Soilborne plant pathogen dispersal and assessment: Building a remote sensing-based global surveillance system for plant disease

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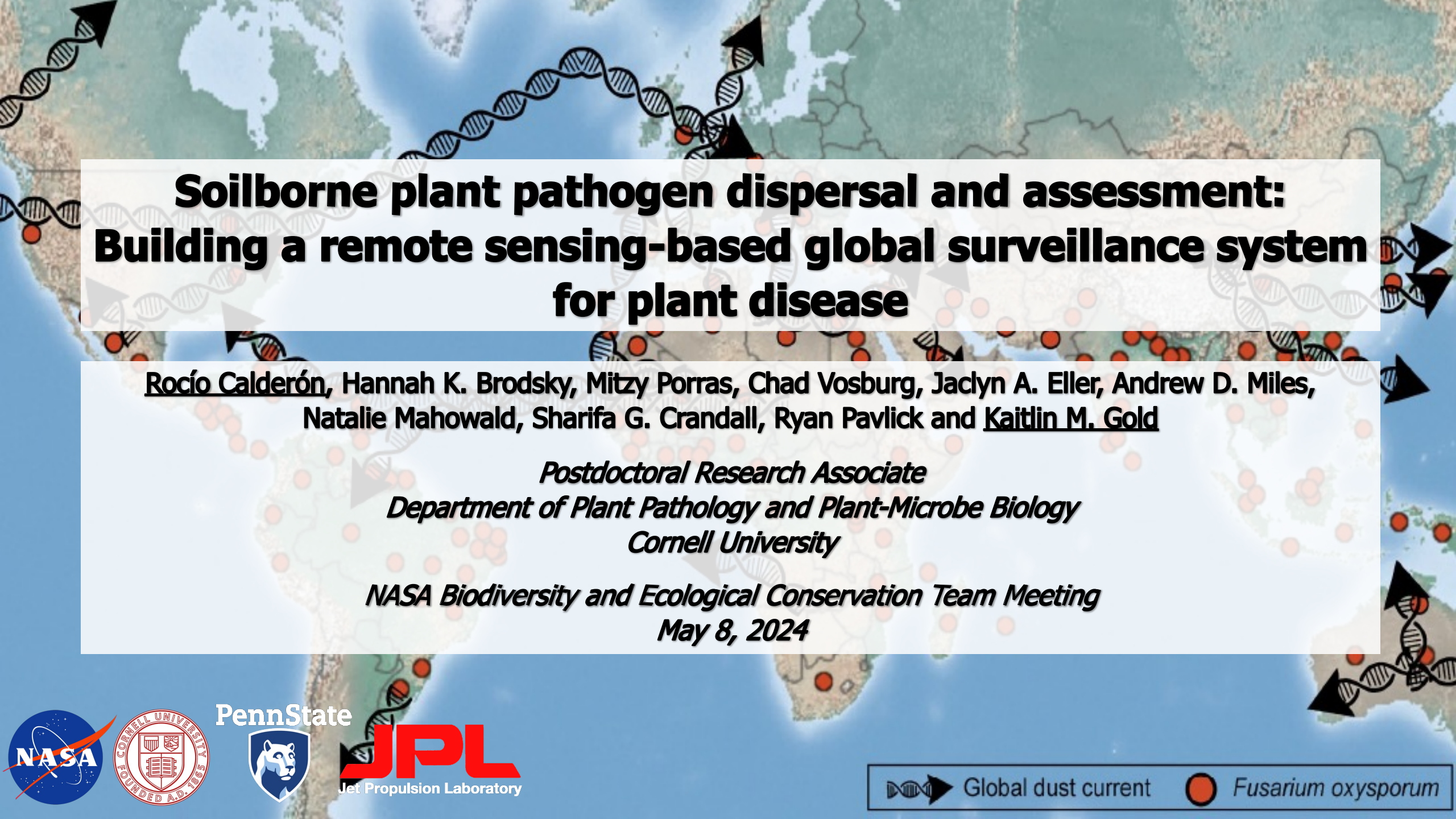

Soilborne fungal plant diseases: Fusarium wilt

- Fungi cause 80% of plant diseases: the most aggressive fungi are soilborne
- Fusarium wilt: Plant disease caused by the soilborne fungus *Fusarium oxysporum*
- Top 10 most damaging fungi: annual yield losses 10-60% (Dean et al. 2012)
- Endemic to all six crop-producing continents
- > 100 susceptible hosts
- *F. oxy* spores survive in soil > 30 years
- Emergence of new virulent *F. oxy* strains (*F. oxy* f. sp. *cubense* race TR4)
- Expanded conducive environment range in a warming climate (Shabani et al. 2014)

Fusarium wilt of banana

Fusarium wilt of cotton

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Fusarium wilt of banana


Fusarium wilt of cotton

Fusarium wilt will increasingly threaten food security and biodiversity unless steps are taken to tighten biosecurity at the global scale

Research project and involved fields

Remote Sensing
Build susceptibility assessment for FW risk from remote sensing data streams within the plant disease triangle framework

JPL
Jet Propulsion Laboratory

Global FW Surveillance System

Aerosol Transport
Use an ESM to assess the possibility and patterns of *F. oxy* spore long-range transport during global dust events

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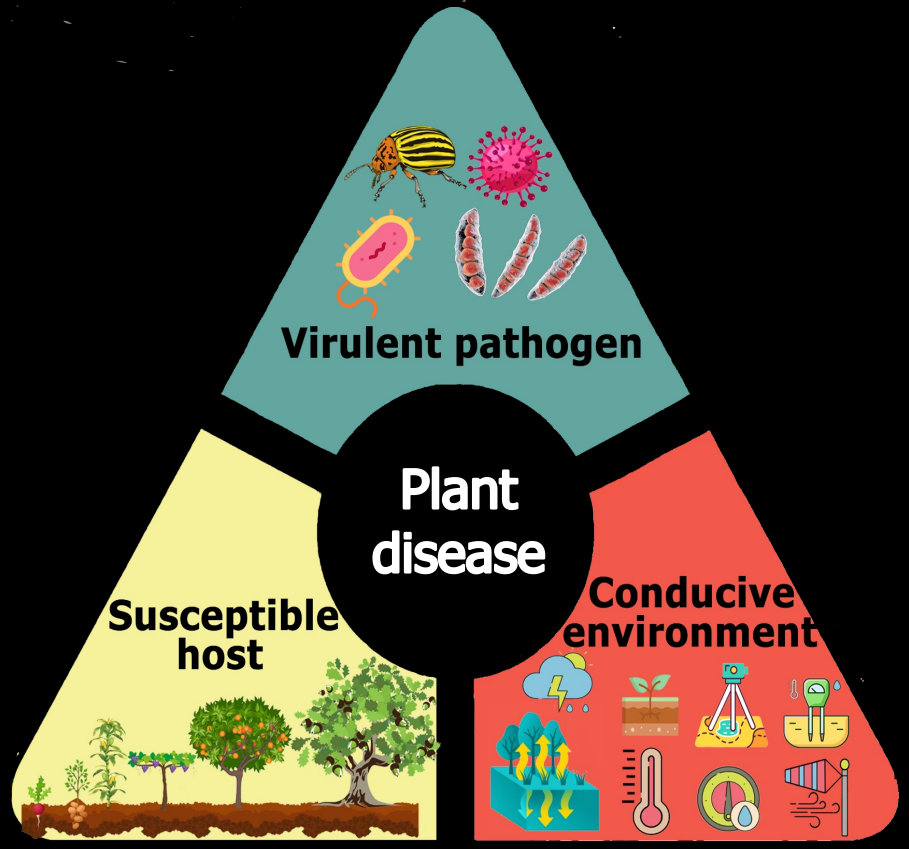
Remote Sensing: Susceptibility assessment



