

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:

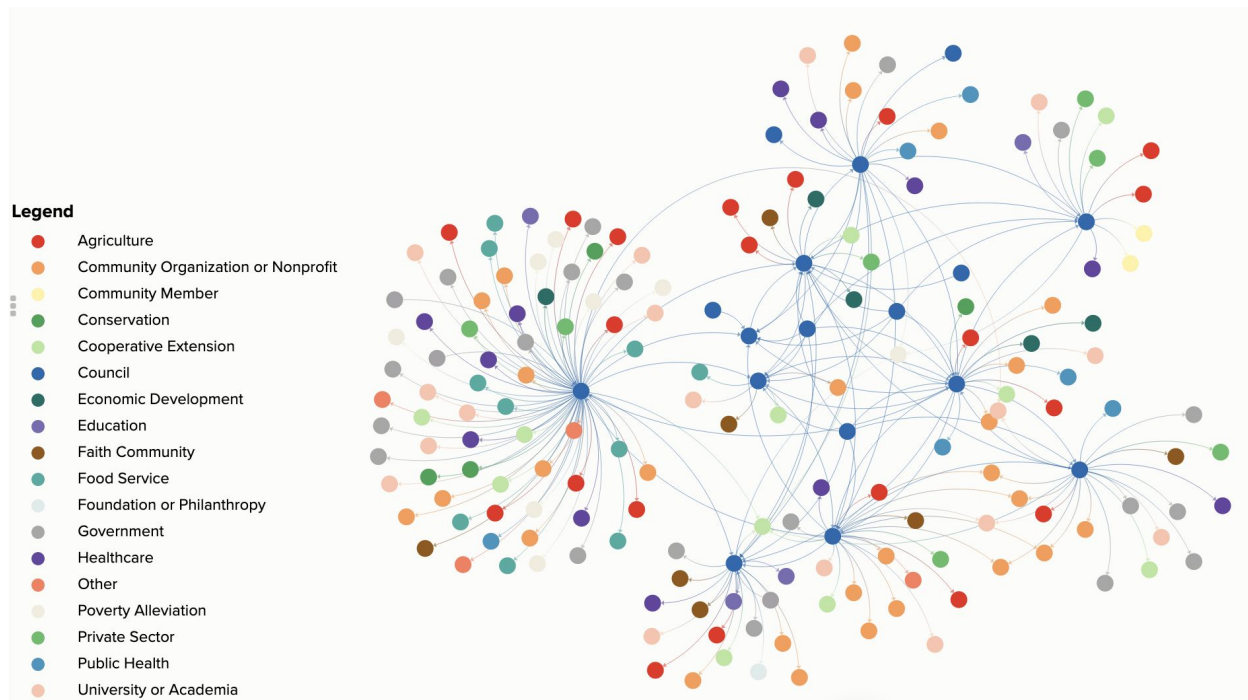
- Visualizing relationships
- Analyzing relationship characteristics
- Informing and studying network interventions

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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

