Disease Modelling and Visualization with GIS

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UC Davis School of Veterinary Medicine-Cooperative Extension Poultry Laboratory

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My Background

- Grew up in Corona/Norco, around animals

- Major in electrical engineering
  - Focus on computer and digital systems
  - Undergraduate research at UC Davis pastured poultry farm
    - Lighting and door closer automation, student project engineer

- Before academia: consulting engineer

- Research focus:

  - Food safety, zoonotic diseases, poultry epizootics
    - Newcastle Disease (vND) and Highly Pathogenic Avian Influenza (HPAI) in particular
  - Poultry production in developing countries
  - Cybersecurity in agriculture
  - Enabling small scale agriculture
  - Disaster preparedness

Experience and science and engineering first principles go a long way

My Job

- Research Data Analyst in the UC Davis Cooperative Extension Poultry Lab
  - Planning and executing experiments
  - Writing code to support projects in the lab (Python, R, etc.)
  - Planning and creating solutions for data management and availability (databases, git repositories)
  - Project data analysis
    - Excel to geospatial analysis with GIS
  - Creating tools that communicate results to stakeholders (the public, veterinarians, farmers, state & federal gov't agencies)
    - Mobile apps, dashboards, ArcGIS maps & apps, reports

"All models are wrong, some are just less wrong than others"

Concepts

- Disease – abnormal condition that adversely affects an organism (in this case, caused by a pathogen)
- Epizootic – Outbreak of an infectious disease in which a greater number of individuals than normal have the disease
- Pathogen – a disease-causing organism (virus, bacterium, fungus, prion, protozoan)
- Population – all of the same type of individuals in a geographic area (commercial poultry, backyard poultry, etc.)
- Pathogenicity – ability of a pathogen to produce disease in a host
- Virulence – the degree to which a pathogen is able to produce disease, often correlate with its ability to replicate in the host
- Prevalence – Proportion of a population that is infectious at a given time
- Immune – Unable to become infectious

Disease Modelling Basics

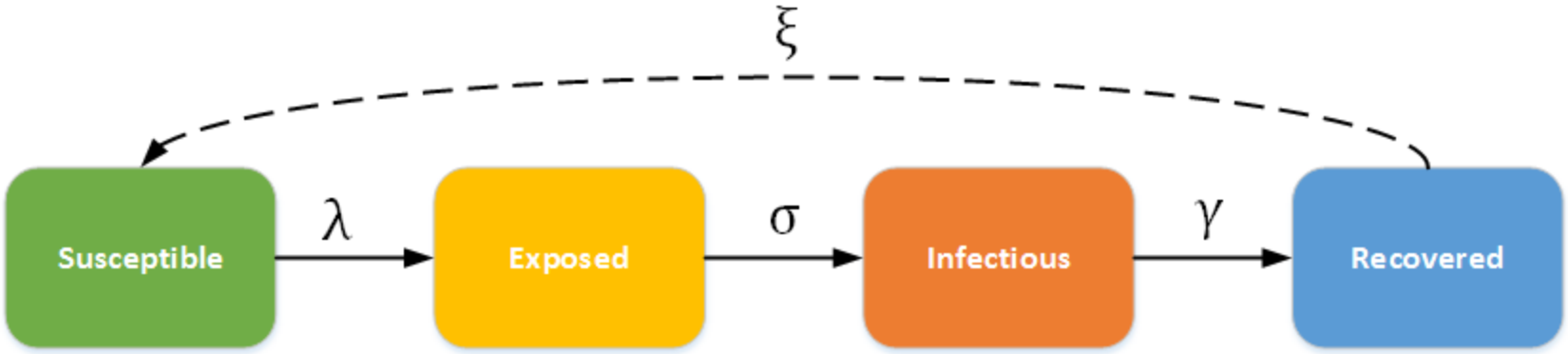
- **Goal: create a model that accurately represents the spread of disease throughout a population over time.**

- How?