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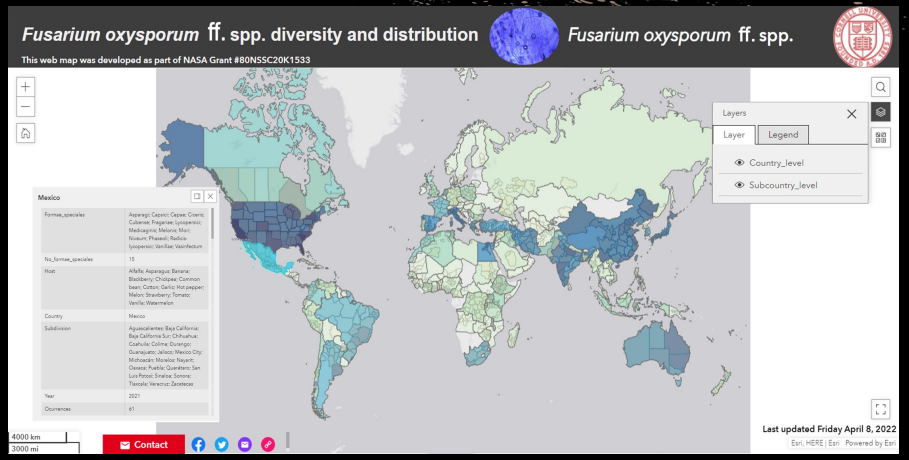

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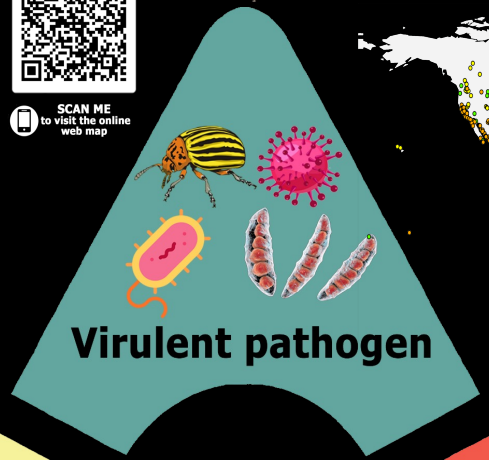
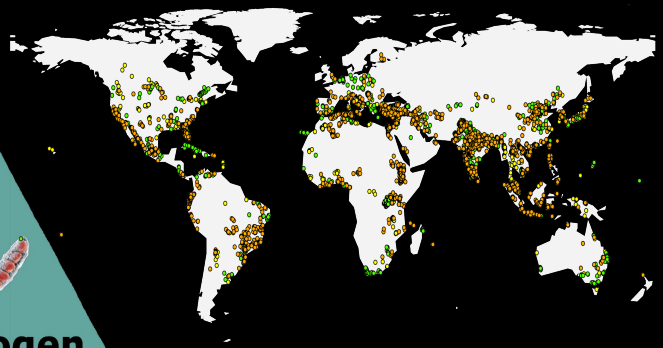
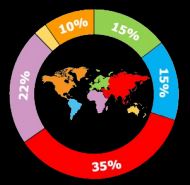
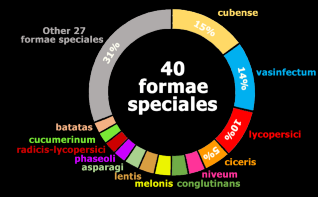
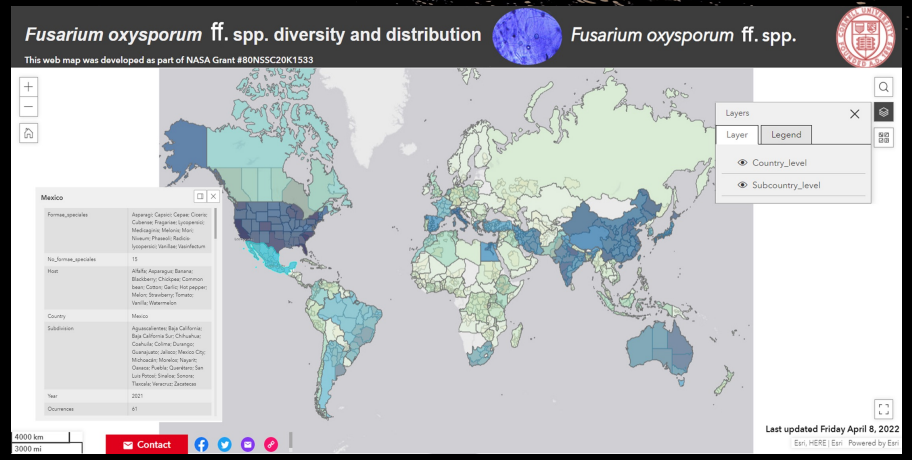








Remote Sensing: Susceptibility assessment



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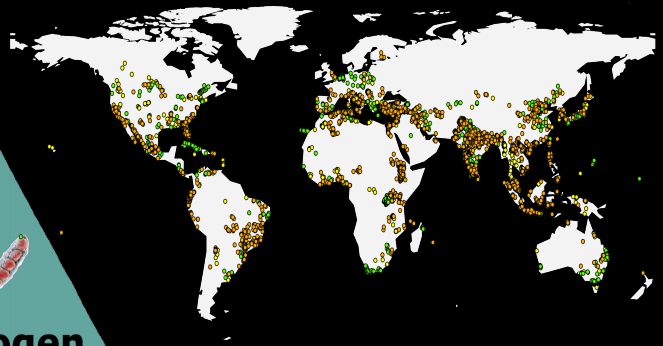
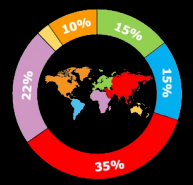
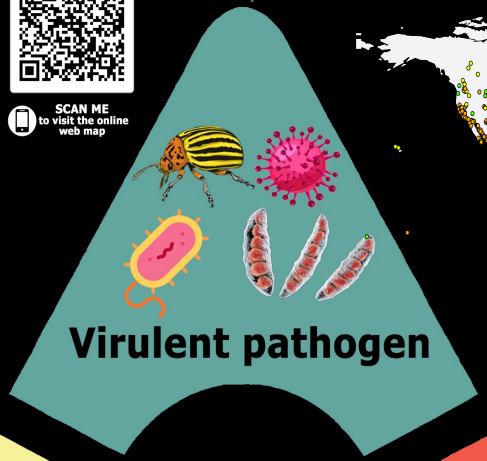
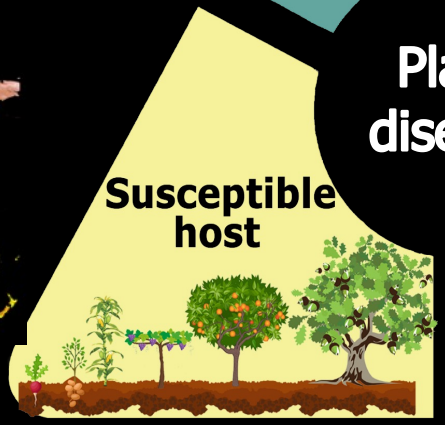
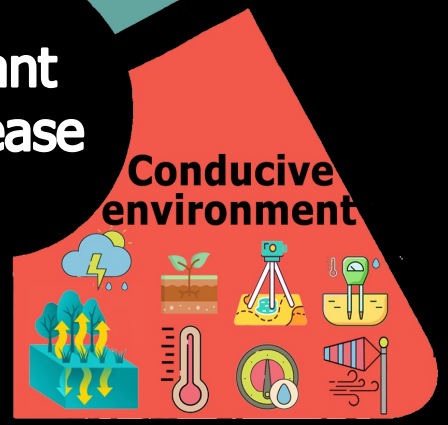








