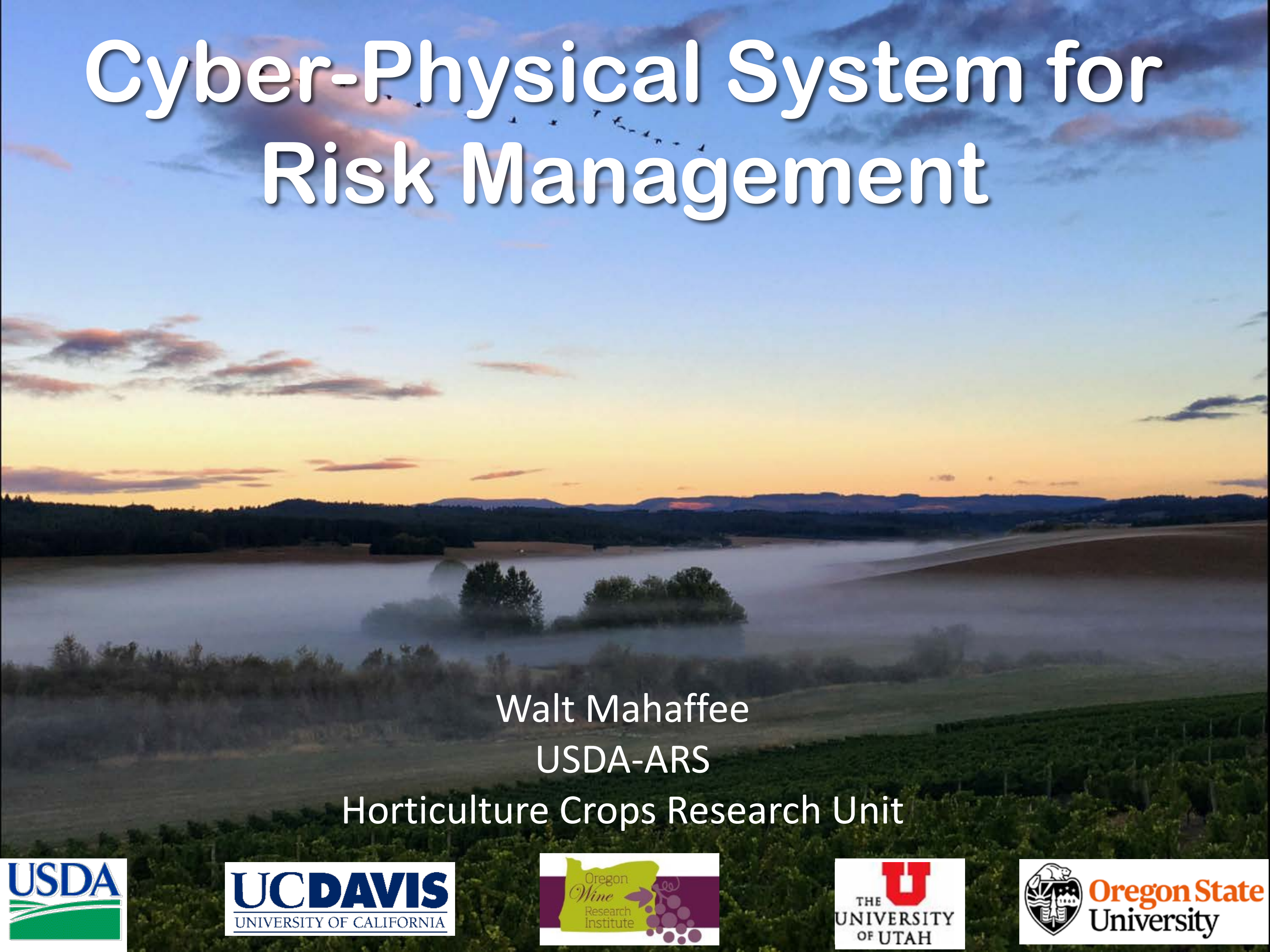

Cyber-Physical System for Risk Management

Walt Mahaffee
USDA-ARS
Horticulture Crops Research Unit

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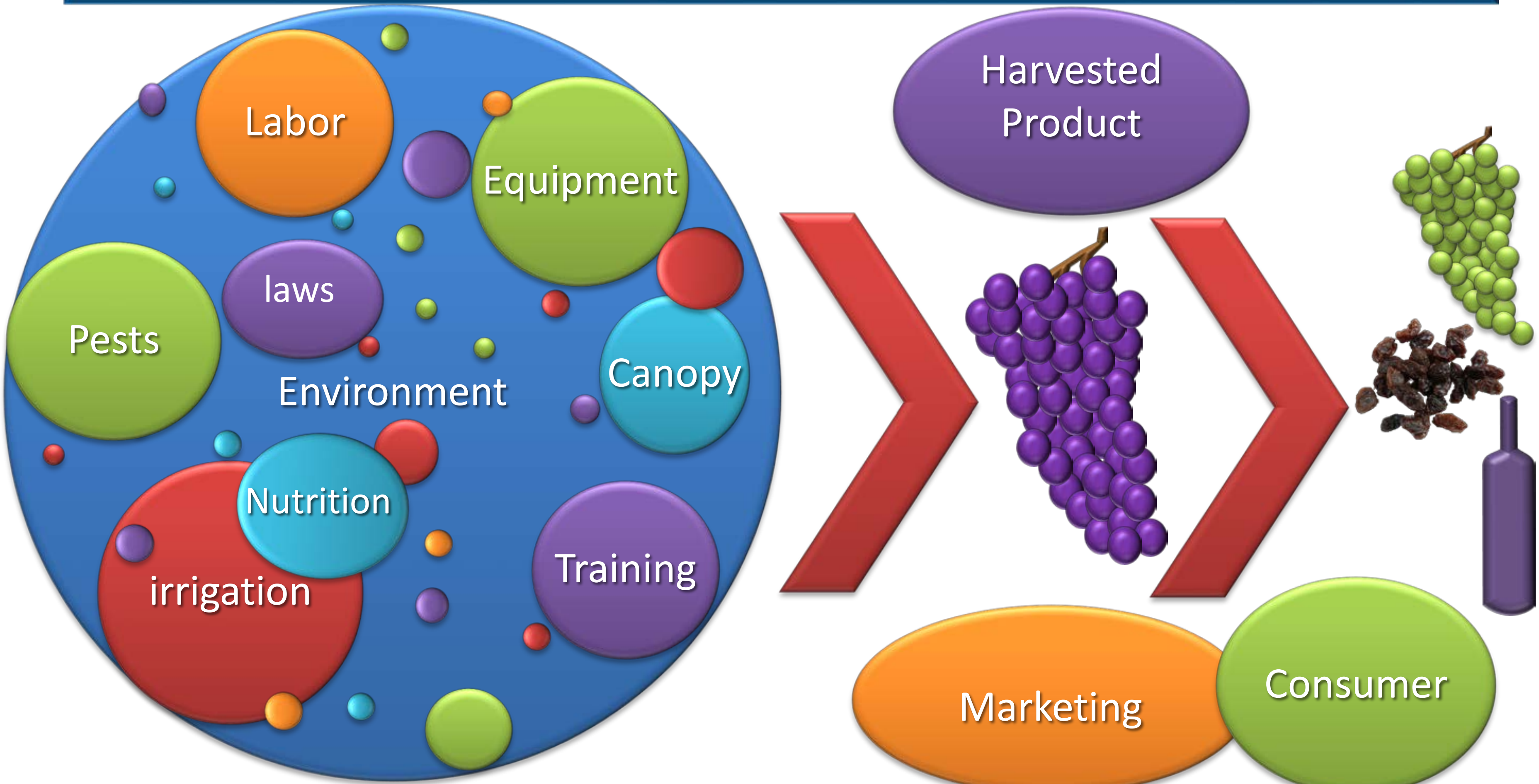
What is Farm Management?



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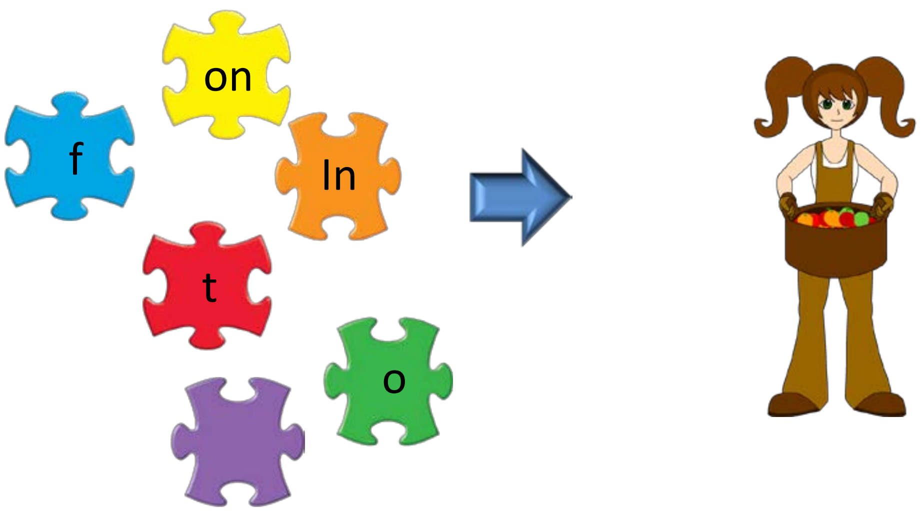
Farm Manager Decision Process

Farm Manager Decision Process



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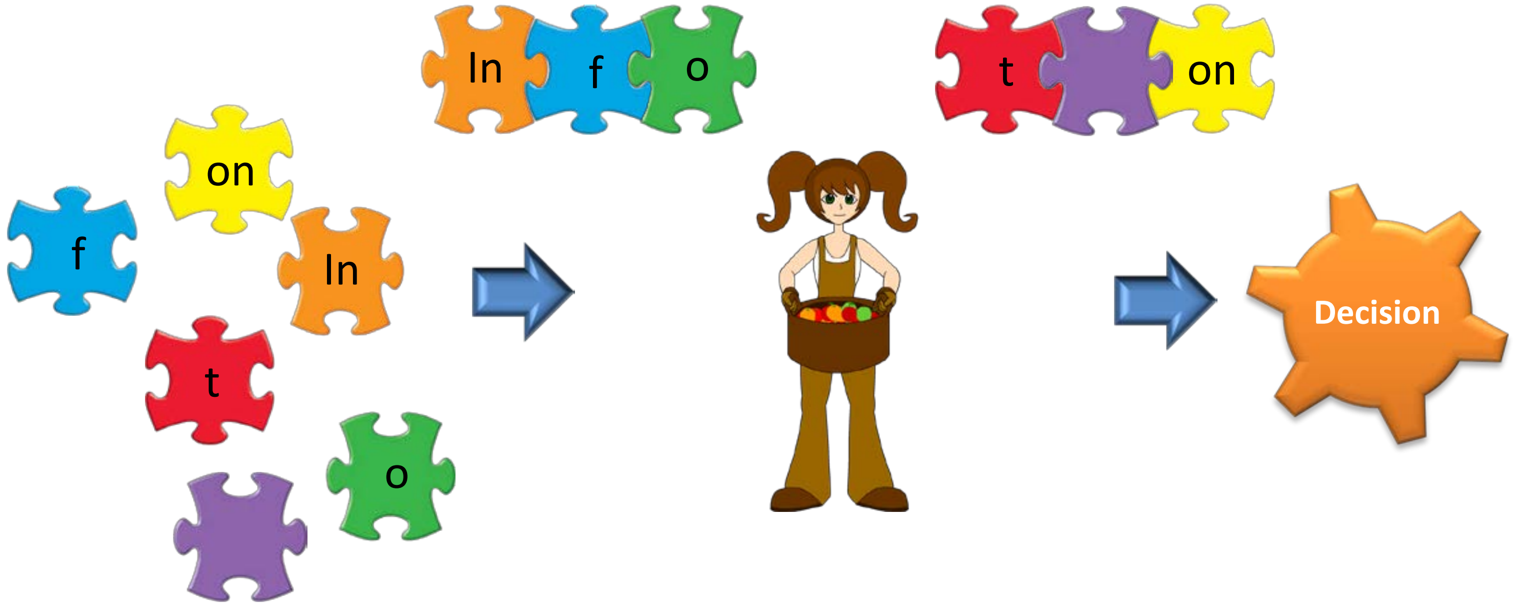
Farm Manager Decision Process



