PoPS

# Managing pest outbreaks through participatory iterative ecological forecasting

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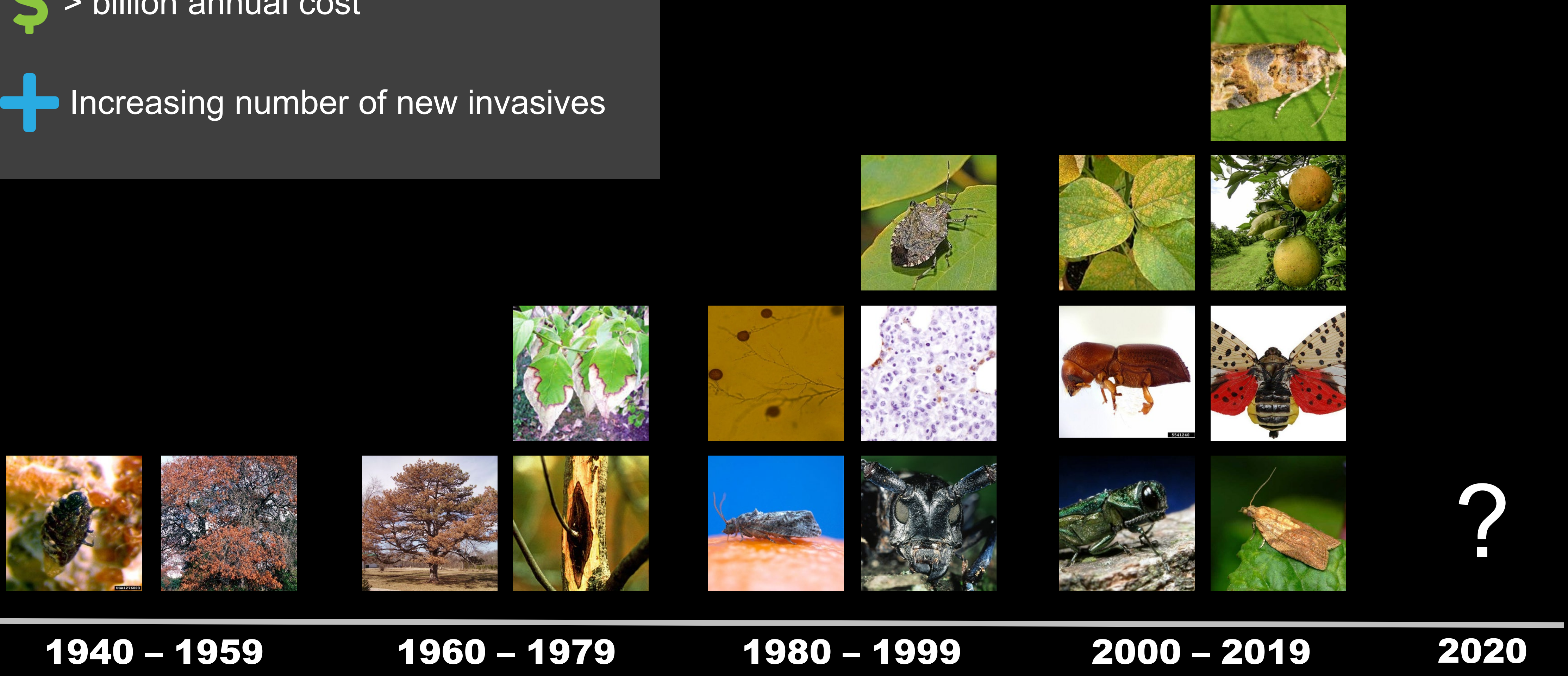
Center for Geospatial Analytics
NC STATE UNIVERSITY

# Invasive Pests and Pathogens are Increasing Globally

$ > billion annual cost

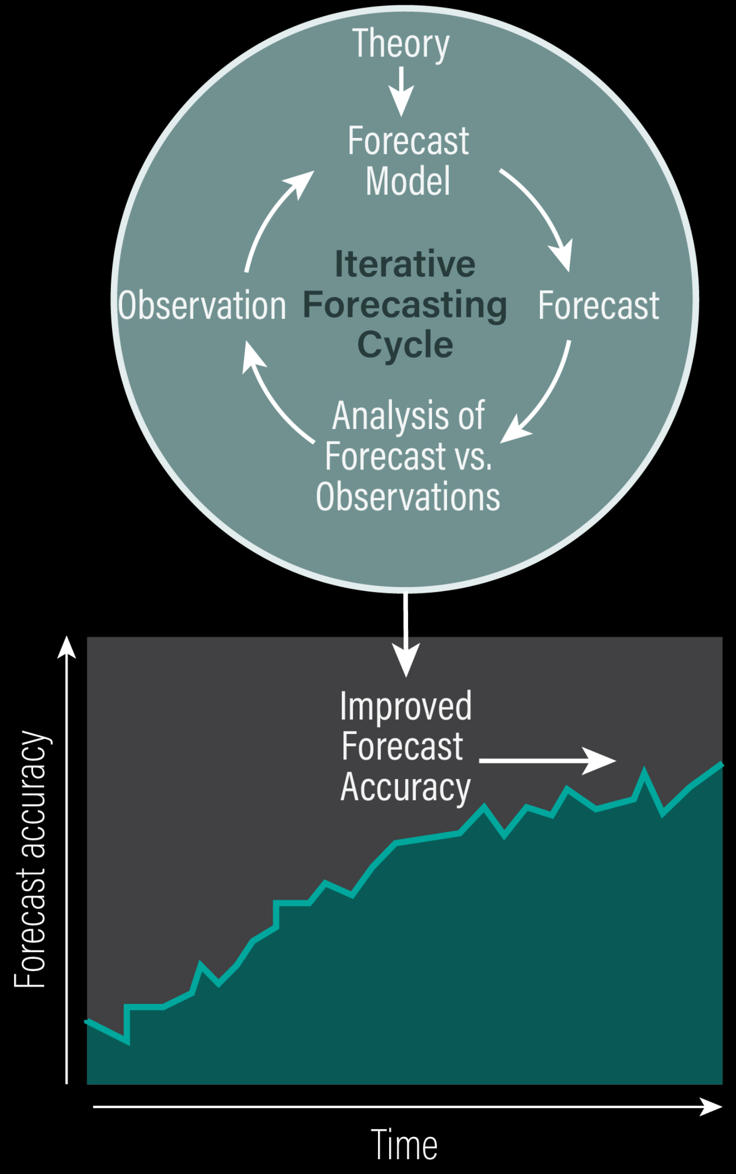
+ Increasing number of new invasives




*Each box represents ~500 new introduced species

Based on data from Seebens, Hanno, et al. *Nature communications* 8 (2017): 14435.

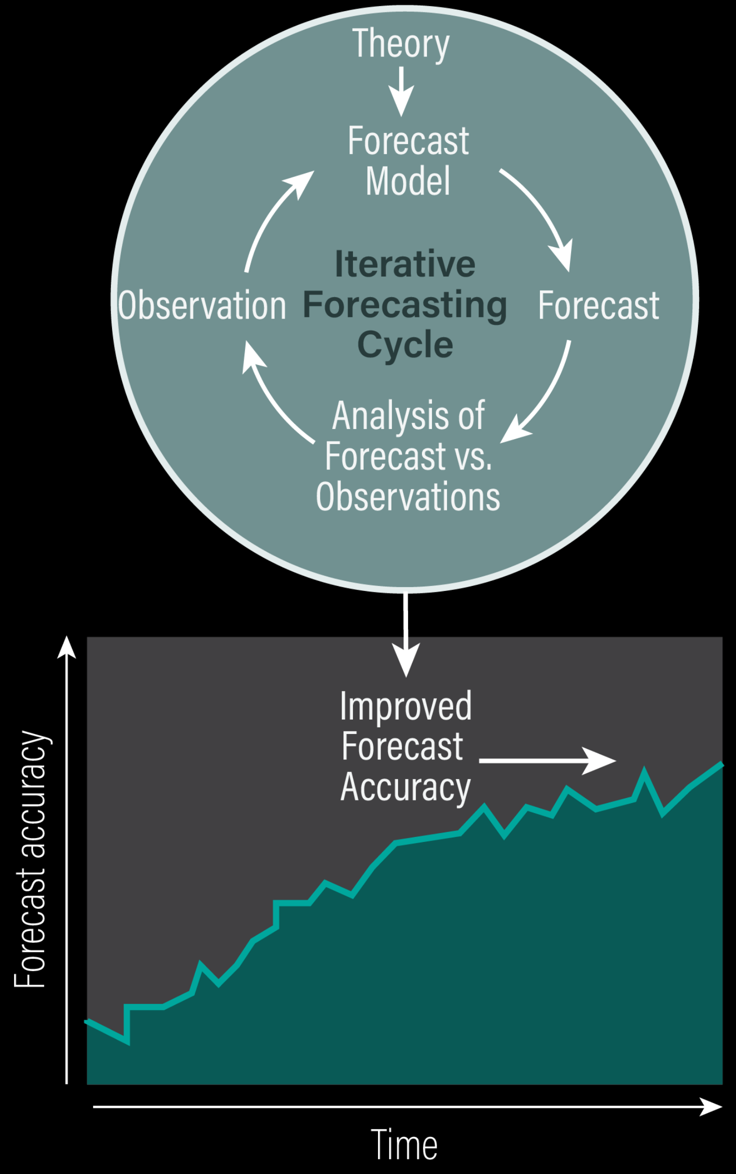
# Iterative Forecasting Improves Forecasts Steadily Over Time




**Iterative Forecasting in Ecology:**

We believe iterative ecological forecasting can help us improve our ability to model pest and pathogen spread.

