Agent-Based Modeling

Slides 1-26 were created and shared with the permission of Dr. Marco Janssen

Slides 26-50 were created by Beth Tellman

Agent-Based Modeling

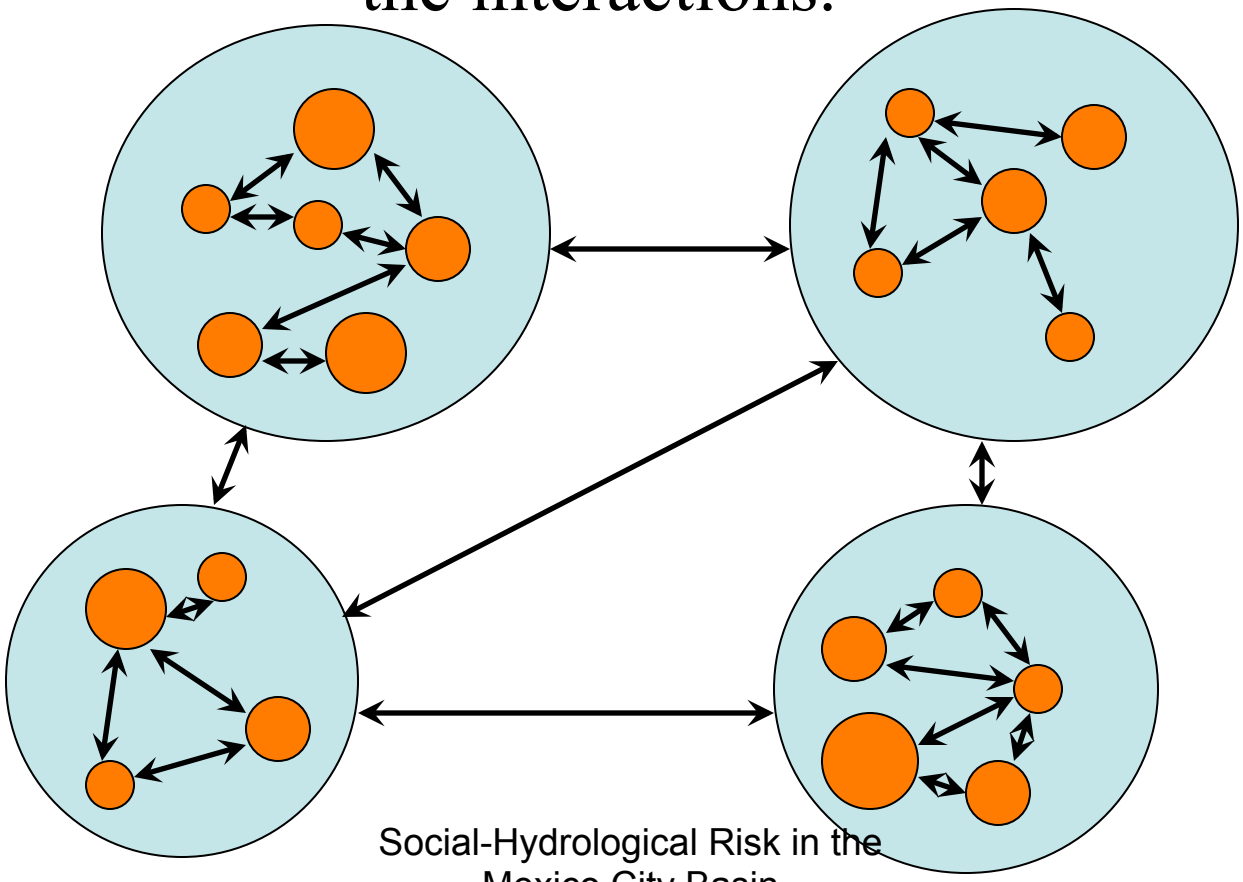
- Using computer simulation to understand macro-level patterns from micro-level behavior:
  - How do traffic jams emerge?
  - Why are some movies a hit and others a flop?
  - Why do financial markets fluctuate?
  - Why does one trust strangers on eBay?
  - How does the structure of social interactions affect disease transmission?