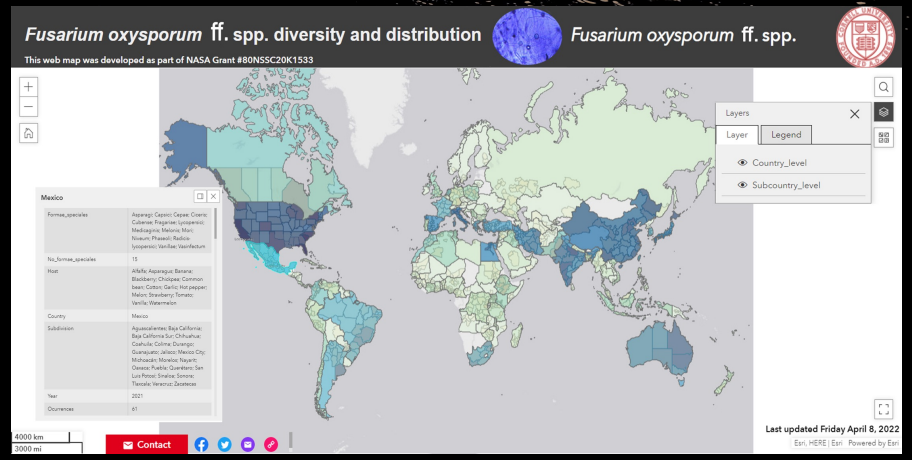
Plant disease



Landsat MODIS

esa SIF SCIAMACHY GOME-2

Remote Sensing: Susceptibility assessment



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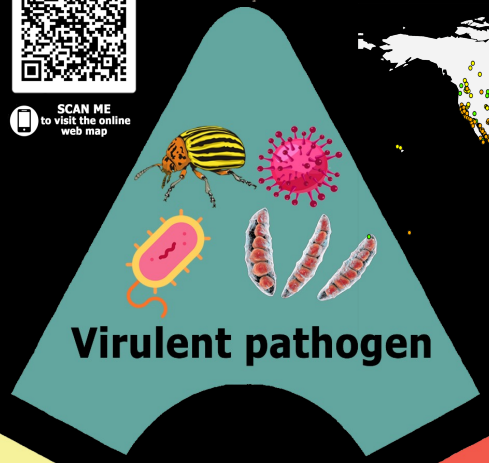

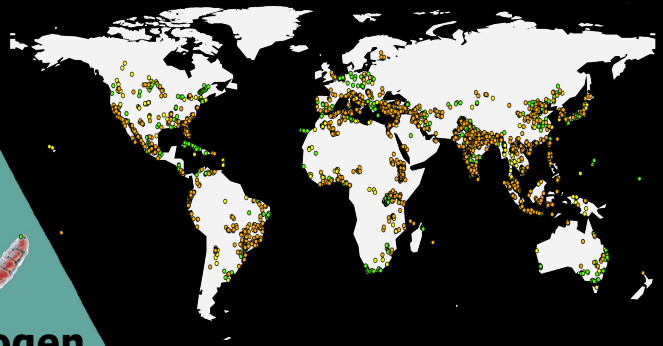

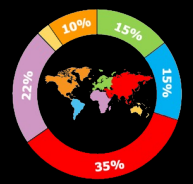

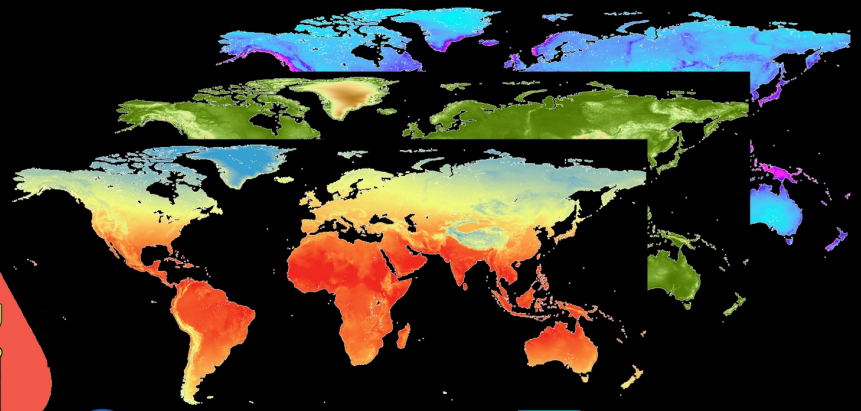

NASA Landsat NASA MODIS

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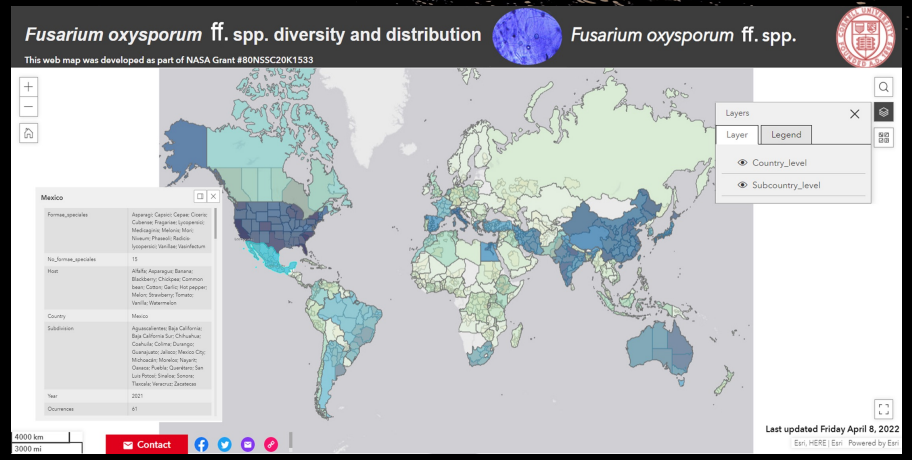
NASA MODIS esa CCI-SM CHELSA

