

Climate Data and Climate Models for Plant Pests



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Climate Change Impacts Global Food Security

- Altered growing seasons
- Altered patterns of water availability and drainage
- Changes in geographic distributions of pests

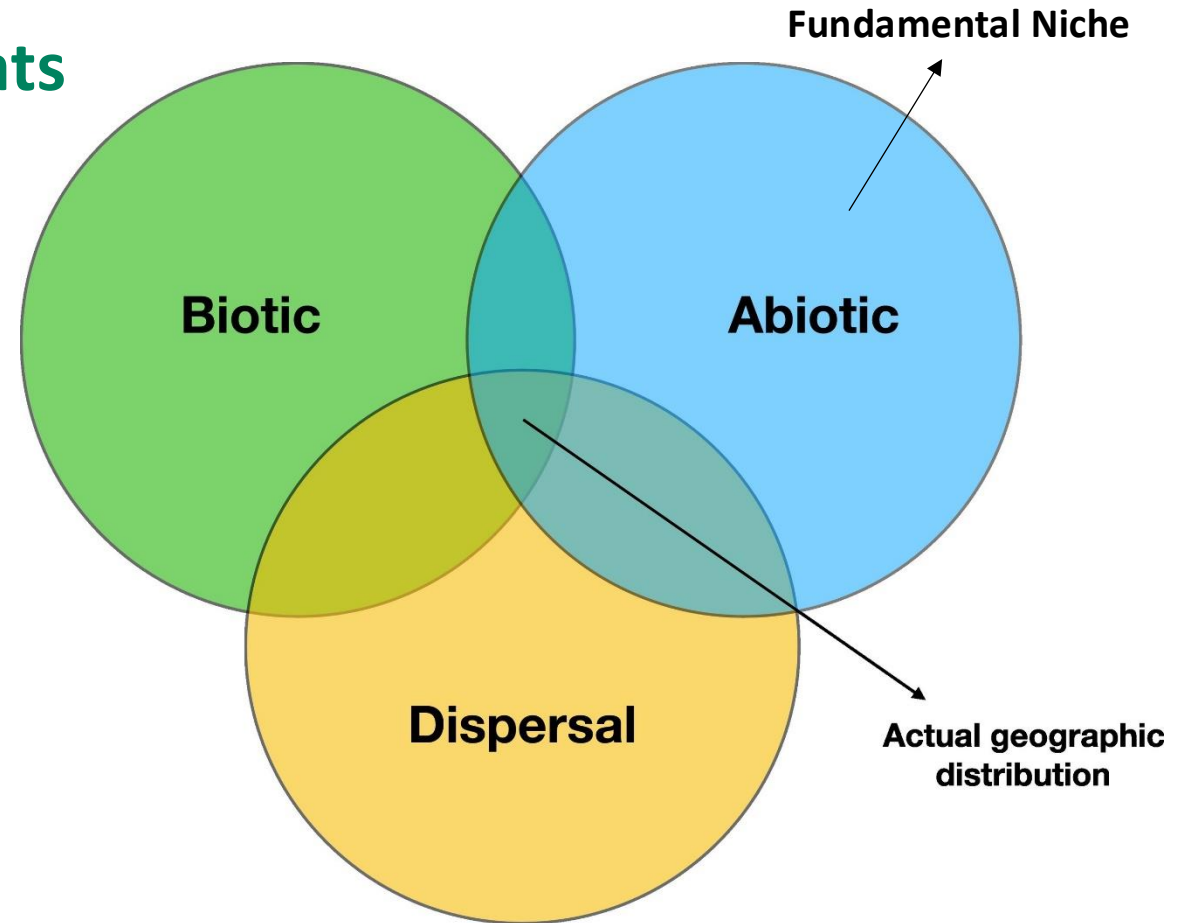


Leaf damage due to *Phytophthora infestans*

By Howard F. Schwartz, Colorado State University, United States - <http://www.forestryimages.org/browse/detail.cfm?imgnum=5362902>, CC BY 3.0, <https://commons.wikimedia.org/w/index.php?curid=7933322>

How invasive pests colonize new habitats

- Dispersal
 - Global Trade
- Suitable biotic conditions
 - Biotic release
- Suitable abiotic conditions
 - Physiological tolerance
 - Fundamental Niche

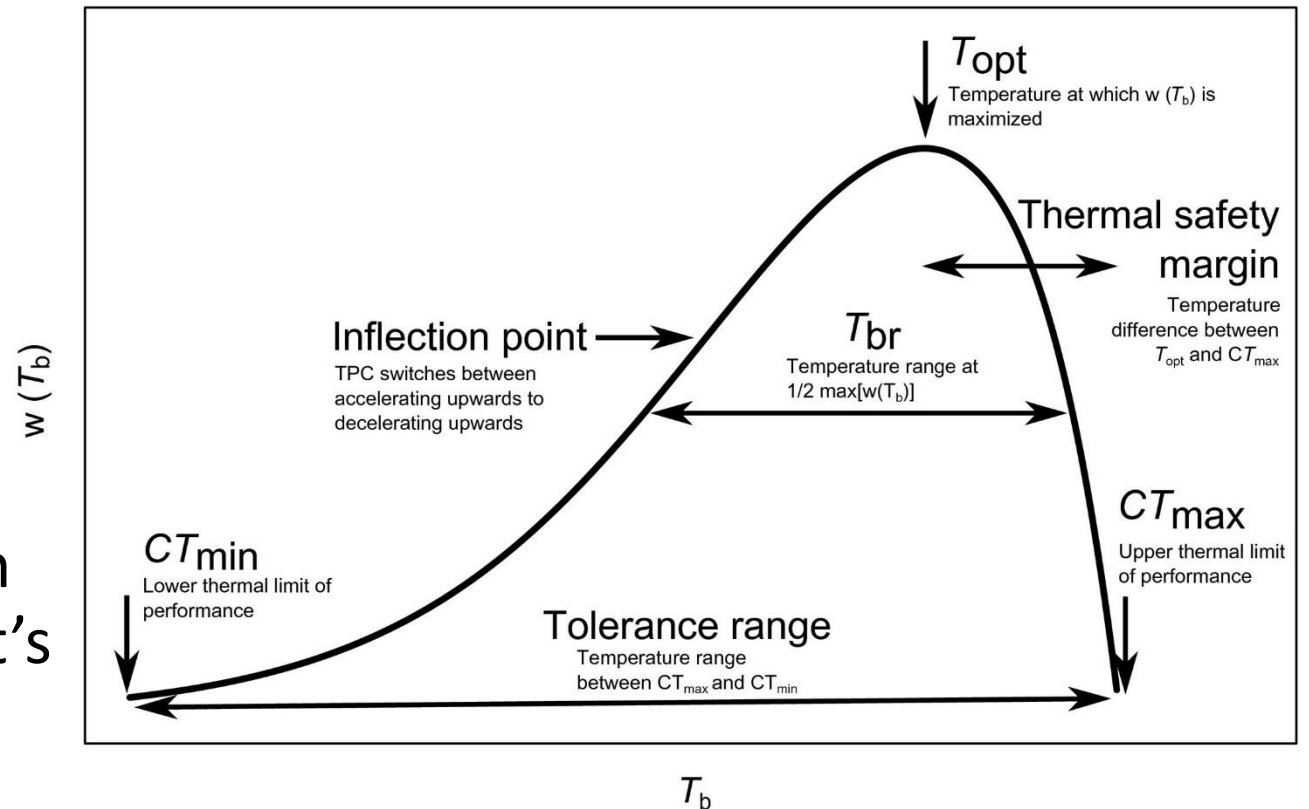


Trends in Ecology & Evolution

Poggiato, G. et al. 2021. On the Interpretations of Joint Modeling in Community Ecology, Trends in Ecology and Evolution 36(5):391–401

Which environmental conditions support pest populations?

