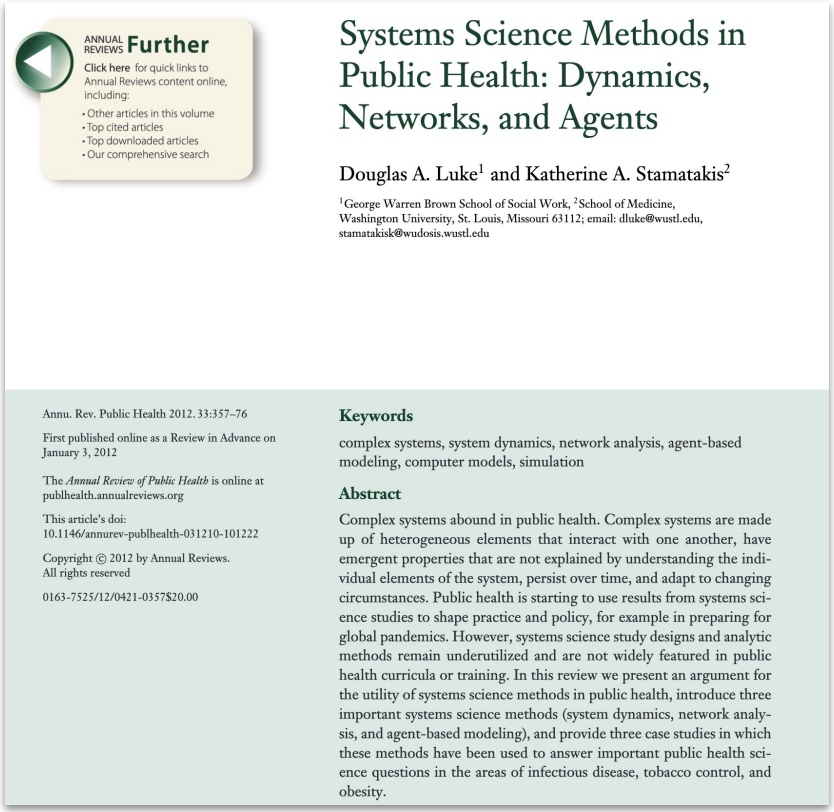
Systems Science Methods & ABM Example

Rural Food Access Working Group
April 20th, 2023
Larissa Calancie, PhD
Friedman School of Nutrition Science and Policy

Systems Science Methods in Public Health



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Systems Science Methods in Public Health: Dynamics, Networks, and Agents

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Keywords

complex systems, system dynamics, network analysis, agent-based modeling, computer models, simulation

Abstract

Complex systems abound in public health. Complex systems are made up of heterogeneous elements that interact with one another, have emergent properties that are not explained by understanding the individual elements of the system, persist over time, and adapt to changing circumstances. Public health is starting to use results from systems science studies to shape practice and policy, for example in preparing for global pandemics. However, systems science study designs and analytic methods remain underutilized and are not widely featured in public health curricula or training. In this review we present an argument for the utility of systems science methods in public health, introduce three important systems science methods (system dynamics, network analysis, and agent-based modeling), and provide three case studies in which these methods have been used to answer important public health science questions in the areas of infectious disease, tobacco control, and obesity.

Complex systems:

- Large number of heterogeneous elements
- Elements interact
- Emergent effects that are different from effects of individual elements
- Effects persist over time and adapt to change

Methods:

- Social Network Analysis (SNA)
- System Dynamics (SD)
- Agent-Based Modeling (ABM)
- GIS
- Hierarchical modeling
- Structural equation modeling

Social Network Analysis

“The measurement and analysis of relationships and flows among actors, including people, organizations, and other information processing entities”

Good for:

- Visualizing relationships
- Analyzing relationship characteristics
- Informing and studying network interventions