Why Agent-based Models

- Agent-based models are a suitable tool to study in a systematical way complex adaptive systems, in which many local units interact and adapt leading to emergent phenomena at macro-level scale.
- Examples of complex adaptive systems:
  - Ant colonies
  - Immune system
  - Economic system
  - ..

Complex Adaptive System

A heterogeneous collection of individual units that interact locally, and evolve based on the outcomes of the interactions.



Examples of Complex Adaptive Systems

- Ant colonies (SHOW)
- Immune systems
- Economic systems
- Cities
- ..

Emergence

- Local interactions of “agents” leading to macro-level patterns.
  - For example:
    - Path formations in public spaces
    - Stadium “waves”
    - Others?

Example: Balinese water temples

- How are the farmers able to coordinate water supply and control pests?
- Steven Lansing & Kremer's classic study …

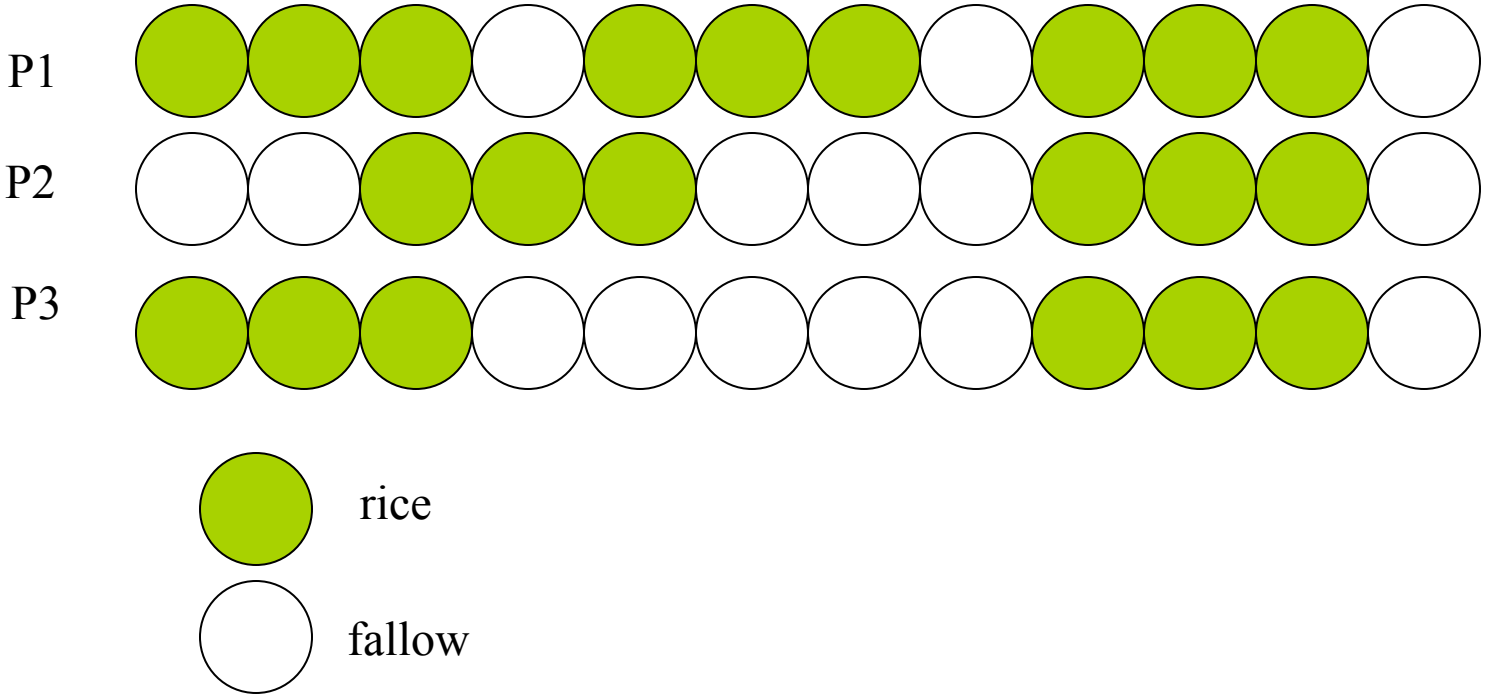
Source: Lansing, J.S. and J.N. Kremer (1993) Emergent Properties of Balinese Water Temple Networks: Coadaptation on a Rugged Fitness Landscape *American Anthropologist* 95 (1) 97-114.