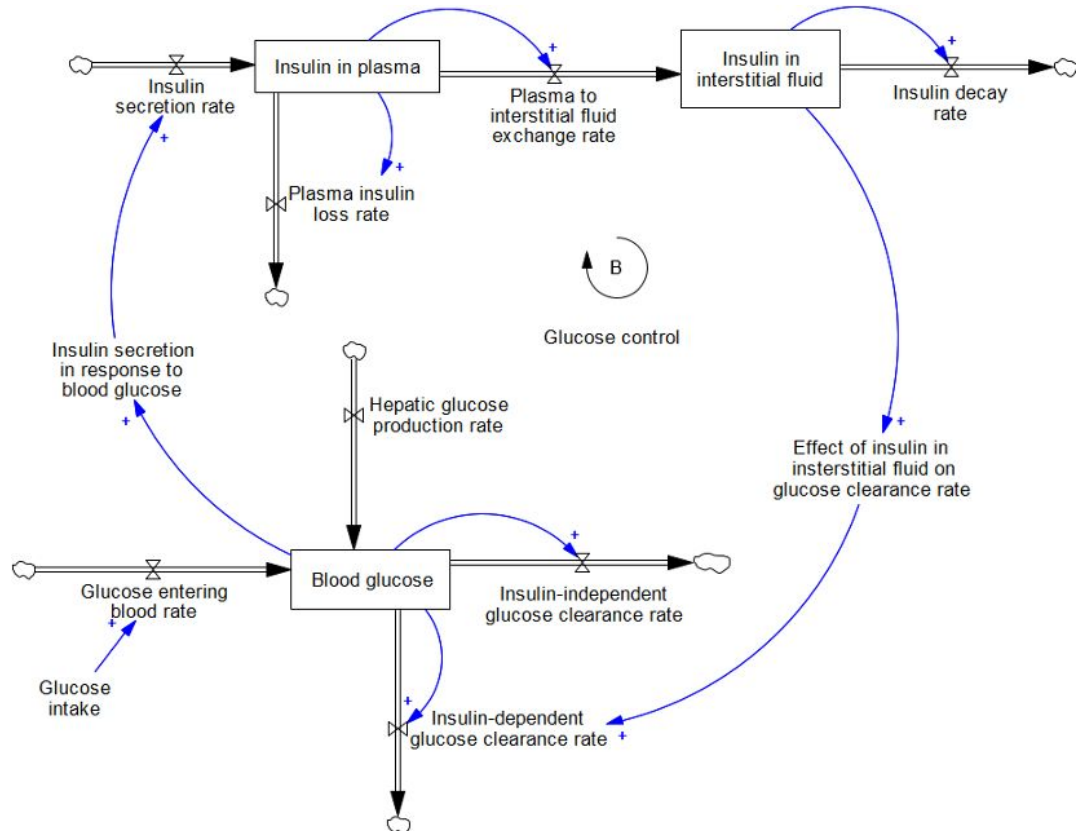
System Dynamics

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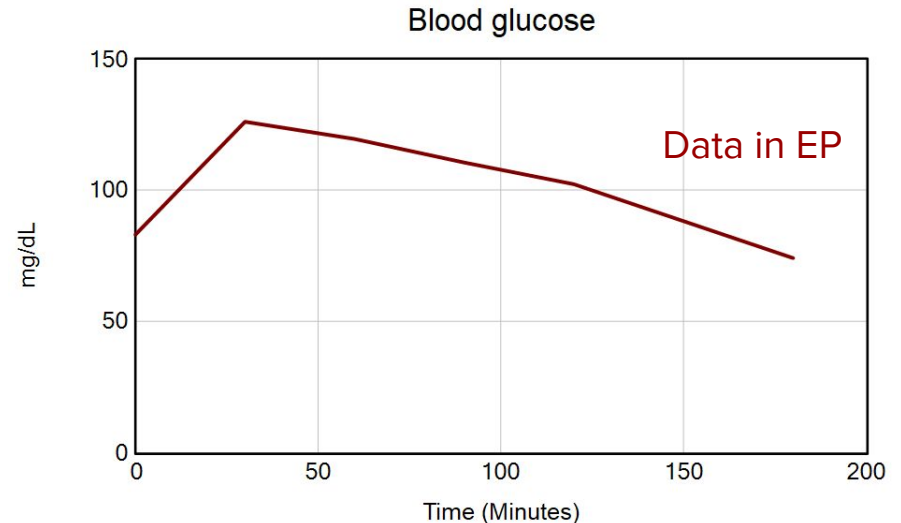
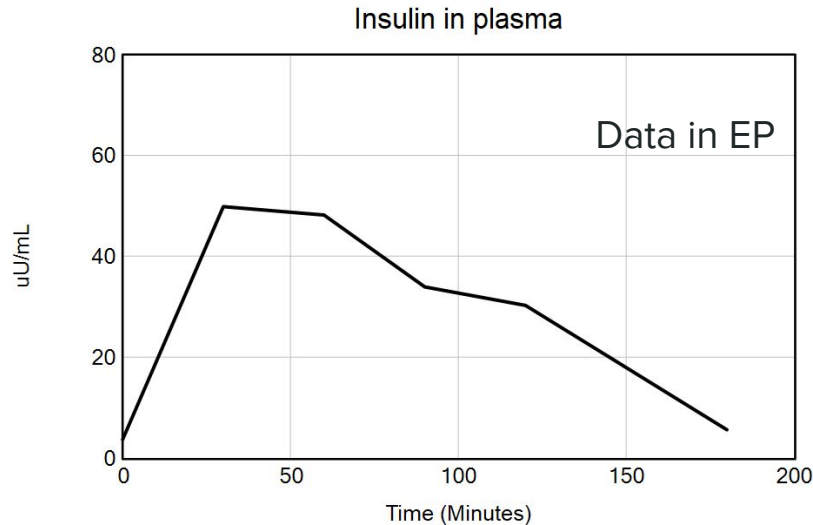
- Nonlinear processes, “feedback”
- Delays and accumulations
- Considering “unintended consequences”
- Engaging stakeholders