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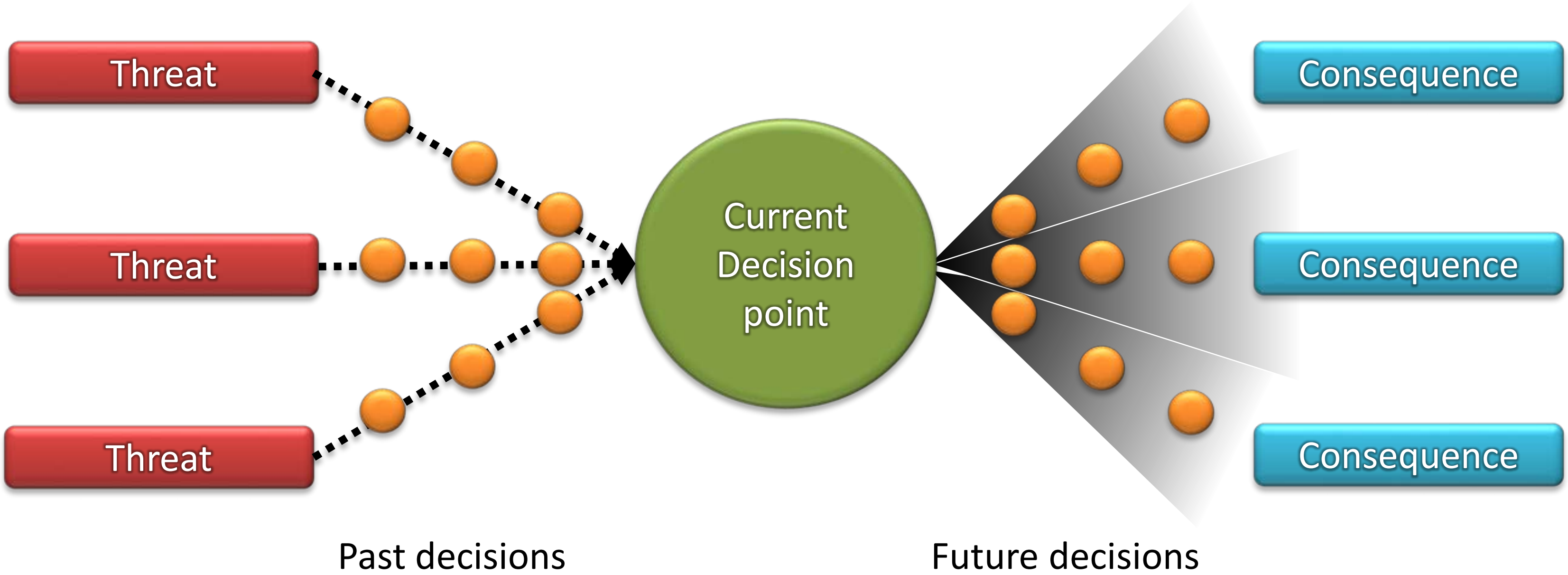
Input Optimization

- **Timing of individual practices**
  - Task specific
- **Decision support systems (e.g.disease forecasting)**
  - Generally based on historical data
  - Requires reaction – often immediate
- **Improving Methods**
- **Sprayer technology, automation, etc**

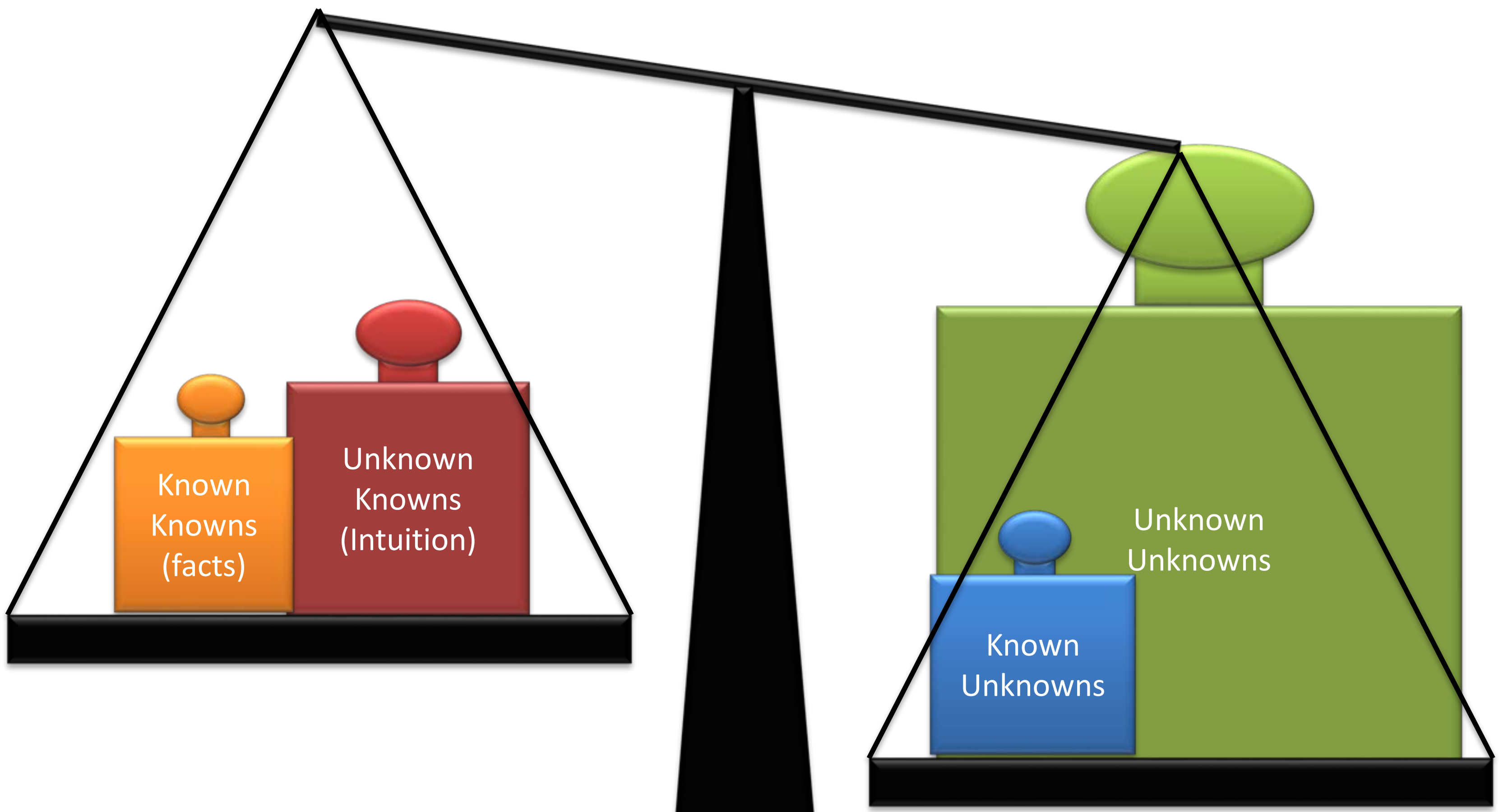
- **What's missing?**

Risk Management

– Balancing threats and consequences with incomplete data to achieve the goal of not failing (managers are averse to ambiguity not risk)



Risk Perception



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Risk Management Goal

Minimize Maximum Regret

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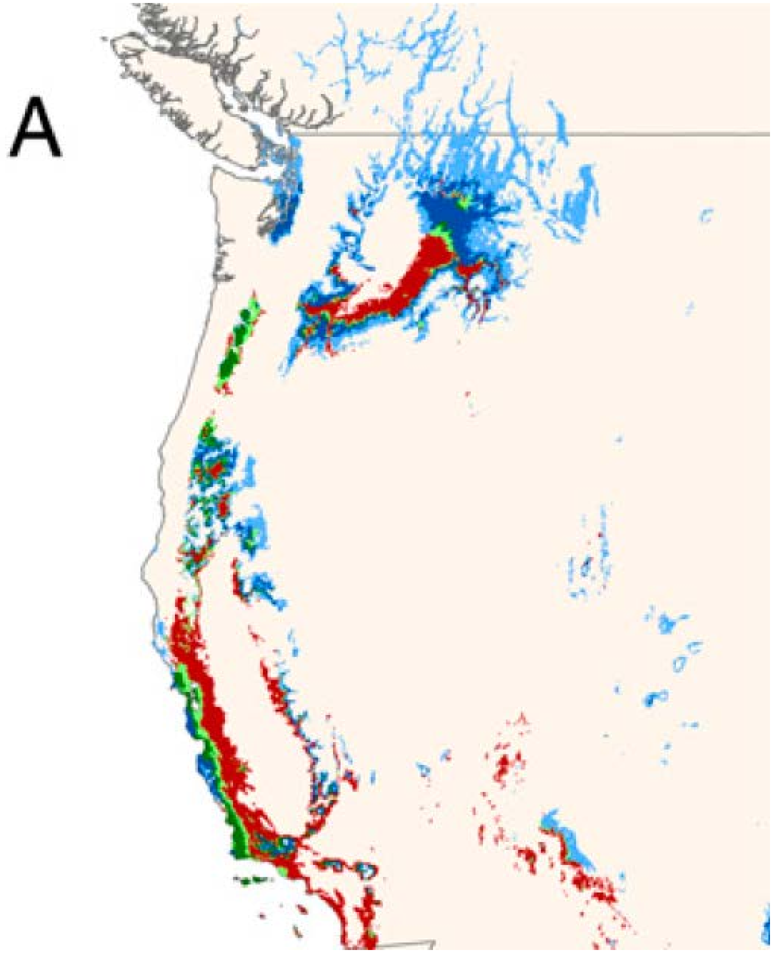
The Risk Pool is Changing