# Iterative Forecasting Improves Forecasts Steadily Over Time

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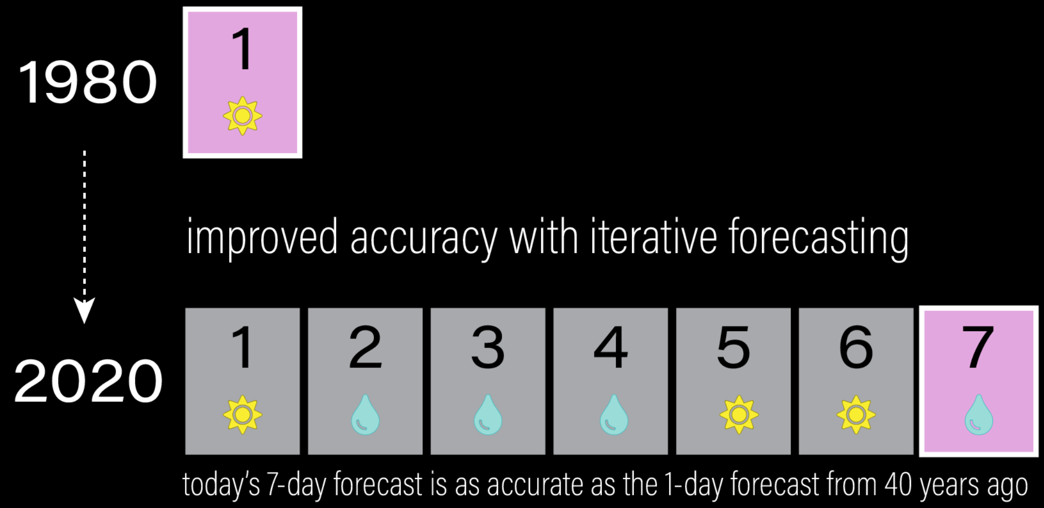
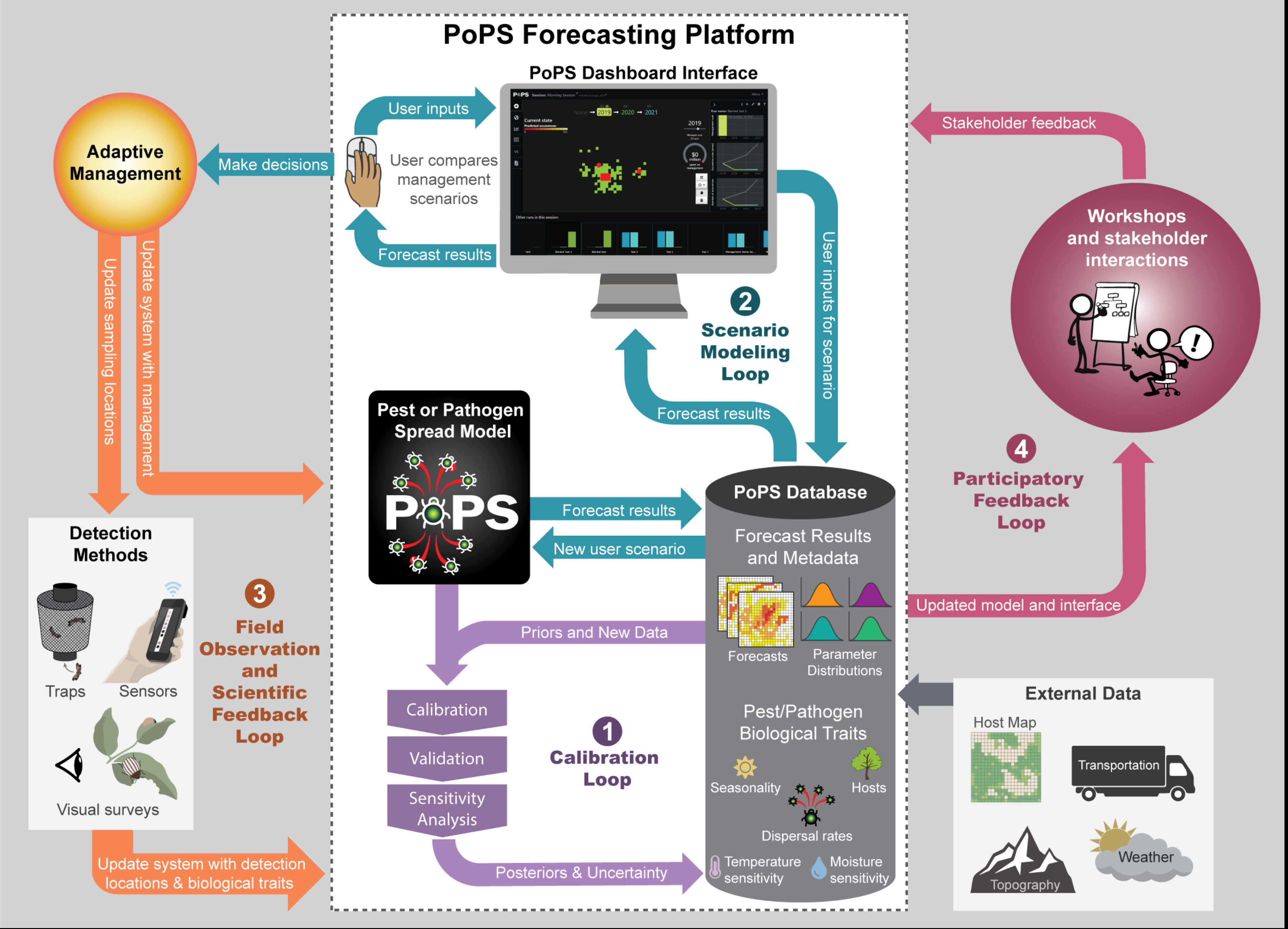
**Iterative Forecasting in Weather:**





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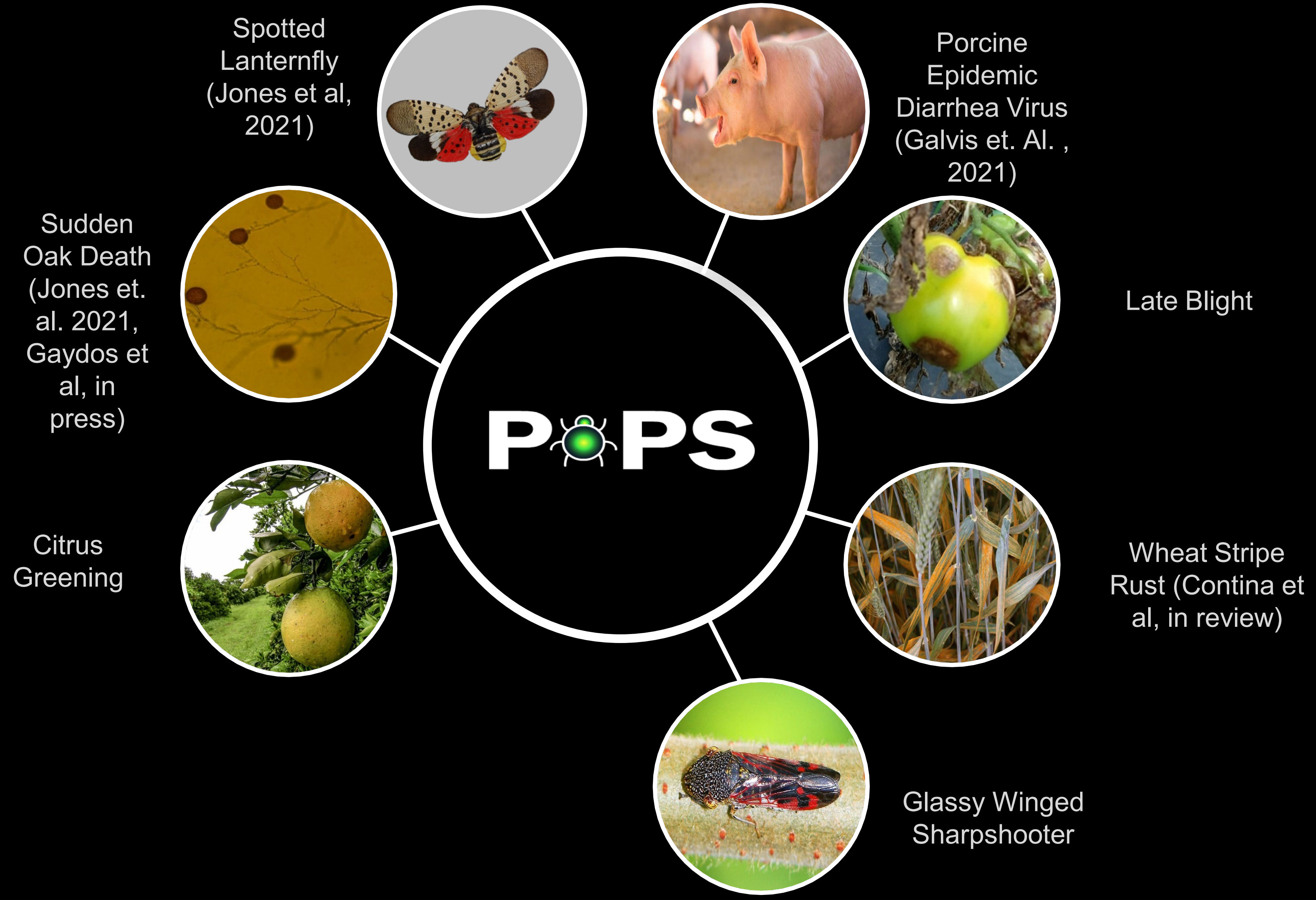
# PoPS Forecasting Platform

Open-Source Model

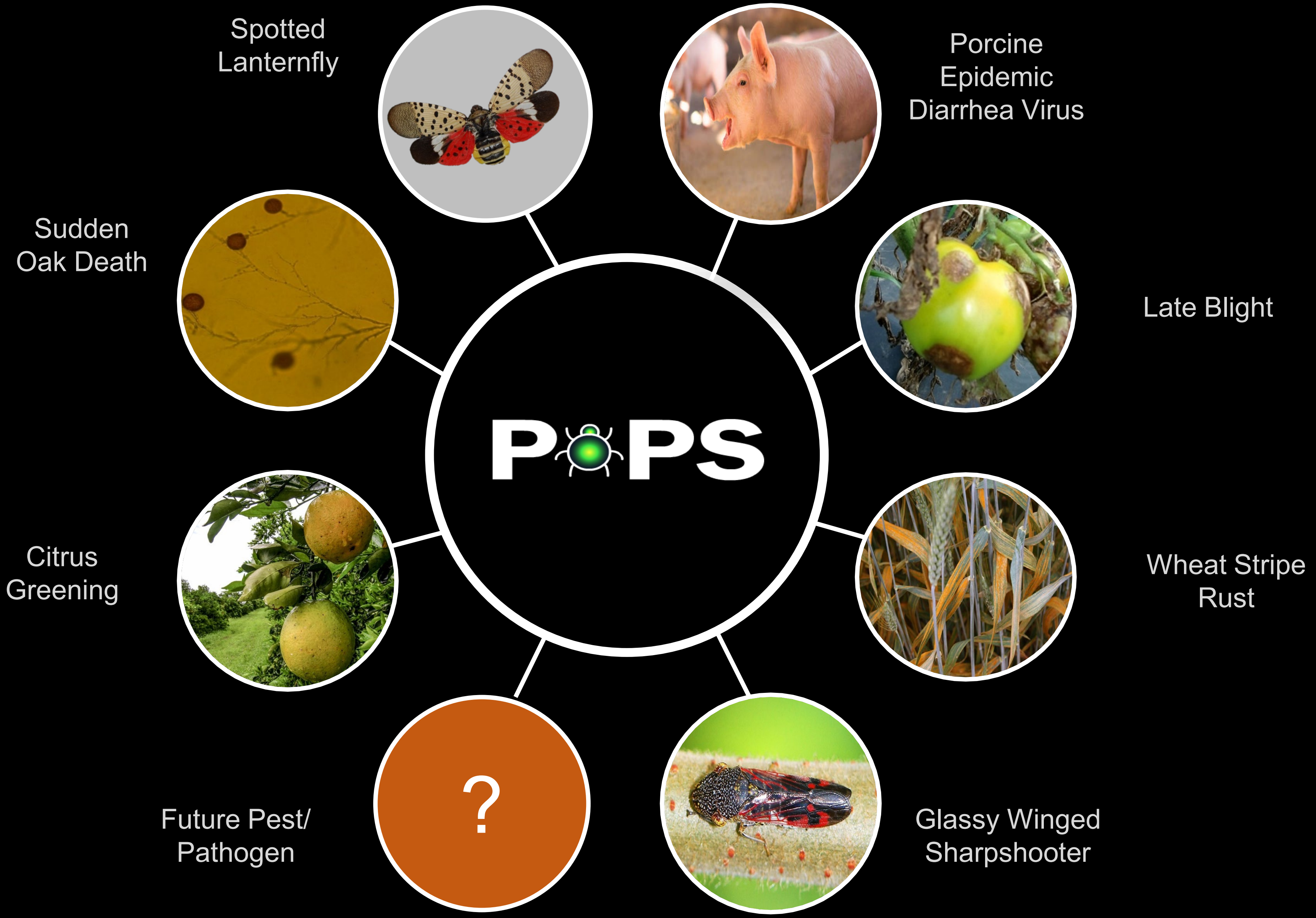
- Modular
- Spatially explicit
- Dynamic