  - Identify…
    - Pathogen of concern, disease history
    - Populations affected
      - For vND: Commercial poultry, backyard poultry, gamefowl, non-poultry birds, humans
    - Transmission process
      - E.g. Respiratory transmission, food and water transmission, oral, etc.
    - Interactions between populations
    - Density and location of populations affected
  - Compare to observed data
    - Adjust model
  - Test mitigation strategies with finished model

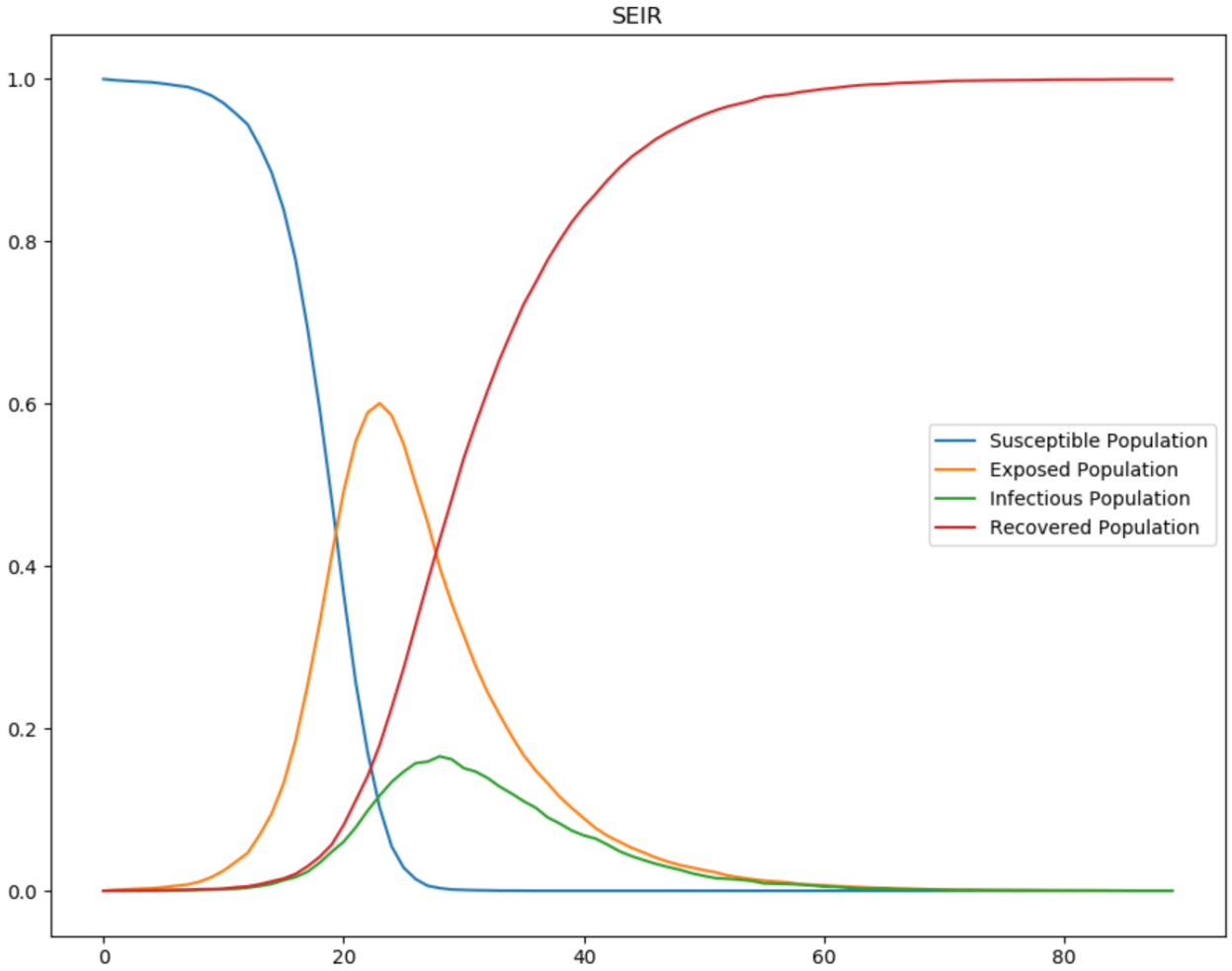
SEIR(S) Model

Susceptible – individual able to become infected
Exposed – individual is infected, but not yet infectious due to incubation period
Infectious – individual is infected and able to infect others
Recovered – individual is no longer infectious, or removed from population
(**S**usceptible) – individual able to become infected again