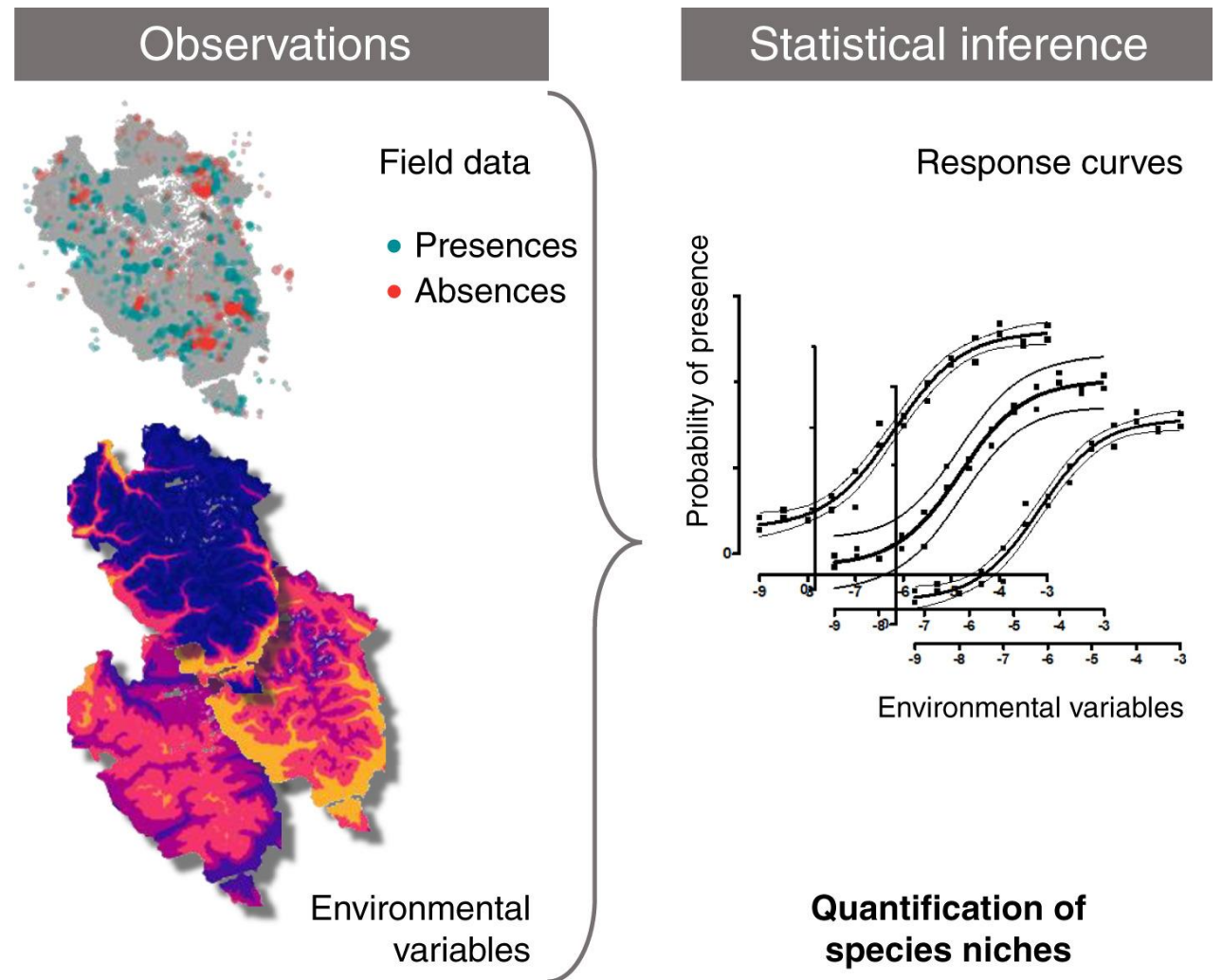
- Physiological study
- Pest species reared under environmental gradients to measure physiological tolerance.
- Impractical given the number of pest species available?
- What if we had detailed information about prevailing conditions in a pest's home range?



Sinclair, B.J. et al. 2016. Can we predict ectotherm responses to climate change using thermal performance curves and body temperatures? Ecology Letters 19: 1372–1385

Ecological Niche Models

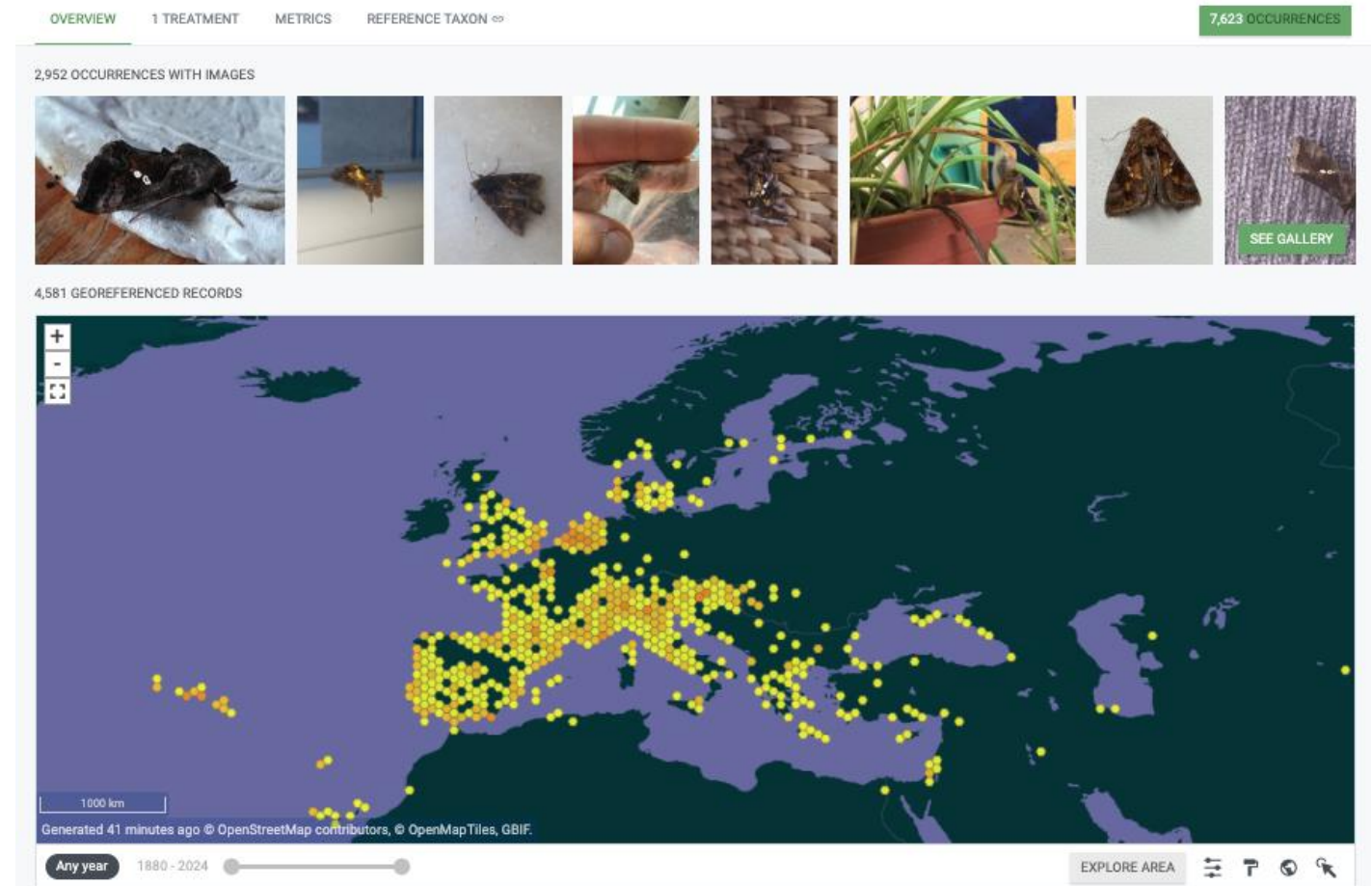
- Relationship between the probability of species occurrence and environmental conditions.
- Occurrence data
- Environmental data
- Models that are sophisticated enough to capture complex relationships
- Models can then be used to assess probability of species occurrence in different places and at different times.