# PoPS Forecasting Platform

Database and Storage

- Forecasts
- All calibrated parameters and uncertainty
- Weather coefficient
- Host data

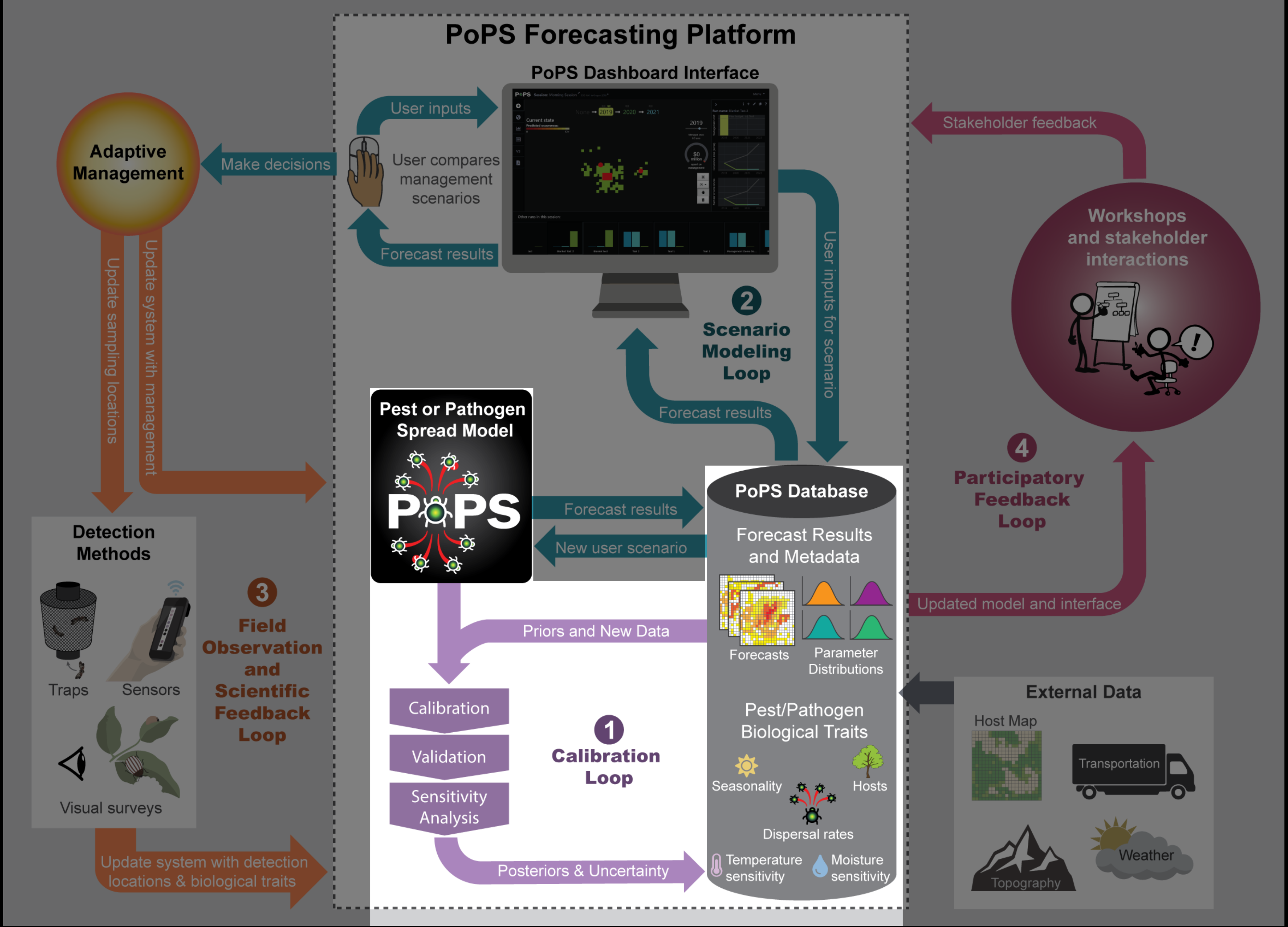


# Spotted Lanternfly in Pennsylvania:

## An example of iterative forecasting improvements


- Discovered in Berks County, PA in 2014
- Over 90 counties quarantined across 11 states
- ***$13+ Billion*** in crops and forest at risk
- Has spread to New Jersey, Delaware, Virginia, New York, Virginia, West Virginia, Ohio, Connecticut, Indiana, Rhode Island, Massachusetts, Vermont, and Maryland.

Sucks the sap out of branches and stems!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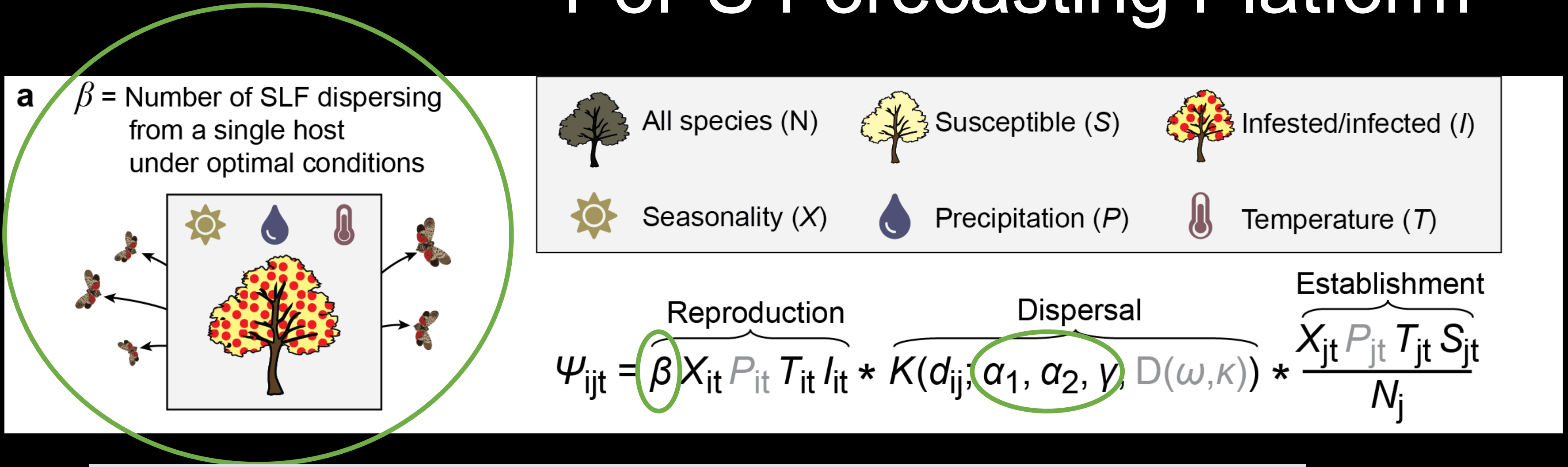



(c) **CONFUSION MATRIX**
**FOR VALIDATION STATISTICS**

| | | PREDICTED Positive (PP) | PREDICTED Negative (PN) | |
|---|---|---|---|---|
| OBSERVED | Positive (P) | True Positive (TP) | False Negatives (FN) | Observed Positives (OP=TP+FN) |
| OBSERVED | Negative (N) | False Positives (FP) | True Negatives (TN) | Observed Negatives (ON=FP+TN) |
| | | Modeled Positives (MP=TP+FP) | Modeled Negatives (MN=FN+TN) | TOTALS (T = MP+MN = OP+ON) |

Accuracy
((TP+TN)/T))

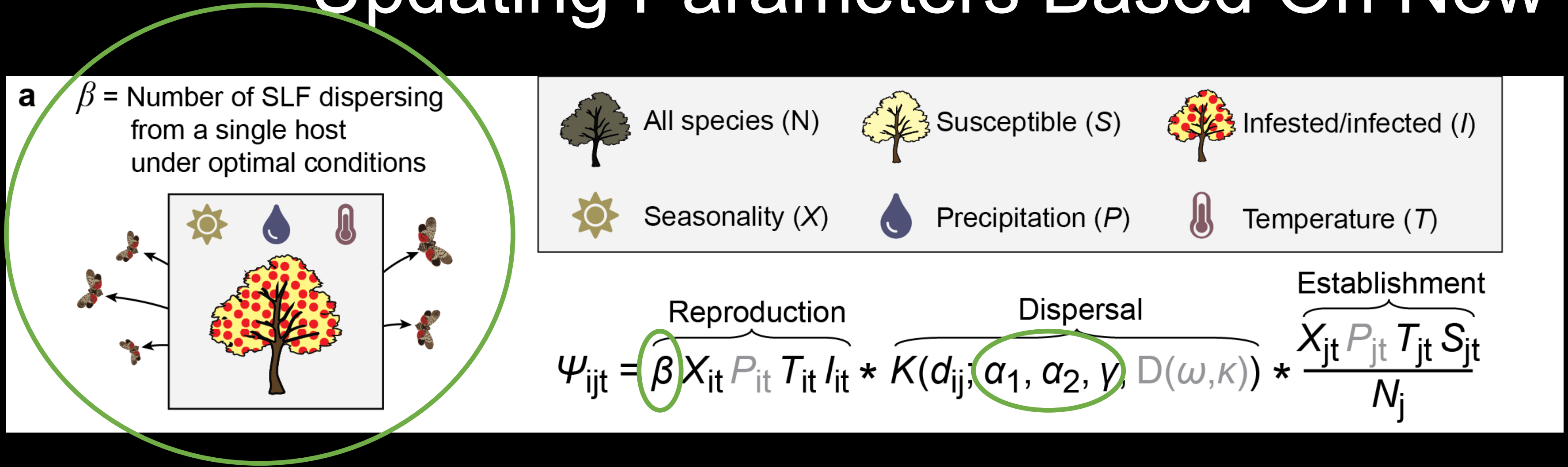
Precision
(TP/PP))