This flowchart shows the progression of an individual infected in an SEIR(S) model. *Institute for Disease Modelling 2024.*

SEIR(S) Model



SEIR model for an outbreak with an 8-day incubation period. *Institute for Disease Modelling 2024.*

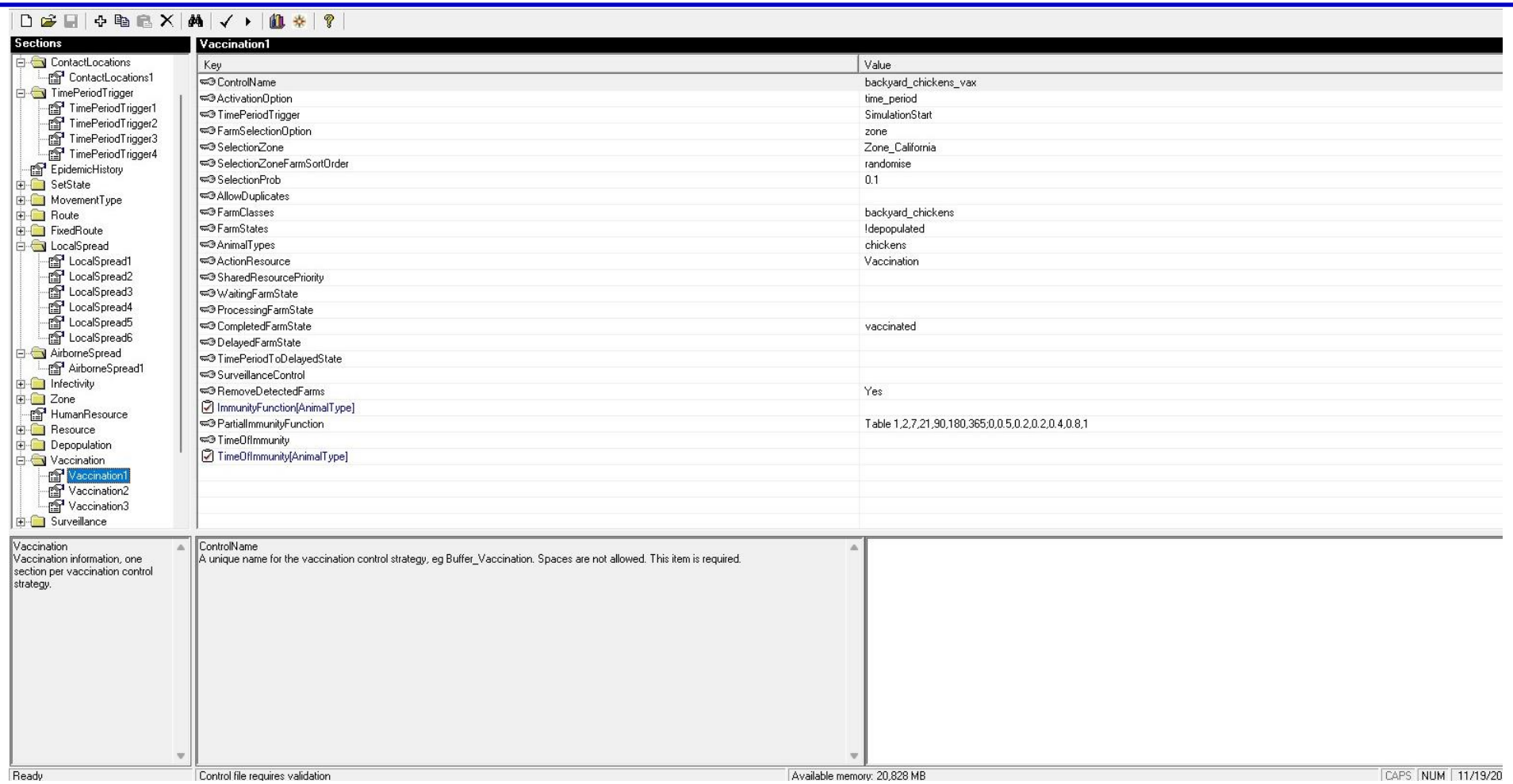
$$\frac{dS}{dt} = \mu N - \nu S - \frac{\beta SI}{N}$$
$$\frac{dE}{dt} = \frac{\beta SI}{N} - \nu E - \sigma E$$
$$\frac{dI}{dt} = \sigma E - \gamma I - \nu I$$
$$\frac{dR}{dt} = \gamma I - \nu R$$

Underlying SEIR model differential equations. *Institute for Disease Modelling 2024.*

Where S+E+I+R is the total population N.

