Introduction to Agent-Based Modeling

EES 4760/5760

Agent-Based and Individual-Based Computational Modeling

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Class #1: Thursday, August 22 2019

Who Are You?

1. Who are you? (Name, year, major)
2. Computational skills (if any)
   - programming, statistical analysis, …
3. What do you want to get from this class?
4. Ask me a question about computational modeling
5. Something interesting about yourself

Getting Started

For Tuesday:

- Download and install NetLogo on your computer.
  - URL in syllabus and assignment sheet
- Set up Box account
  - Details in syllabus and assignment sheet
  - https://vanderbilt.box.com
  - Make folder for this class with your last name:
    - lastname_EES_4760 or lastname_EES_5760
    - Share it with me as Editor
    - Homework goes in subfolders:
      - HW_1, HW_2, …

Course Web Site

- ees4760.jgilligan.org
  - Syllabus
  - All reading and homework assignments for the semester
  - Slides from class.
  - Files you will need for homework assignments.
  - Links to helpful resources.
- Slides:
  - The title slide has QR code with link to online version.
  - PDF versions are also posted to course web site (link on title slide)
  - Slides have two-dimensional navigation (in a browser, hit "?" for help)

Agent-Based Modeling

- Simulate individuals:
  - Autonomous
  - Heterogeneous
  - Quasi-local
  - Bounded rationality
- Simulate environment
- Emphasize simplicity, minimal assumptions
- **Emergence:** Large-scale phenomena arise from small-scale individual interactions
  - Interesting when large-scale is not easily predicted from small-scale

Simple Experiments

- Play with economics
  - Simple agents trade with each other
  - Confirm 1st welfare theorem:

    Trading leads to Pareto equilibrium
  - Find conditions for satisfying theorem:
    - Not necessary for traders to be completely rational
      - How much rationality do you need?
    - Equilibration can be slow
    - Time-varying preferences can prevent equilibration
- Dynamics of agent-based models connect to nonlinear dynamics and chaos

Economics of Cooperation
Game Theory

- Prisoner's Dilemma Game:

A \ B	B Cooperates	B Defects
A Cooperates	(3,3)	(0,4)
A Defects	(4,0)	(1,1)

- Nash Equilibrium:
  - No matter what player A does, player B is better off defecting
  - No matter what player B does, player A is better off defecting
  - **End result:** Both players end up worse off than if they had both cooperated.