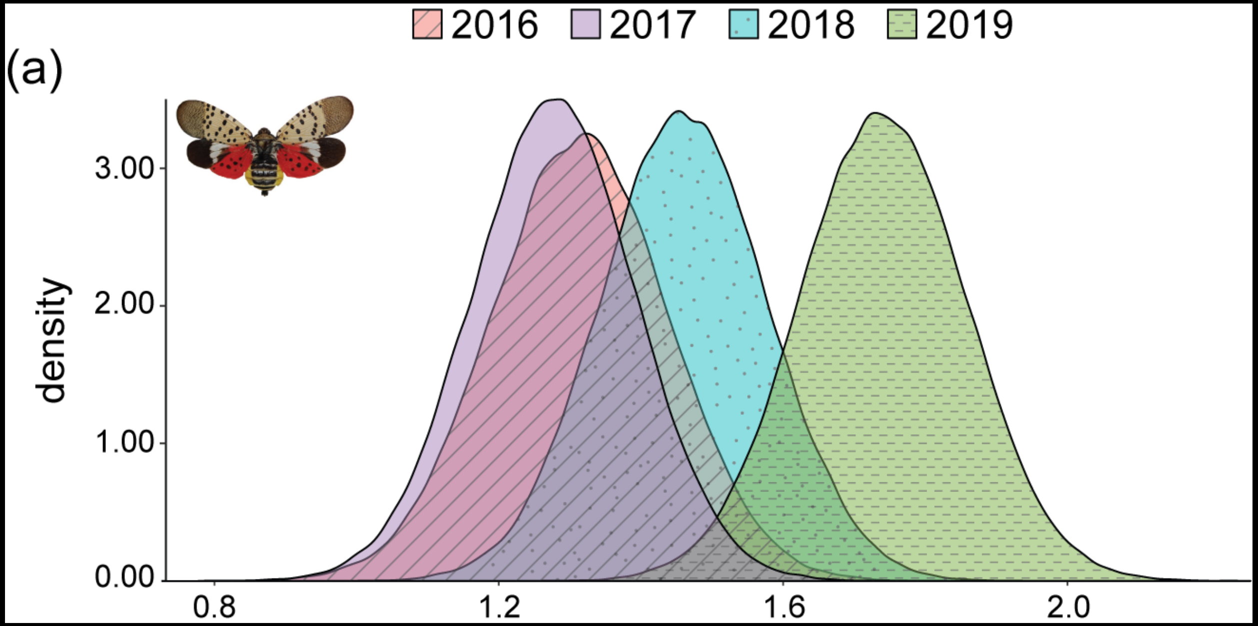
Recall/sensitivity
(TP/OP))

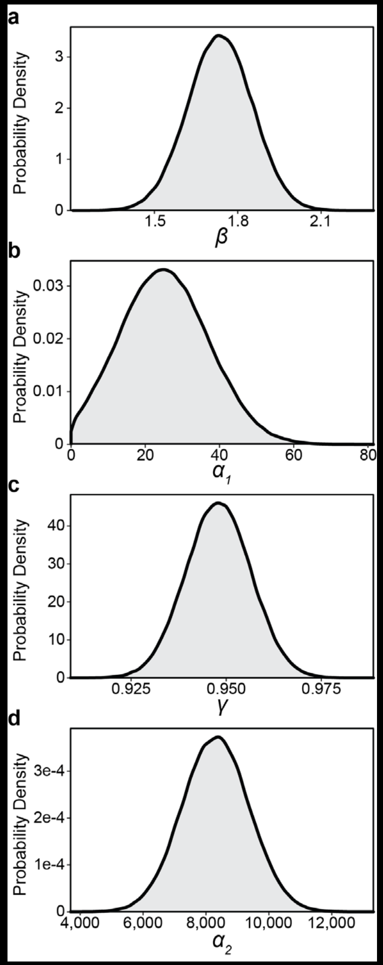
Specificity
(TN/ON))

Odds ratio
((TP+TN)/(FP+FN))