Projected Viticulture Suitability
2050

- Current Suitability
- Suitability Retained > 50% GCMs
- Suitability Retained > 90% GCMs
- Novel Suitability > 50% GCMs
- Novel Suitability > 90% GCMs

www.pnas.org/cgi/doi/10.1073/pnas.1210127110

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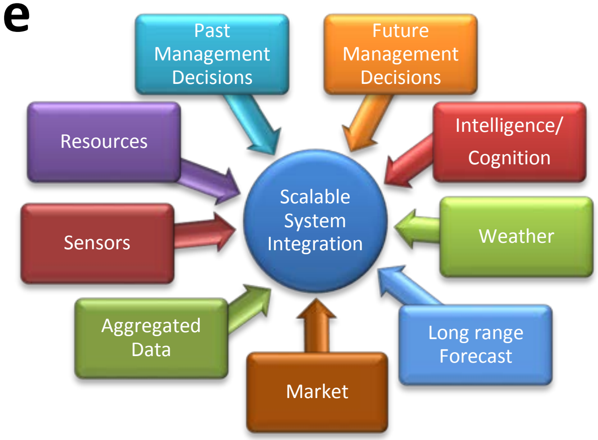
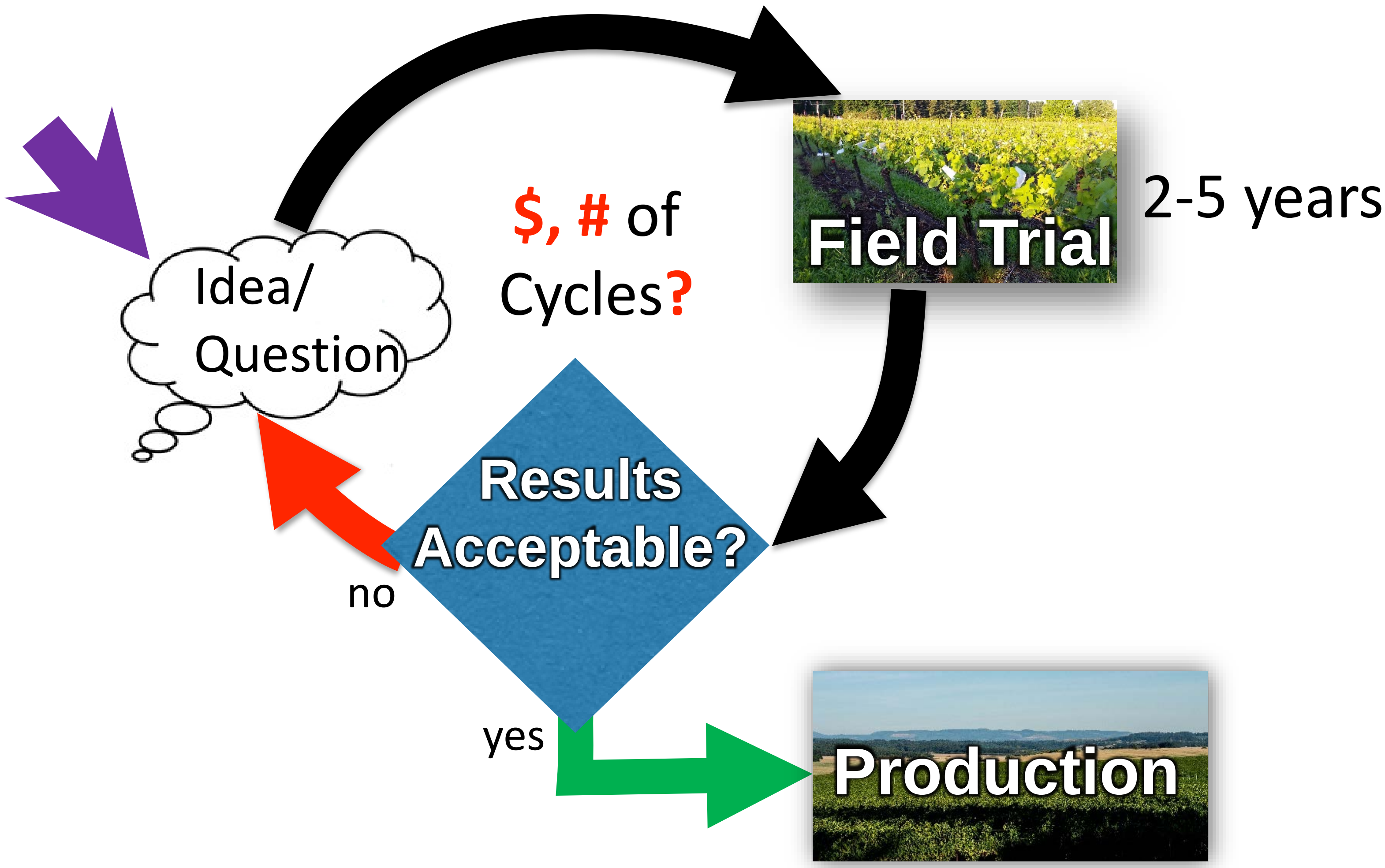
Requirements of a Risk Management System

- **Provide actionable information - not just make decisions**
- **Be minimally invasive and low maintenance**
- **Predict what needs to be done ahead of time**
- **Be scalable**
  - Multiple start points (e.g. cost to buy in) that build upon each other
  - Field, farm, region/hourly, daily, weekly
- **Have known accuracy and robustness**
  - i.e. what are the odds
- **Learns**
- **Be intuitive, usable and flexible**



Traditional Innovation Process



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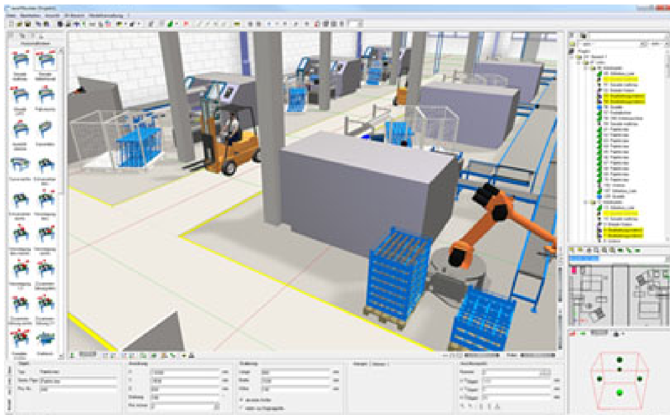
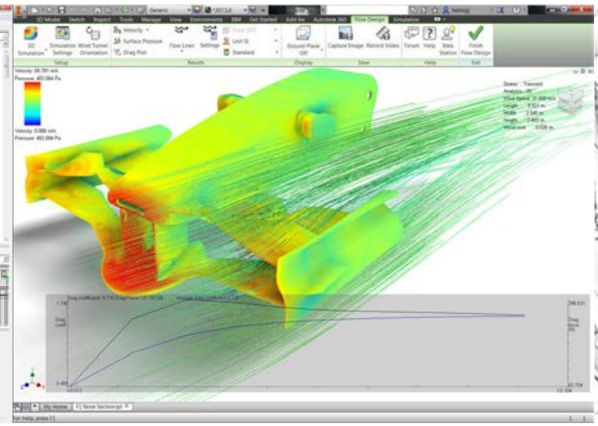
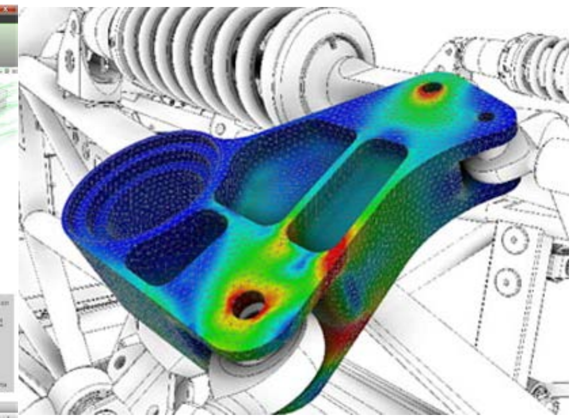
Simulation Environments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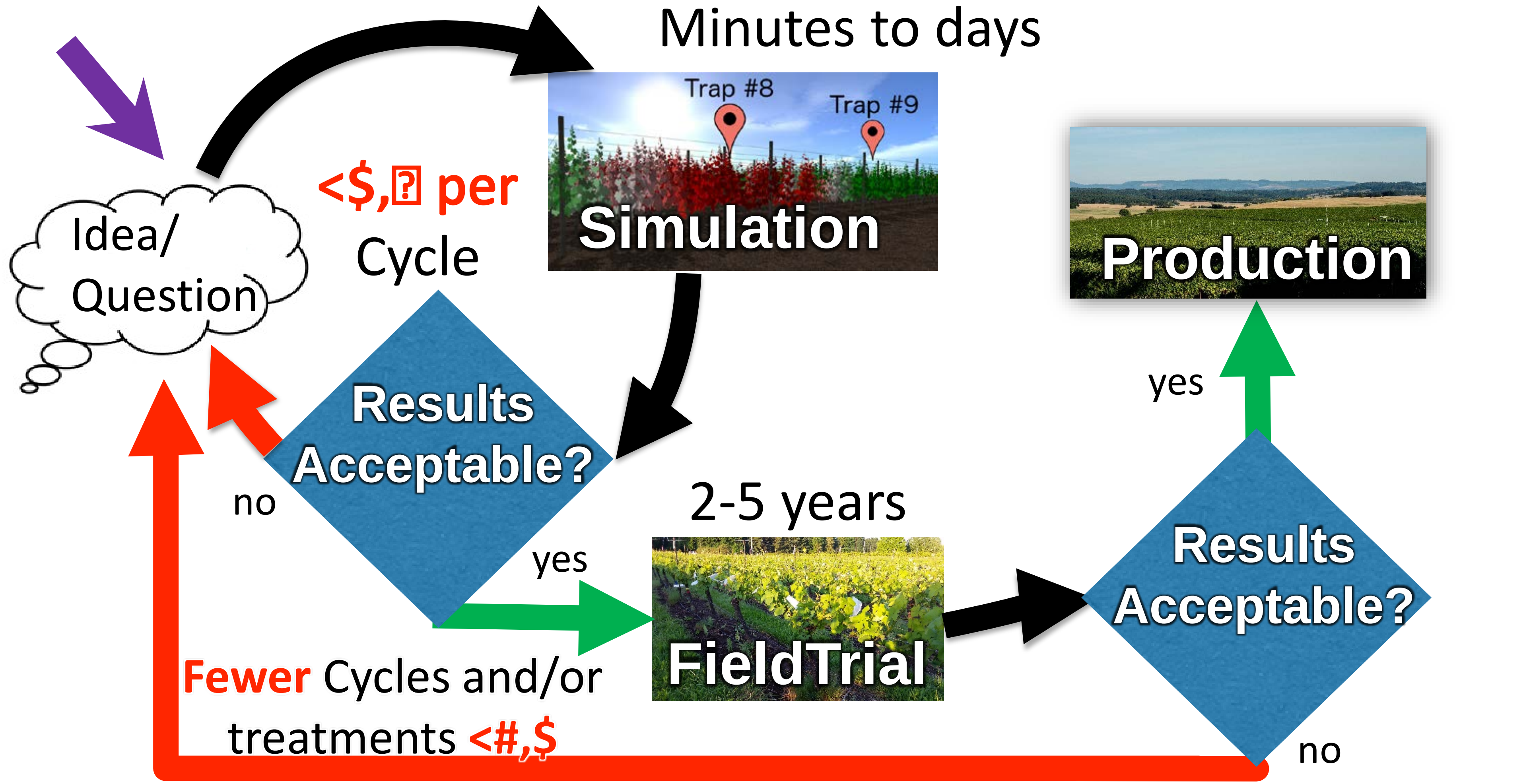
Proposed Innovation Process



AgRISCE

Pronounce - Ag risky

Agriculture Risk Insight System and Cyber-physical Environment for decision support

- **All models are wrong**; **some are useful**
  - George Box

- Advantages of Simulations
  - Face complex situations which encourage development of problem solving techniques
  - Test decisions without fear of outcomes
  - Learn to combine information that is taught in isolation or out of context
  - Create adaptability
  - Assess risk perception and reactions

- Woessner, M. 2015. Teaching with SimCity: Using Sophisticated Gaming Simulations to Teach Concepts in Introductory American Government. Political Science & Politics 48(02):358-363 doi:10.1017/s104909651400211x..