Thuiler, W. 2024. Primer: Ecological Niche Modeling. *Current Biology* 34(6):225–229.

Occurrence Data

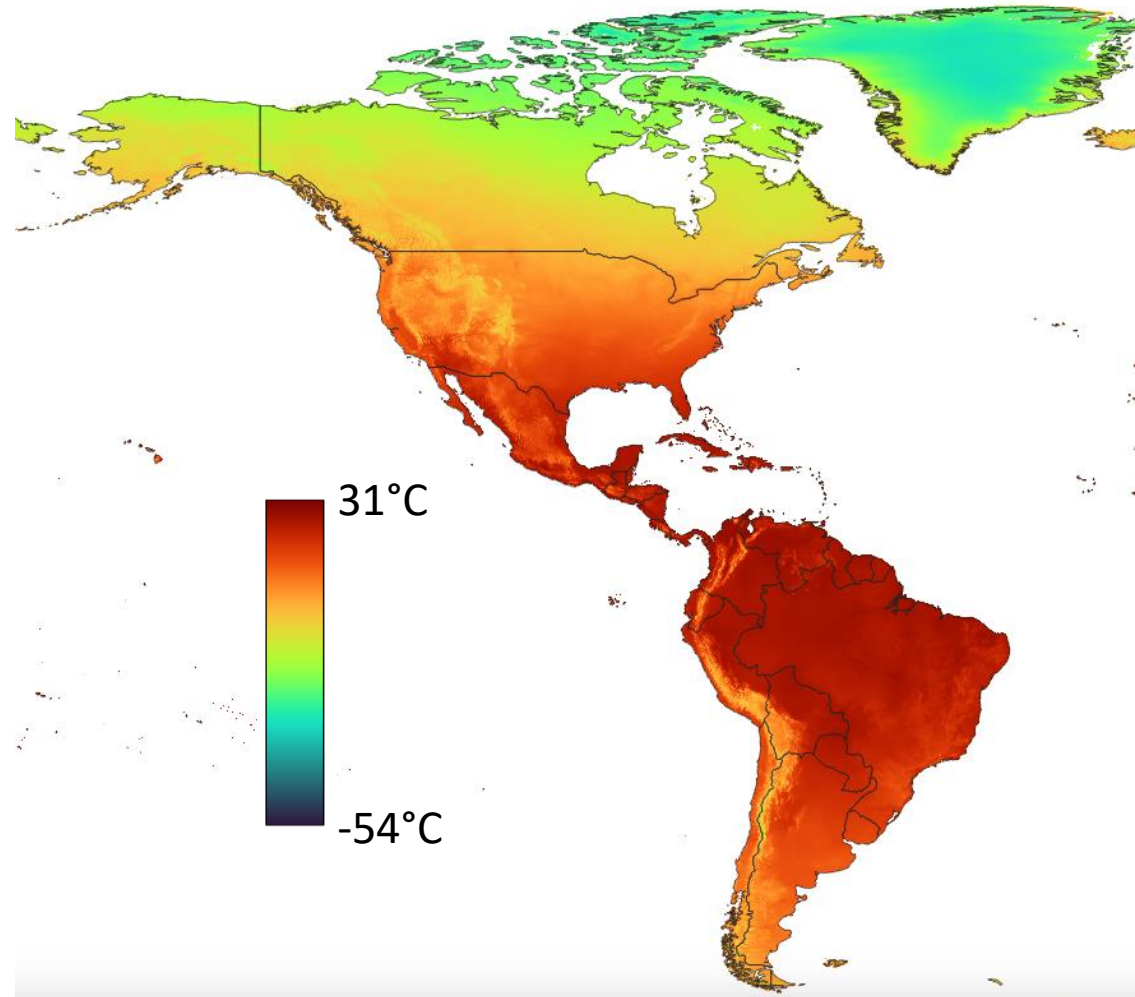
- Records of places that a species was known to be
 - Surveys
 - Curated collections
 - Databases
- Georeferencing of older records can be automated
- Challenge: Few such records for microbial organisms



GBIF.org search for Golden Twinspot Moth (*Chrysodeixis chalcites*)

Environmental Data

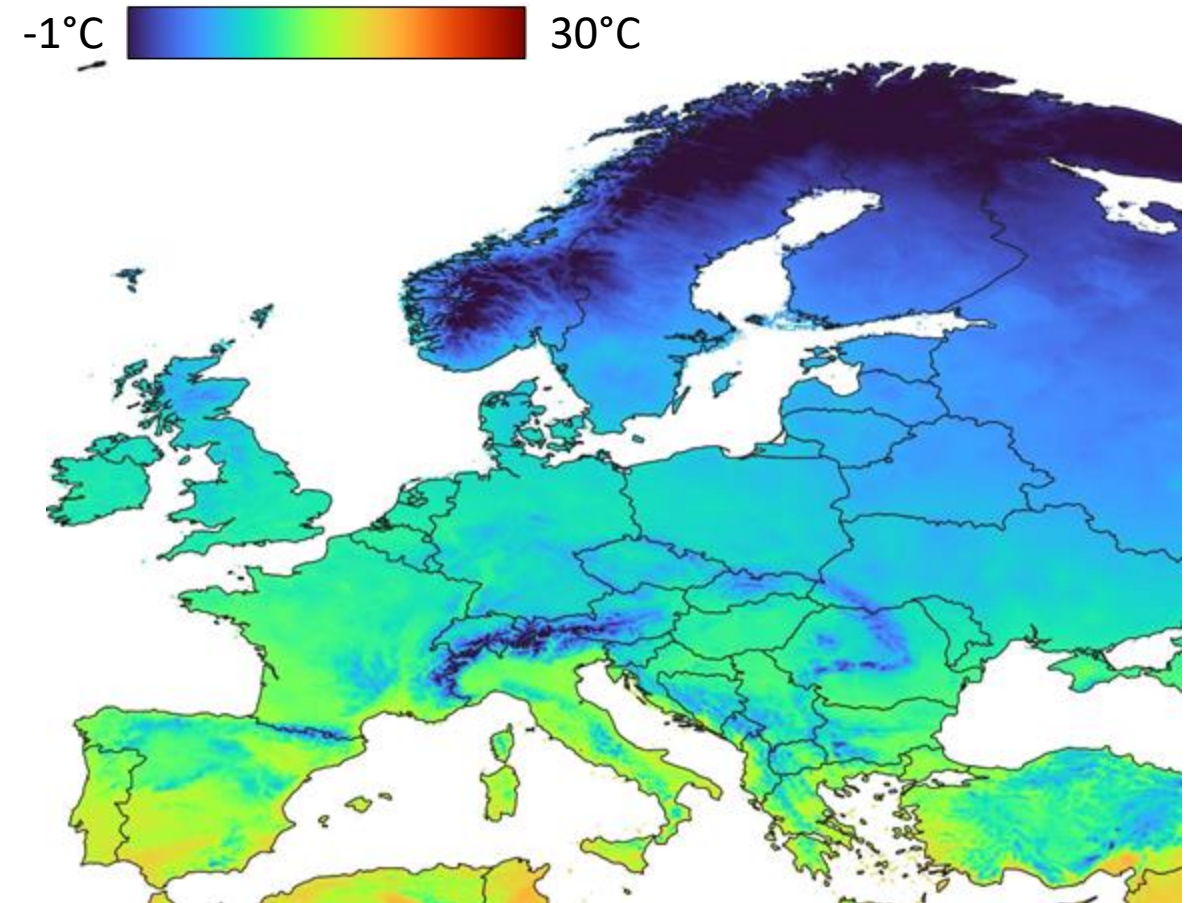
- Usually downloadable as heat-maps
- Interpolated from data stations, surveys
- Remote sensing
- Hybrid: transformations applied to data layers to infer other environmental variables
- Future climate conditions