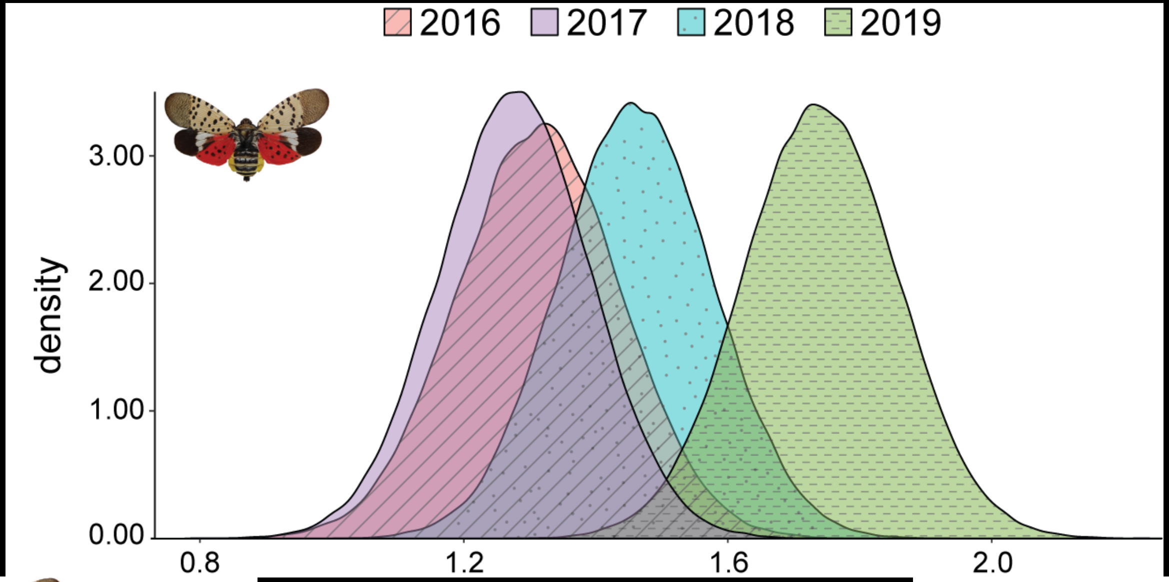
# Updating Parameters Based On New Data

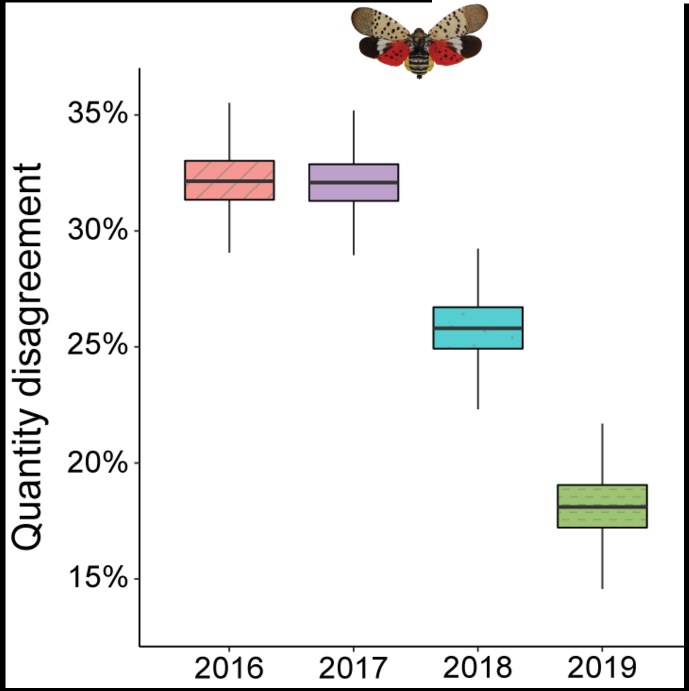


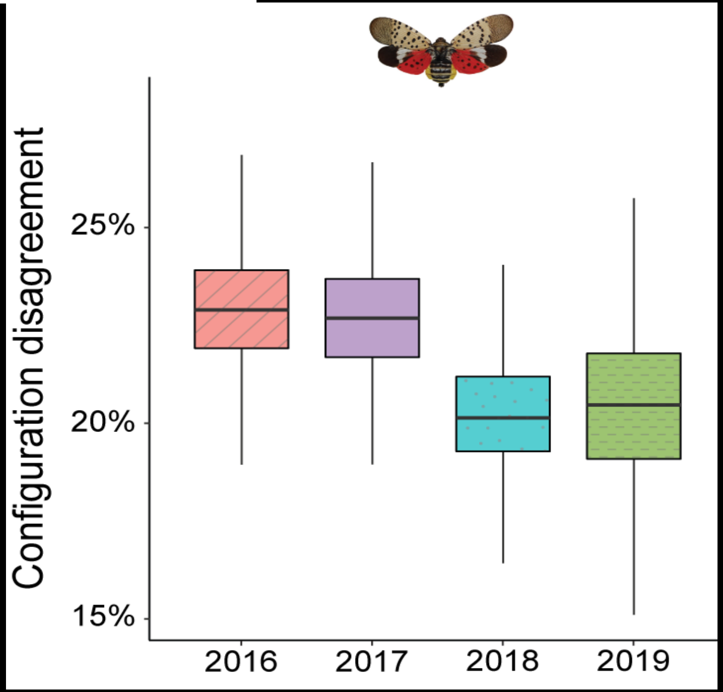



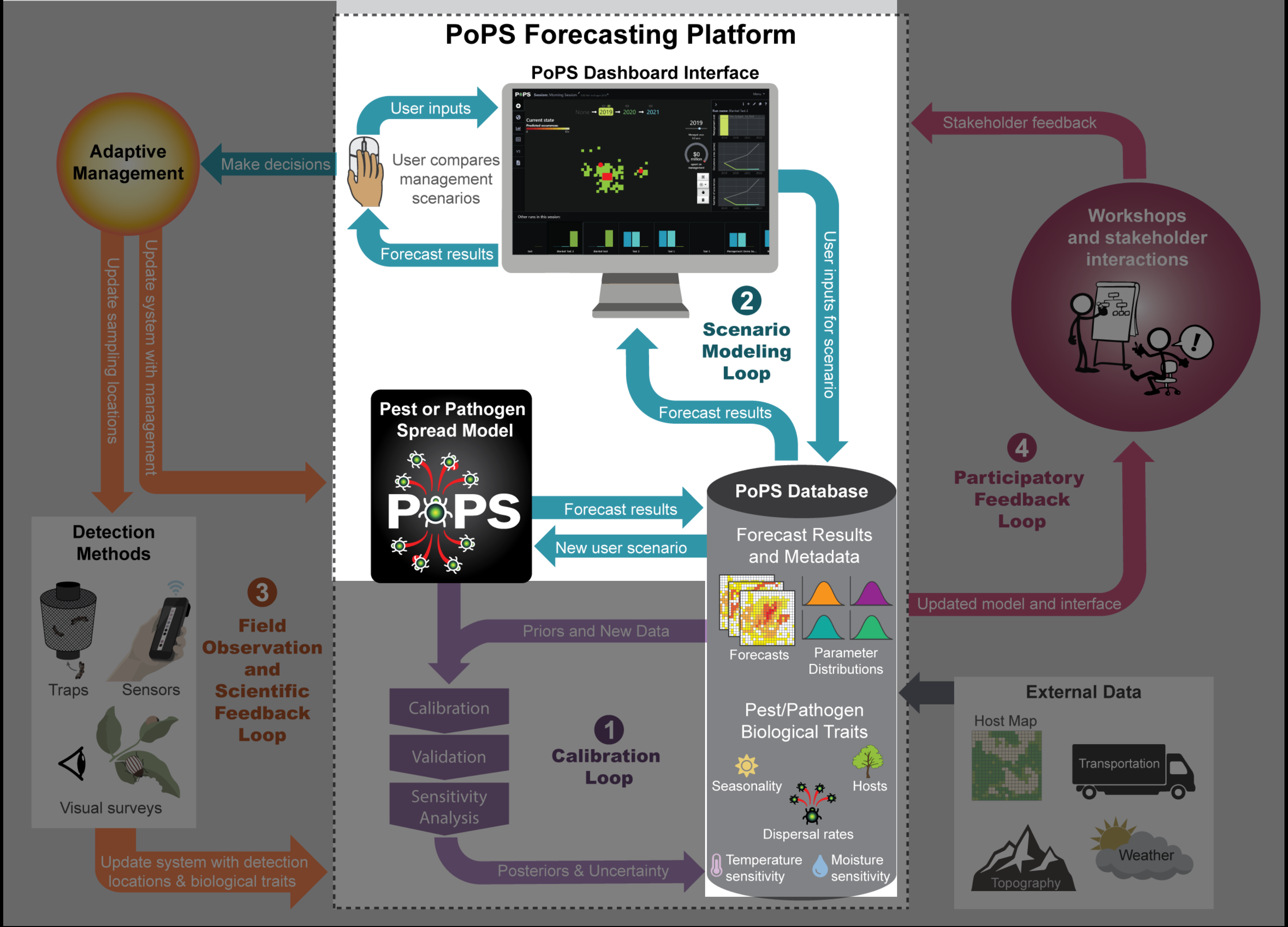



# Iteratively updating parameters improves forecast accuracy





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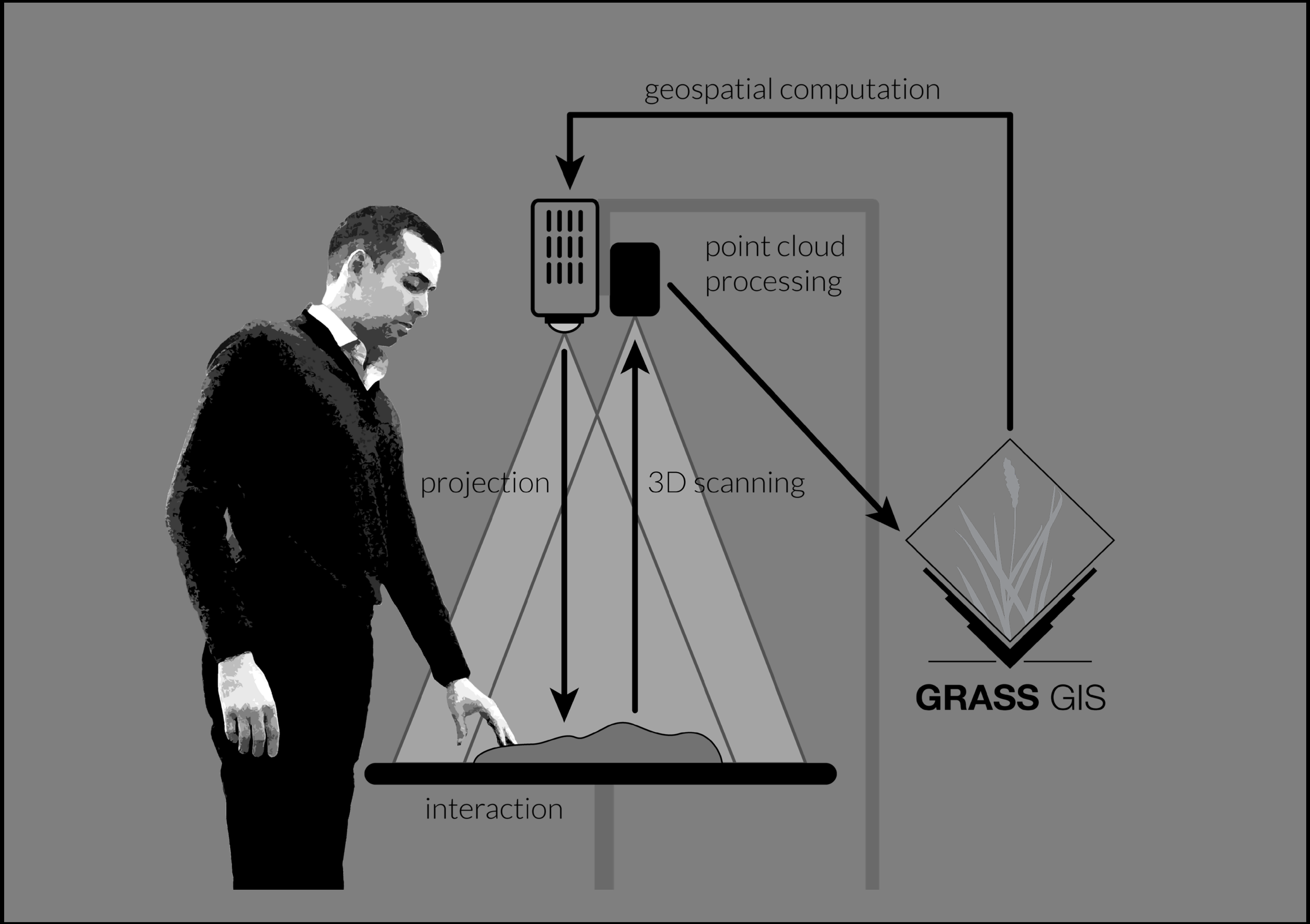
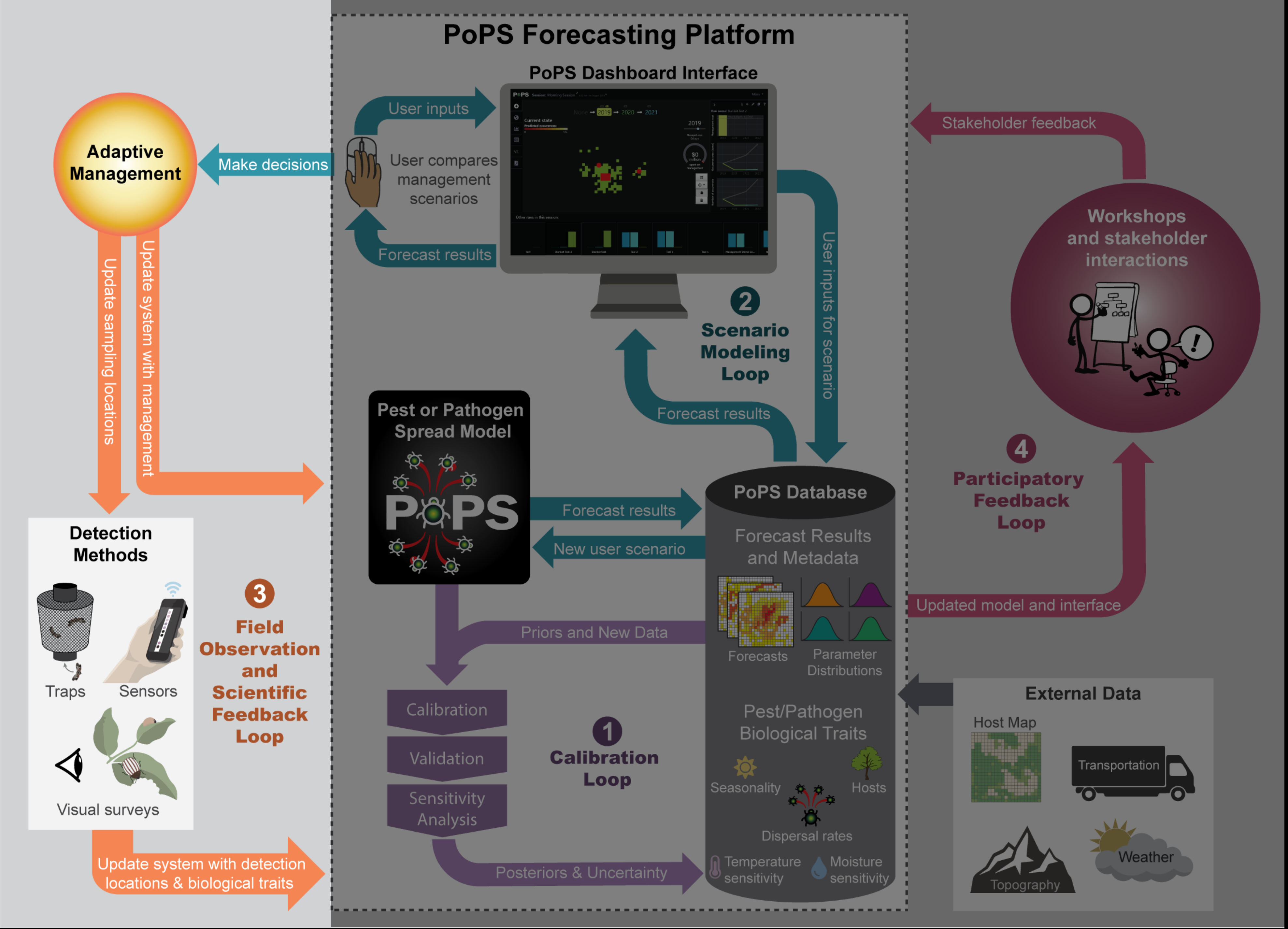
# PoPS Forecasting Platform Spatial Decision Support