MSWEP GloH2O GMTED2010

SoilGrids

Remote Sensing: Susceptibility assessment



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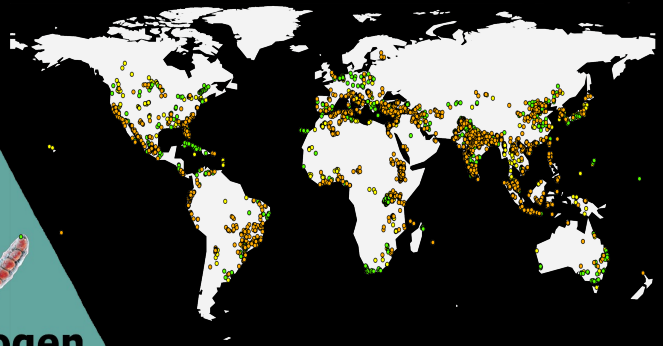

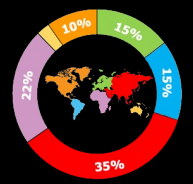

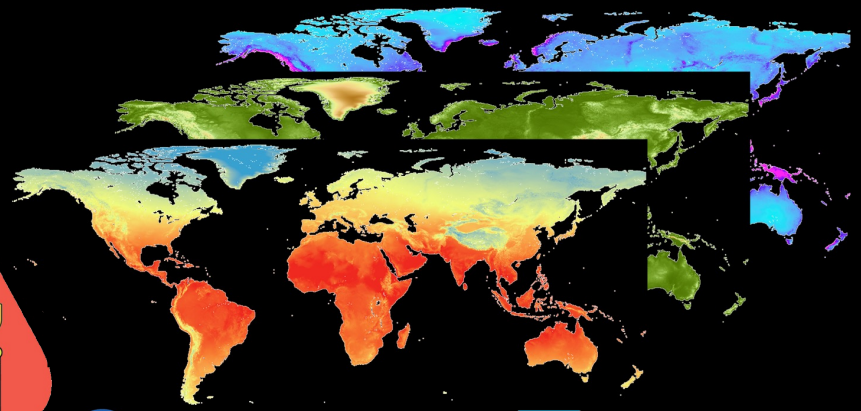

Landsat MODIS

SCIAMACHY GOME-2

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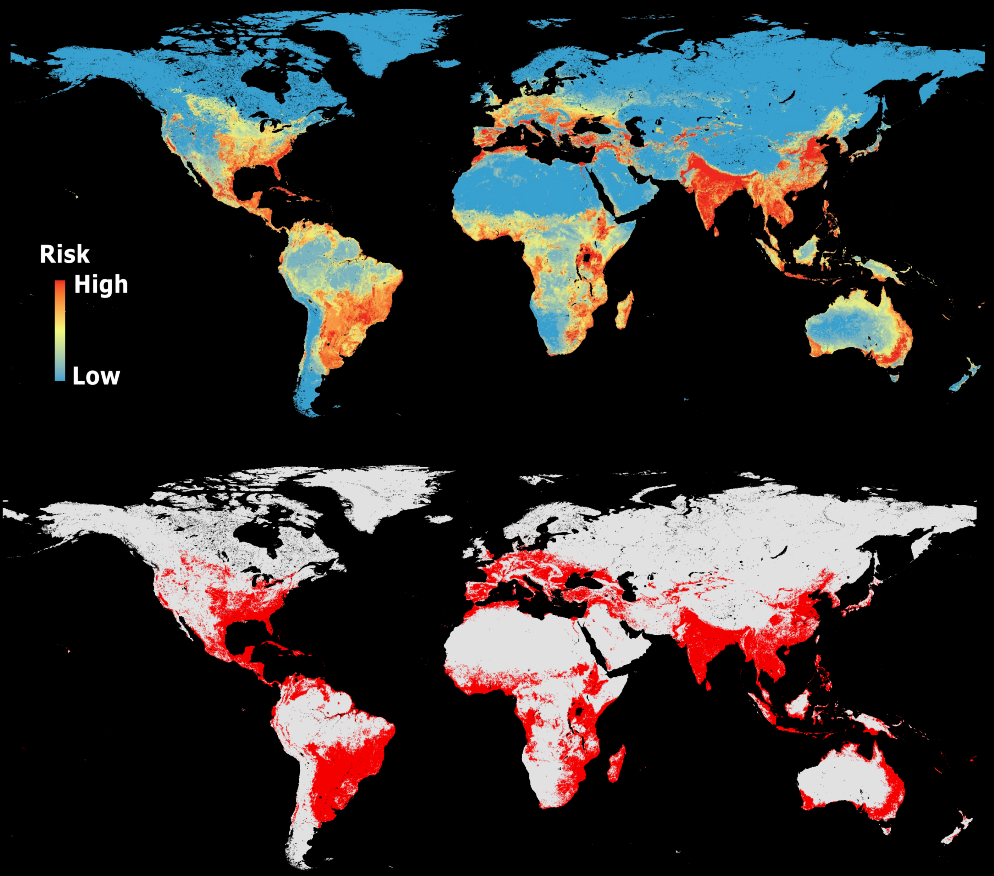
Remote Sensing: ensemble model results