Location of subaks and irrigation systems

- Synchronization of cropping pattern lead to effective control of pests (same variety of rice at the same time. When harvest, field can be burned and flooded to remove pest habitat).
- But when number of subaks is too large it leads to water demand problems.

Source: Lansing, J.S. and J.N. Kremer (1993) Emergent Properties of Balinese Water Temple Networks: Coadaptation on a Rugged Fitness Landscape *American Anthropologist* 95 (1) 97-114.

Cropping pattern



Model of Lansing and Kremer

- Model of the ecosystem dynamics.
- Simple behavioral rule for subaks:
  - As a new year begins, each of the 172 subaks in the model begins to plant rice or vegetables.
  - At the end of the year, each subaks look at its closest neighbors to see whether they got higher yields. If so, the subak copies the cropping pattern of the best neighbor.

Source: Lansing, J.S. and J.N. Kremer (1993) Emergent Properties of Balinese Water Temple Networks: Coadaptation on a Rugged Fitness Landscape *American Anthropologist* 95 (1) 97-114.

Thomas Schelling

- Harvard professor of political economy at the Kennedy School
- Acclaimed scholar of foreign policy, conflict and bargaining theory, military policy, racial segregation
- Still an active scholar in his 80's now at the University of Maryland

Schelling and multi-agent modeling

- Schelling was the first to make a concerted attempt to apply agent-based computer modeling to social science
  - Although he worked during a time when computing power was limited and it was difficult to actually carry out
  - His research came before there was any formal field of complexity

Racial Discrimination in the 1960s

- Schelling became interested in problems of racial discrimination and segregation during the 1960s
- The Civil Rights Movement of the 1950s and 1960s was organized as a formal response to legal segregation in the American south
- While legal segregation was broken-down by the late 1960s, the problem of **de facto segregation** was a serious problem – particularly in northern cities

De Facto Segregation

- While it was possible to use a variety of methods to over-come segregation in law, Civil Rights activists found it much harder to break-down segregation which occurred “as a matter of fact,” without the coercive force of the state behind it
- It was this segregation that Schelling observed in places like Boston

Schelling's experiment

- Schelling began to explore the concept of segregation with a simple experiment of pennies and dimes on a checkers board
  - *What if you randomly put two different types of coin on the squares of a board?*

Schelling model (1)

- The model contains N agents
- There are equal numbers of two types of agent
- The agents are placed at random on squares
- There is a small percentage of empty squares

Schelling model (2)