β = infectious rate
σ = incubation rate
γ = recovery rate (1/duration of infection
ν = death rate
μ = birth rate

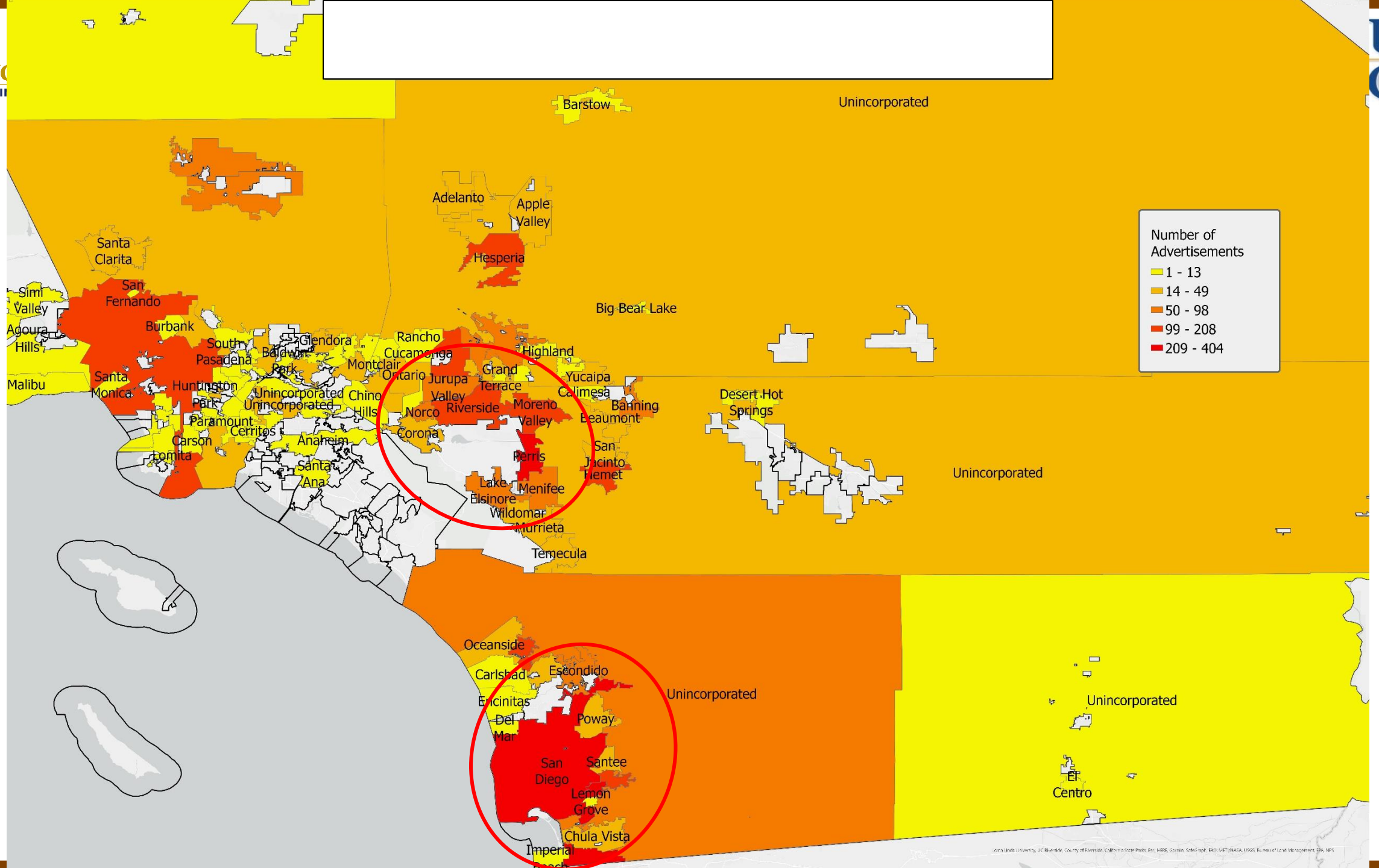
Modelling Tools



For our model, we use InterSpread PLUS by EpiSoft which is specifically designed for disease transmission between farms. Alternatives exist, including USDA CEAH's Animal Disease Spread Model (ADSM), which is free on Github, and various disease specific models available at idmod.org

Model Parameters

- Premises
  - Includes type of animal
- Contact rate – average number of contacts between individuals that allow for disease transmission in a given period
- Probability of transmission – the probability that an infectious individual will transmit infection to a susceptible individual
- Movement restriction – quarantine zones and compliance with quarantines
- Vaccination rates
  - Immunity functions and partial immunity
- Depopulation
- Human resources
  - Important for how quickly depopulation and vaccination can be achieved


Barstow
Unincorporated
Adelanto
Apple Valley
Hesperia
Santa Clarita
San Fernando
Simi Valley
Agoura Hills
Burbank
Big Bear Lake
Malibu
Santa Monica
Huntington Park
South Pasadena
Glendora
Baldwin Park
Montclair
Rancho Cucamonga
Ontario
Jurupa Valley
Grand Terrace
Highland
Yucaipa
Calimesa
Chino Hills
Norco
Riverside
Moreno Valley
Banning
Beaumont
Desert Hot Springs
Unincorporated
Unincorporated
Paramount
Cerritos