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Current Research Team

- **Brian Bailey –** Crop modeling, UC Davis
- **Chris Daly** – Meso-metereology, Oregon State Univ.
- **Sal Hernandez** – Network analysis - connectivity, Oregon State Univ.
- **Travis Lybbert –** Economics, UC Davis
- **Walt Mahaffee** – Plant Pathology, USDA-ARS-Hort. Crops Res. Lab
- **Eric Pardyjak** – Micro-meteorology, Univ. Utah
- **Rob Stoll –** Turbulent Transport, Univ. Utah

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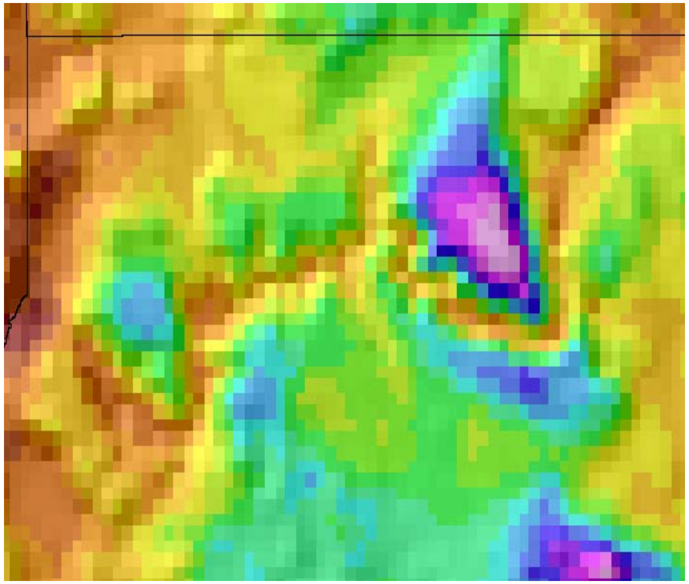
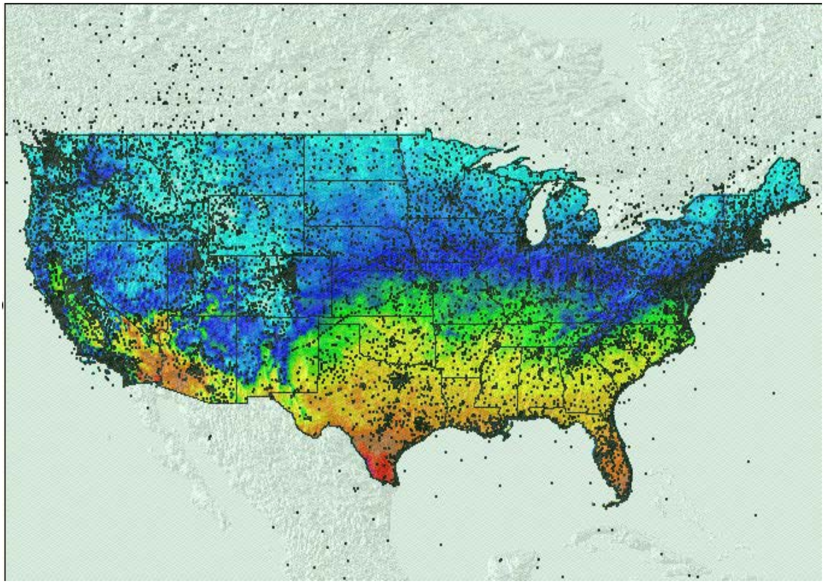
Problems with Weather Data

Forecasts Delivered on 4K girds



4 km/pixel

Limited distribution of Sensors and temporal resolution of collection



Terrain and Climate have Signatures

Wind machine

PRISM GROUP

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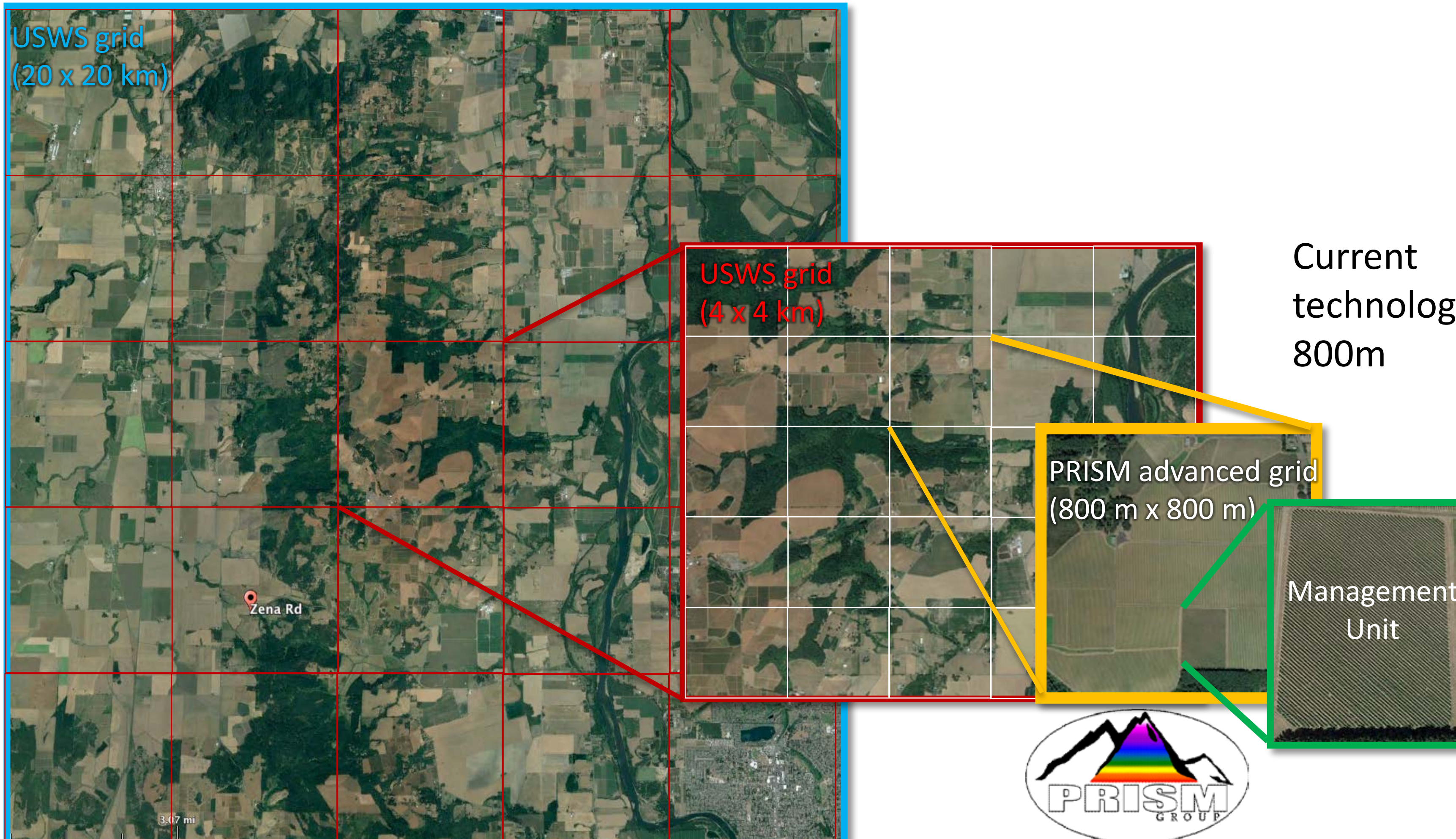
Interpolation down to 100m grid



Current
technology
800m

Probabilistic Sensor Deployment

Erath Family Foundation

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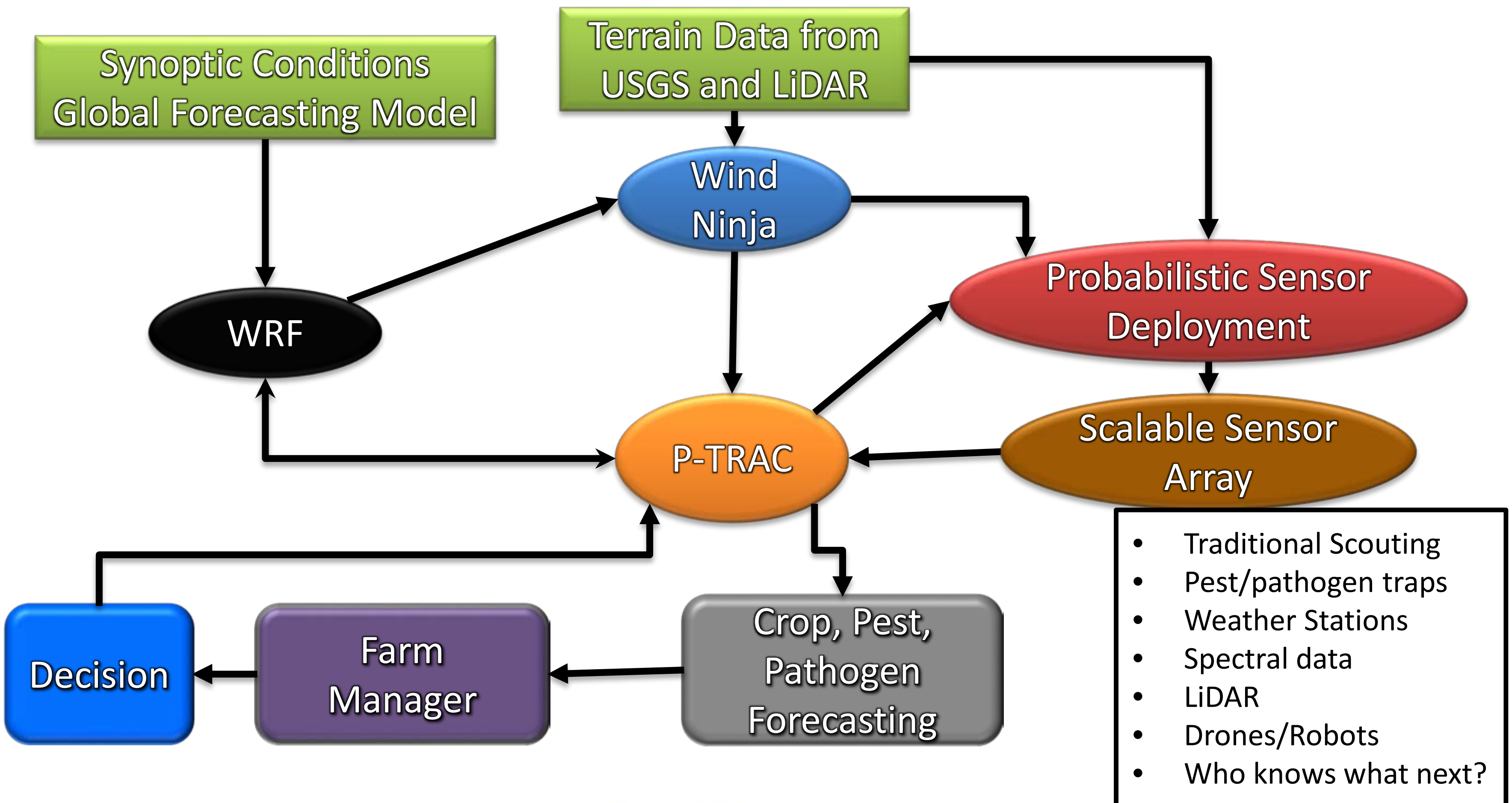
Model Coupling and Feed Back