Average annual temperature 1970–2000. Worldclim.org

Environmental Data: Future Climate

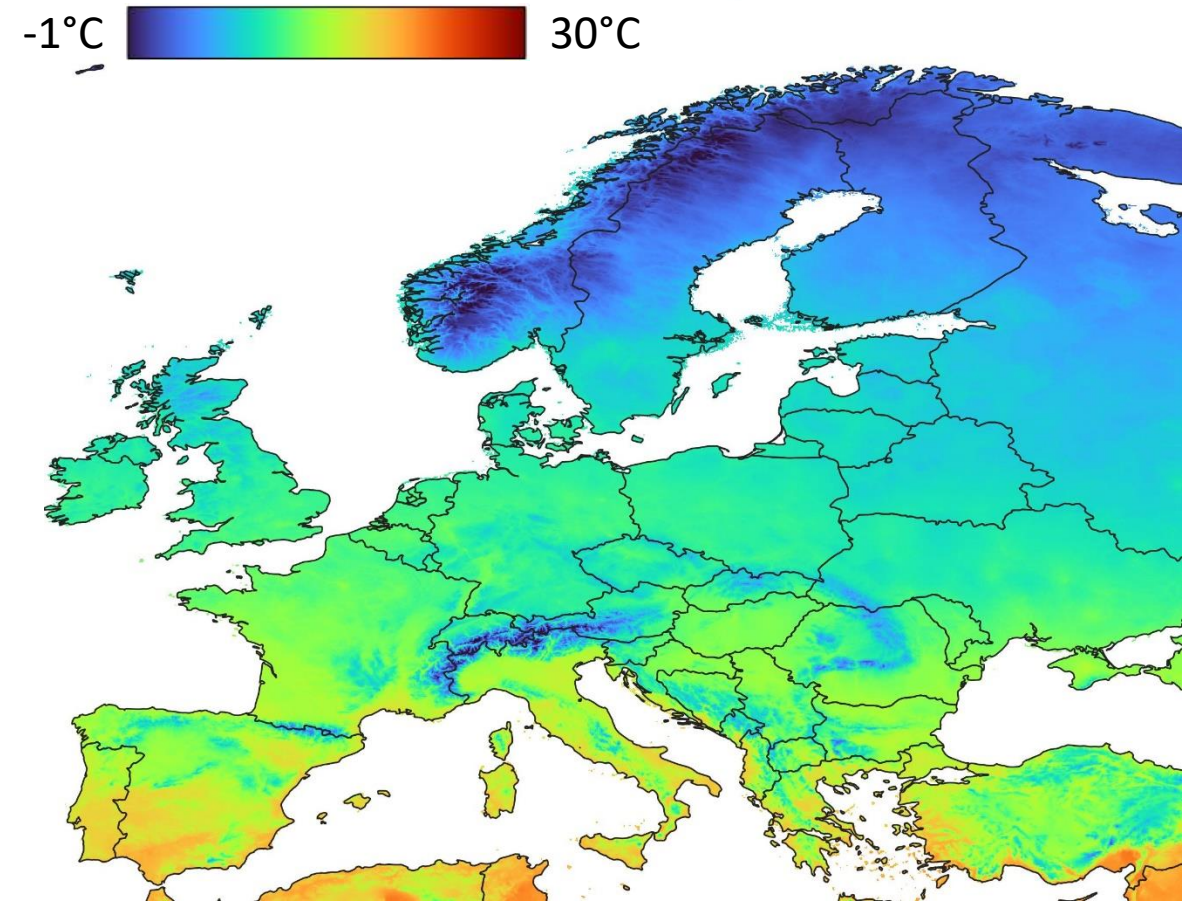
- World Climate Research Program-Coupled Model Intercomparison Project (WRCP-CMIP)
- Projections for 19 climate variables: 2040, 2060, 2080, 2100
- Socioeconomic scenarios
 - Least change: global cooperation to limit fossil fuel use
 - Most change: global competition and increased fossil fuel use



Average Annual Temperature 1970–2000

Environmental Data: Future Climate

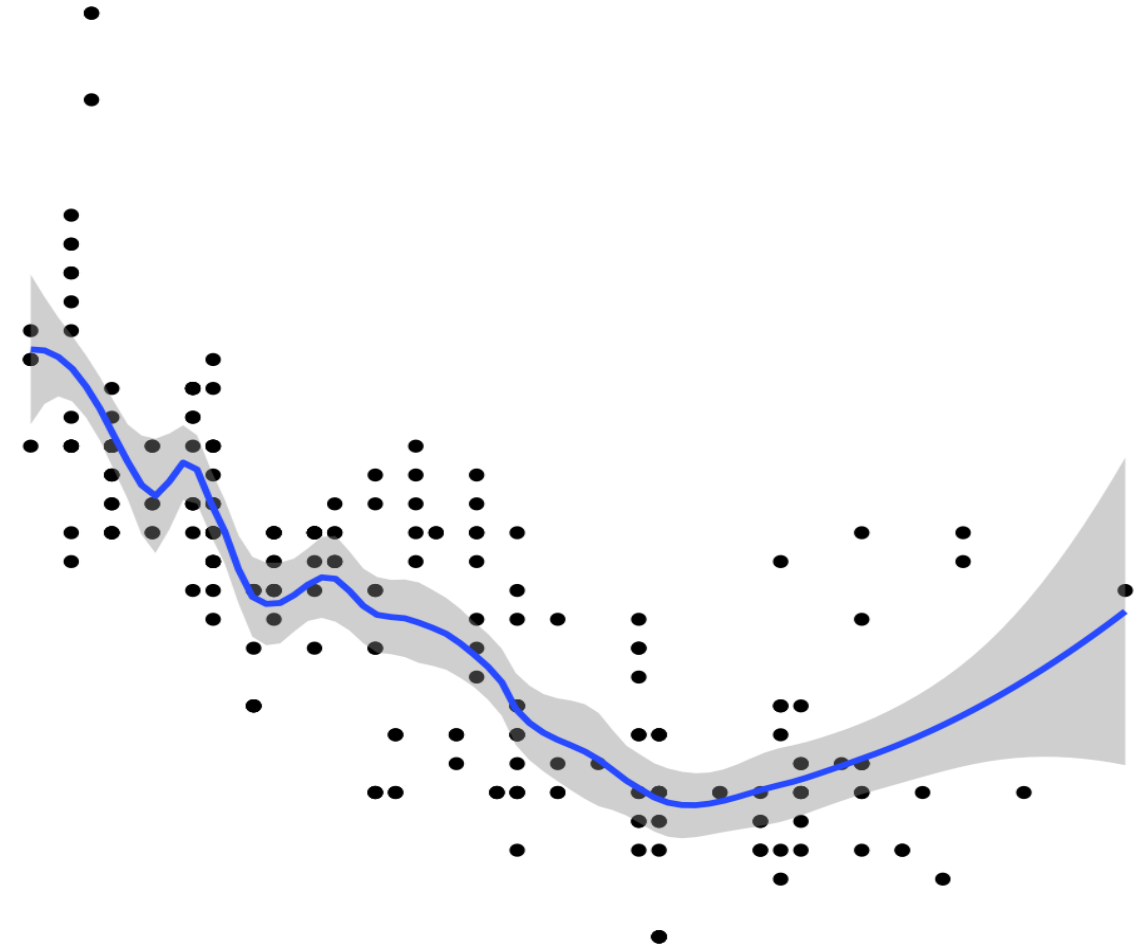
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Average Annual Temperature 2040–2060