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



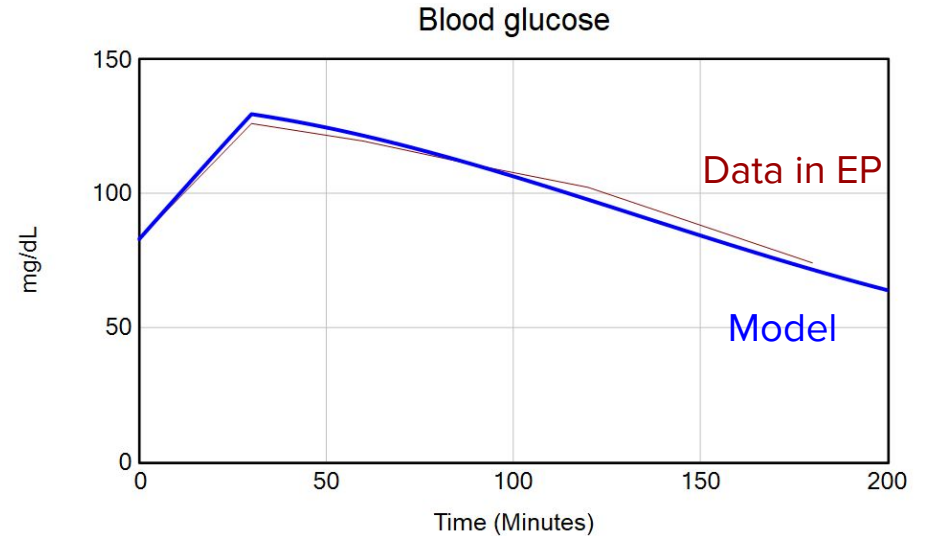
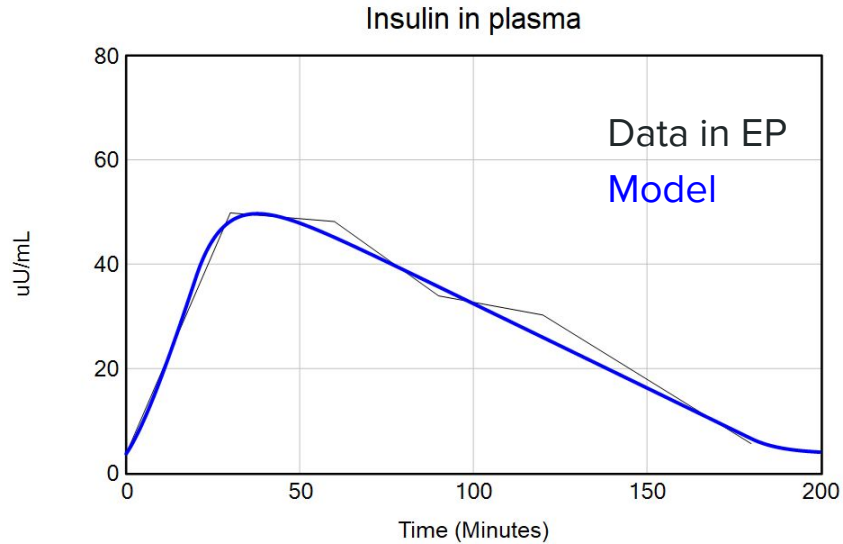
System dynamics simulation modeling - *Preliminary results*

Replicating research data in early pregnancy (EP):