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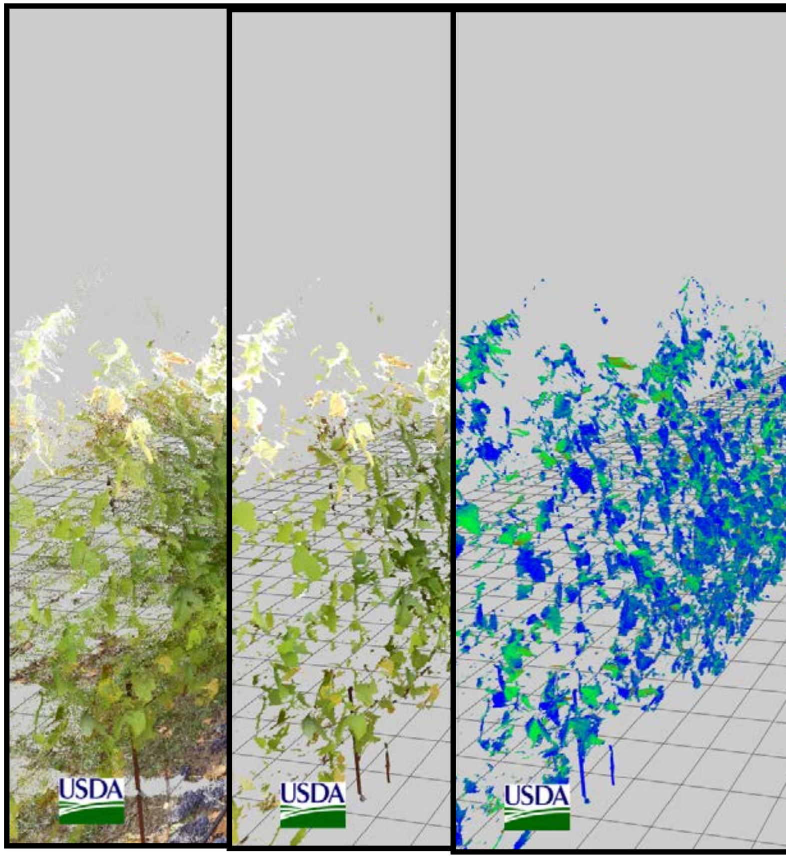
Measuring Canopy Structure

Brian Bailey



Ground based LiDAR

Erath Family Foundation

Leaf Temperature

Brian Bailey

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Water Use

Brian Bailey

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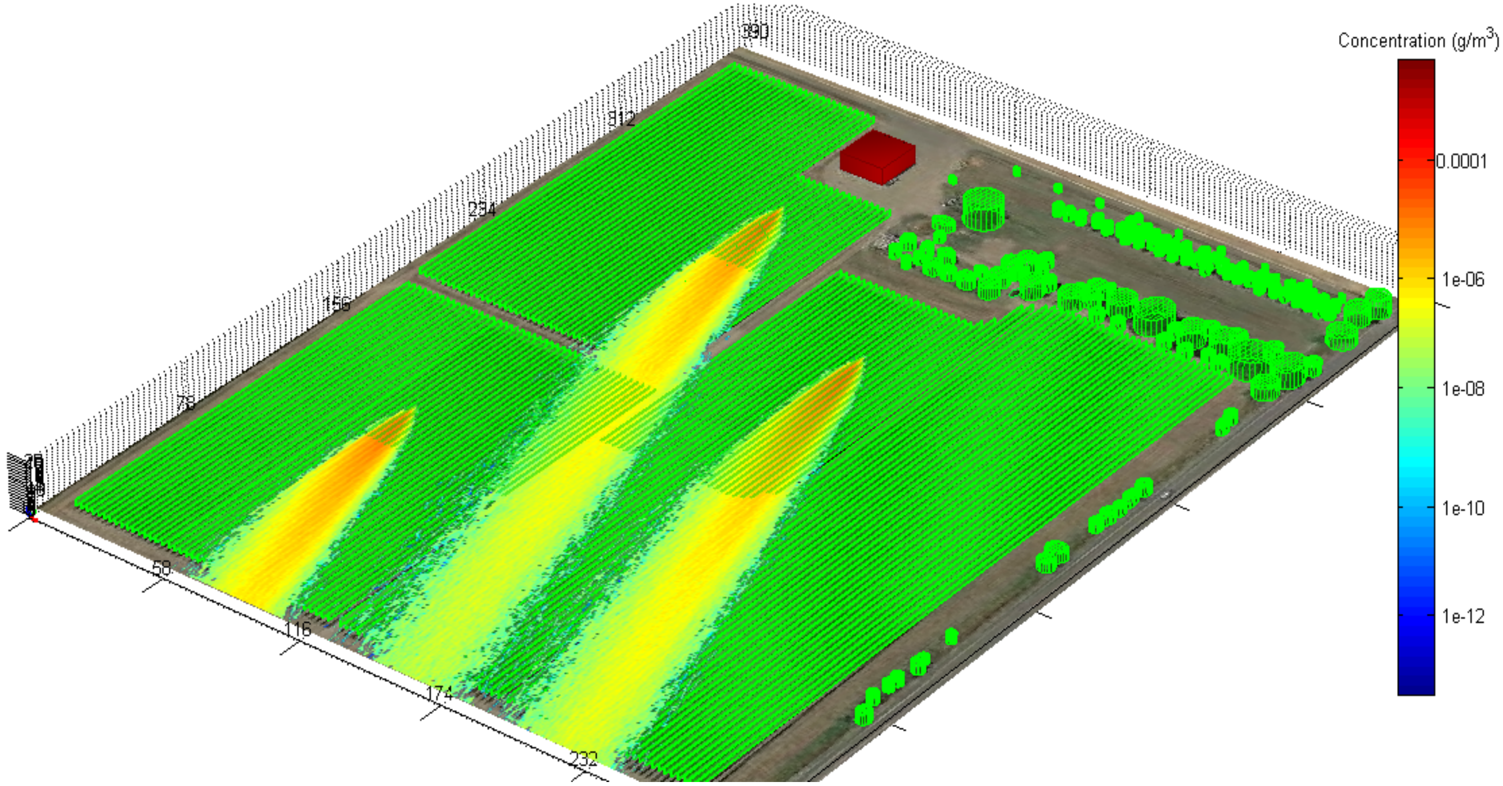
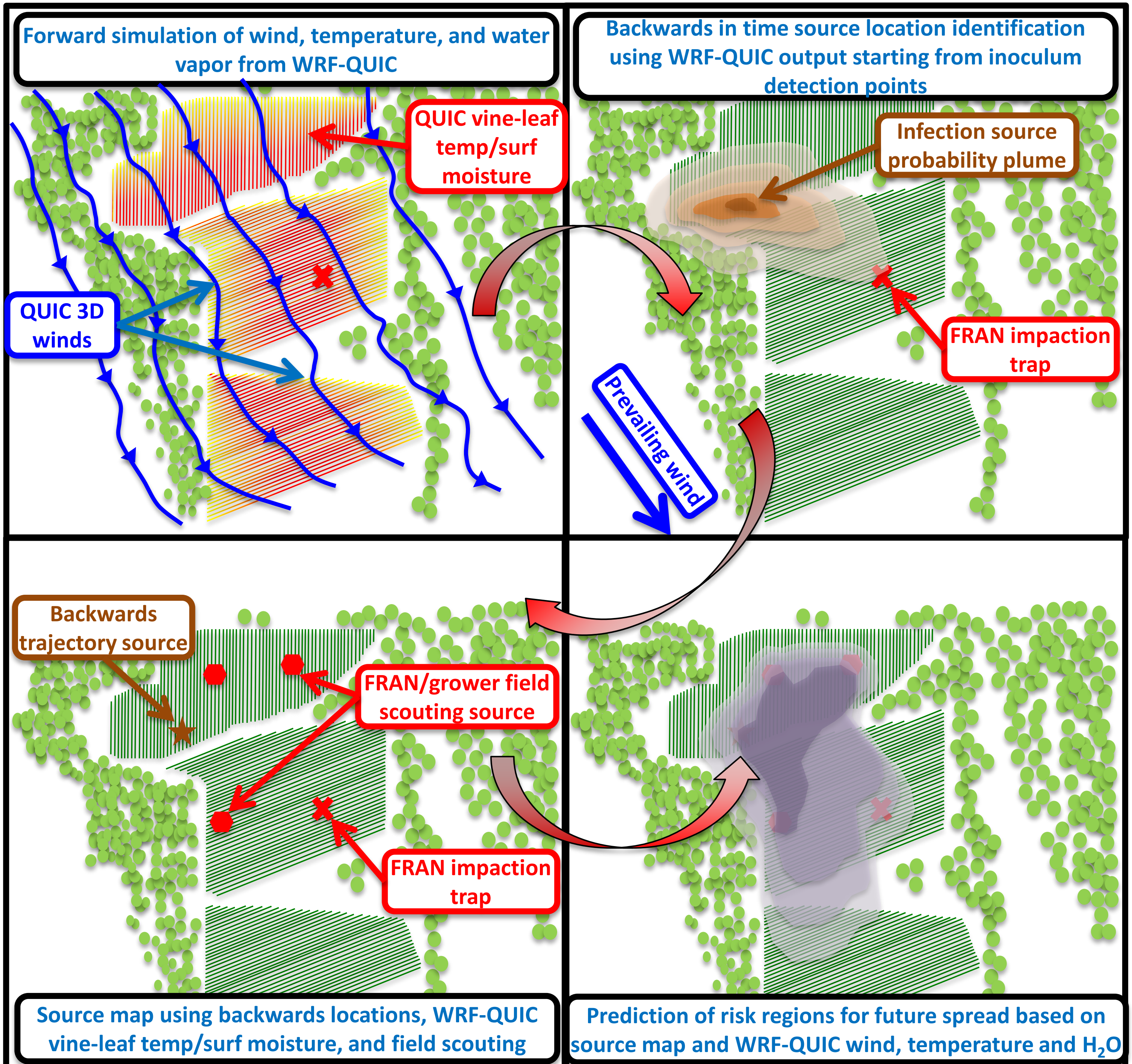
QUIC Dispersion Prediction