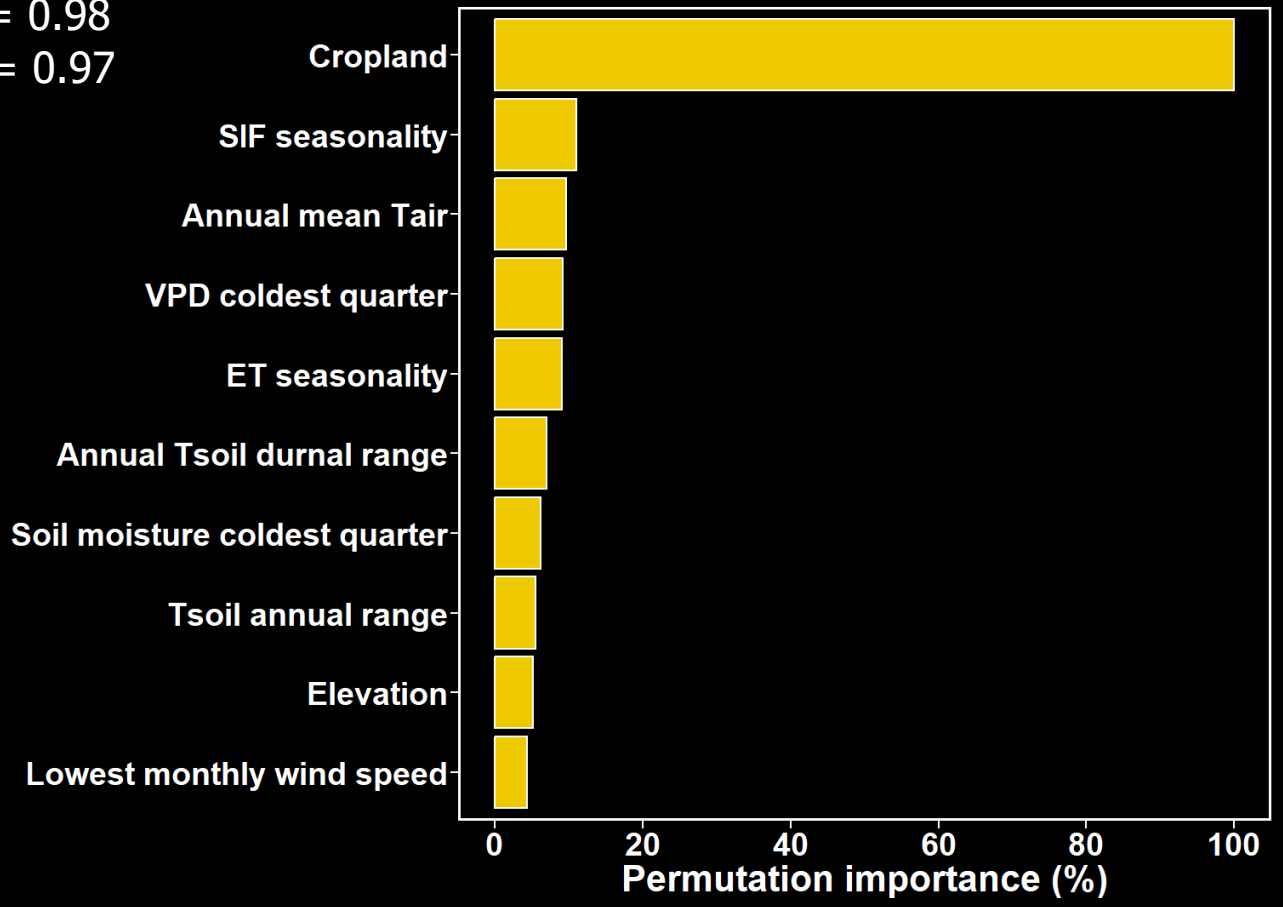
Present-time global projection



AUC = 0.99
TSS = 0.95
TPR = 0.98
TNR = 0.97

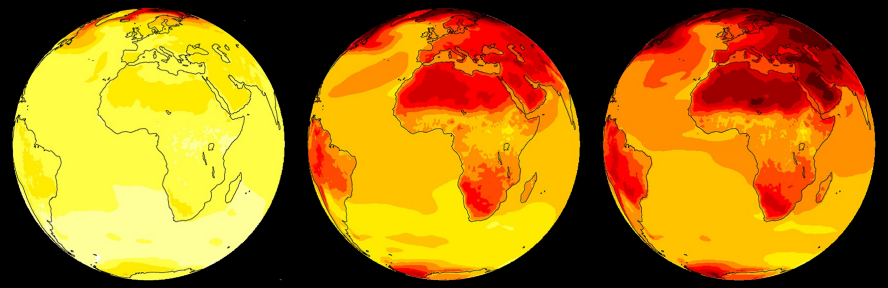
21% of global land and 65% of global cropland susceptible to FW

Variable importance



Remote Sensing: Global FW risk under CC in 2100

SSP 1 - RCP 2.6 | **SSP 3 - RCP 7.0** | **SSP 5 - RCP 8.5**



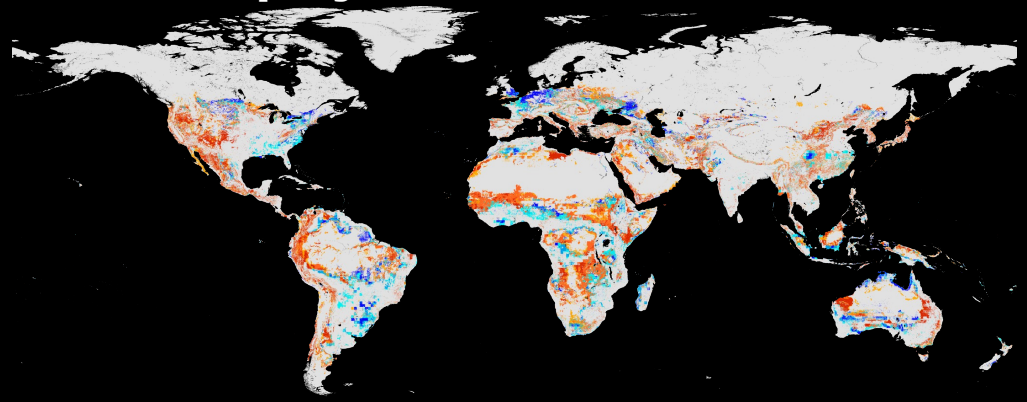
Sustainability
Low-emissions

Regional rivalry
Intermediate-emissions

Fuel development
High-emissions

-10 -5 0 5 10
Temperature change in 2100 (ºC)

Agreement in projected trends across CC scenarios



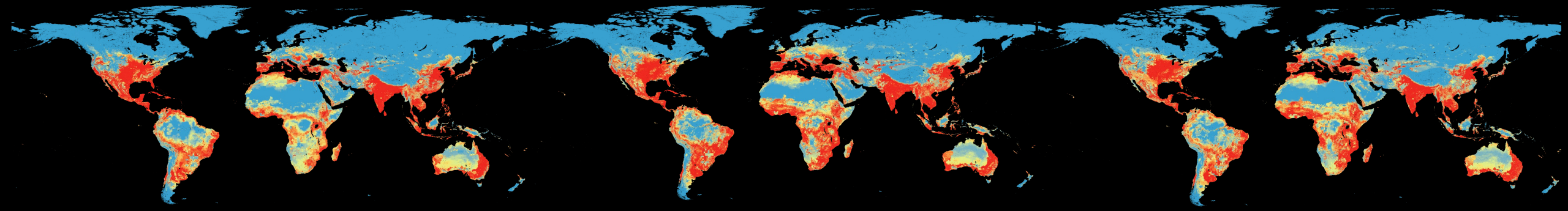
No. of scenarios that follow the same trend