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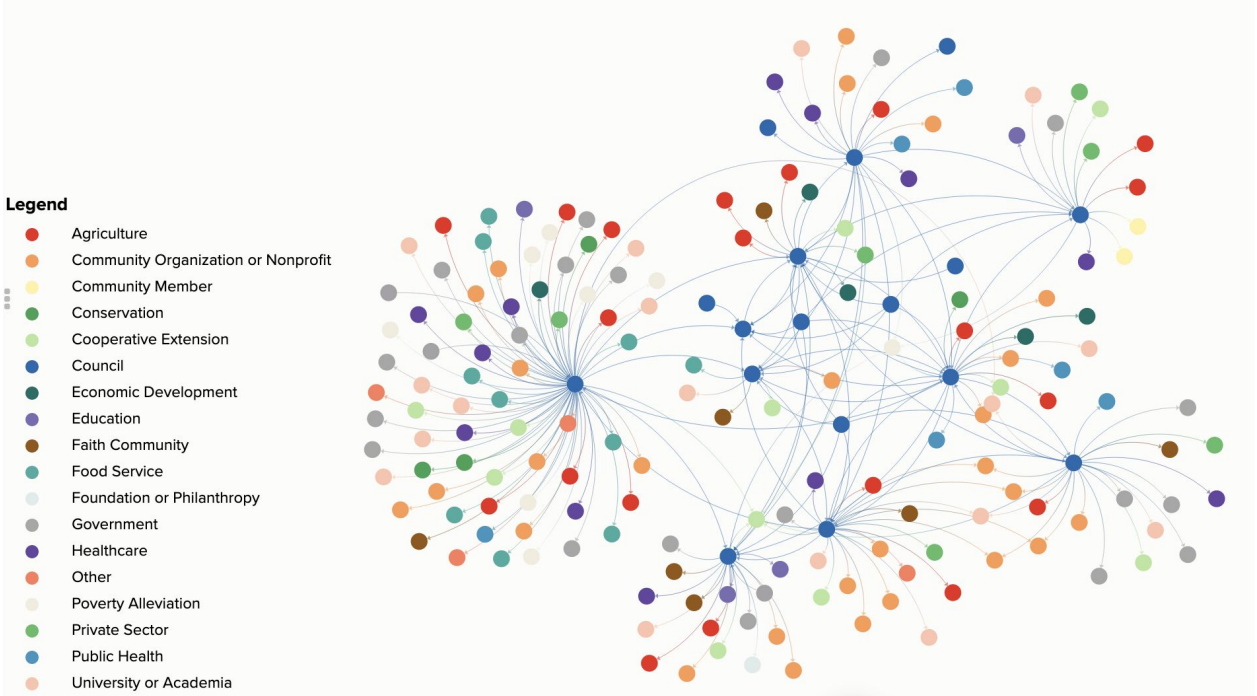

https://kumu.io/lcalancie/kansas-food-councils-2022-v2

System Dynamics

“Uses informal and formal models with computer simulation to uncover and understand endogenous sources of complex system behaviors”

Good for:

- Nonlinear processes, “feedback”
- Delays and accumulations