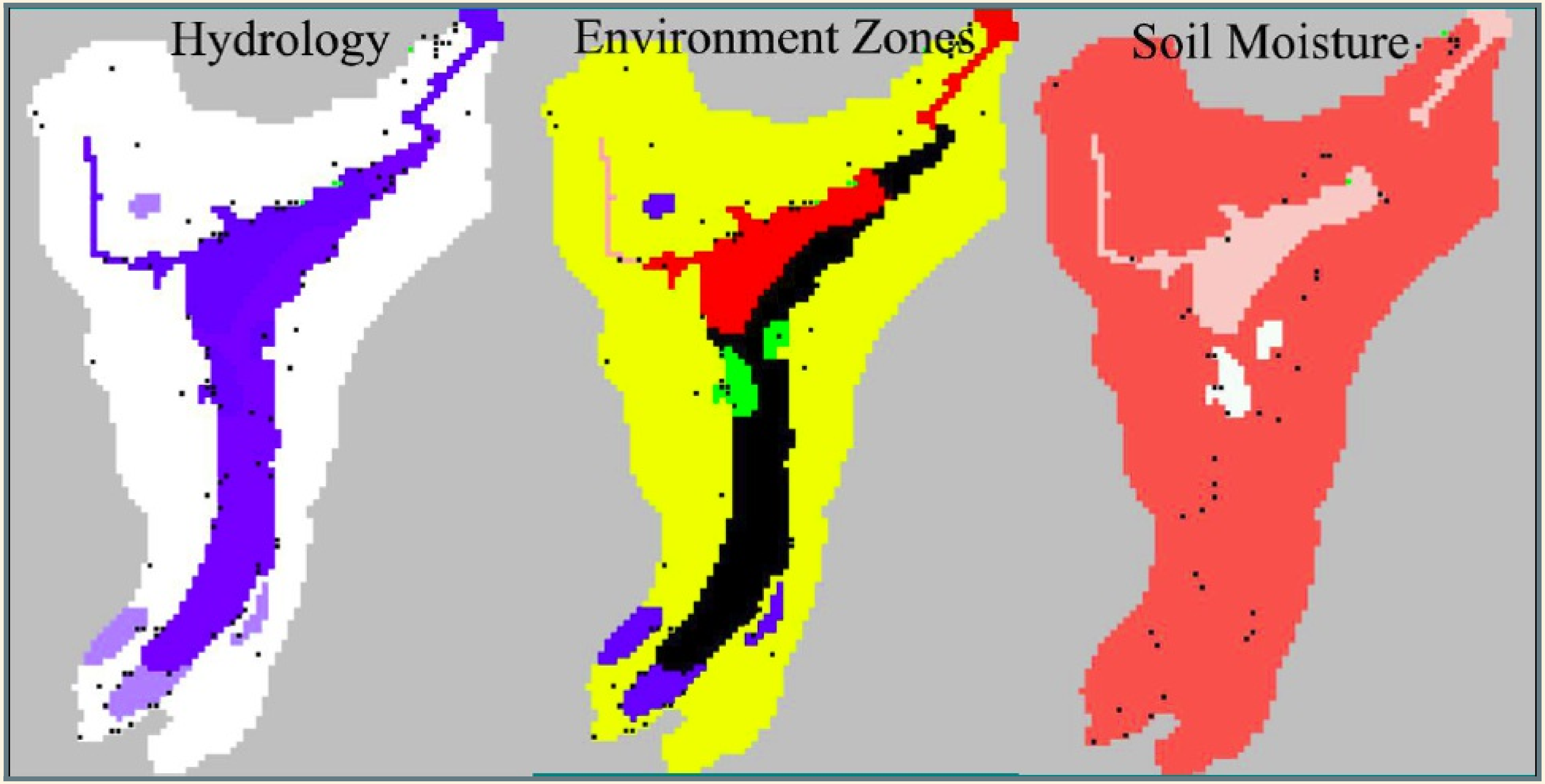
Iterated Prisoner's Dilemma

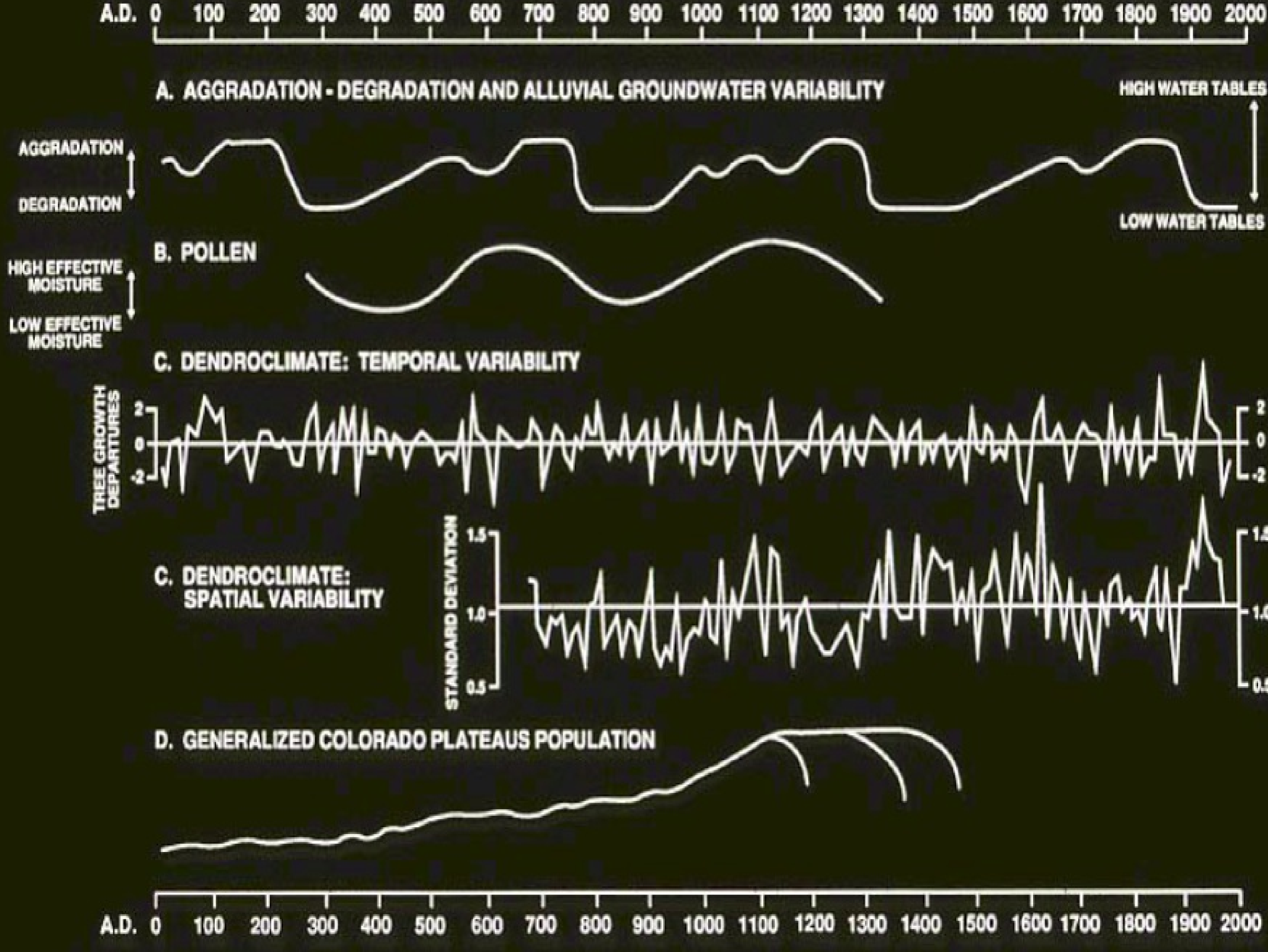
- R. Axelrod (1981)
- Tournament of algorithms
- Winner: "tit-for-tat"
- Evolutionary Game Theory:
  - Basic principles of good strategies:
    - Be nice
    - Be provocable
    - Don't be too envious
    - Don't be too clever
- Nay & Gilligan (2015)
  - Real-world strategies involve randomness, unpredictability

Example: Artificial Anasazi

Axtell, Dean, Epstein, *et al.*

Modeling Environment




A.D. 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
A. AGGRADATION - DEGRADATION AND ALLUVIAL GROUNDWATER VARIABILITY
HIGH WATER TABLES
AGGRADATION
DEGRADATION
LOW WATER TABLES
B. POLLEN
HIGH EFFECTIVE MOISTURE
LOW EFFECTIVE MOISTURE
C. DENDROCLIMATE: TEMPORAL VARIABILITY
TREE GROWTH DEPARTURES
2
0
-2
C. DENDROCLIMATE: SPATIAL VARIABILITY
STANDARD DEVIATION
1.5
1.0
0.5
D. GENERALIZED COLORADO PLATEAUS POPULATION
A.D. 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

Constructing model

- Paleoclimate:
  - Assess different kinds of soil
  - Assess tree rings, pollen, etc.
  - Reconstruct drought severity index
- Society:
  - Archaeology gives #, location of households
- Make assumptions about:
  - # people per household,
  - Agriculture,
  - …
- Devise rules for behavior:
  - Marriage, reproduction, migration, …
- Simulate years 800–1300