Gain 3 2 1 | No changes | Loss 1 2 3

SSP1 – RCP 2.6 → 27.6%

SSP3 – RCP 7.0 → 32%

SSP5 – RCP 8.5 → 29.8%



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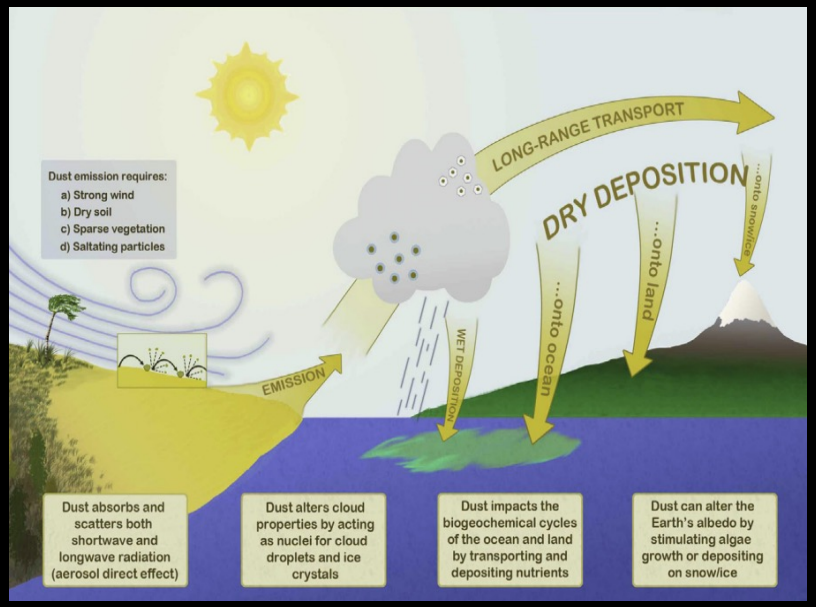
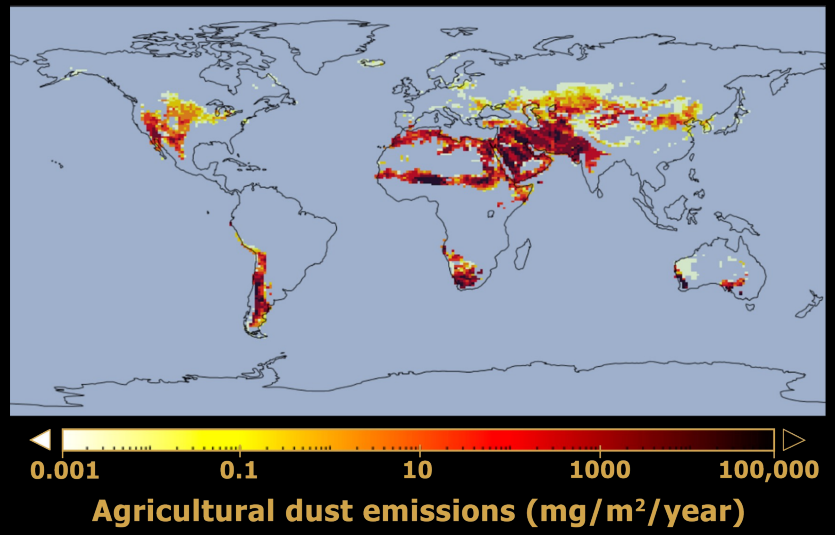
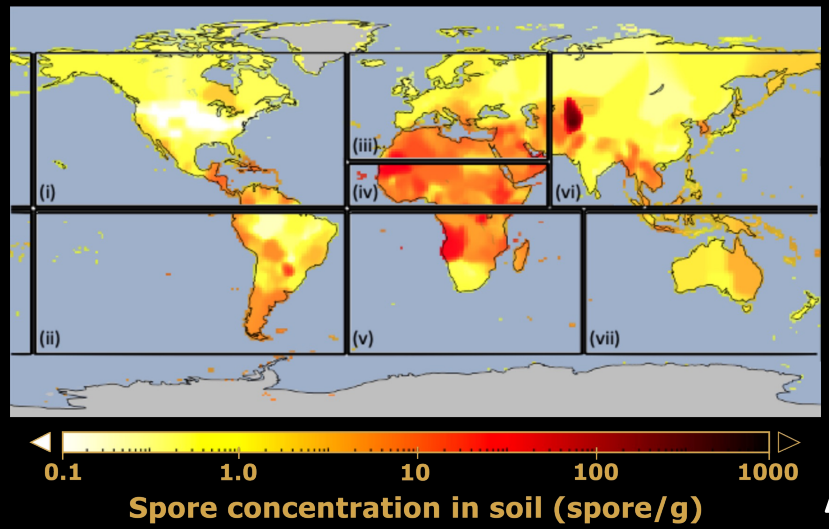
Aerosol transport: model modifications

Earth System Model: CESM2-CAM6 MIMI



Schematic of interactions between dust and climate (Mahowald et al. 2014)

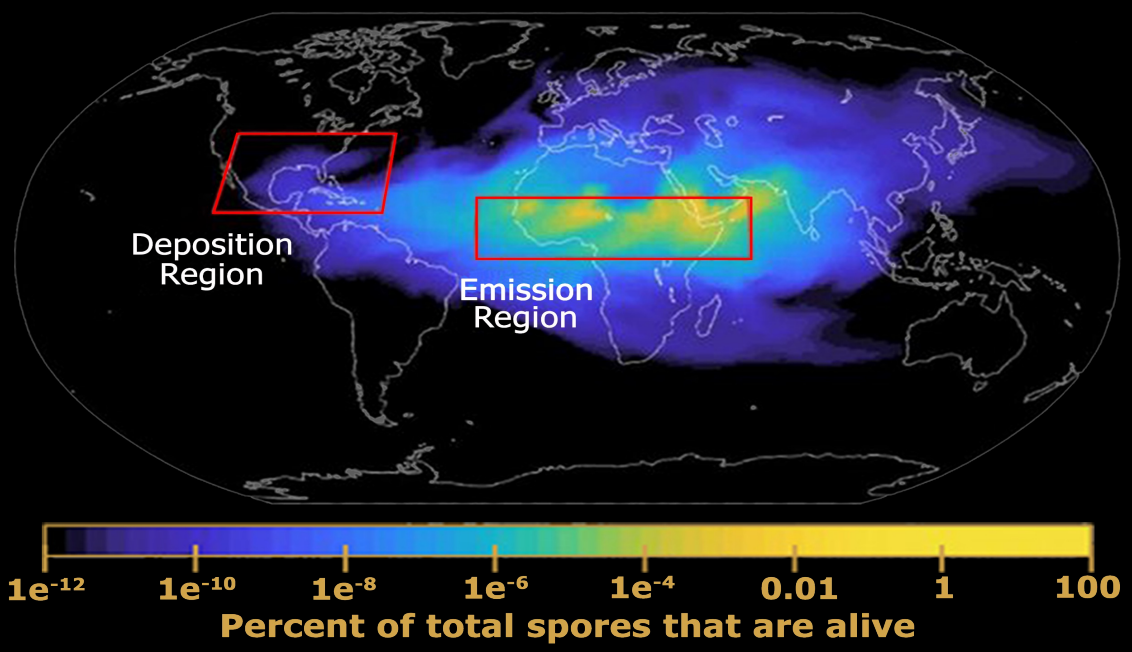


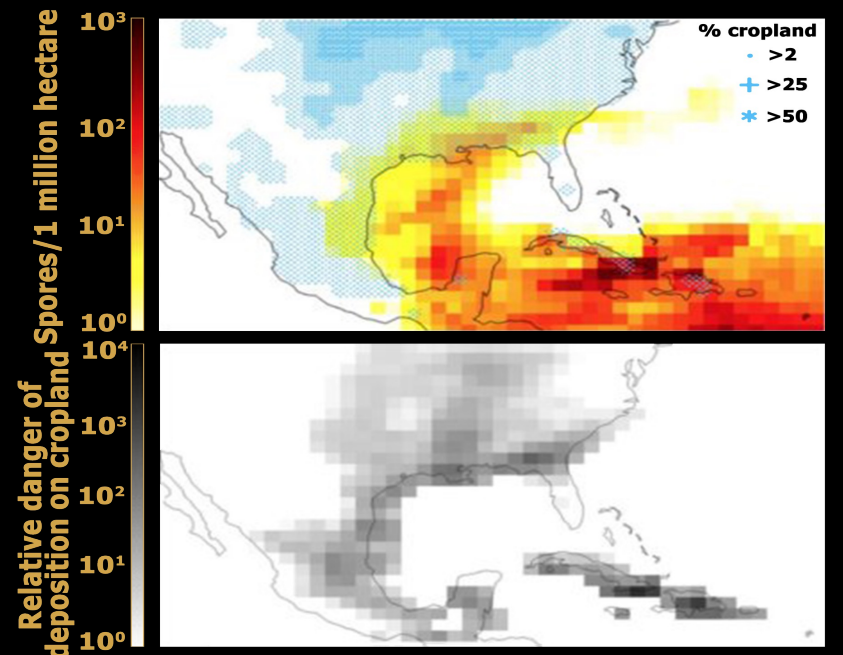


Brodsky et al. (2023)