- Considering “unintended consequences”
- Engaging stakeholders

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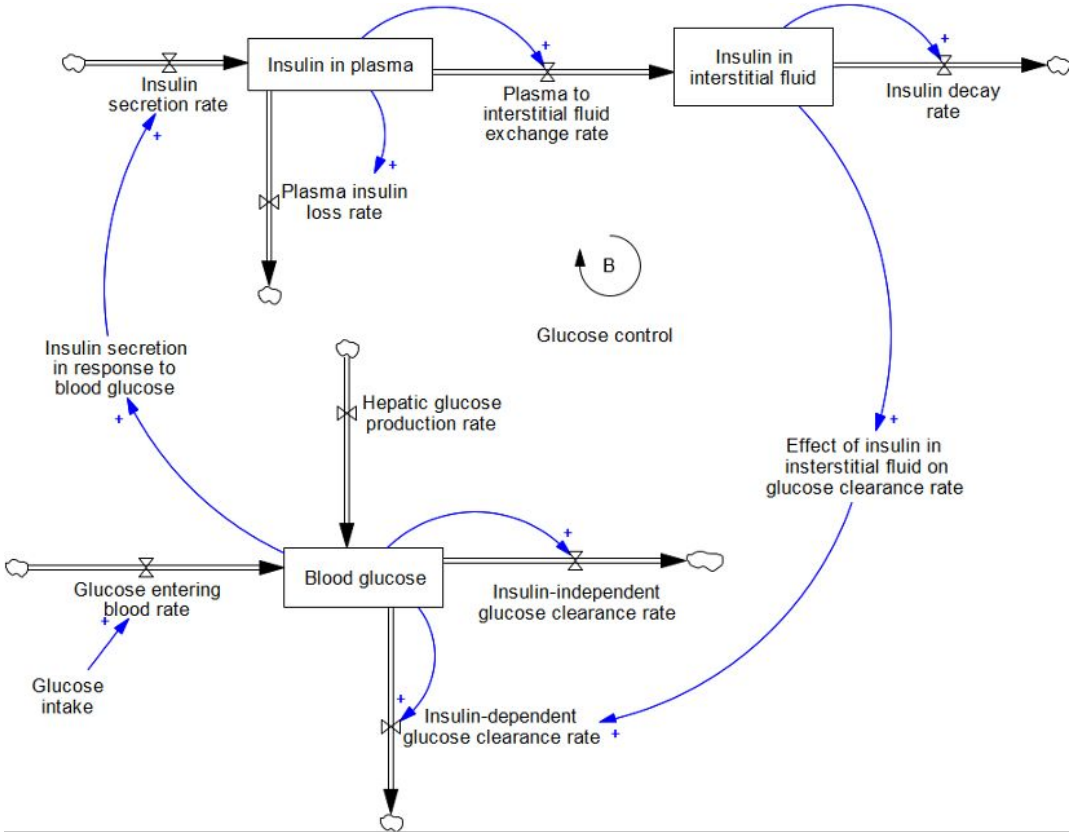
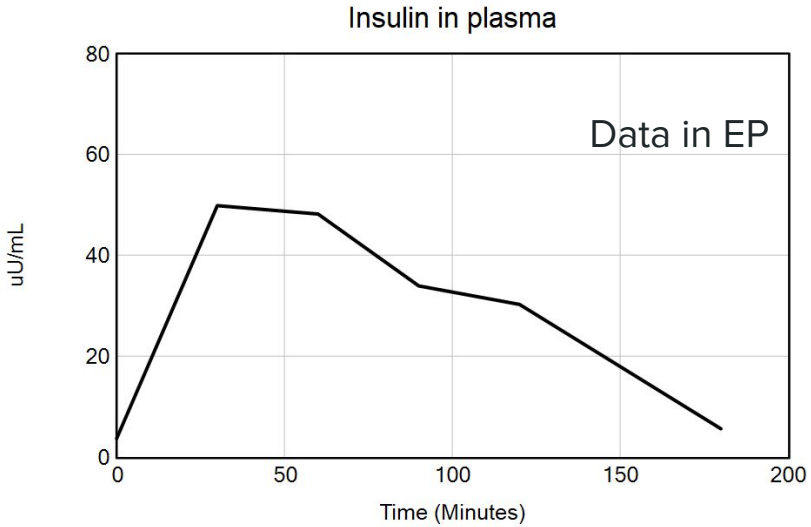
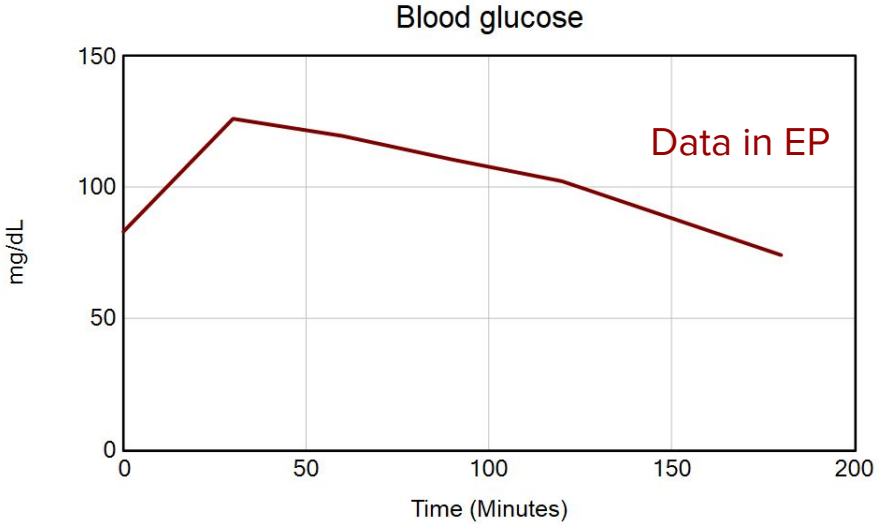
Figure 1. Simplified stock and flow diagram of maternal insulin and glucose dynamics during an oral glucose tolerance test (OGTT).