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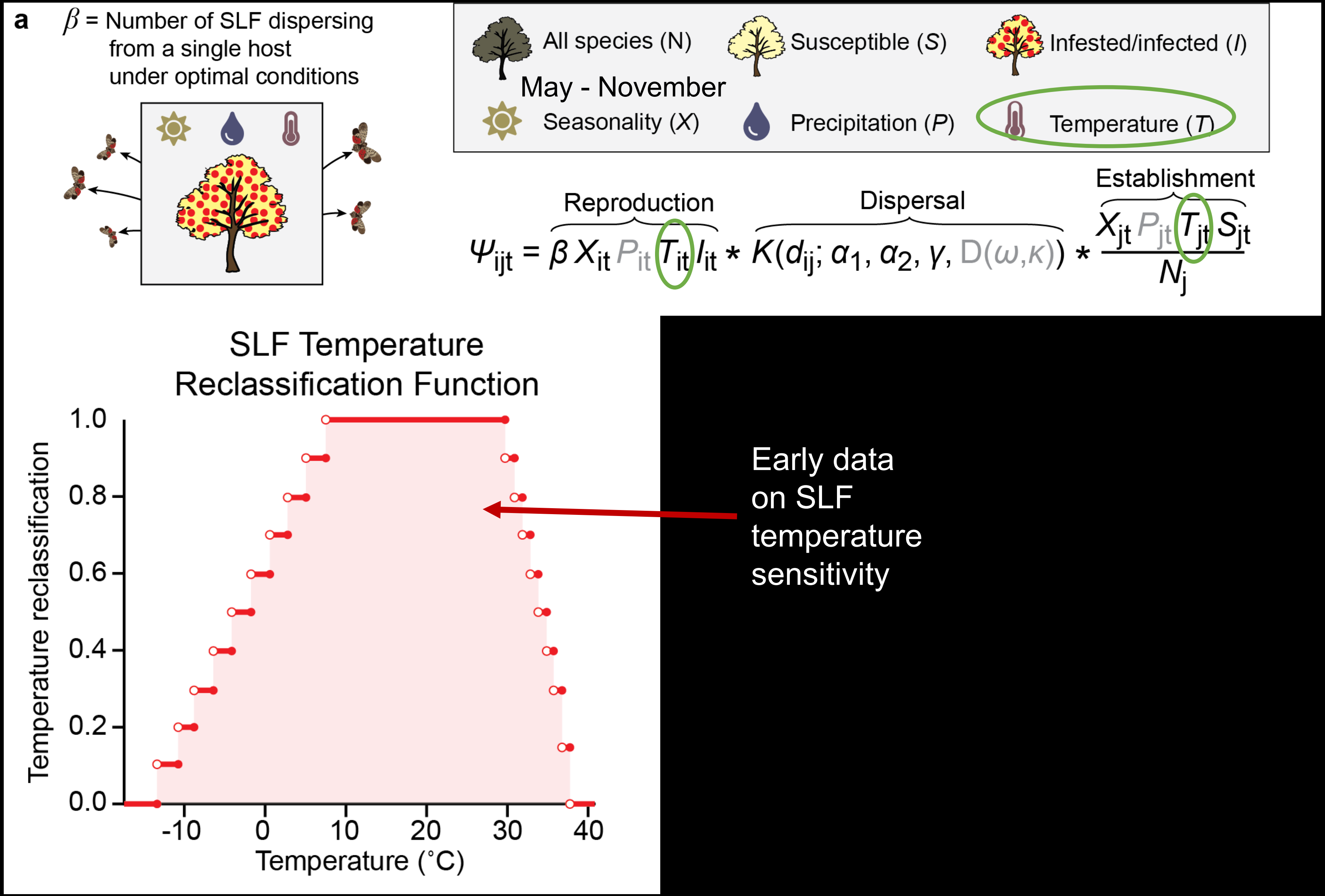
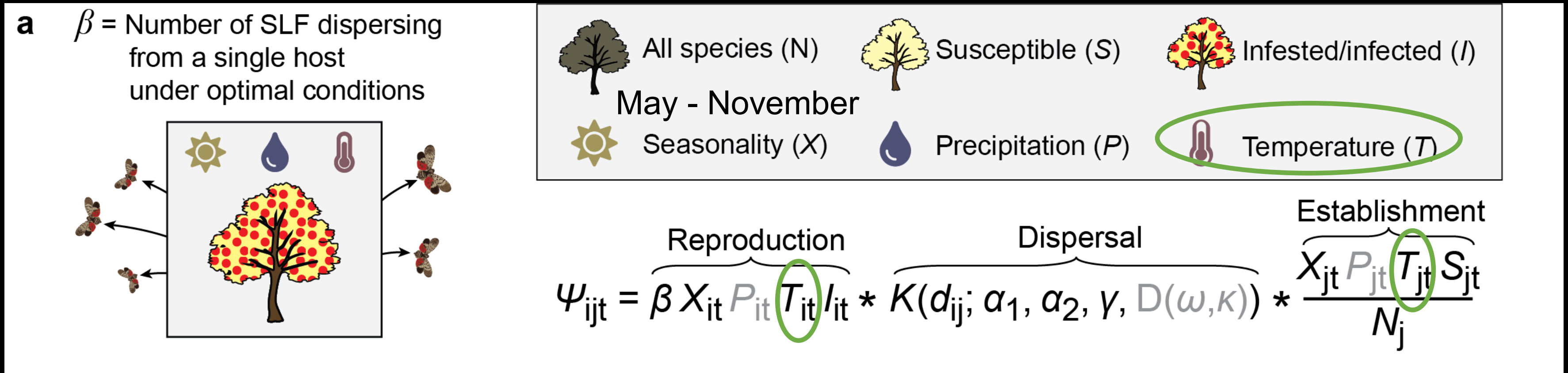
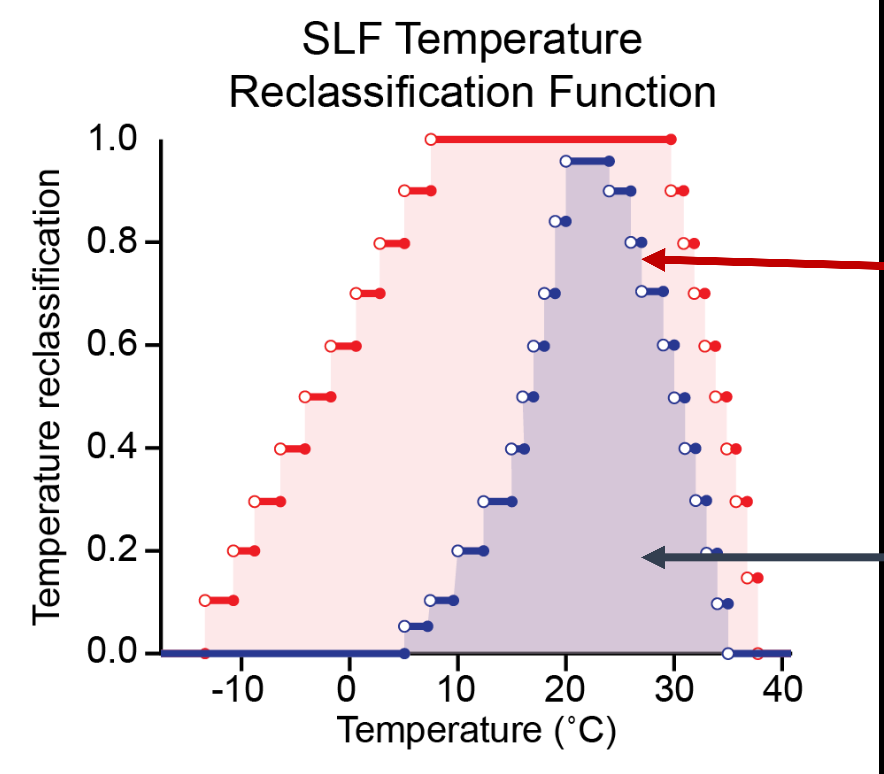
# Improved Understanding of Temperature Influence




Early data on SLF temperature sensitivity

# Improved Understanding of Temperature Influence

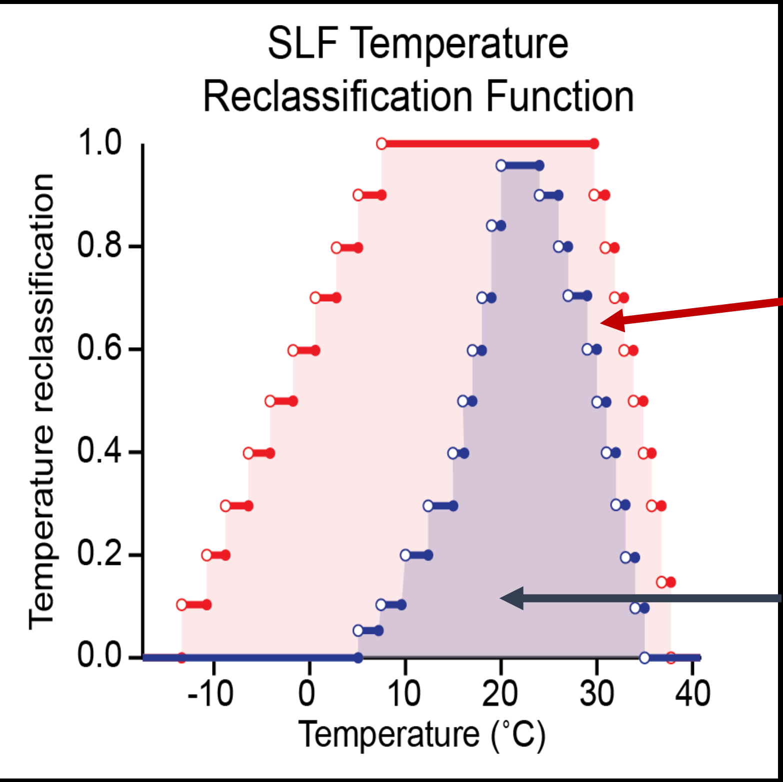



Early data on SLF temperature sensitivity

Updated SLF temperature sensitivity (based on new data)