Aerosol transport: Godzilla case study

- Use a major dust storm (Godzilla event) as a case study of the possibility of transatlantic atmospheric transport of *F. oxy* spores: if transport can ever happen, it would have happened then
- Simulations showed that 13000 out of 4 trillion spores from North Africa that reached the Americas were still viable
- The danger index (i.e., the number of viable spores deposited onto cropland) was higher in Mexico, Cuba, Haiti, and the Dominican Republic than in the continental US

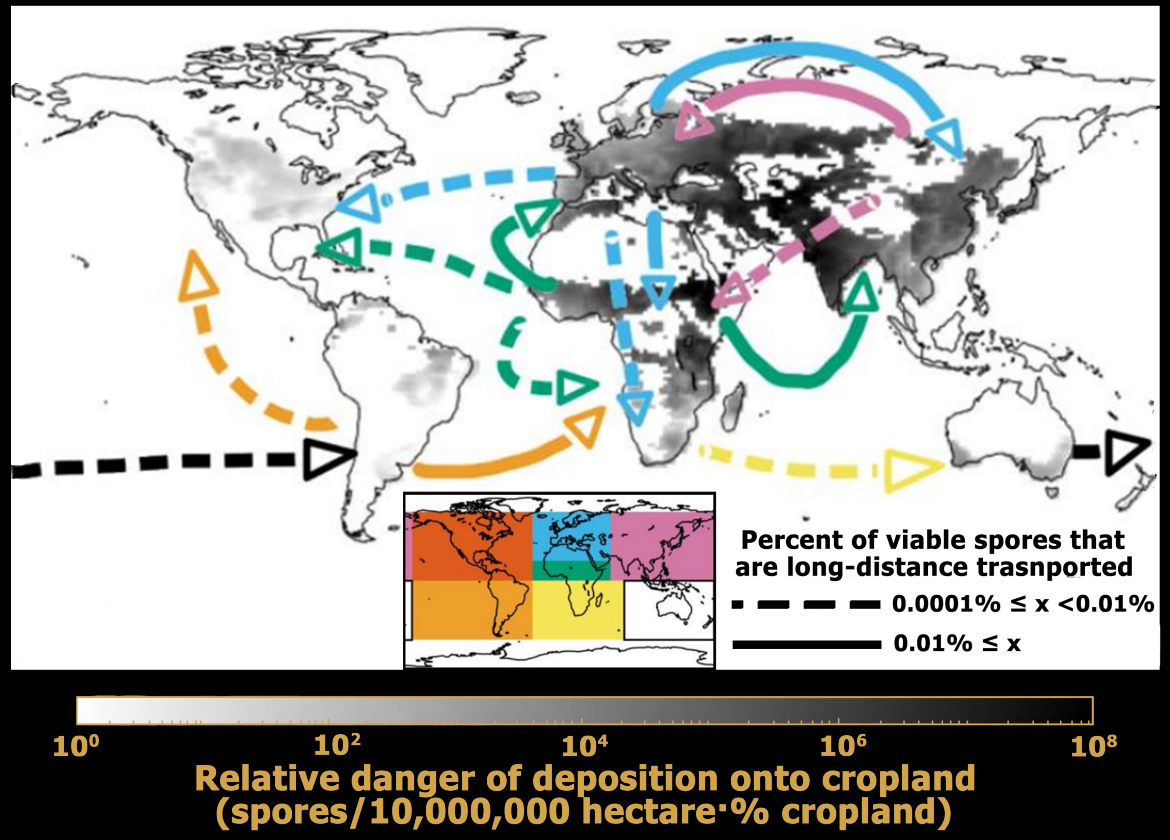




Brodsky et al. (2023)

Aerosol transport: global implications

- Dominated by interactions between western Eurasia, North Africa, and Northern Sub-Saharan Africa
- A high danger of viable spore deposition on cropland across Eurasia-Africa
- Sub-Saharan Africa is a hub for long-distance spore transport (53% of all viable spore deposition)



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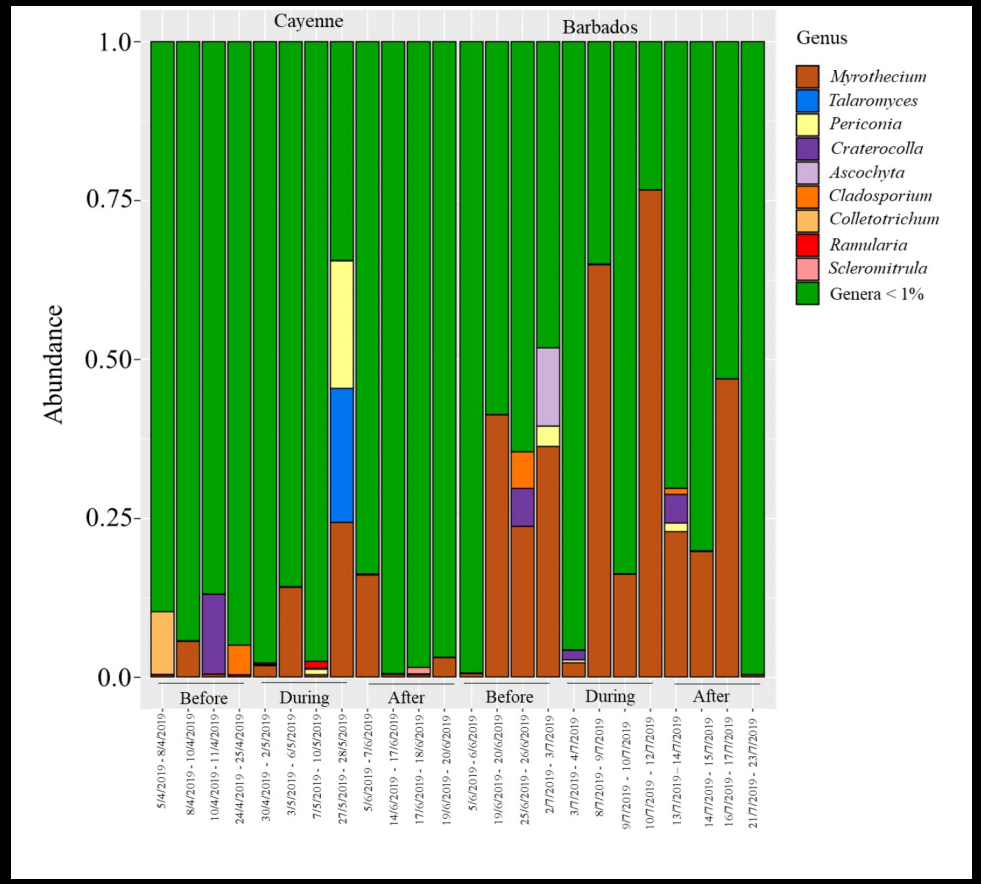
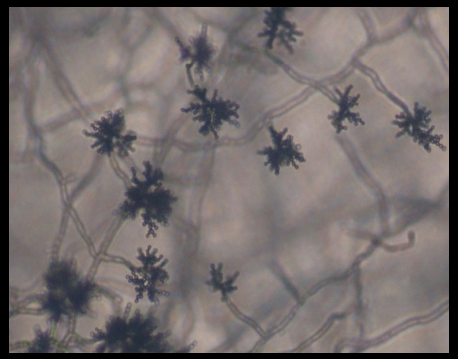
Aerial fungal microbiomes: composition