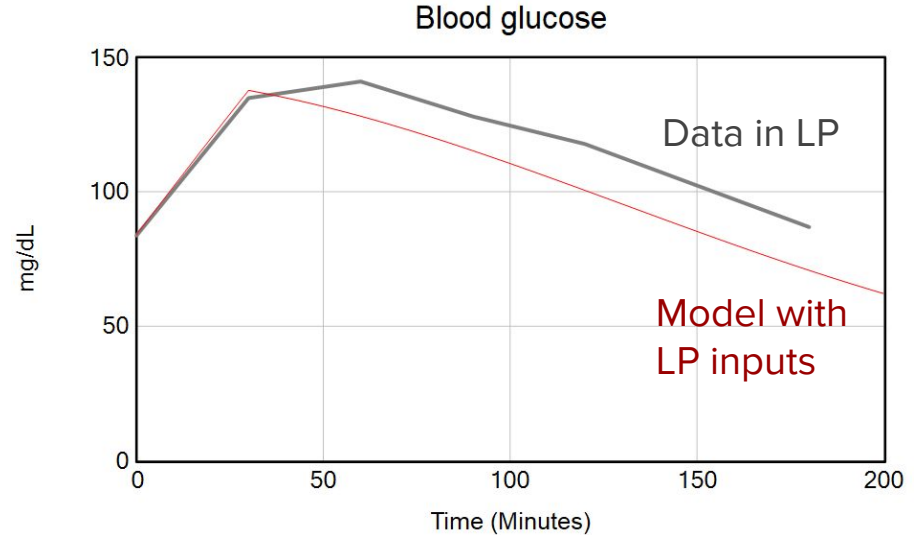
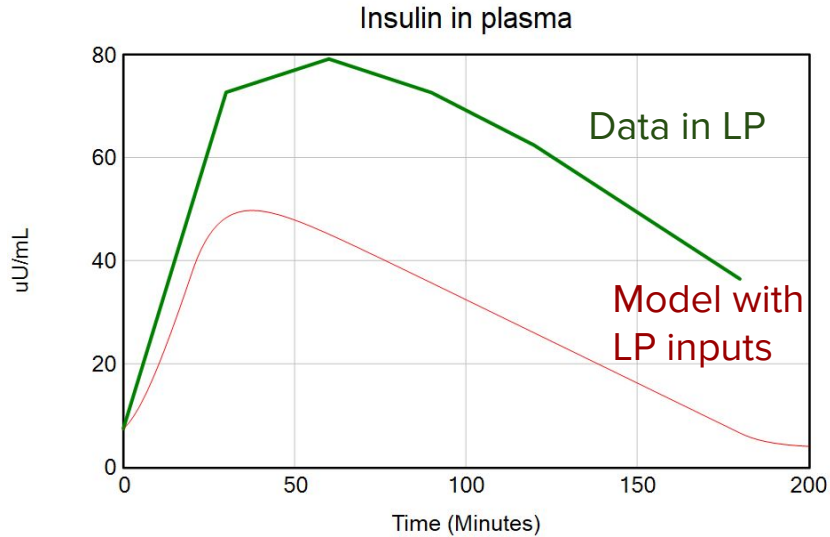
System dynamics simulation modeling - *Preliminary results*

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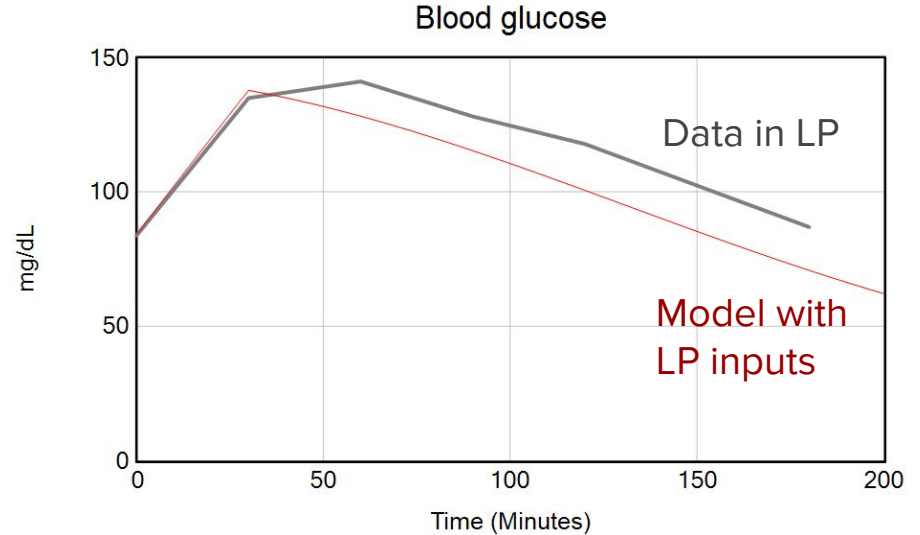
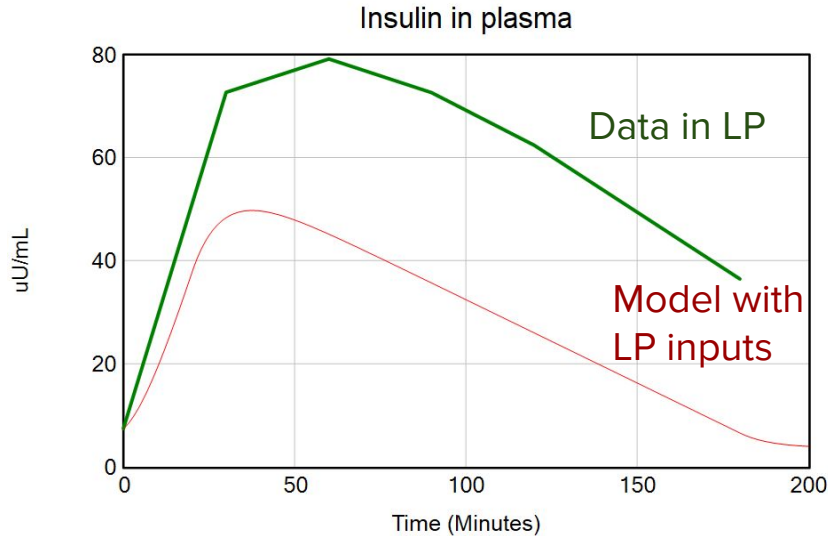
System dynamics simulation modeling - *Preliminary results*