QUIC Dispersion Prediction

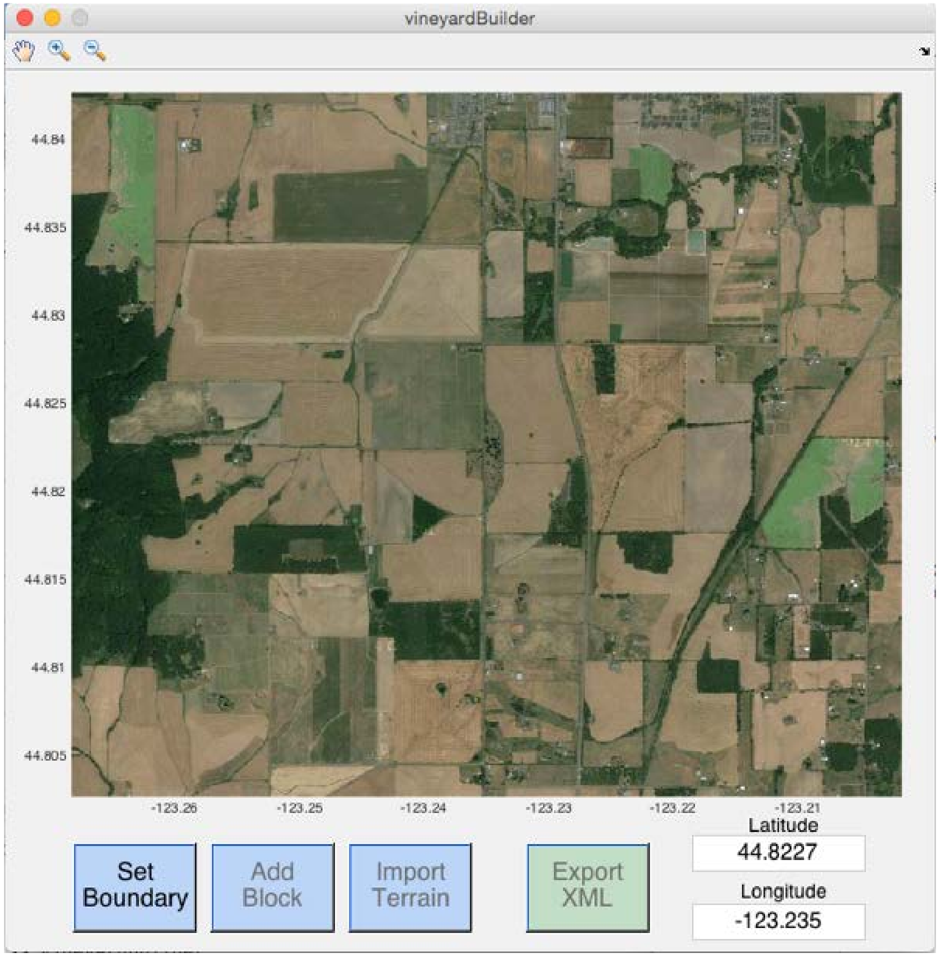




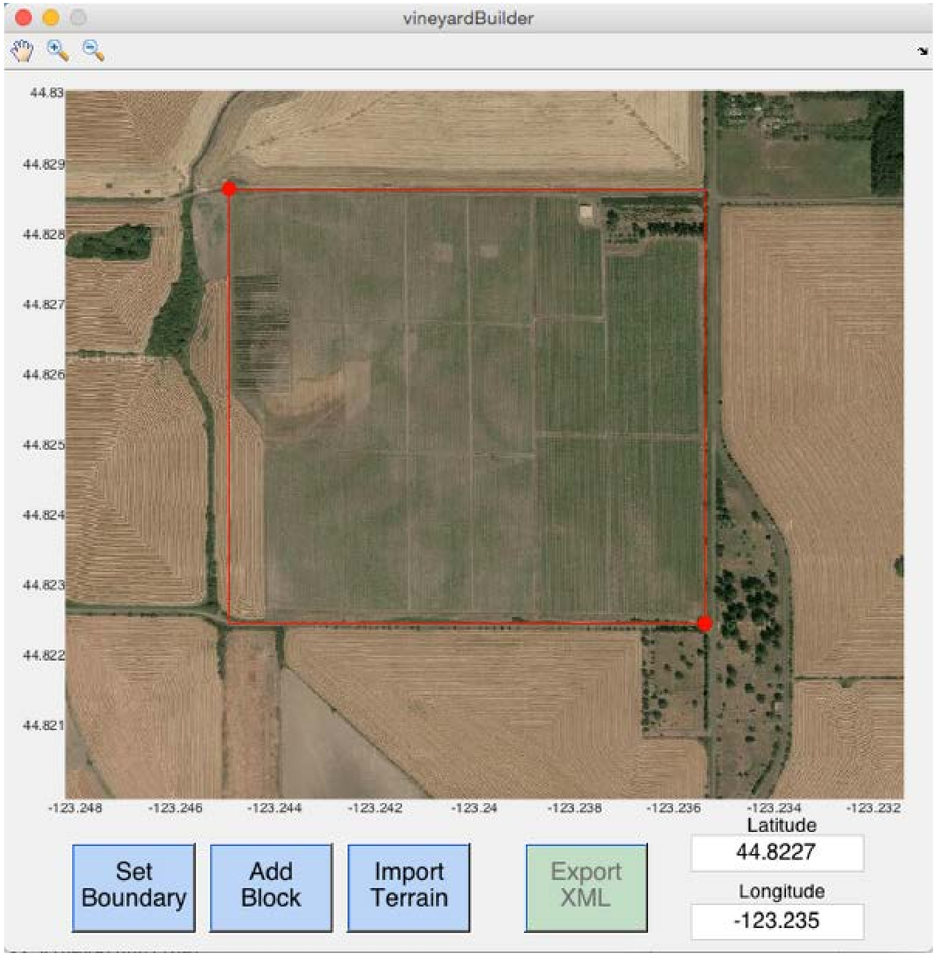
Forward simulation of wind, temperature, and water vapor from WRF-QUIC
QUIC vine-leaf temp/surf moisture
QUIC 3D winds
Backwards in time source location identification using WRF-QUIC output starting from inoculum detection points
Infection source probability plume
FRAN impaction trap
Prevailing wind
Backwards trajectory source
FRAN/grower field scouting source
FRAN impaction trap
Source map using backwards locations, WRF-QUIC vine-leaf temp/surf moisture, and field scouting
Prediction of risk regions for future spread based on source map and WRF-QUIC wind, temperature and H_2O