Models

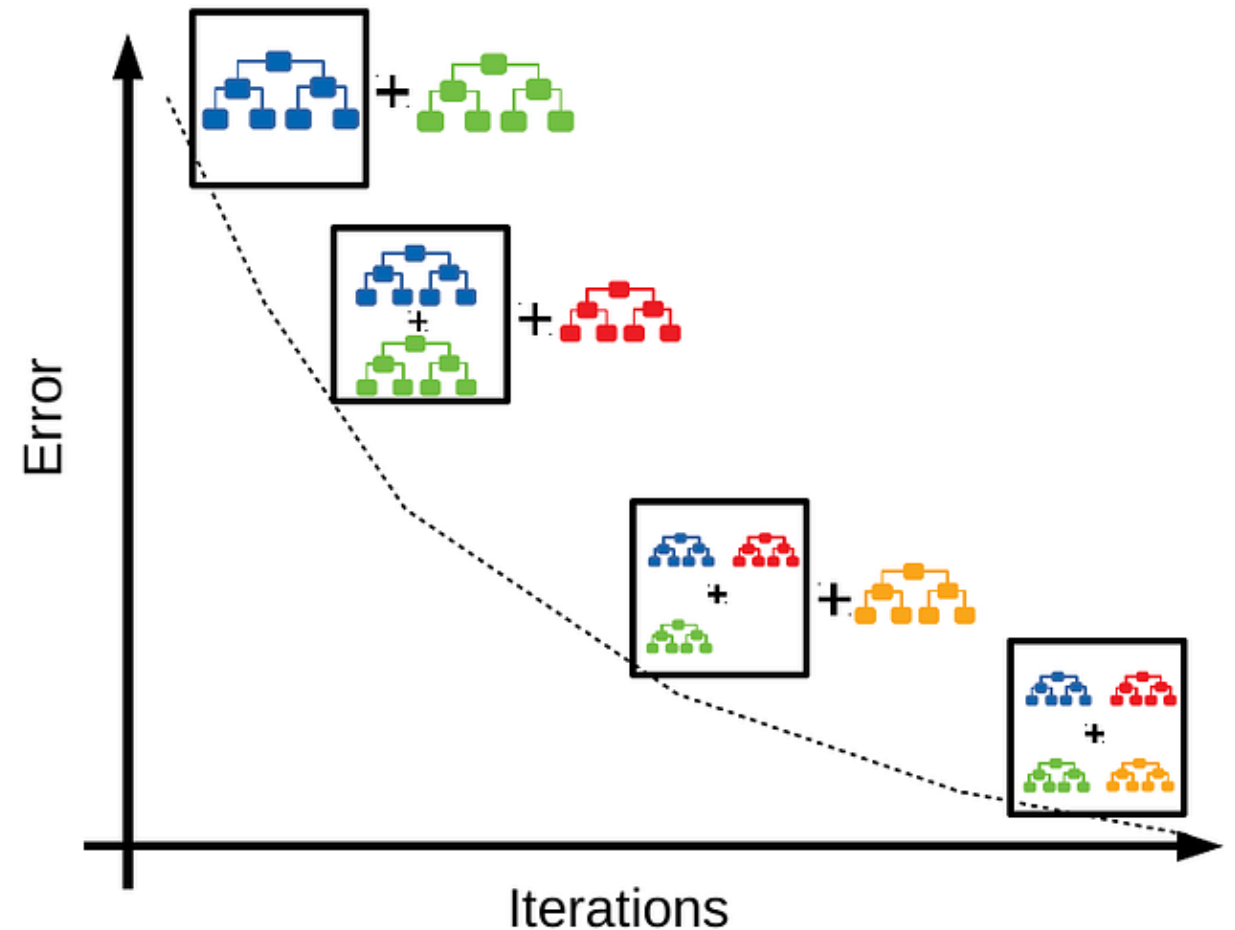
- What is the relationship between species occurrence and environmental conditions?
- Standard Models
 - General Linear Models
 - Generalized Additive Models
 - Envelope Models
 - Random Forest Models



<https://environmentalcomputing.net/statistics/gams/>

Models

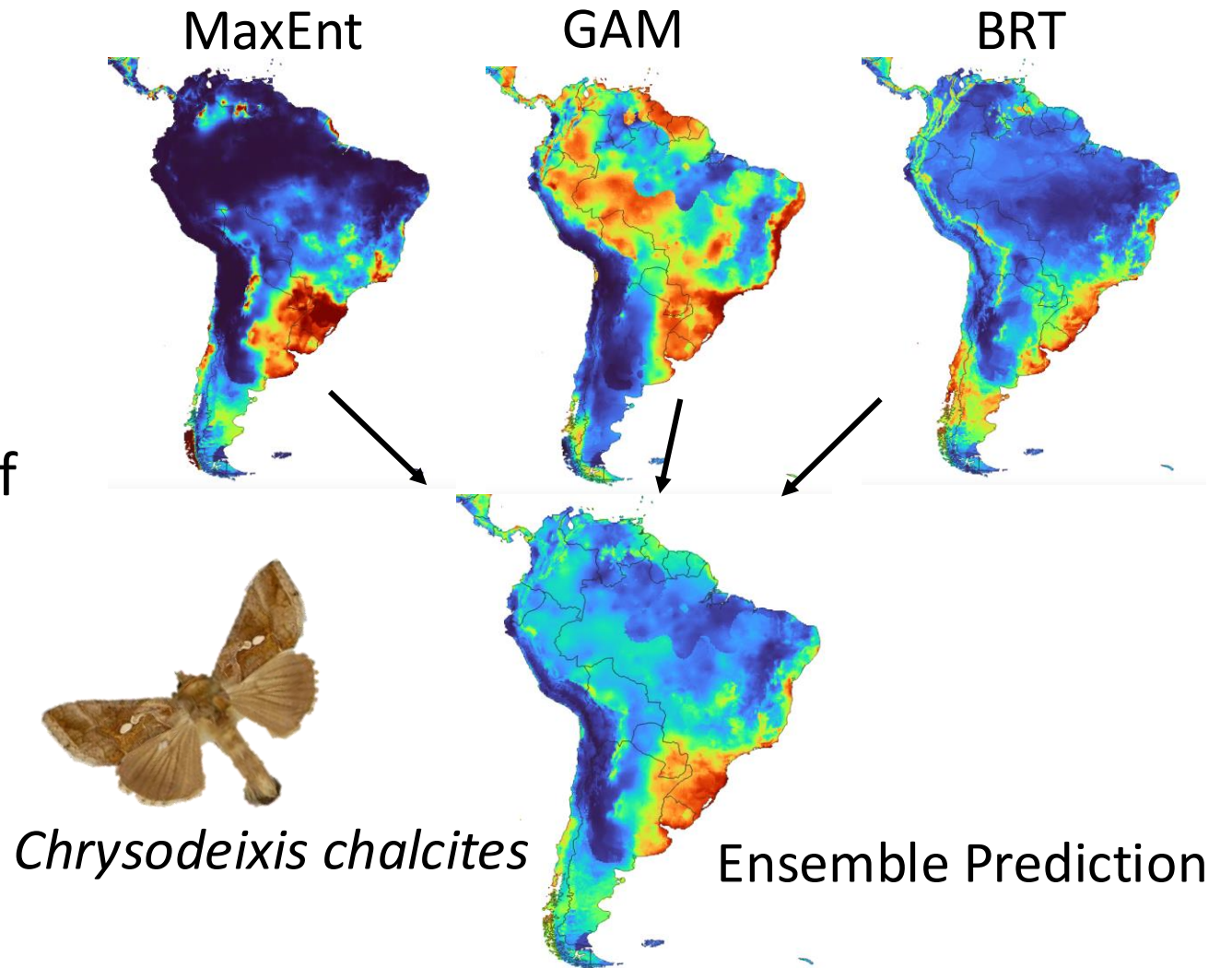
- What is the relationship between species occurrence and environmental conditions?
- AI Models
 - Maximum Entropy
 - Boosted Regression Trees
 - Neural Networks
- No model works best all of the time.