System dynamics simulation modeling - *Preliminary results*

Replicating research data in early pregnancy (EP):





System dynamics simulation modeling - *Preliminary results*

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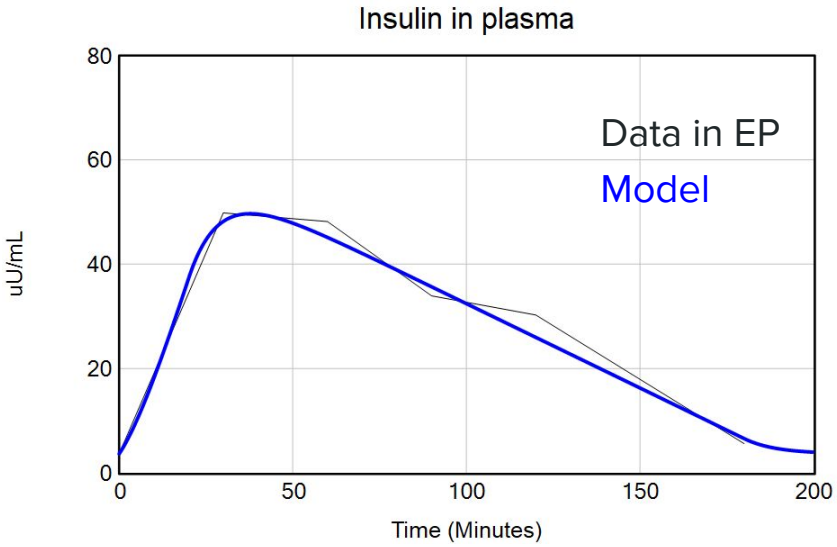
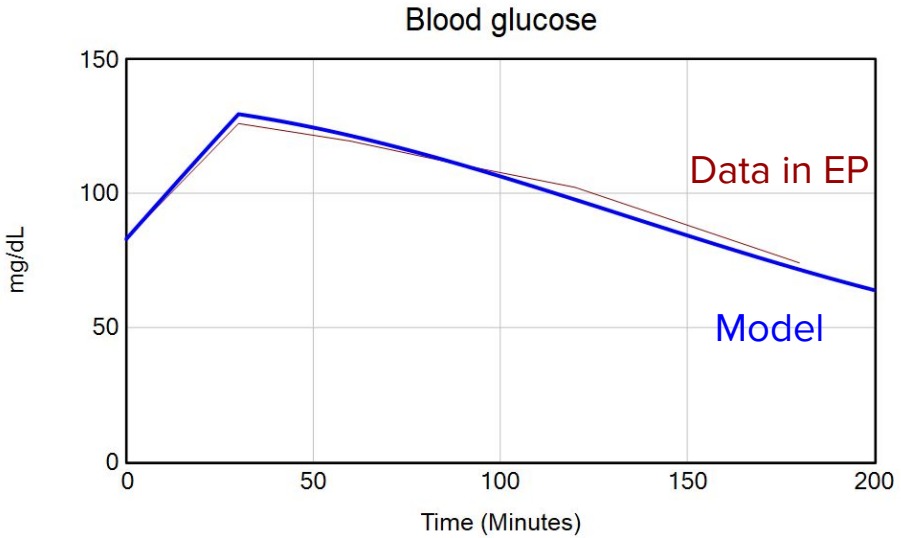
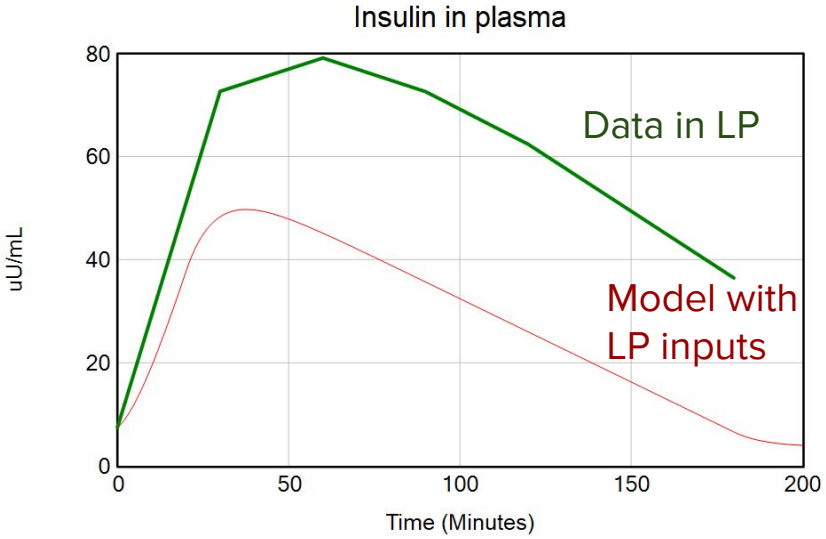
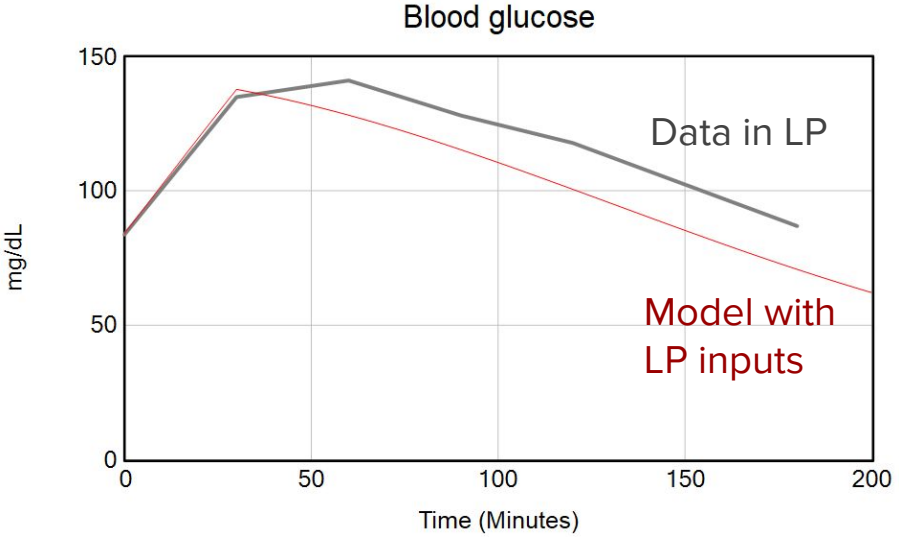




System dynamics simulation modeling - *Preliminary results*

Using model calibrated for early pregnancy (EP) with late pregnancy (LP) data:





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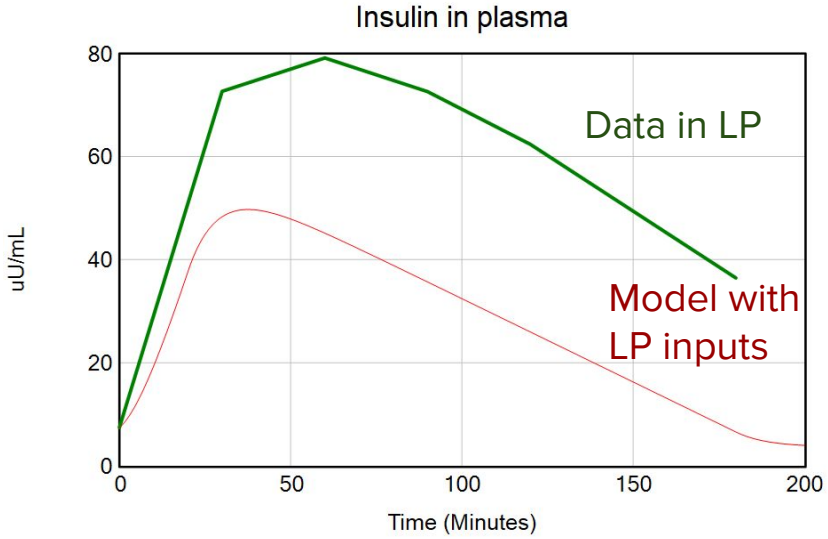
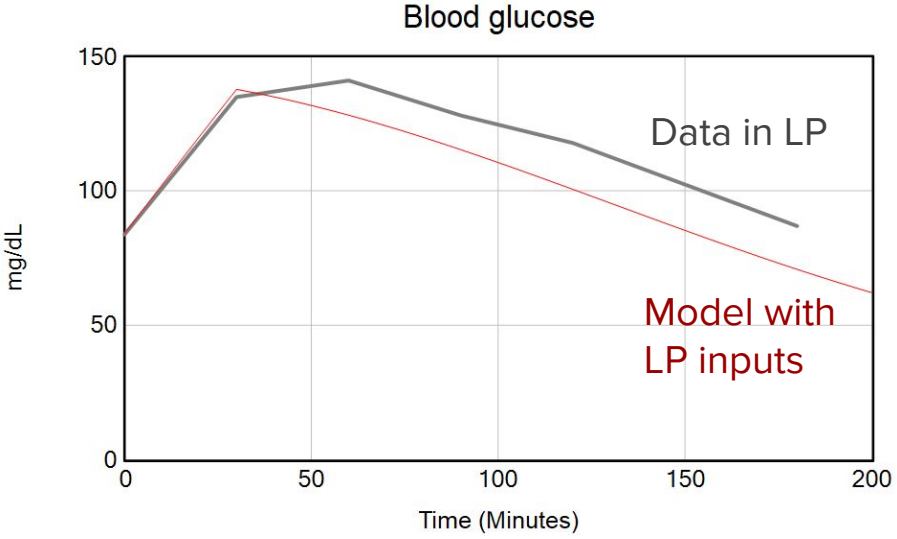
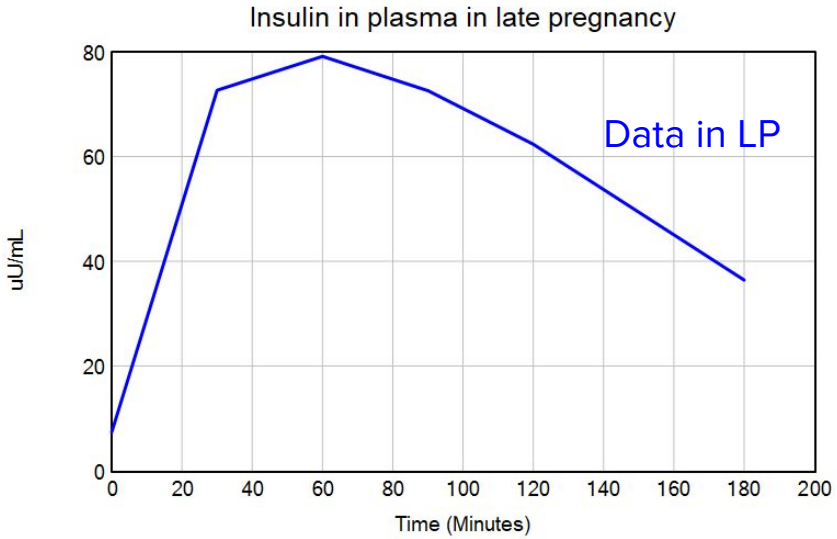


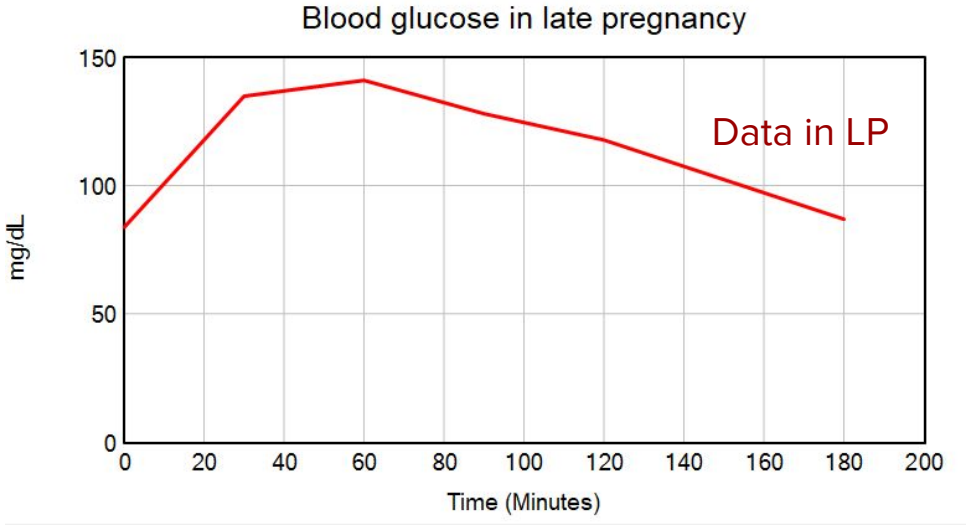


Insulin resistance

System dynamics simulation modeling - *Preliminary results*

Replicating research data in late pregnancy (LP):