Results

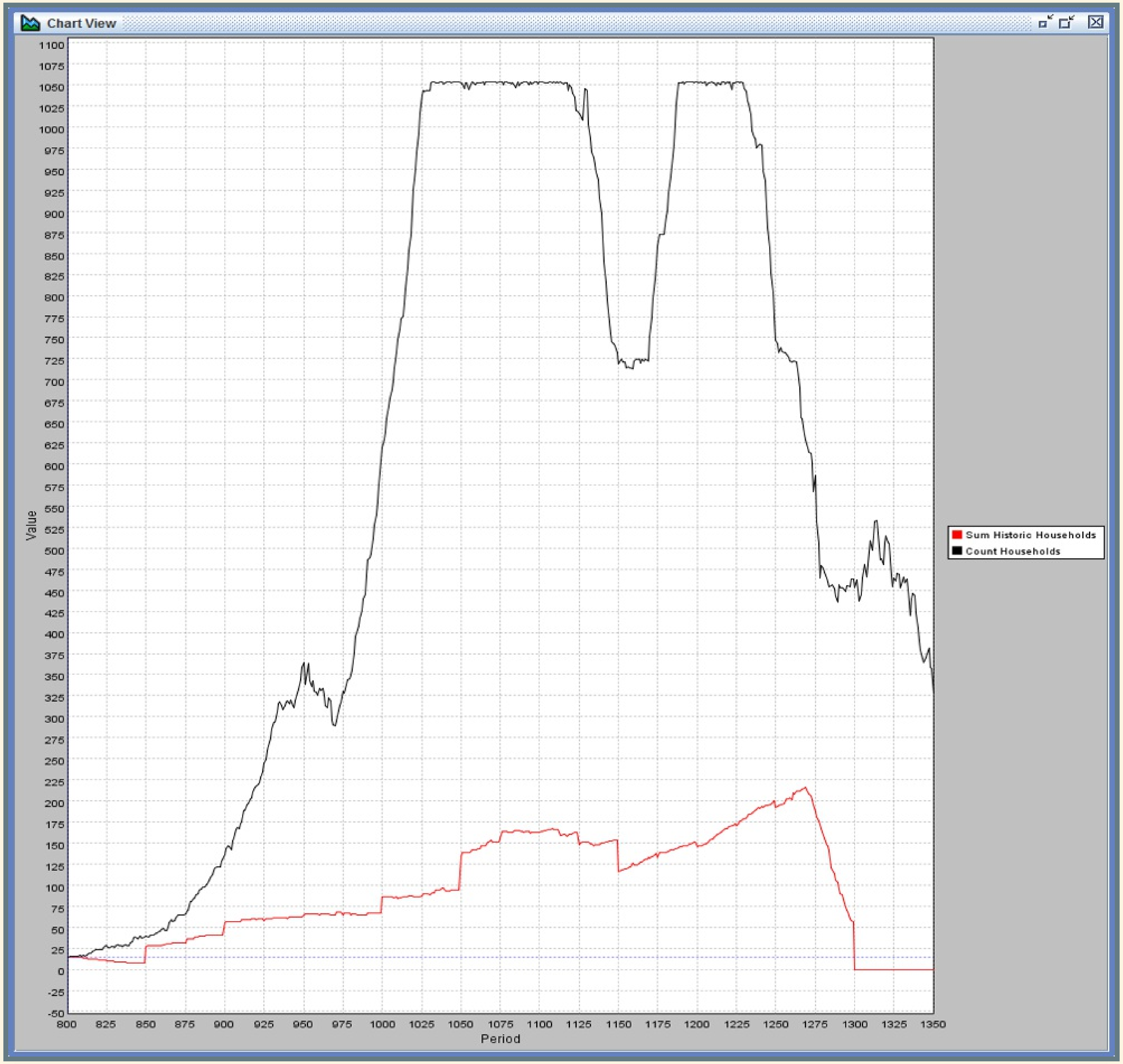