Simulating an Epidemic

Crop Builder Tool



Defining Simulation Boundries



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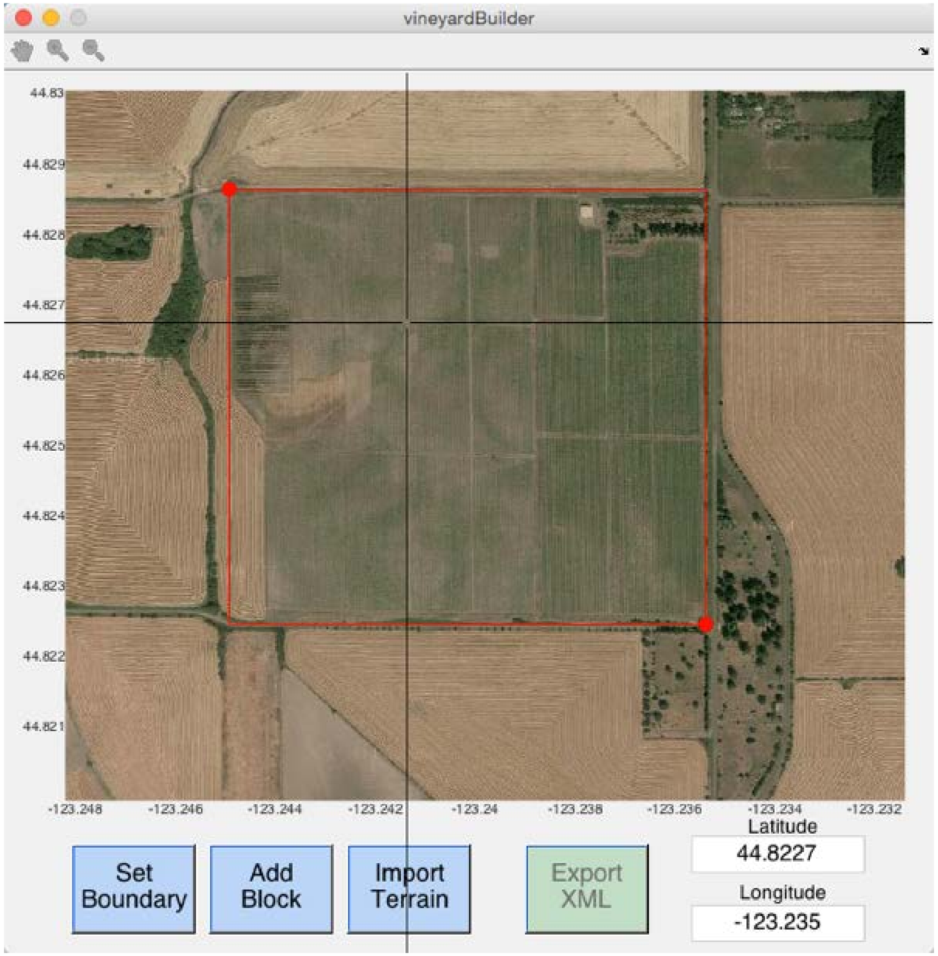
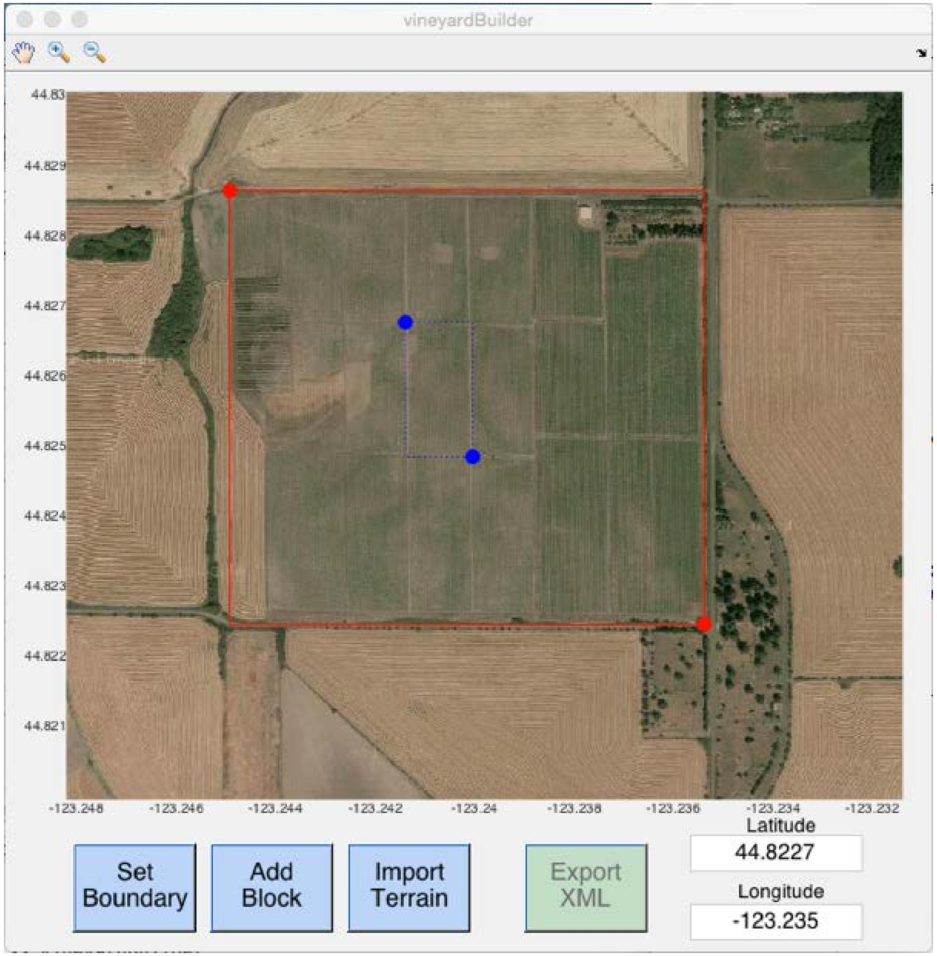
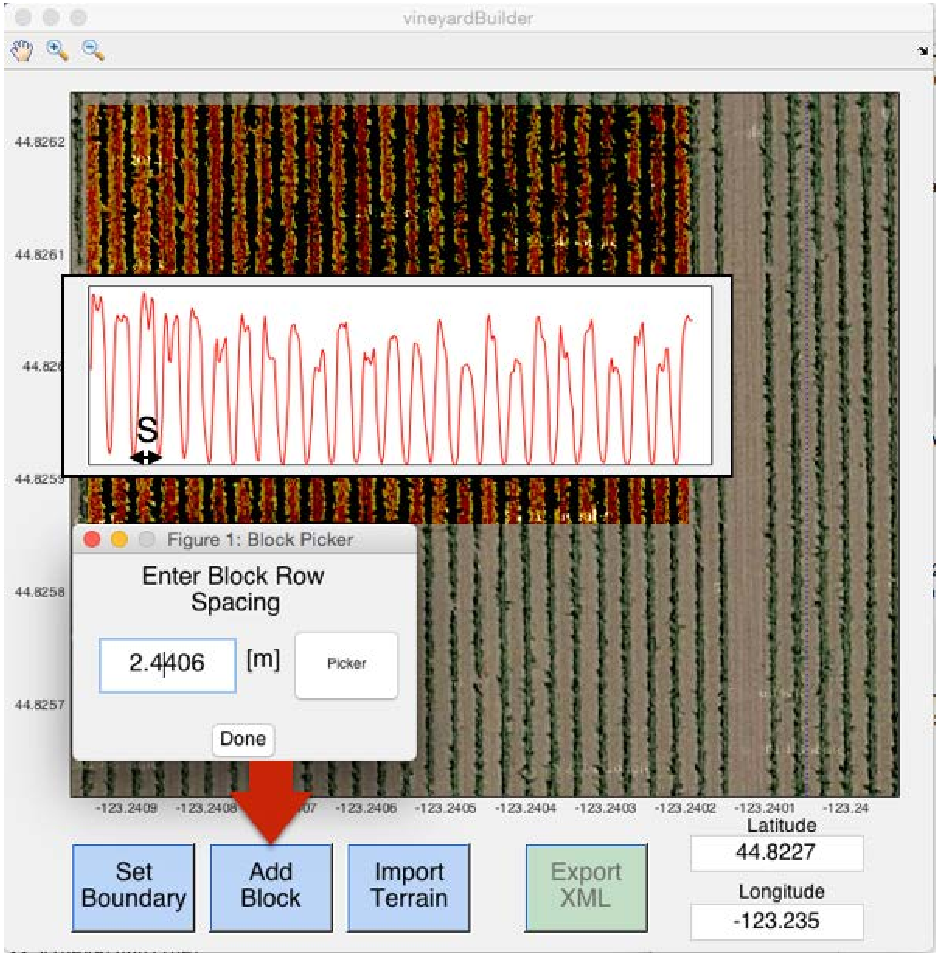
Defining Management Units



Defining Management Units



Adding Crop Spacing



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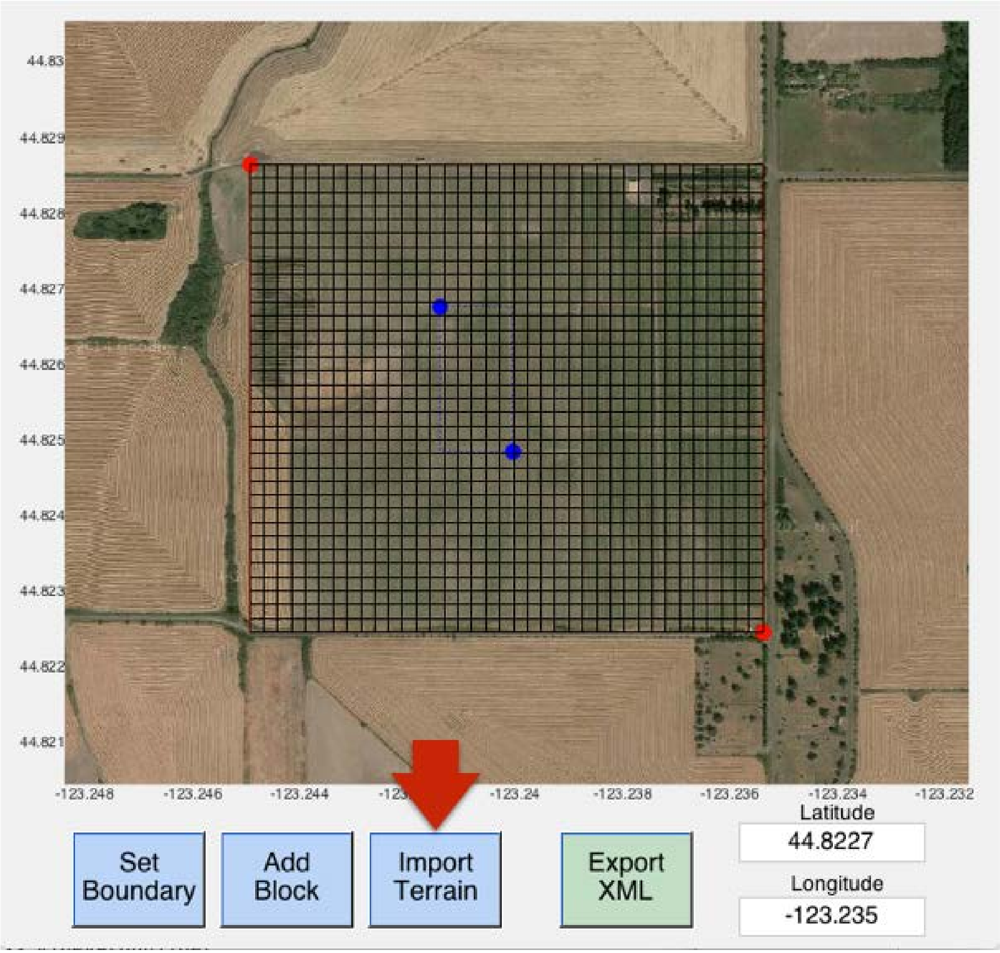
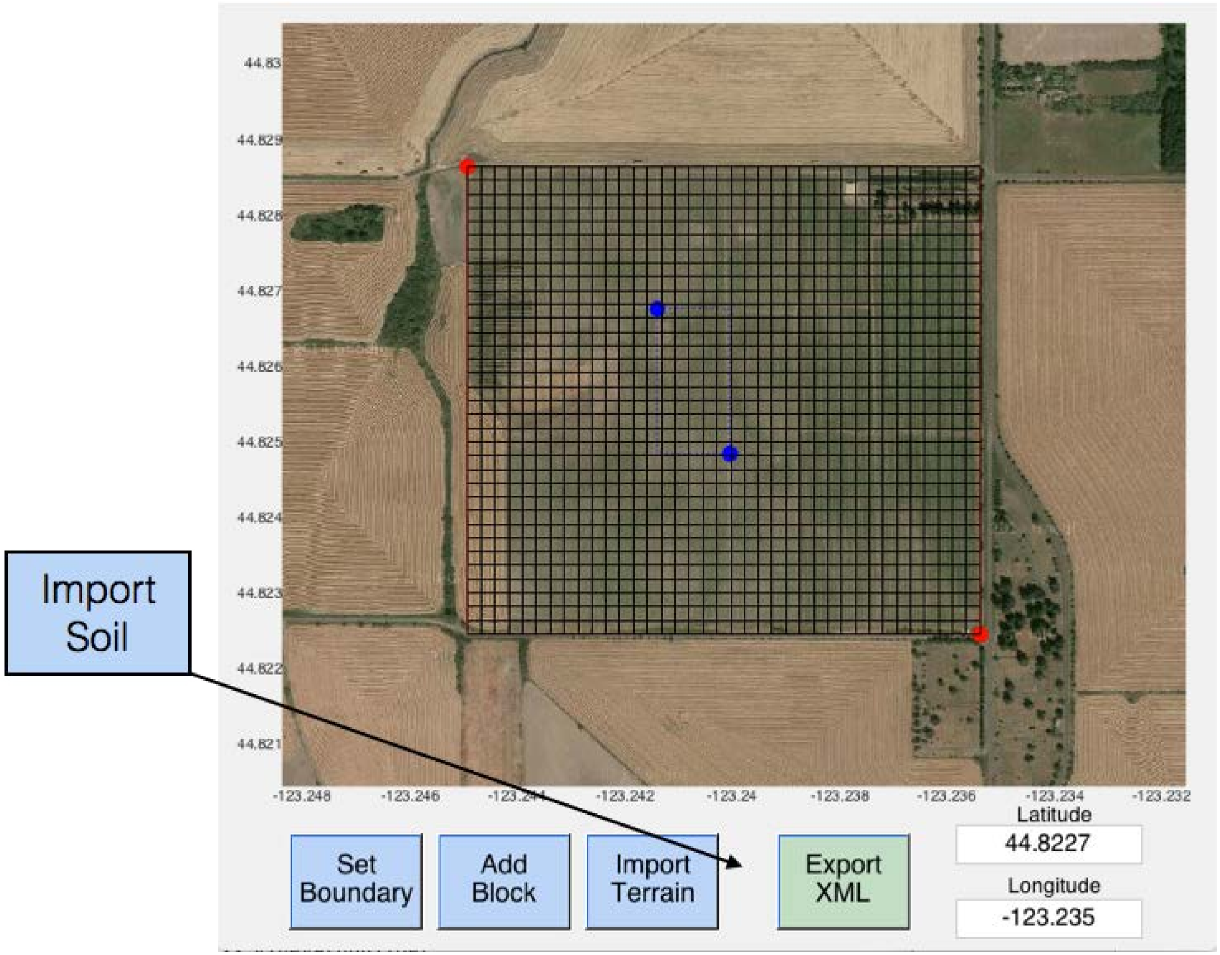
Adding Terrain Information