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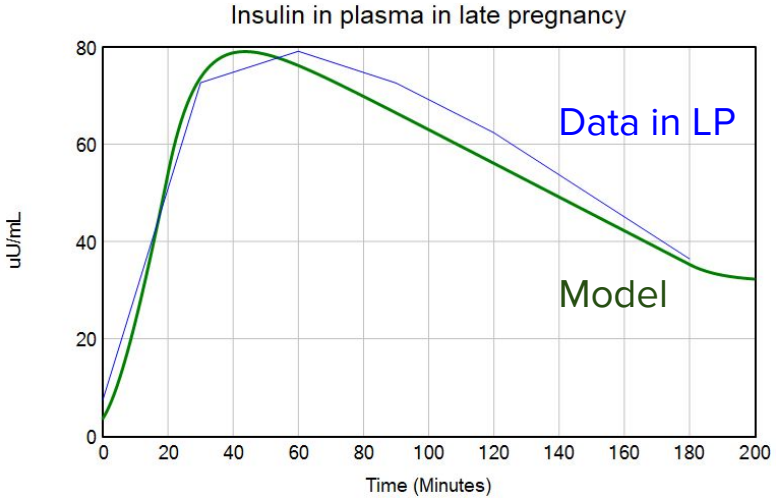
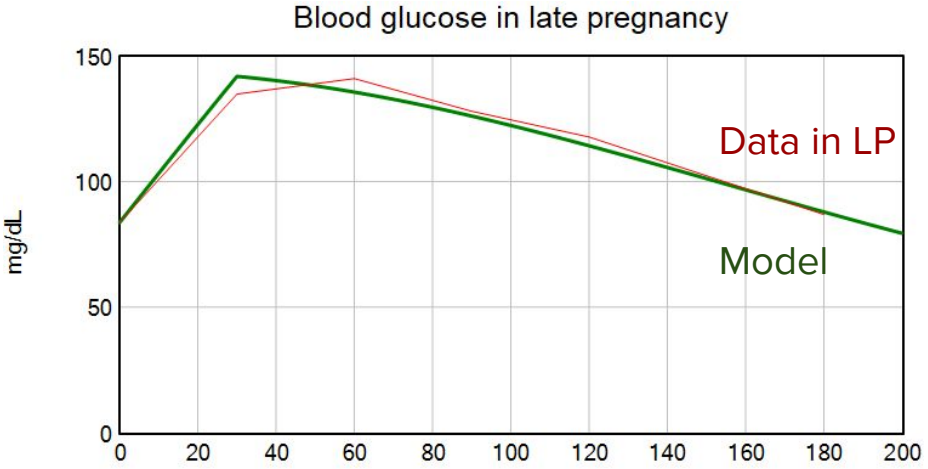
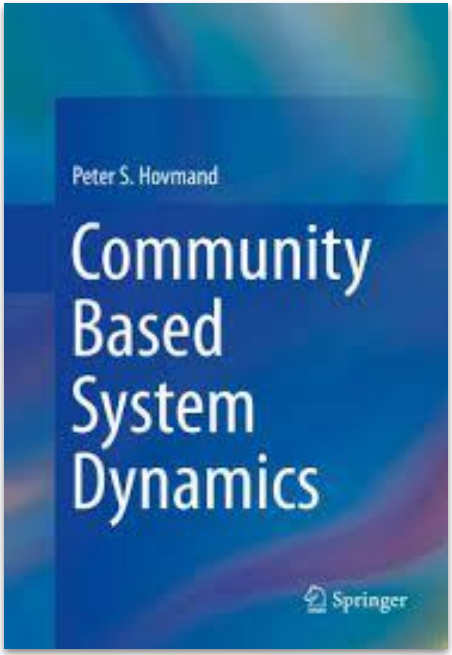




Changed: 1) Slope of glucose clearance rate to interstitial insulin concentration, 2) Increased insulin release rate, 3) Increased plasma to interstitial fluid exchange time, and 4) increased non-insulin dependent glucose clearance time