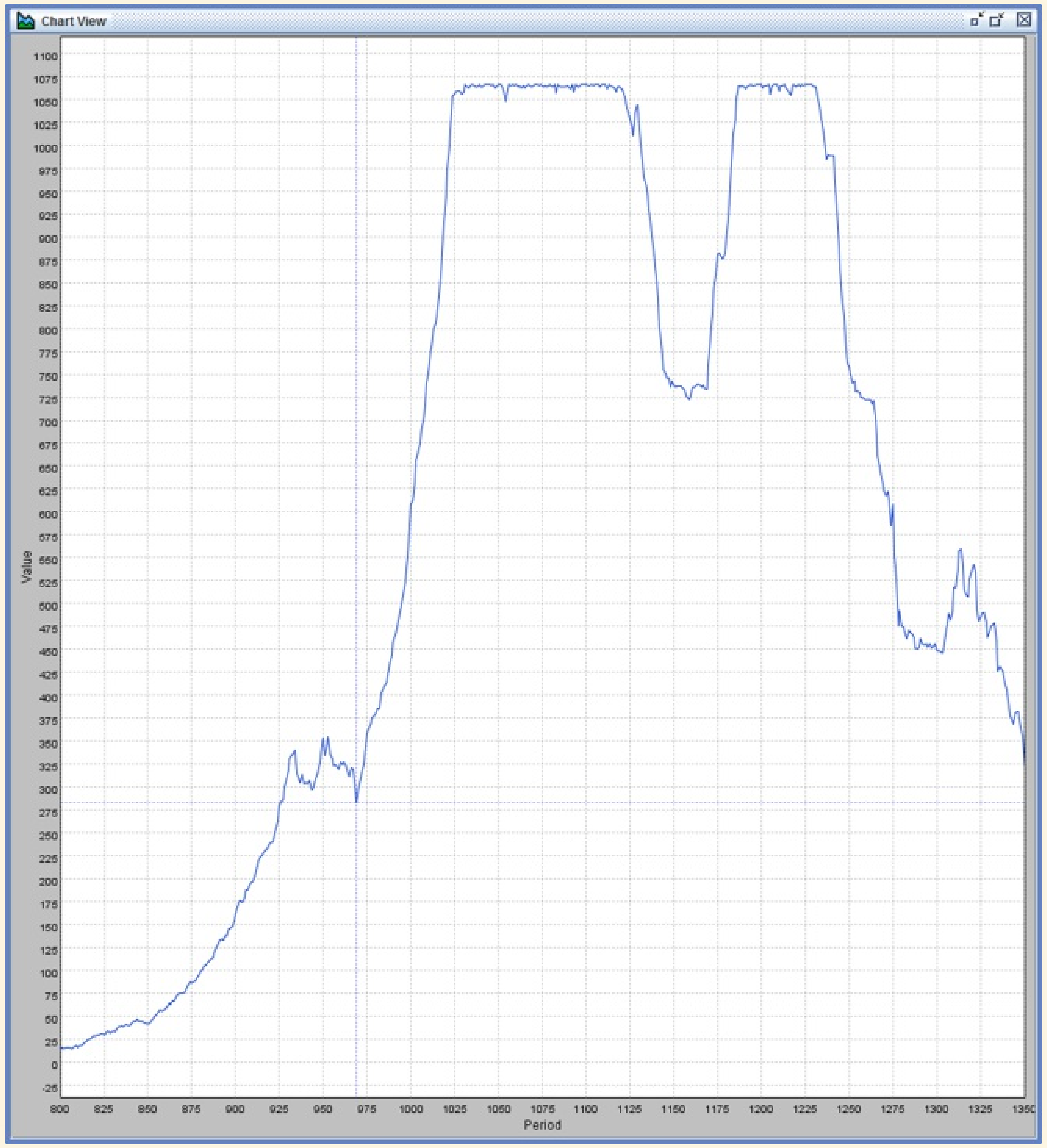