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



System dynamics simulation modeling - *Preliminary results*

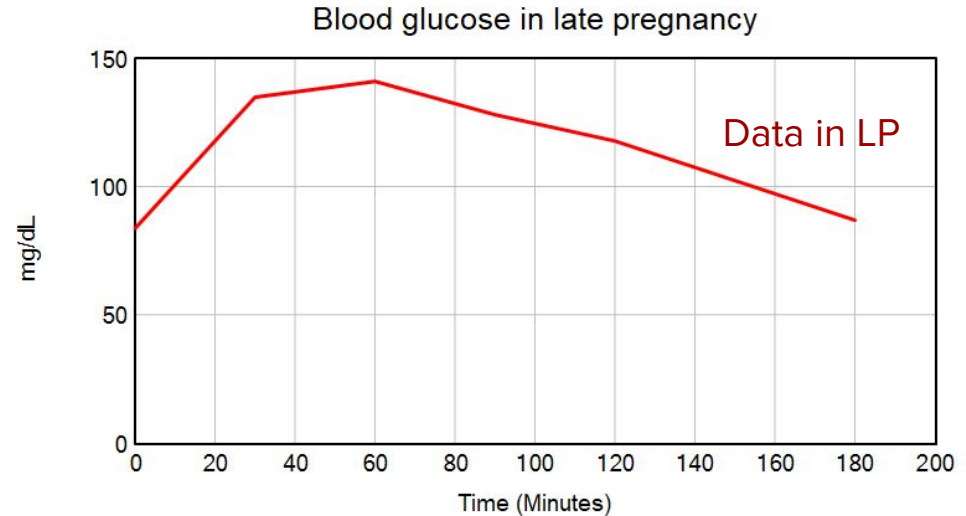
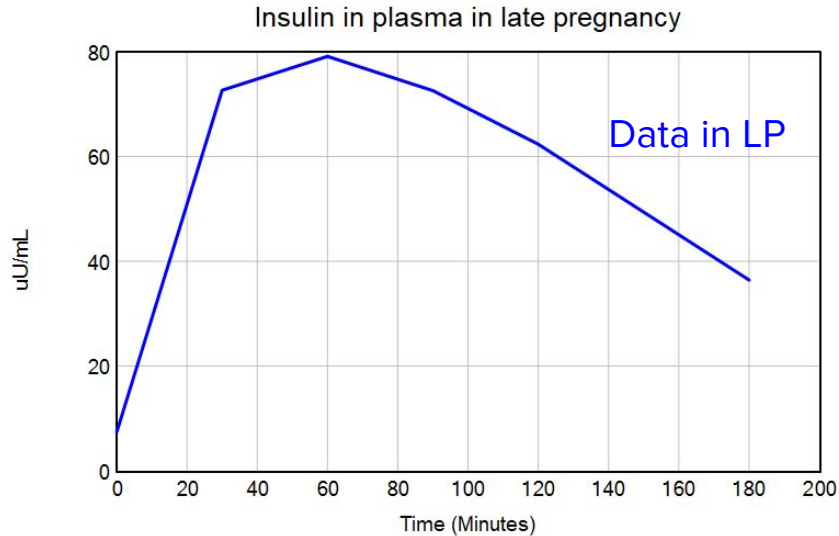
Using model calibrated for early pregnancy (EP) with late pregnancy (LP) data:



Insulin resistance

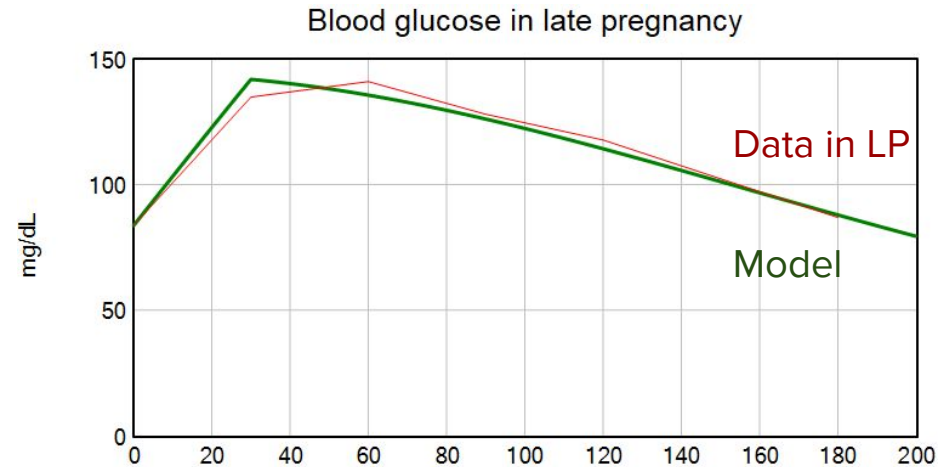
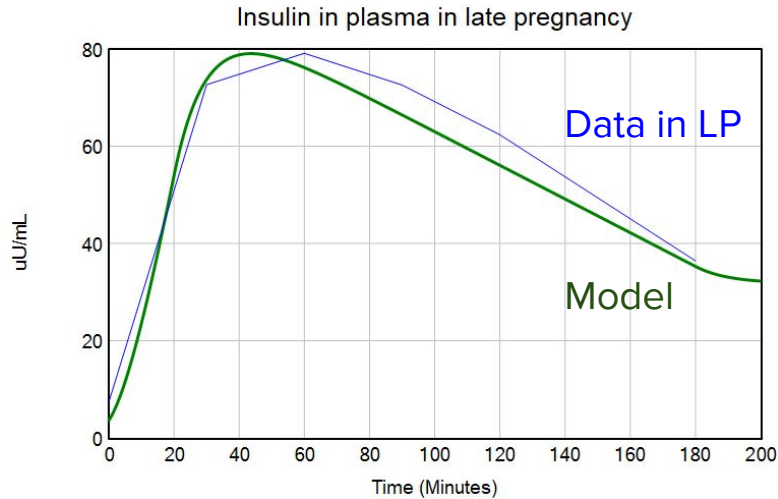
System dynamics simulation modeling - *Preliminary results*

Replicating research data in late pregnancy (LP):



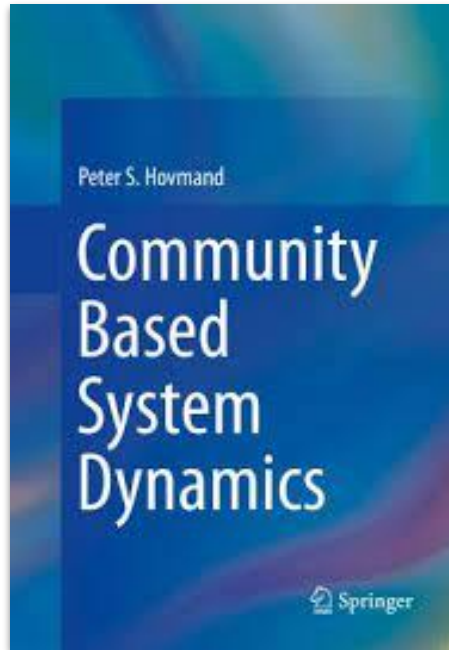
System dynamics simulation modeling - *Preliminary results*

Replicating research data in late pregnancy (LP):