Community-Based System Dynamics

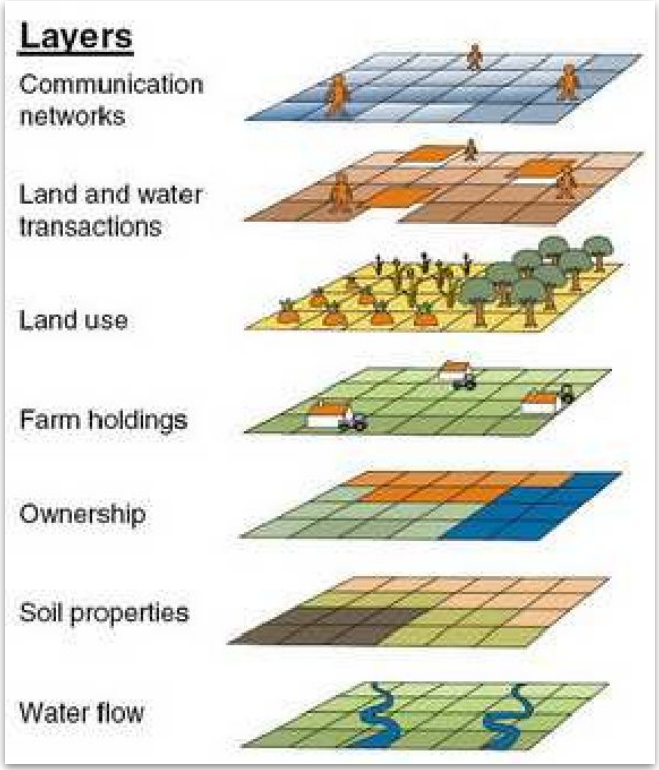


Agent-Based Modeling

“Uses computer simulations to examine how elements of a system (agents) behave as a function of their interactions with each other and their environment”

Good for:

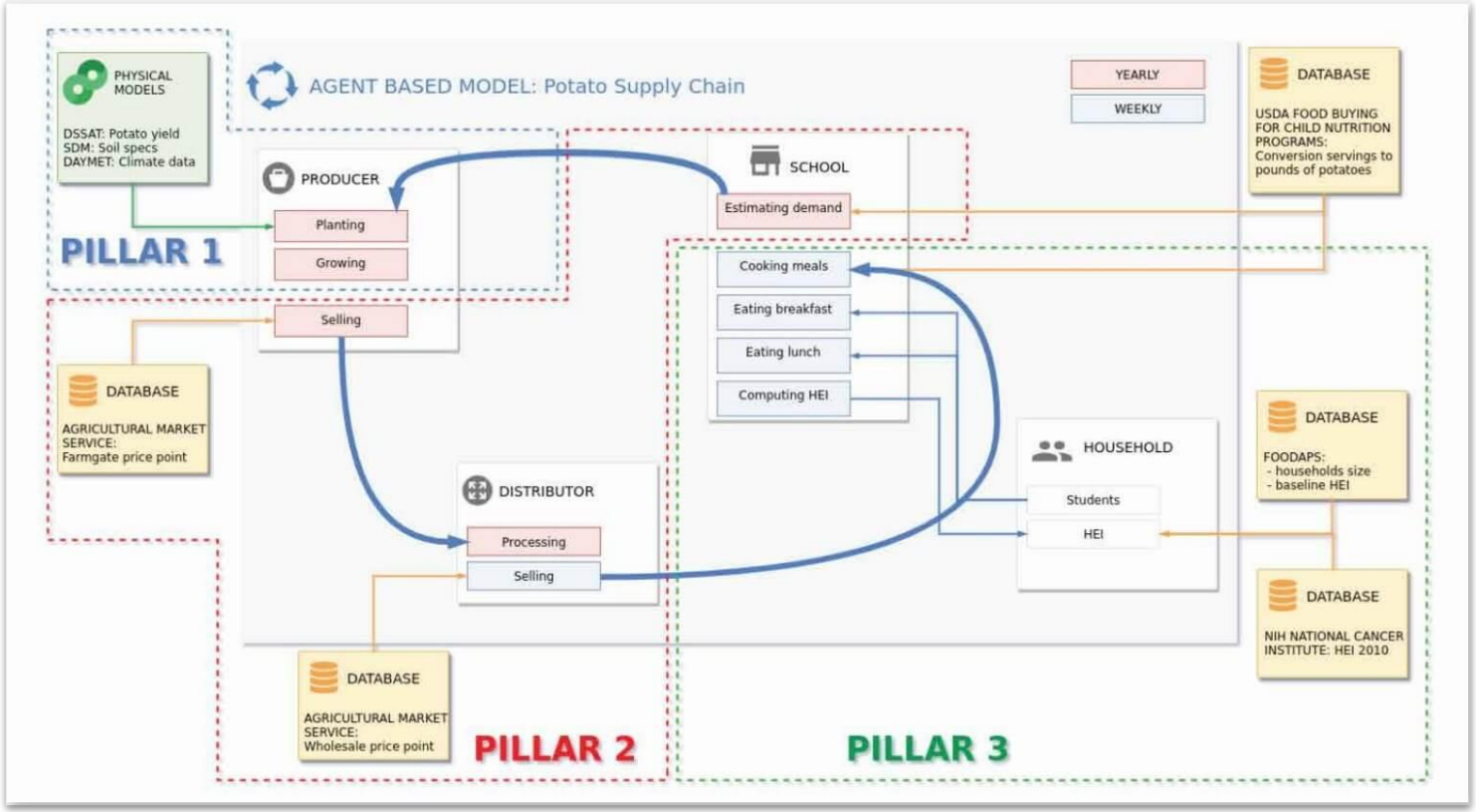
- Agent heterogeneity
- Spatial distribution
- Emergent behavior
- Dynamic, nonlinear behavior
- Combining features of SD and SNA