Pal, A.. 2020, Gradient Boosting Trees for Classification: A beginners guide,
<https://affine.ai/gradient-boosting-trees-for-classification-a-beginners-guide/>

Ensemble Prediction

- No model works best all of the time.
- Model disagreement due to random error inherent in each model.
- Model agreement due to signal in data.
- Ensemble is a harmonized account of multiple model predictions and generally performs better than any model alone.
- Ensembles can be applied globally



Predicting Crop Pest Distributions with Climate Change

- How are habitats suitable to known crop pests expected to change from 2020–2080?
- Climate Data
 - Four time periods
 - Four socioeconomic scenarios
- Threat Index: Average habitat suitability in the US.
- Highly predictive models for 18 of 24 selected pest species



Nick Galle, Jesus Castillo, Nico Reger, Laura Bianchi, Kay Hankins, and Austin Brenek.

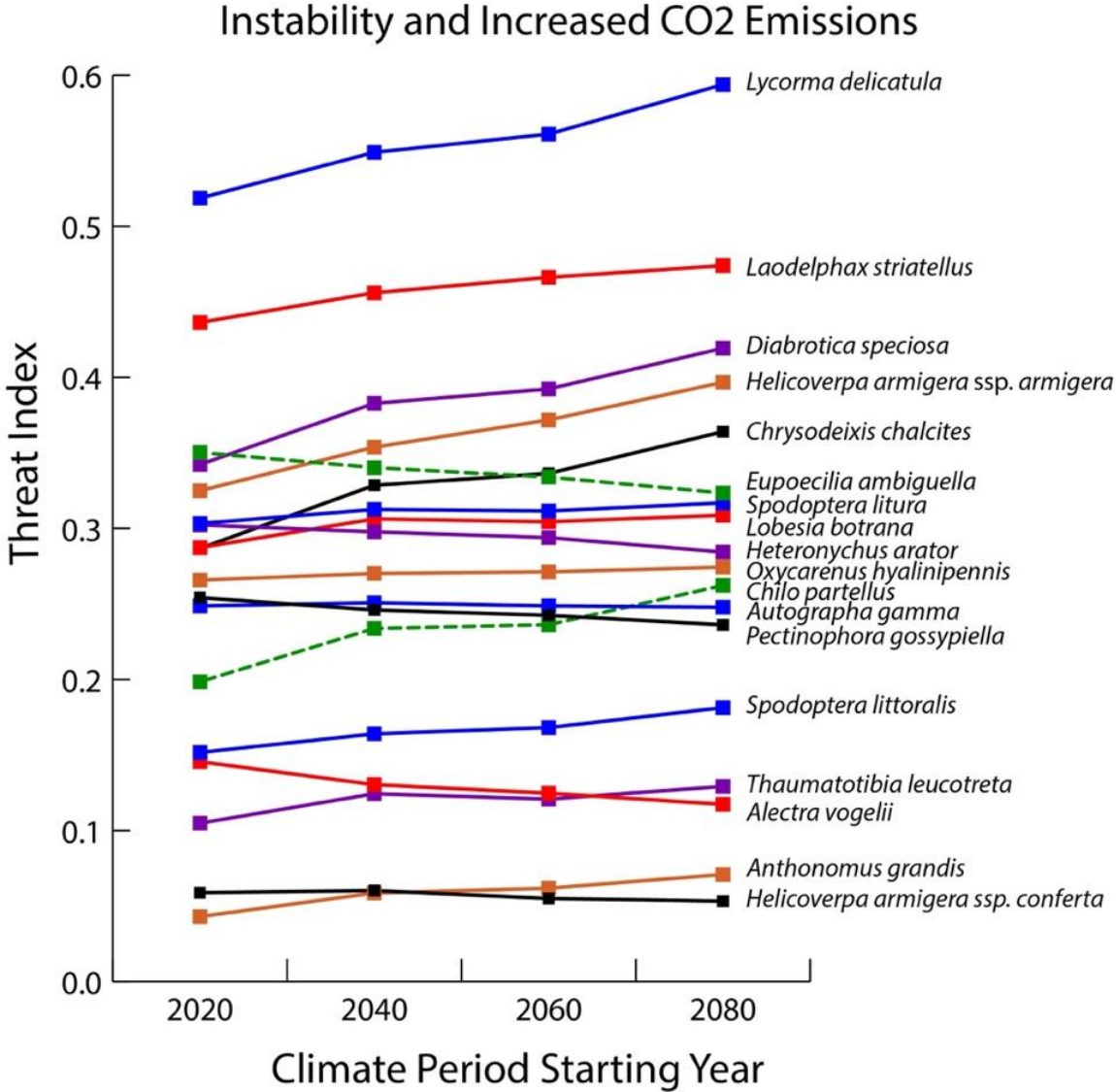
Free tools for ENM

- Occurrence data freely available from GBIF.org
- Bioclimatica data from worldclim.org
- Models and predictions generated using R packages 'terra' and 'dismo', based on tutorials at rspatial.org
- Many other free data sources and tools not used in this project.



Results

- Threat Index: proportion of suitable habitat available in contiguous US
- Of 18 pests,
 - nine demonstrate marked increase in suitable habit
 - six demonstrate no change
 - three show declining suitable habitat.
- Not surprising as species environmental requirements are highly variable.