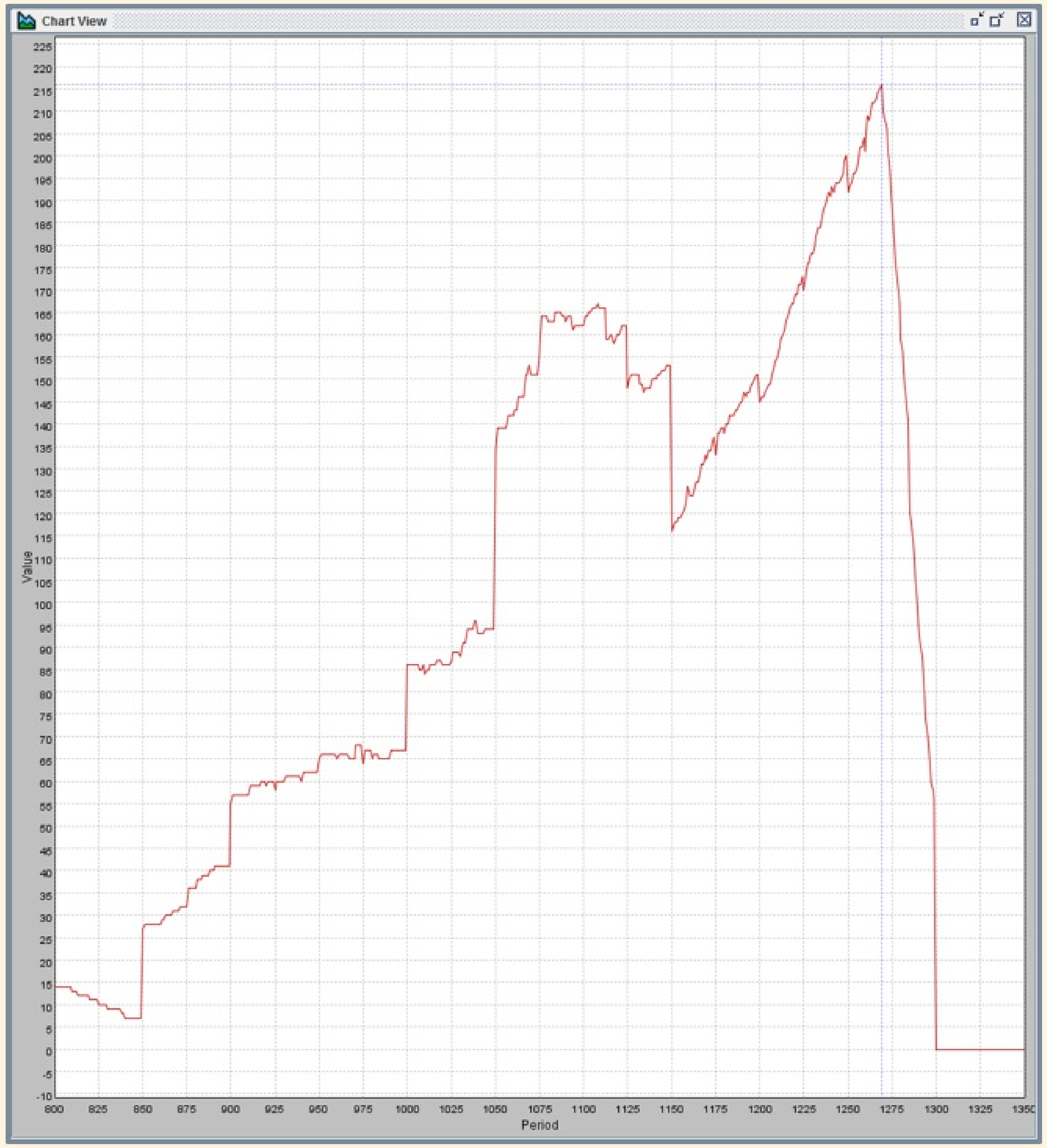
Chart View
Value
Period
Sum Historic Households
Count Households