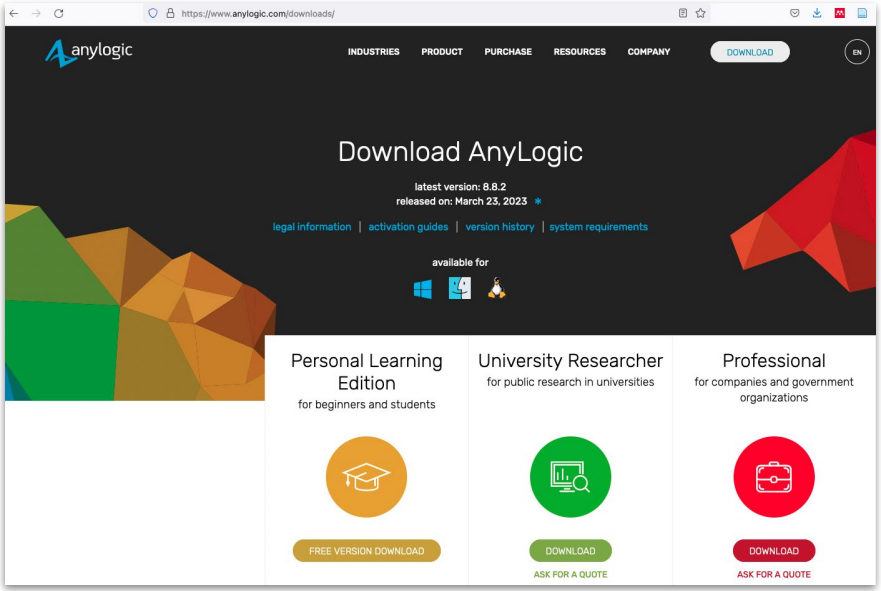
Kremmydas, Dimitrios. “Agent based modeling for agricultural policy evaluation: A review.” (2012).

ABM - Example from Colorado State University

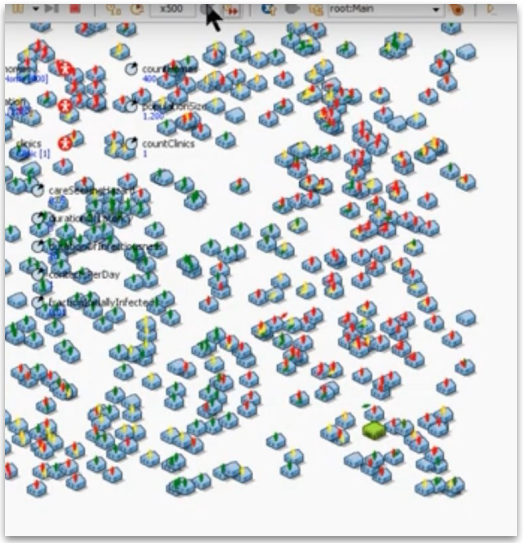
https://foodsystems.colostate.edu/research-impacts/urban-rural-linkages/models/


PHYSICAL MODELS
DSSAT: Potato yield
SDM: Soil specs
DAYMET: Climate data
AGENT BASED MODEL: Potato Supply Chain
YEARLY
WEEKLY
DATABASE
USDA FOOD BUYING FOR CHILD NUTRITION PROGRAMS: Conversion servings to pounds of potatoes
PRODUCER
Planting
Growing
PILLAR 1
SCHOOL
Estimating demand
Cooking meals
Eating breakfast
Eating lunch
Computing HEI
Selling
DATABASE
AGRICULTURAL MARKET SERVICE: Farmgate price point
HOUSEHOLD
Students
HEI
DATABASE
FOODAPS:
- households size
- baseline HEI
DISTRIBUTOR
Processing
Selling
DATABASE
NIH NATIONAL CANCER INSTITUTE: HEI 2010
DATABASE
AGRICULTURAL MARKET SERVICE: Wholesale price point
PILLAR 2
PILLAR 3

Agent-Based Modeling - Brief Tutorial



Example adapted from: Nathaniel Osgood's Care Seeking Hybrid Model v1



https://www.youtube.com/watch?v=3WtCxuXncC4&list=PLcAxwev2PmV8979npzBJLGN-iSCa2uH3L&index=3

Resources

Free AnyLogic PLE download - https://www.anylogic.com/downloads/personal-learning-edition-download/

Care seeking model tutorial - https://www.youtube.com/watch?v=3WtCxuXncC4&list=PLcAxwev2PmV8979npzBJLGN-iSCa2uH3L&index=2

AnyLogic in 3 days - https://www.anylogic.com/upload/al-in-3-days/anylogic-in-3-days.pdf

https://thesystemsthinker.com/

https://systemdynamics.org/