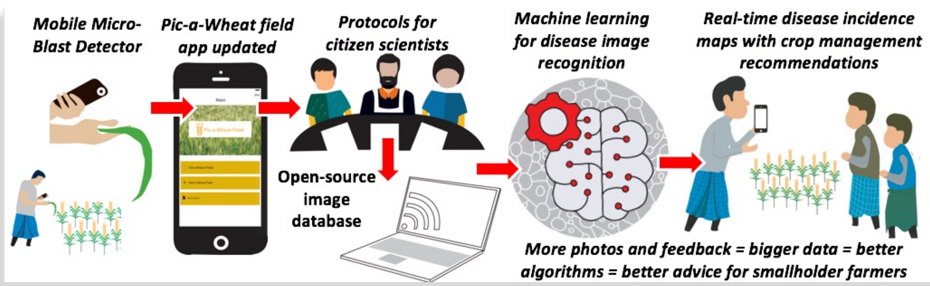
Disease disruptive data science:
Leveraging mobile microscopy, citizen science, and machine learning to enable real-time wheat blast management advisories in Bangladesh and Brazil

Background: Though it is the second most important crop globally, sustained wheat production in the tropics and sub-tropics is increasingly challenged by numerous fungal diseases. Wheat blast, caused by the *Magnaporthe oryzae* pathotype *Triticum,* is a crucial concern. First discovered in Brazil in 1985, wheat blast since has spread to Bolivia, Paraguay, and Argentina. In 2016, it suddenly appeared outside South America in Bangladesh, and again in 2017 with news reports of further spread to India. Late-season fungicides are only partly reliable. 7 million hectares are at risk of reoccurring infection in South Asia, with losses to smallholders of up to 1.77 MT worth \$264 million year^{-1} with light infections of just 10%[1].

Where extension services can monitor initial occurrence and climatic conditions, inoculum build-up risk can be assessed and early-season advisories on how to control wheat blast can be deployed. Protectant fungicides, for example, are most effective when applied before rachis infection occurs[2]. Early leaf infections on Poacea hosts are however microscopic, and difficult to distinguish from other diseases. These challenges emphasize the need for early-season identification to provide reliable advisories.

This proposal responds to the crop disease threats by leveraging mobile microscopy, citizen science, and machine learning to enable ICT-based real-time management advisories in Bangladesh and Brazil. Most disease surveillance programs rely on highly-trained experts and expensive and time-consuming sampling and lab procedures. Advances in epidemiology, data science, and ICTs, however indicate that real-time monitoring and advisories are not only necessary, but possible.



Our Idea: we will develop the **Mobile Micro-Disease Detector**, a 3D printable smart-phone clip-on magnifying glass enabling microscopic fungal lesion image collection in the field. The free to download **Pic-a-Wheat Field smartphone app,** developed by the *University de Passo Fundo* (UPF) and international partners, including the CGIAR, will be updated to push microscopic lesion images to the cloud. Secondary school and university students, extension agents and farmers will be mobilized as citizen scientists through existing and complementary R4D projects led by CIMMYT and UPF in Bangladesh and Brazil, respectively, to capture tens of thousands of wheat leaf lesion images. Open-source machine-learning image recognition algorithms operating in a cloud computing environment will crunch data at speed and distinguish microscopic wheat blast leaf lesions from tan spot and spot blotch. Resulting data will be presented in real-time as disease distribution maps on Pic-a-Wheat Field, which will be upgraded to provide accompanying crop management advisories.

[1] Mottaleb, K.A., et al. 2017. Wheat blast threat to South Asia's food security: an ex-ante analysis. PloS One (Acceptable following minor revisions).

[2] Fernandes, J.M.C., et al. 2017. A weather-based model for predicting early season inoculum build-up and spike infection by the wheat blast pathogen. Trop Plant Path 42:230-237.

This innovative approach to real-time microscopic image recognition has major implications for the early detection and diagnosis of other crop and even animal diseases, with potential to transform epidemiological studies across the CGIAR and its partners in the global south. No previous efforts have been undertaken to link microscopic image collection by citizen scientists with machine-learning enabled disease monitoring systems, nor have these ideas been linked to real-time management advisories.

Our hypothesis is that by enabling citizen scientists to collect tens of thousands of microscopic leaf lesion images for rapid identification confirmation by cloud-based machine learning algorithms, farmers and extension services will be empowered to make crucial early-season disease management decisions more rapidly, ultimately reducing risk of large-scale crop losses for smallholder farmers.

Project piloting: We will employ disease disruptive data science to deliver the following innovations:

1. **Mobile Micro-Disease Detector:** A 3D printable smart-phone clip-on accessory (3.5 mm diameter, 100 × magnification) based on PNNL[3] will enable microscopic leaf lesion image collection in the field.
2. **Updates to the Pic-a-Wheat Field smartphone application** to catalogue and push time- and GPS-stamped microscopic leaf lesion images to the cloud for big data processing.
3. Easy to understand **protocols and guidelines for citizen scientists** to collect disease images at scale.
4. An **open-source database** of thousands of microscopic wheat disease leaf lesion images.
5. **Cloud-based machine-learning automated image recognition algorithms** to crunch big data at speed and distinguish microscopic wheat blast leaf lesions from tan spot and spot blotch, and to confirm observations with climate-based epidemical information. Using data collected from established weather stations, a proven disease risk model will validate diagnoses [see [2]].
6. Algorithms producing **real-time and publically accessible disease incidence maps** pushed to Pic-a-Wheat Field, indicating geographical disease distribution **with accompanying crop disease management recommendations.**

This activity is a synergistic add-on to CIMMYT and UPF's ongoing pathology projects, which will provide in-kind co-funding on a 1:1 basis. Piloting will take place during the coming 2017-18 wheat growing season in Bangladesh (2017-18) and Brazil (2018). 75 citizen scientists in each country will be given **Mobile Micro-Disease Detectors** to acquire tens of thousands of microscopic lesion images. Image number and data size will increase over time, enabling algorithm fine-tuning. **All algorithms and Mobile Micro-Disease Detector technical designs will be made open-source as public goods that can be utilized by the CGIAR and its partners across a range of crops and diseases to benefit smallholder farmers.**

$100,000 is requested to partially cover PIs supervision (TJ Krupnik and P Singh CIMMYT) and UPF co-PI (JCF Fernandes). in Bangladesh and for Brazil, respectively. Funds for 2 field supervisors/country, one shared and ICT specialist, respectfully, are requested. Hard and software requirements are one 3D printer per country, 50 smartphones in Bangladesh only (as smartphones are well established in Brazil), as well as cloud computing/data storage. If successful, this disease disruptive data science approach will be expanded to include microscopic lesions on maize and rice, and validated in Bolivia, Paraguay, India, and Pakistan through CIMMYT's ongoing R4D collaborations.

[3] Pacific Northwest National Laboratory. 2017. The PNNL Smartphone Microscope. URL: http://availabletechnologies.pnnl.gov/technology.asp?id=393. Verified 15 August, 2017.