Comparison

Simulated



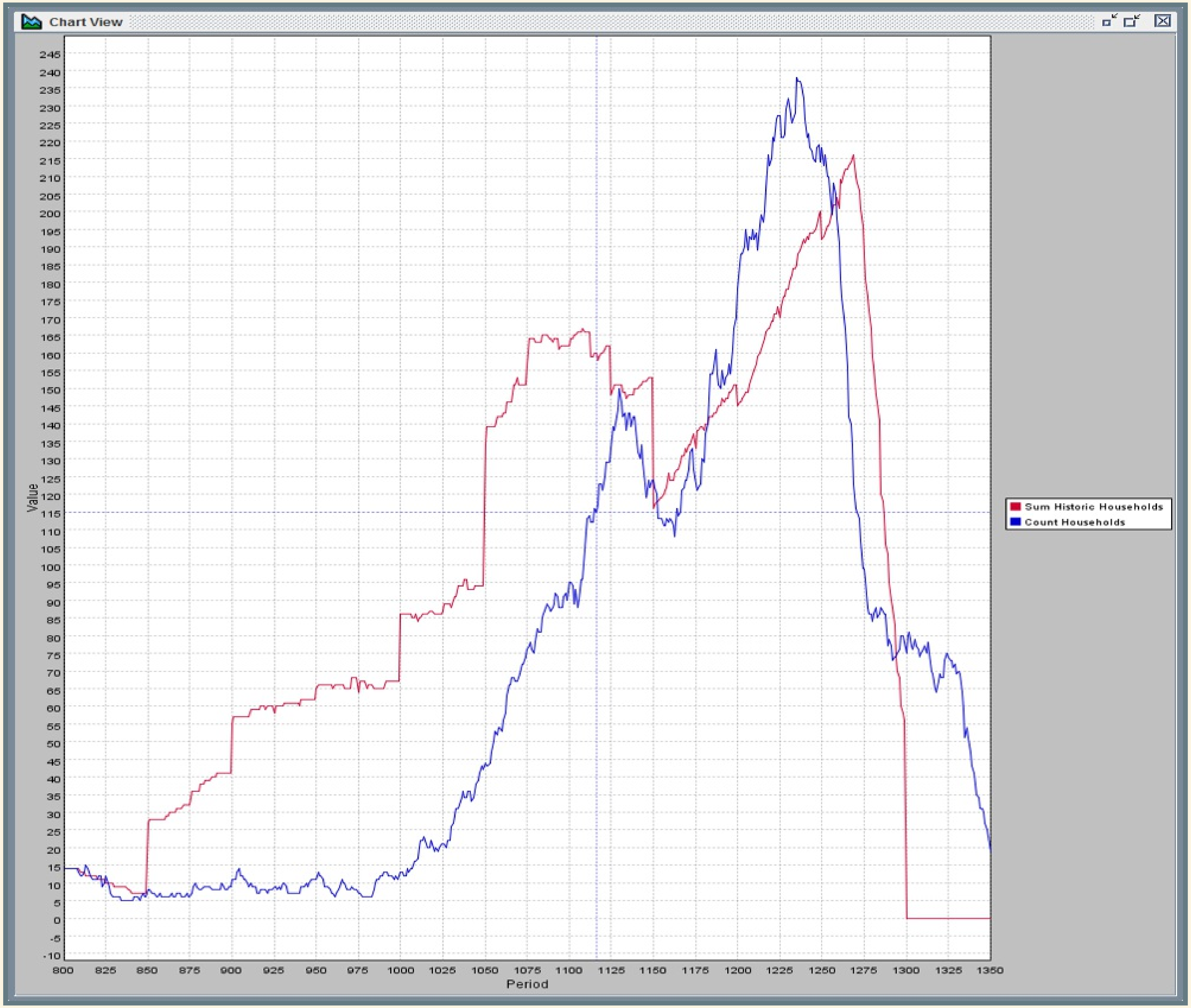
Historical



Improvements

- Make agents heterogeneous
- Fit parameters to historical data

Results



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