# Improved Understanding of Temperature Influence Increases Accuracy

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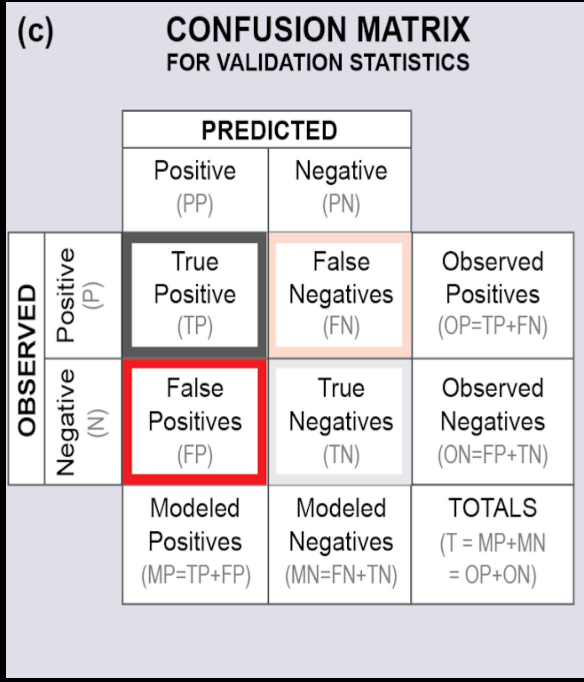


| | Old Temp | Kreitman Temp Changes |
|---|---|---|
| Accuracy ((TP+TN)/T)) | 78.1 (3.1) | 85.5% (2.1) |
| Precision (TP/PP) | 80.1 (3.7) | 81.83% (3.7) |
| Recall/sensitivity (TP/OP) | 95.6 (1.7) | 91.1% (1.8) |
| Specificity (TN/ON) | 61.3 (7.3) | 80.8% (5.1) |
| Odds ratio ((TP+TN)/(FP+FN)) | 38.0 (.92) | 43.26 (.97) |

# Adding New Model Features Based on Field Observations

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|---|---|---|---|---|
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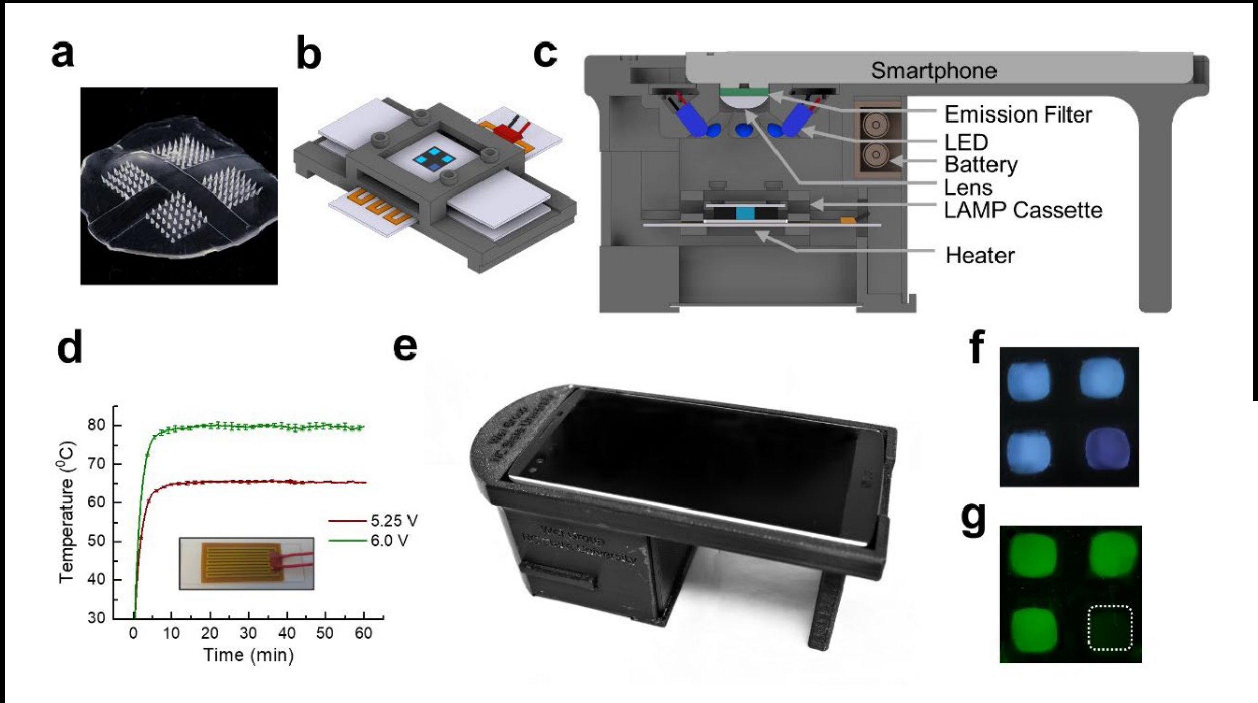
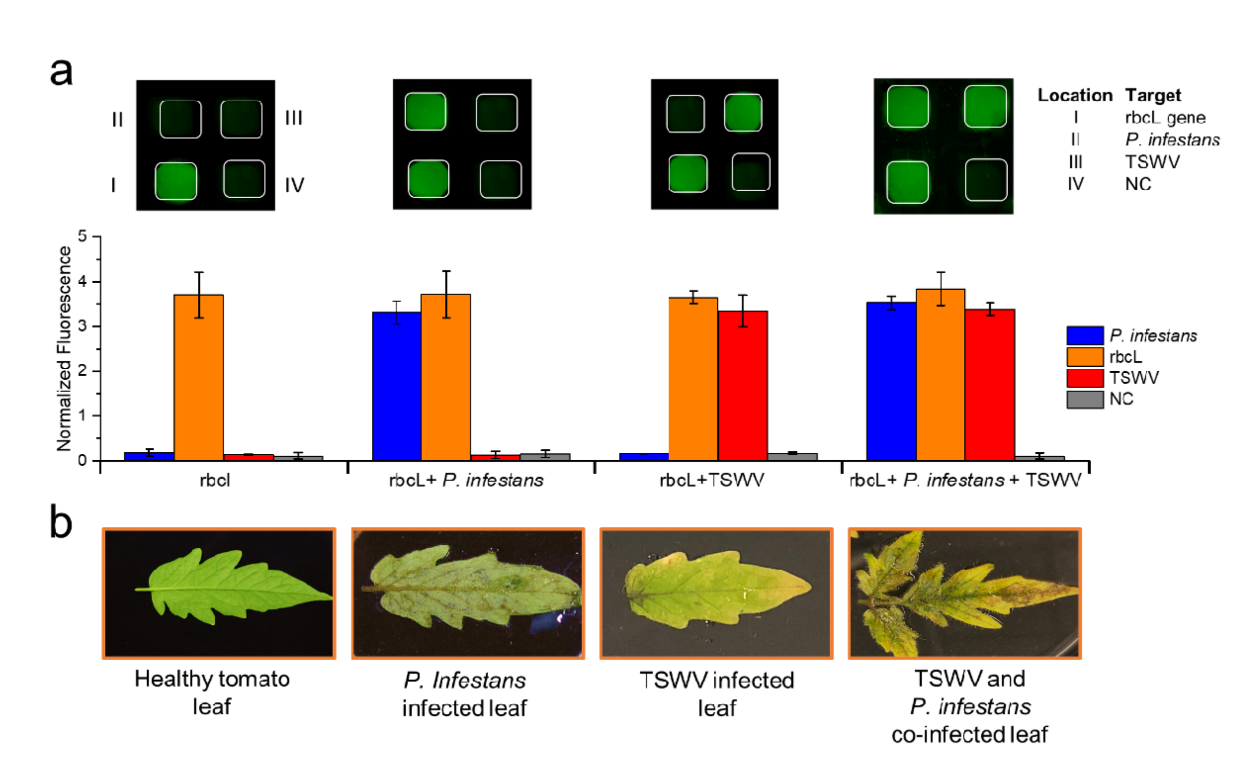
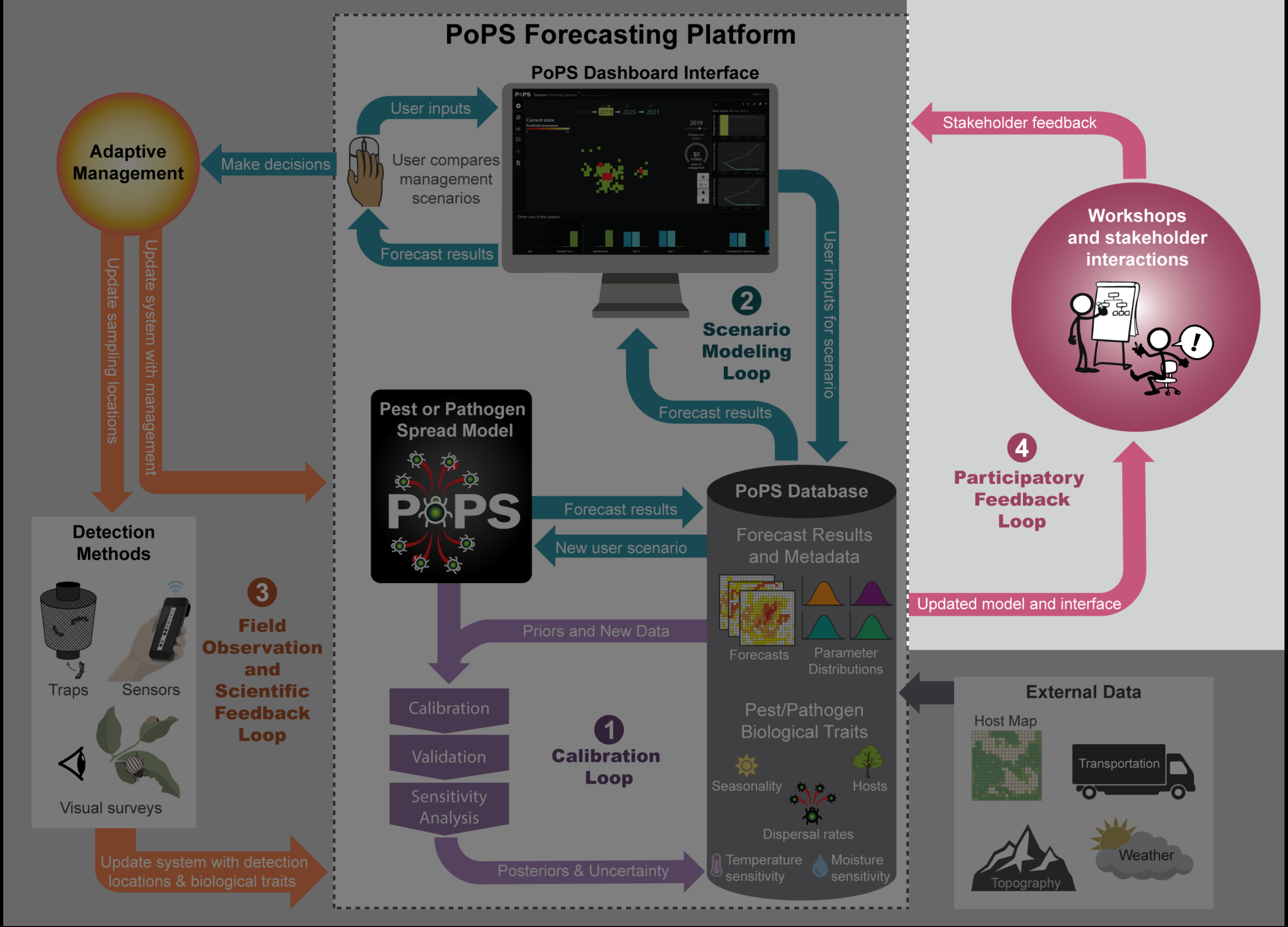
| | | Modeled Positives (MP=TP+FP) | Modeled Negatives (MN=FN+TN) | TOTALS (T = MP+MN = OP+ON) |

| | Without Large Population Movements | With Large Population Movements |
|---|---|---|
| Accuracy ((TP+TN)/T)) | 85.5% (2.1) | 85.8% (2.0) |
| Precision (TP/PP) | 81.7% (3.8) | 81.8% (3.7) |
| Recall/sensitivity (TP/OP) | 91.0% (1.9) | 91.1% (1.8) |
| Specificity (TN/ON) | 80.7% (5.1) | 80.8% (5.0) |
| Odds ratio ((TP+TN)/(FP+FN)) | 43.25 (.98) | 43.26 (.97) |