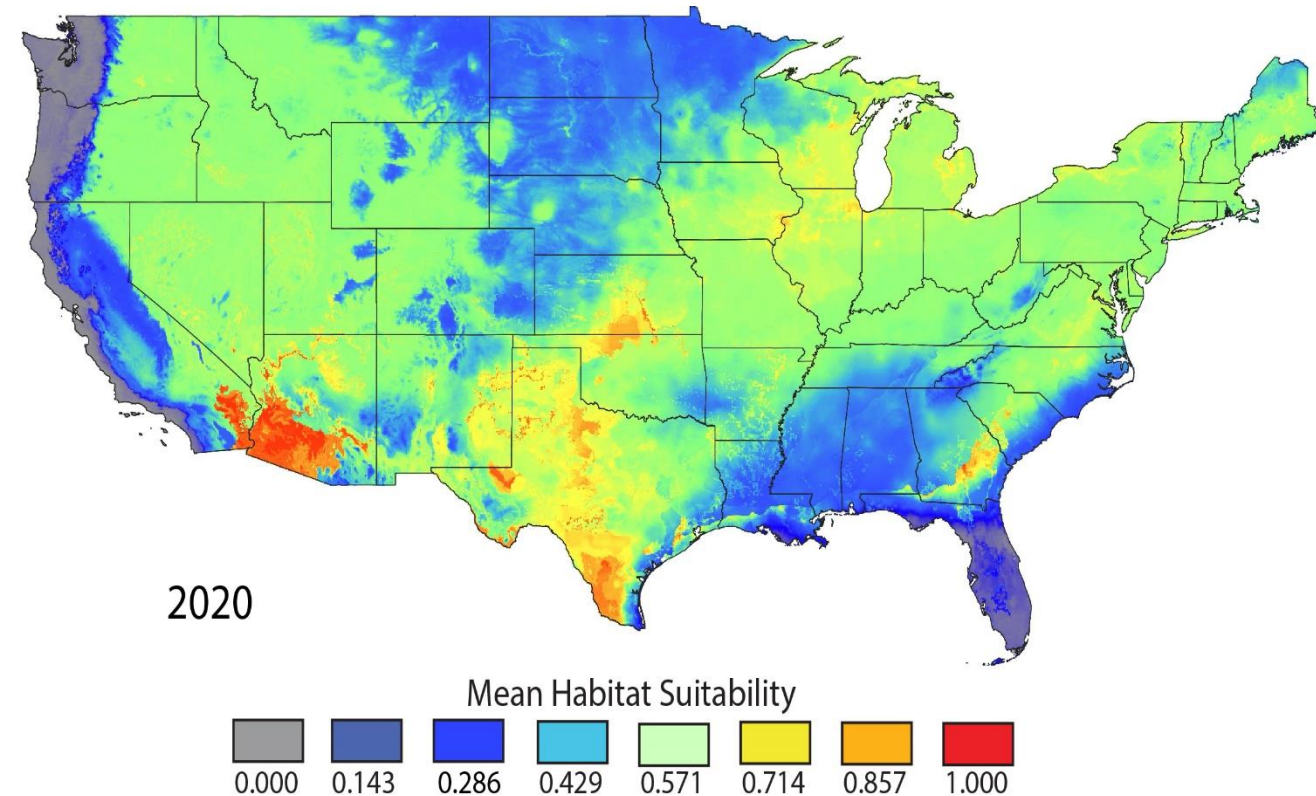


Results

- The spotted lantern-fly (*Lycorma delicatula*), an eastern Asian native species, exhibited both the greatest current habitat suitability, and the most rapid increase in habitat suitability.



Lawrence Barringer, Pennsylvania
Department of Agriculture

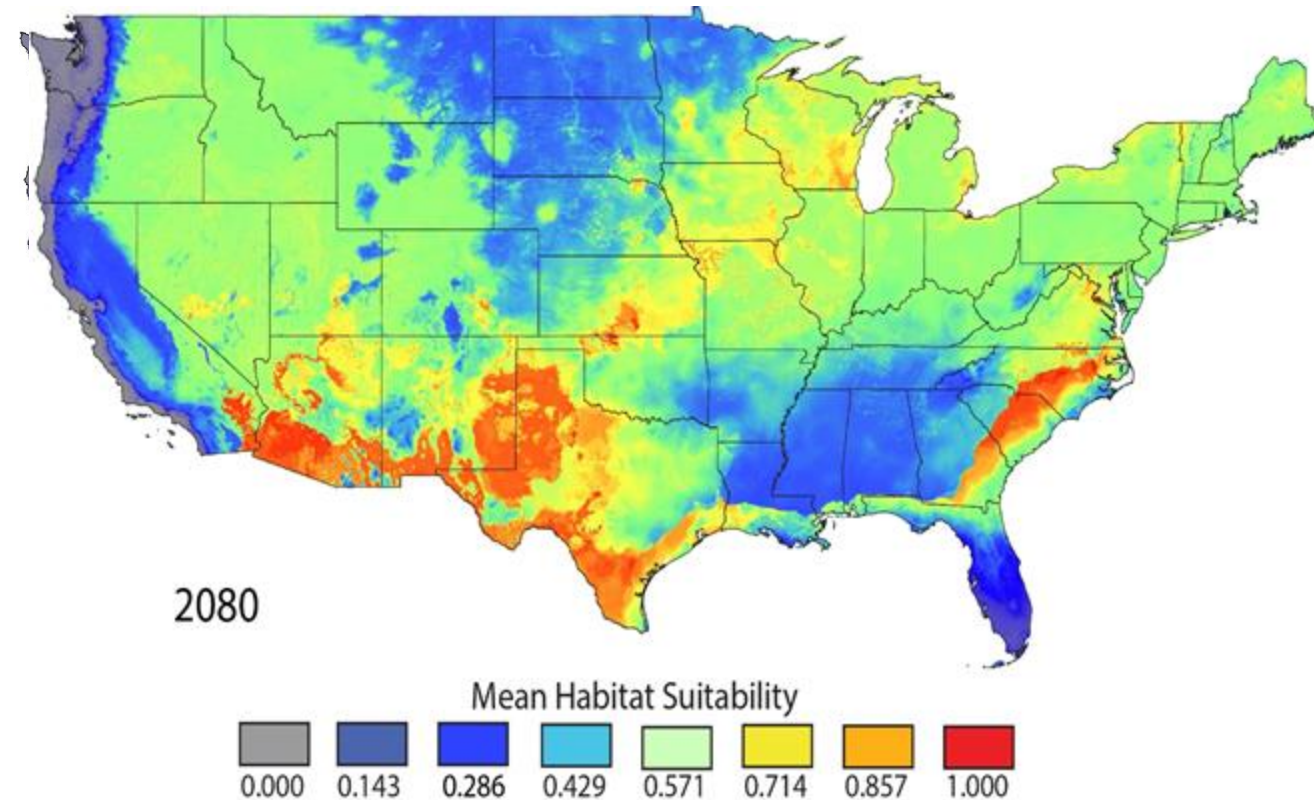


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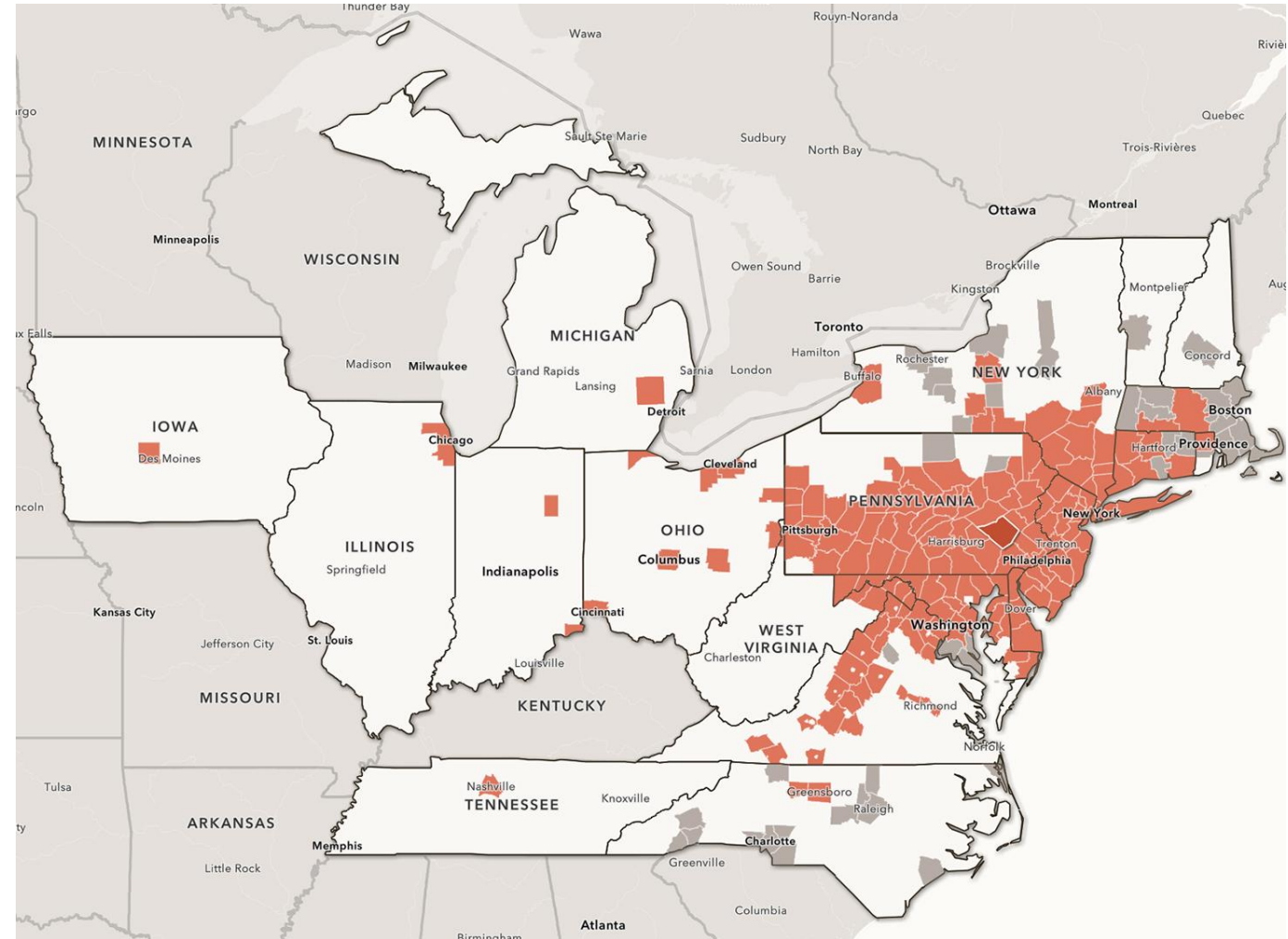