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

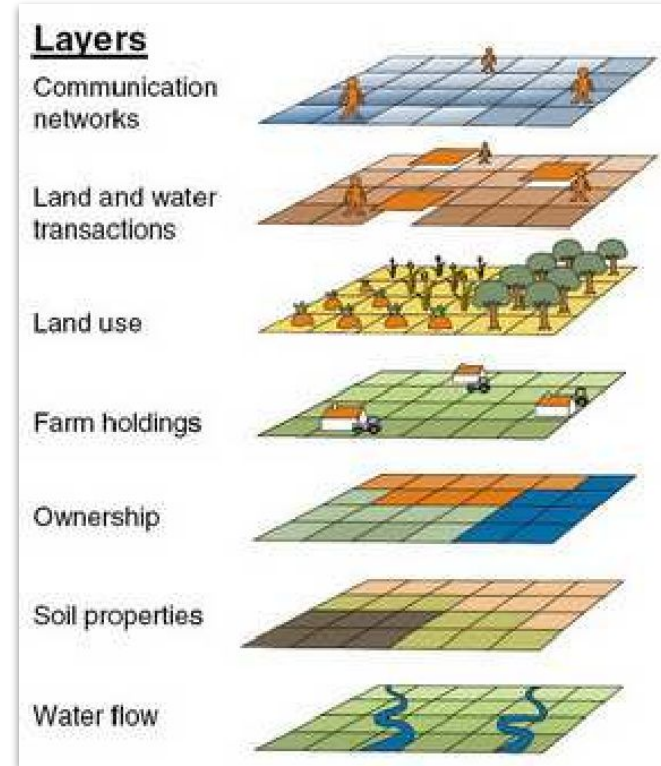


Agent-Based Modeling

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

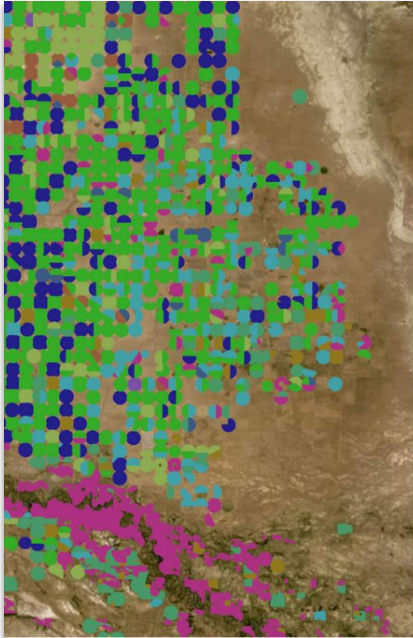
Good for:

- 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



OUR RESEARCH QUESTION

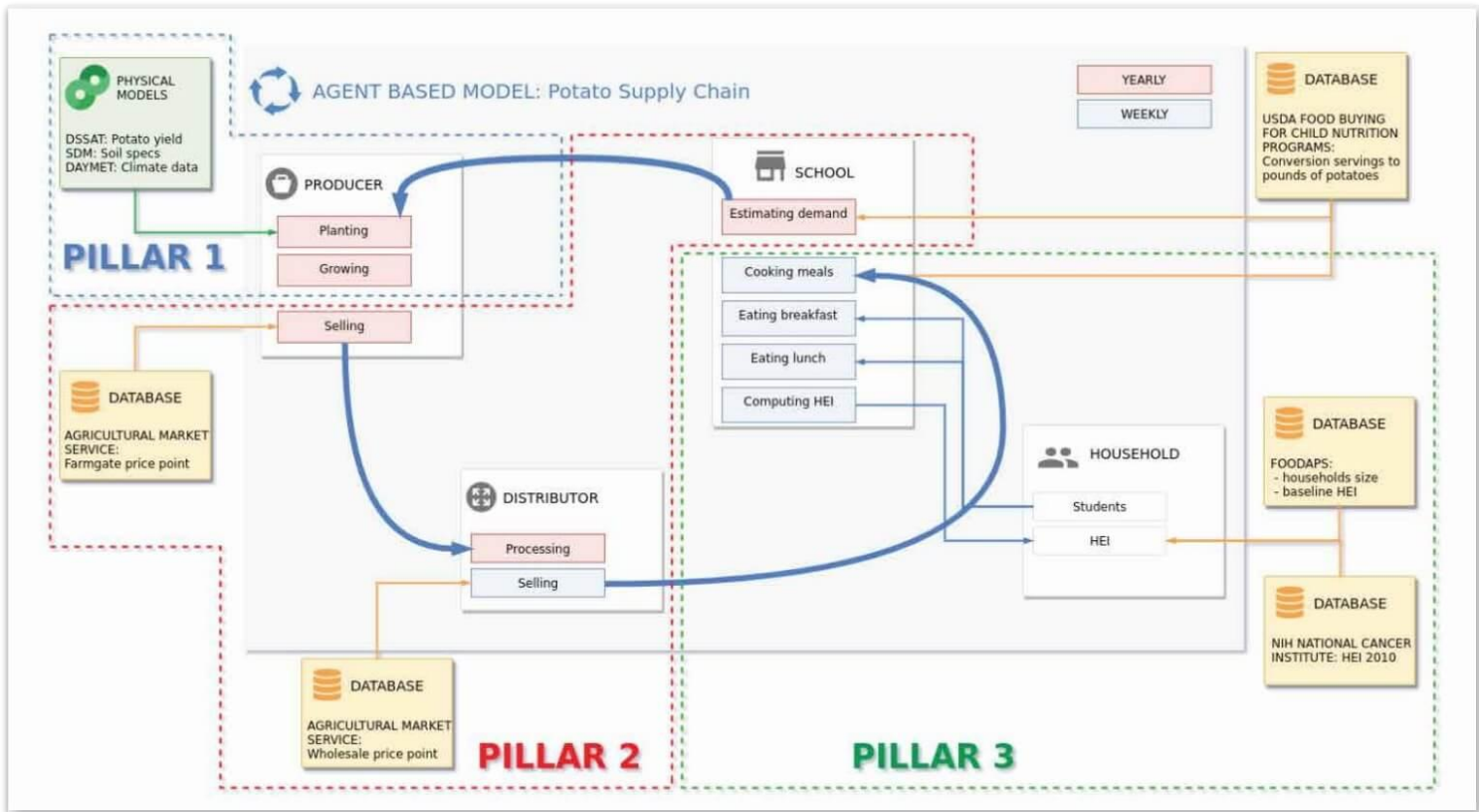
What types of urban food policies, programs, and initiatives support farmers, ranchers, regional communities and economies?