Carson
Lomita
Anaheim
Santa Ana
Corona
Perris
San Jacinto
Hemet
Lake Elsinore
Menifee
Wildomar
Murrieta
Temecula
Oceanside
Carlsbad
Escondido
Encinitas
Del Mar
Poway
San Diego
Santee
Lemon Grove
Chula Vista
Imperial Beach
Unincorporated
Unincorporated
El Centro
Number of Advertisements
1 - 13
14 - 49
50 - 98
99 - 208
209 - 404

InterSpread Plus Spatial Analysis Tool

Time period 1

Data

Required Data

Load Shape file

Load Farm file

Load Infection file

Optional Data

Load Detection file

Load Depopulation file

Load Vacination file

Analyse Data

Analyse iterations

Selected Iteration: 1

Display All Farms

Load All Movements

Display Movements

Map Layers

Detected

Infected

Previous

Next

X: 475507 Y: 2728747

InterSpread Plus Spatial Analysis Tool

Time period 2

Data

Required Data
Load Shape file
Load Farm file
Load Infection file

Optional Data
Load Detection file
Load Depopulation file
Load Vacination file

Analyse Data
Analyse iterations
Selected Iteration: 1
Display All Farms
Load All Movements
Display Movements

Map Layers
Detected
Infected

Previous
Next

X: 475507
Y: 2728747

InterSpread Plus Spatial Analysis Tool

Time period 4

Data

Required Data
Load Shape file
Load Farm file
Load Infection file

Optional Data
Load Detection file
Load Depopulation file
Load Vacination file

Analyse Data
Analyse iterations
Selected Iteration: 1
Display All Farms
Load All Movements
Display Movements