Importing Soil Data



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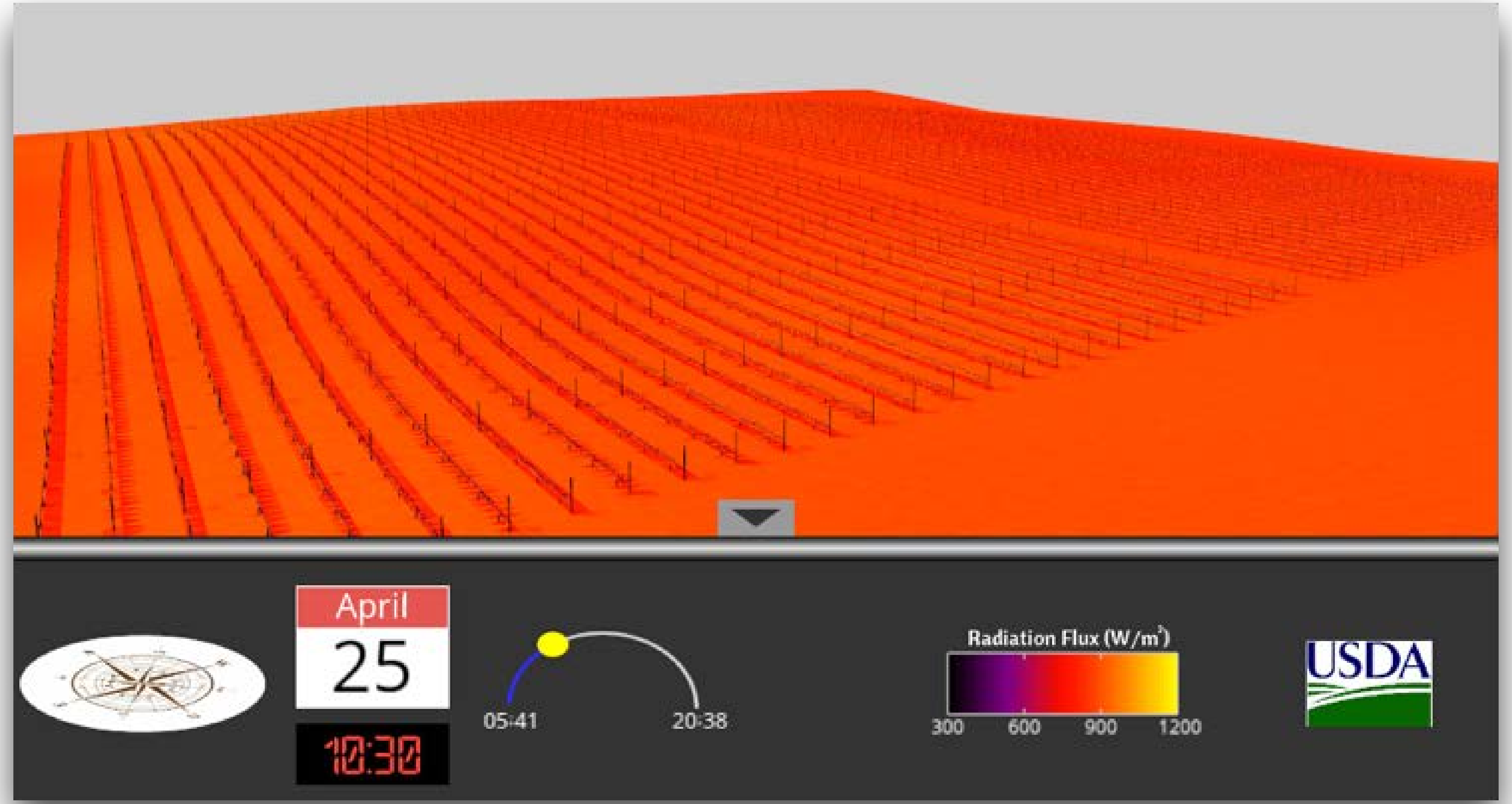
Export to 3D Simulator



Long-Range Vision: Cyber-Physical Systems

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Foliar Pathology Lab 2017

Tara Neill: USDA-ARS

Sarah Lowder, Lindsey Thiessen & Brent Warneke
Graduate Students, Oregon State University

Carley Allen, Jack Blackham, Baily Williams, & Katlyn Thrall:
Undergraduates, Oregon State University

Collaborators

Rob Stoll, Nate Miller, and Eric Pardyjak — The University of Utah

Tim Miles — California State University Monterey Bay

Chad Higgins — Oregon State University

Jason Kelley — University of Idaho

Michelle Moyer, — Washington State University

Amy Peetz — Revolution Crop Consultants

Monica Copper, Mark Battany, Larry Bettiga, Glenn McGourty, Rhonda Smith — UCCE University of California Cooperative Extension

Brian Bailey
Ioannis Stergiopoulos — UC Davis University of California

Funding
USDA-ARS, Washington Grape Growers Association, Oregon Wine Board, American Vineyard Foundation, Erath Family Foundation

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Questions

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Tech Transfer Pipeline

Implementation/ Commercial Partner

GUI Application

API

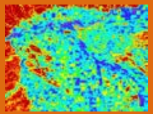
```
int main(){
    addRectangle(center,size);
    float flux = getSolarFlux();
}
```

Research

Source Code

```
int RayLaunch(int N){
    for( int i=0; i<N; i++){
    }
}
```

Data



```
<DataStream, time=12:21>
    <WindSpeed> 4.218 </WindSpeed>
    <DirectSolar> 812.23 </DirectSolar>
```

Theory

$$c = \frac{q}{2\pi \overline{u_a} \sigma_y \sigma_z} \exp\left(\frac{-y^2}{2\sigma_y^2}\right) \exp\left(\frac{-w_s(z-H_e)}{2K_z} - \frac{w_s^2\sigma_z^2}{8K_z^2}\right)$$
$$\times \left[\exp\left(\frac{-(z-H_e)^2}{2\sigma_z^2}\right) + \exp\left(\frac{-(z+H_e)^2}{2\sigma_z^2}\right) - \frac{\sigma_z w_t \sqrt{2\pi}}{K_z}\right.$$
$$\left. \times \exp\left(\frac{w_t(z+H_e)}{K_z} + \frac{w_t^2\sigma_z^2}{2K_z^2}\right) \operatorname{erfc}\left(\frac{z+H_e}{\sigma_z\sqrt{2}} + \frac{w_t\sigma_z}{K_z\sqrt{2}}\right)\right],$$

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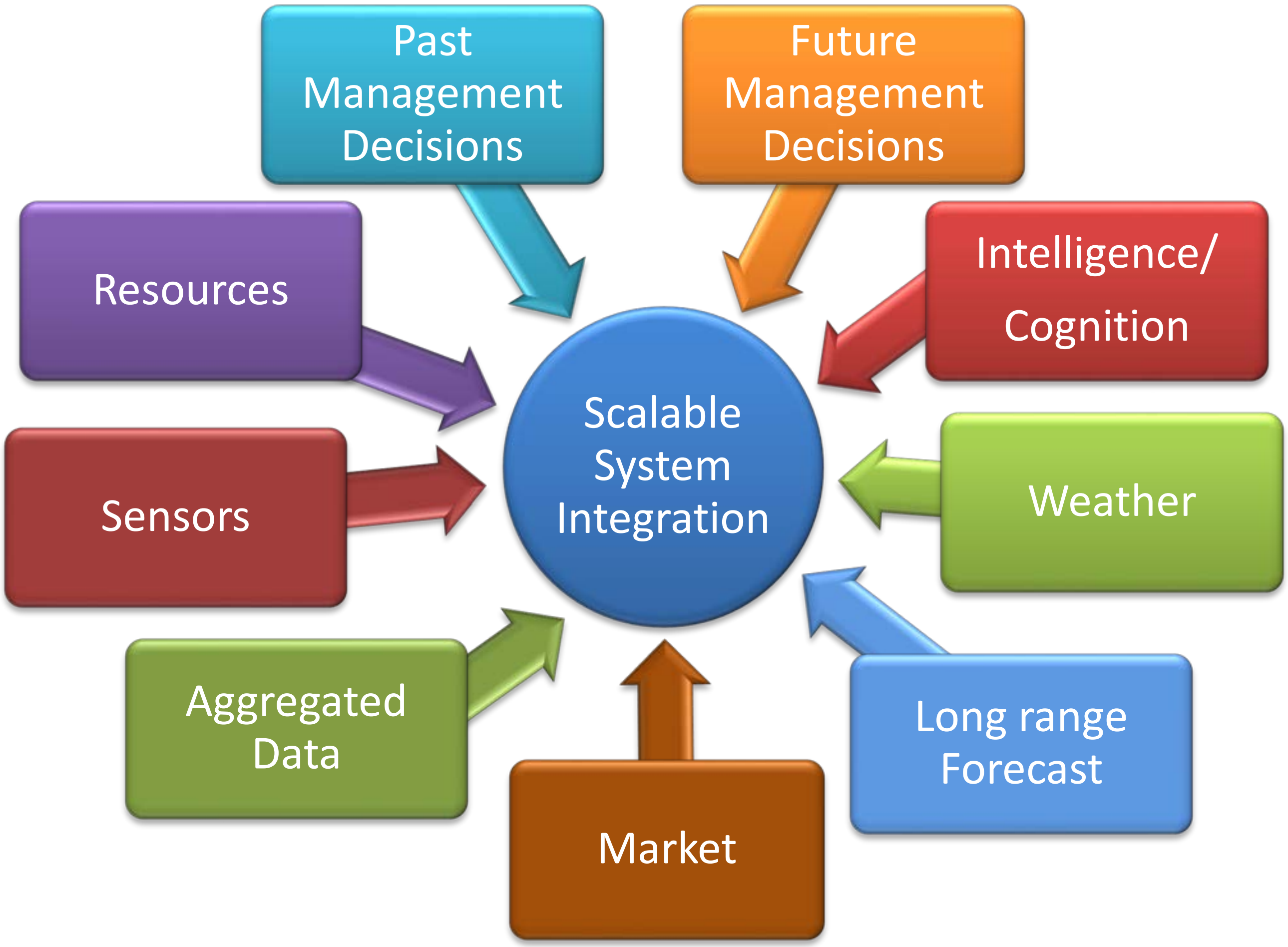
Risk Management System



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Probabilistic Sensor Deployment

- **where to take data so that P-TRAC parameter and prediction variances are minimized**

$Y : True \quad Disease \quad Spread$

$f(\beta; x, \theta) : Spread \quad predicted \quad by \quad P - TRAC$

$\varepsilon : Modelling + Measurement \quad errors$

$Y \equiv f(\beta; x, \theta) + \varepsilon$

- **Approaches:**
  - ✓ **Latin hypercube sampling**
  - ✓ **Optimizing Fisher information**
  - ✓ **Bayesian nonlinear experimental design**

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