HOW WE ARE ANSWERING:

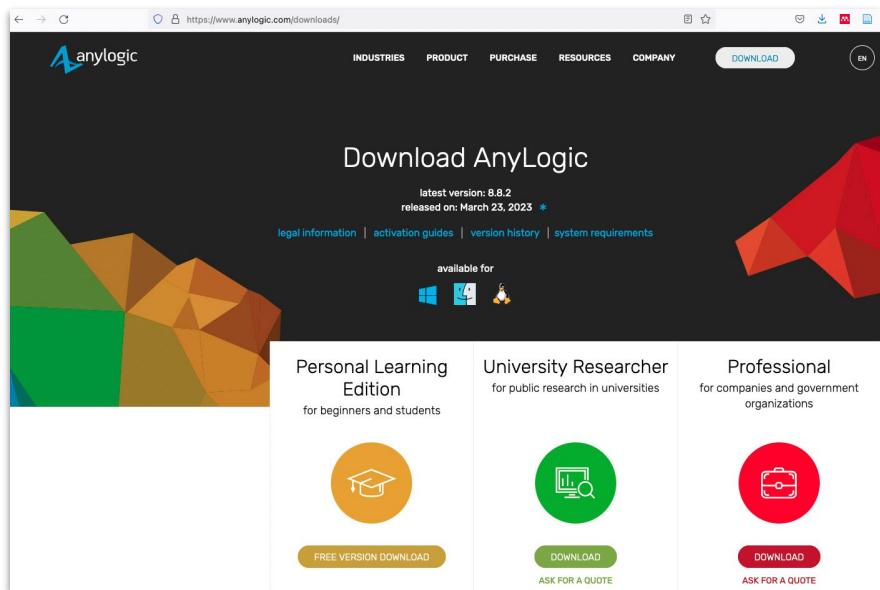
THE AGENT BASED MODEL

Agent-based modeling allows for the simulation of complex systems, and the emergent behavior that may result from the autonomous actions of agents with each other and with their environment. In this case, integrating economic data, social decision making factors, biophysical crop data, and life cycle analysis allows us to model complex rural to urban food chains across several Colorado commodities. In focusing on rural-urban linkages, this model allows us to simulate a variety of potential changes to the Denver food policy environment, and to observe any resulting effects or feedbacks throughout various stages of the supply chain, from school purchasing decisions to potential changes in producer planting regimes, which may effect environmental outcomes include soil health and CO₂ emissions.

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

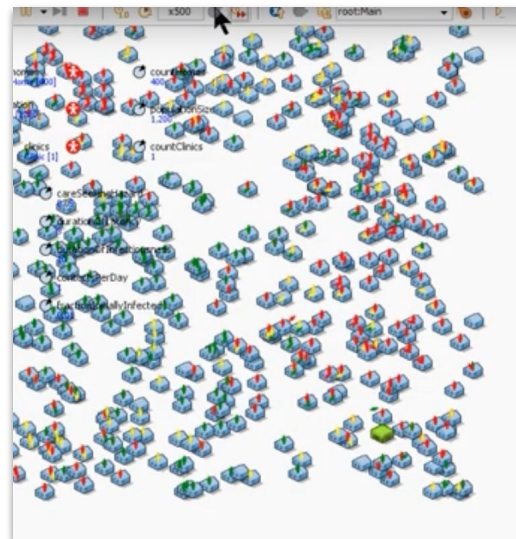


Agent-Based Modeling - Brief Tutorial



The screenshot shows the AnyLogic website's download page. The header includes the AnyLogic logo and navigation links for Industries, Product, Purchase, Resources, and Company. The main heading is "Download AnyLogic", with the latest version (8.8.2) and release date (March 23, 2023) displayed. Below this, there are links for legal information, activation guides, version history, and system requirements. The page is divided into three columns representing different user types: "Personal Learning Edition" (for beginners and students), "University Researcher" (for public research in universities), and "Professional" (for companies and government organizations). Each column features a distinct icon (graduation cap, magnifying glass, and briefcase respectively) and a call-to-action button: "FREE VERSION DOWNLOAD", "DOWNLOAD" (with "ASK FOR A QUOTE" below it), and "DOWNLOAD" (with "ASK FOR A QUOTE" below it). A large green arrow points upwards from the bottom center towards the "Personal Learning Edition" section.

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



<https://www.youtube.com/watch?v=3WtCxuXncC4&list=PLcAxwv2PmV8979npzBJLGN-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/>