Map Layers
Detected
Infected

Previous
Next

X: 8645
Y: 696701

InterSpread Plus Spatial Analysis Tool

Time period 8

Data

Required Data
Load Shape file
Load Farm file
Load Infection file

Optional Data
Load Detection file
Load Depopulation file
Load Vacination file

Analyse Data
Analyse iterations
Selected Iteration: 1

Display All Farms
Load All Movements
Display Movements

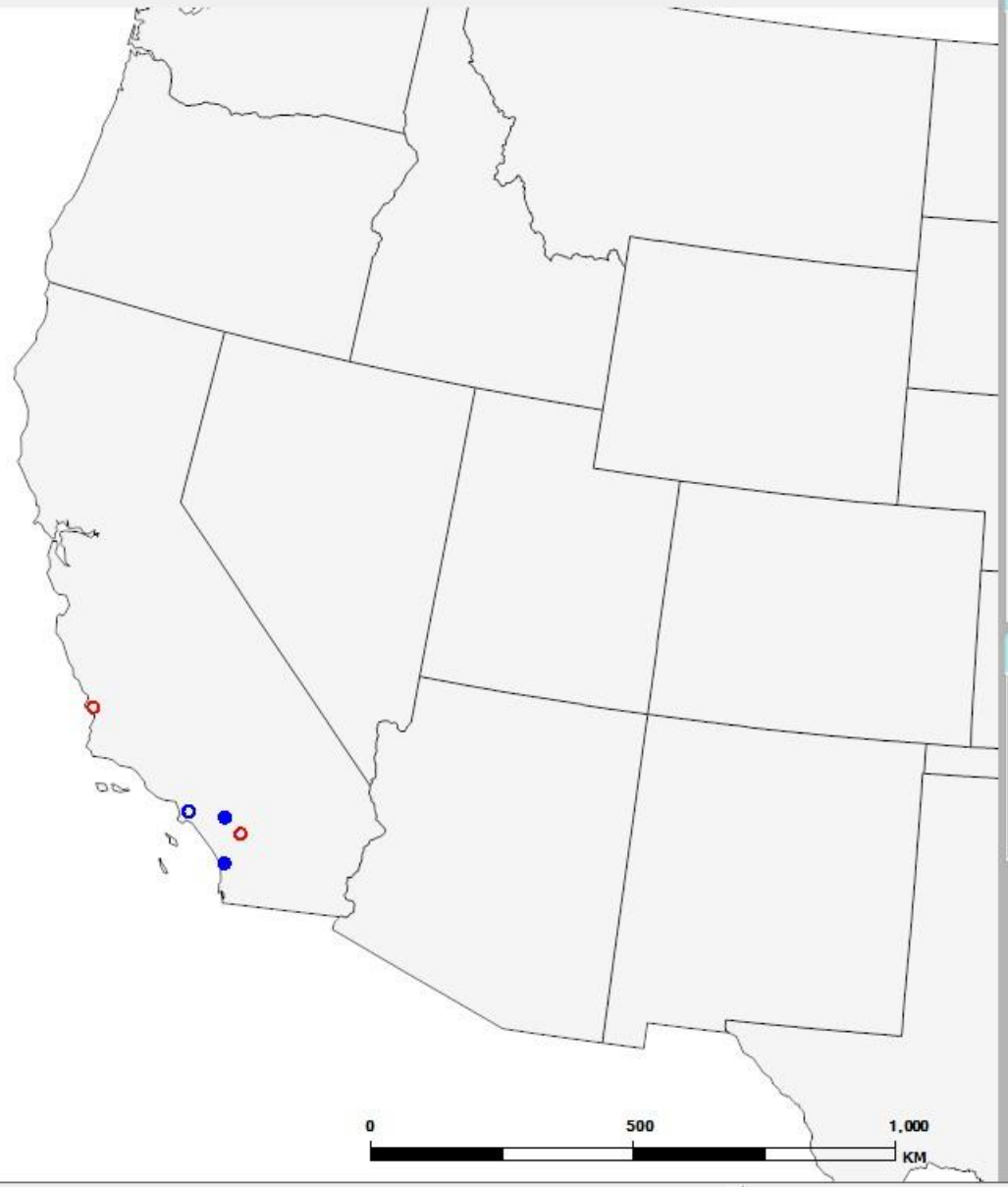
Map Layers
Detected
Infected

Previous
Next

X: 2010764
Y: 1486775

InterSpread Plus Spatial Analysis Tool

Time period 11



Data

Required Data
Load Shape file
Load Farm file
Load Infection file

Optional Data
Load Detection file
Load Depopulation file
Load Vacination file

Analyse Data
Analyse iterations
Selected Iteration: 1
Display All Farms
Load All Movements
Display Movements

Map Layers
Detected
Infected

Previous
Next

X: 2013757
Y: 708672

How Is This Used

- Outbreak response
- Policy changes
- Economic modelling