# PoPS Forecasting Platform Field Operations





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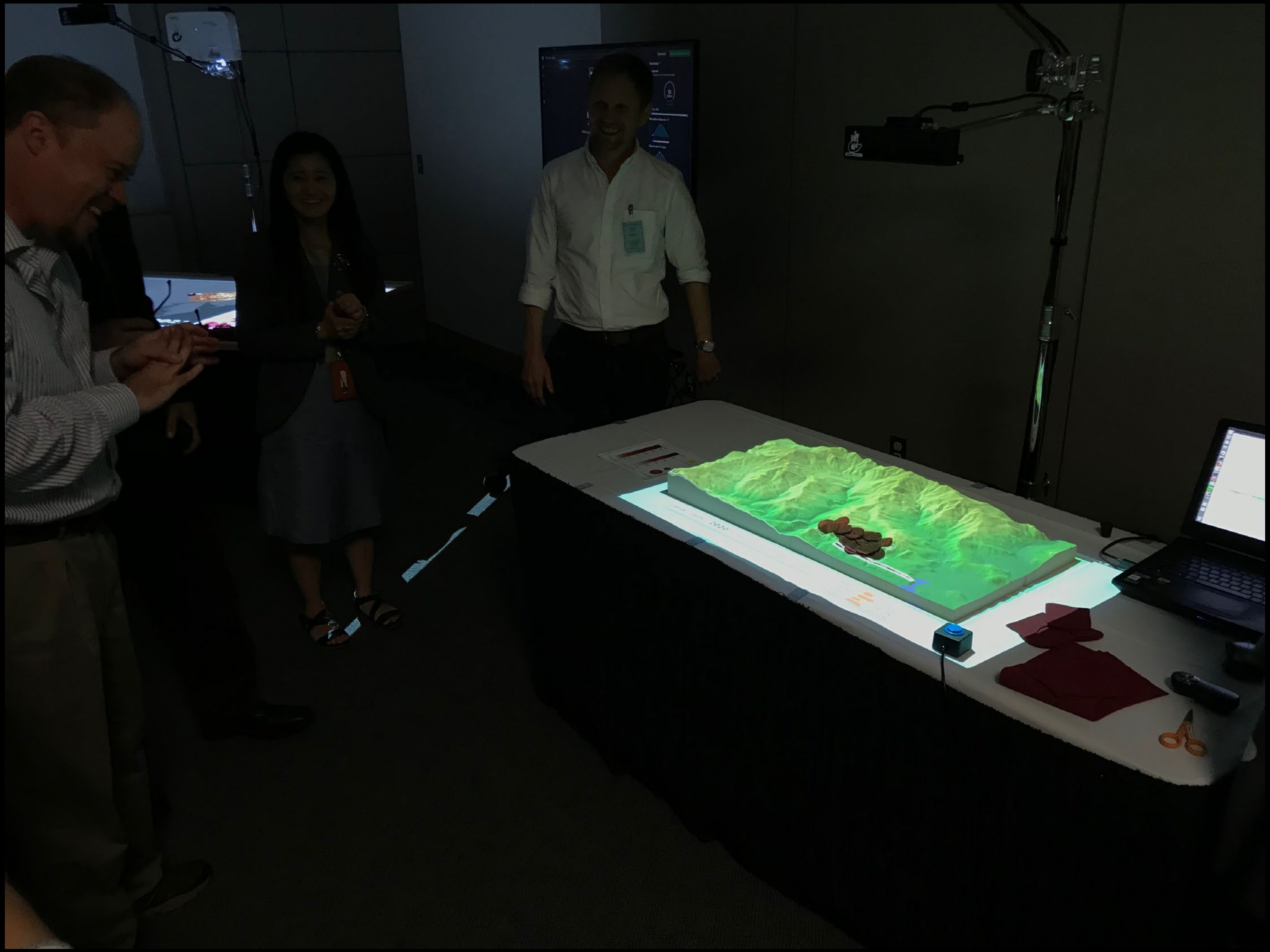
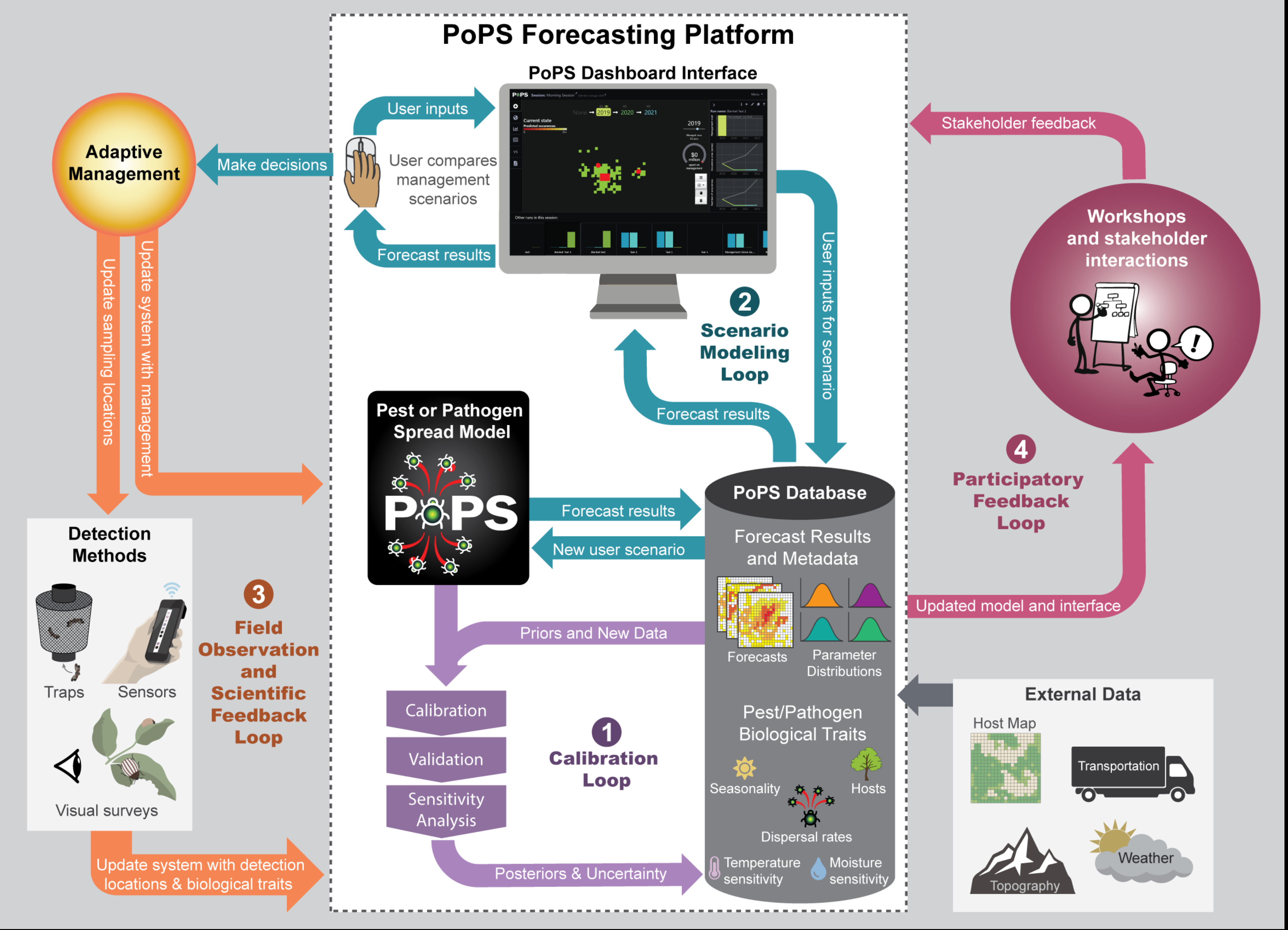
# Forecasting SOD Spread Spatial Decision Support

# Forecasting SLF Spread Spatial Decision Support



30 APHIS personnel from science and technology, field operations, policy, and regulatory working groups on June 26, 2019



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## PoPS

**PoPS** (Pest or Pathogen Spread) is a C++ library for a stochastic spread model of pests and pathogens in forest and agricultural landscapes.

Performs a single time step of spread.

Main functions:
- generate
- disperse
- mortality
- remove

## rpops

Parallelized R-wrapper that iteratively cycles through a series of time steps of the **PoPS** C++ model.

In addition to the forecast, this module also performs:
- Calibration
- Validation

Available as an **R-package** for end-users.

## pops-model-api

Specialized Docker container designed to use Google Cloud Storage buckets and the database to store forecast inputs and outputs.

Calls **rpops**.

## PoPS-Forecasting-Platform

Front-end code for the PoPS interactive web dashboard interface and database.

Calls the **model-api** to run PoPS.

## **PoPS** DASHBOARD INTERFACE


Allows web users to draw management and run various scenarios of PoPS.

## **PoPS** DATABASE

PostgreSQL

## r.pops.spread

GRASS GIS

Parallelized GRASS GIS-wrapper that iteratively cycles through a series of time steps of the **PoPS** C++ model.

## grass-tangible-lanscape

(pops-steering branch)

Couples a physical Tangible Landscape model with **r.pops.spread** so that a user can physically add management and interact with the landscape.

## **TANGIBLE** LANDSCAPE

Allows users to place physical management and run scenarios of PoPS.

PoPS

# Managing pest outbreaks through participatory iterative ecological forecasting

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