Can we detect microbial plant pathogens that move along with dust using genetic data? What are these pathogens?

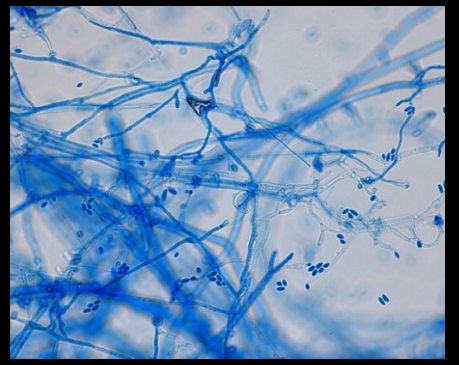


Sample sites

Colletotrichum spp.



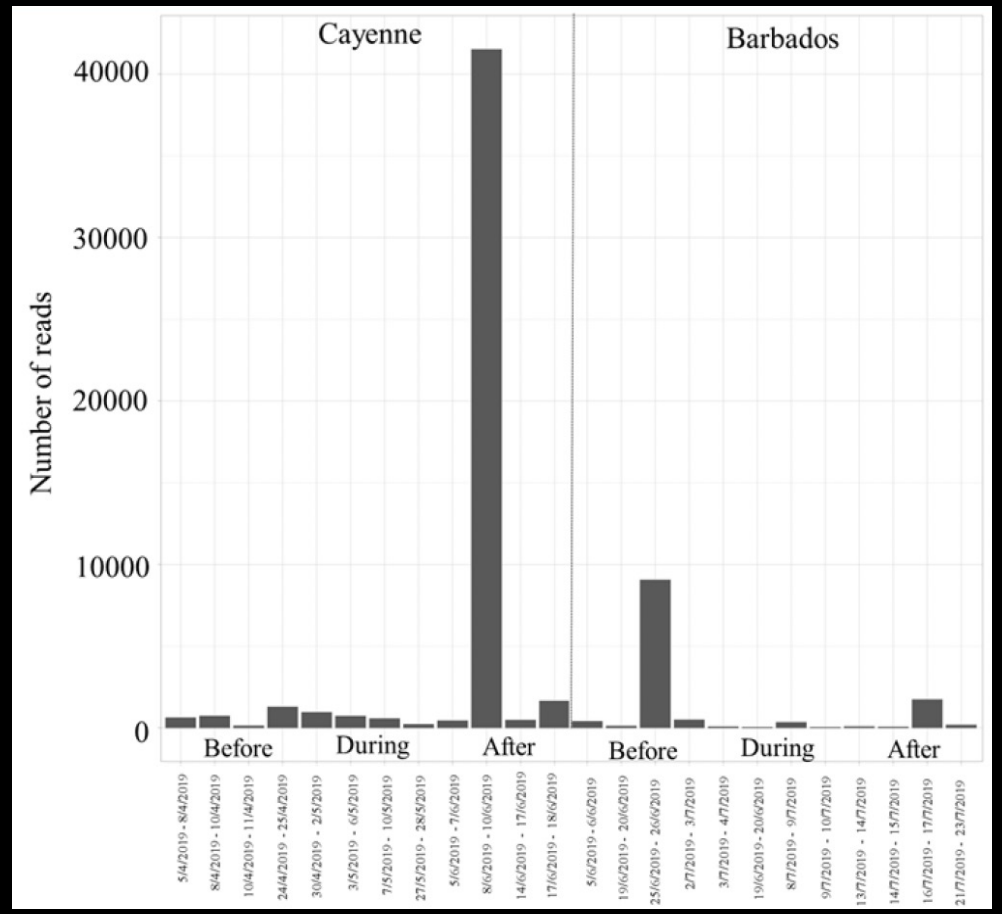
Cladosporium spp.



Fusarium oxysporum

Aerial fungal microbiomes: *Fusarium oxysporum*

- A significant presence of *F. oxy* spores was discovered in Cayenne after the dust storm
- Analyze HYSPLIT trajectories of propagules to find local weather that could elucidate the abundance of spores detected at a finer scale
- Future work: use metagenomics for a better taxonomic resolution and look for functional genes impacting spore viability

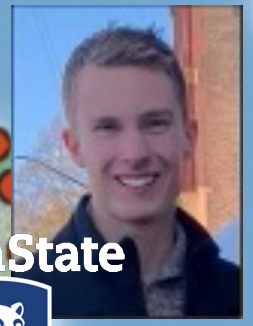
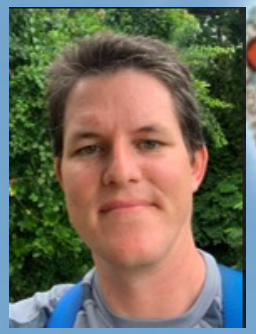


The story thus far …

1. Pathosystem distribution modeling enables us to turn remote sensing data streams into actionable risk assessments within a disease triangle framework (Calderón et al. *in preparation*)
2. Fusarium wilt risk will expand in the future regardless of the climate change scenario, which is mainly driven by cropland area expansion and air temperature increase (Calderón et al. 2023; Calderón et al. *in preparation*)
3. We found modeling evidence of long-distance *F. oxy* spore transport during extreme dust events, which is dominated by Eurasia-Africa interactions (Brodsky et al. 2023)
4. We detected *F. oxy* spores travelling with dust and identified genomic regions that may impact their transport and deposition patterns (Porras et al. *in preparation*)
5. This project lays the foundation for future use of forthcoming high-spatial-resolution hyperspectral satellite systems integrated with other remote sensing tools as a global surveillance system for crop disease





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Thanks!
Questions?

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blogs.cornell.edu/goldlab/

Brodsky H., Calderón R., Hamilton D. S., et al. (2023). Assessing long-distance atmospheric transport of soilborne plant pathogens. *Environmental Research Letters*

Calderón R., Eller, J., Brodsky H., et al. (2023). An interactive, online web map resource of global *Fusarium oxysporum* ff. ssp. diversity and distribution. *Plant Disease*

Global dust current *Fusarium oxysporum*