Results

- The spotted lanternfly has already appeared in forests of the northeastern US and is rapidly spreading west.



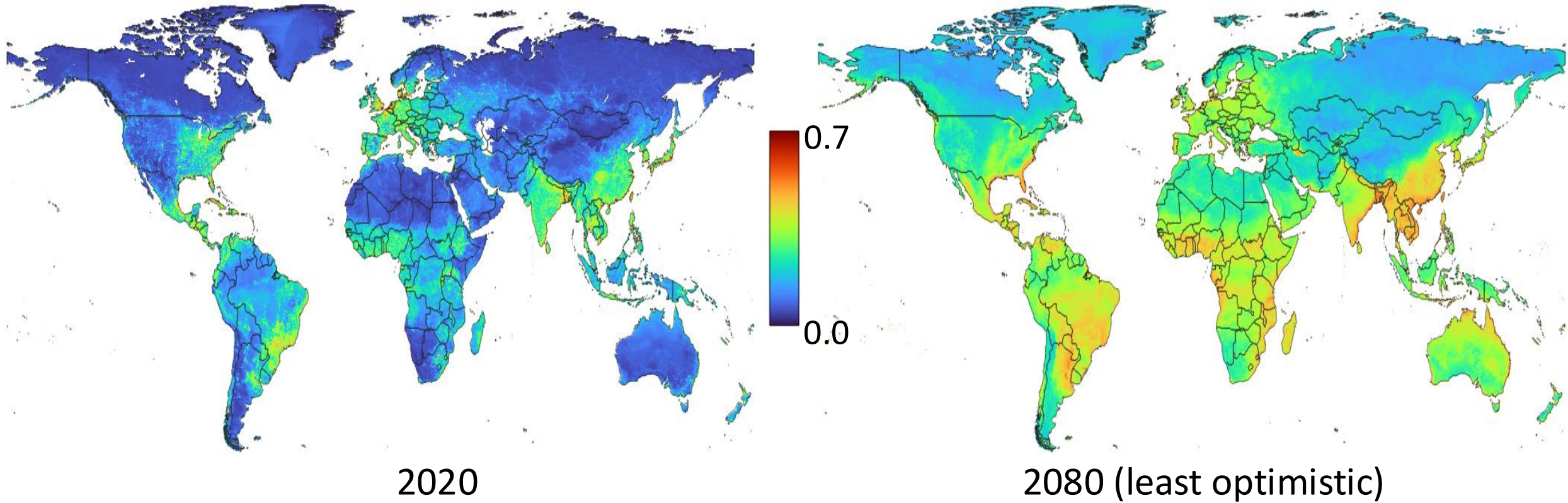
Lawrence Barringer, Pennsylvania
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<https://www.maps.com/spotted-lanternfly-map-tracks-spread-of-invasive-species/>

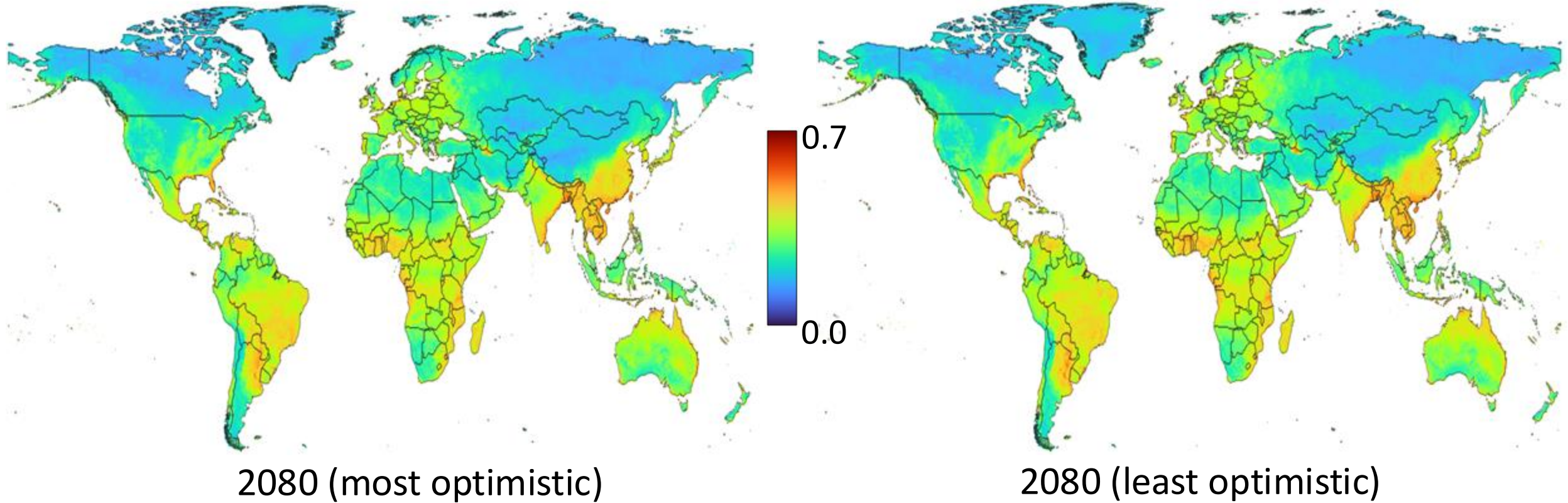
Results

- Overall habitat suitability (averaged across pests) increases over time.



Results

- Socioeconomic scenario makes little difference overall



Conclusions

- Ecological Niche Modeling is a viable approach to estimating pest species distributions, especially when little is known about the pests.
- Data and tools are freely accessible and easy to learn
- We need more occurrence data for microbial pests.
- Change in distributions of pests is coming and we should be prepared for it.



<https://www.usda.gov/media/blog/2023/04/20/protecting-earth-through-climate-smart-agriculture-and-technologies>

Gratitude

USDA-APHIS Farmbill 7221-1a awards AP22PPQS&T00C072 and AP22PPQS&T00C132

Randle and Williams Lab Members

Robert Hijmans and Jane Elith, creators of r-spatial.org