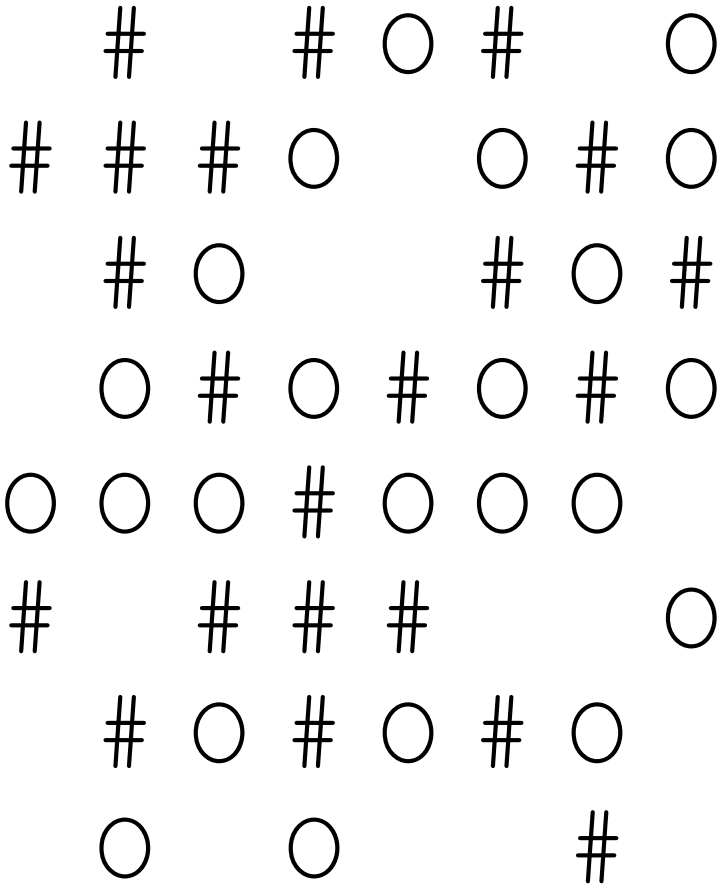
- The 'neighbourhood' of an agent is defined e.g. all 8 squares which surround any given square
- An agent is called at random and decides whether or not to move
- If an agent moves, it moves at random to an empty square

Schelling model (3)

- The agent moves if more than a specified percentage of all agents in its neighbourhood are of a different kind to itself
- The model proceeds to the next step, and an agent is again called at random to decide whether or not to move
- What happens if an agent moves if and only if more than 50 per cent of its neighbours are different i.e will tolerate a 51/49 split?

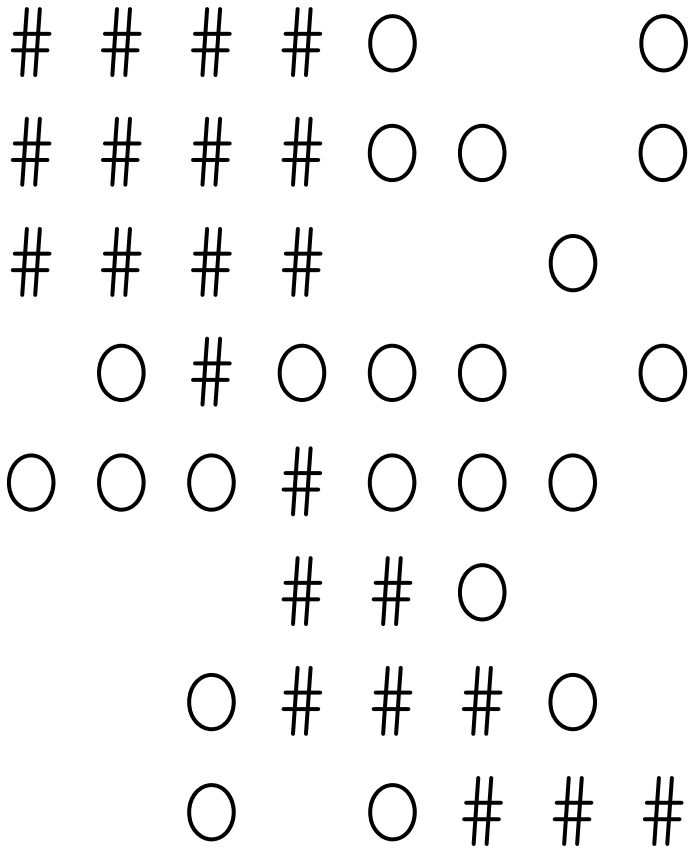
Schelling's Segregation Model

Initial State

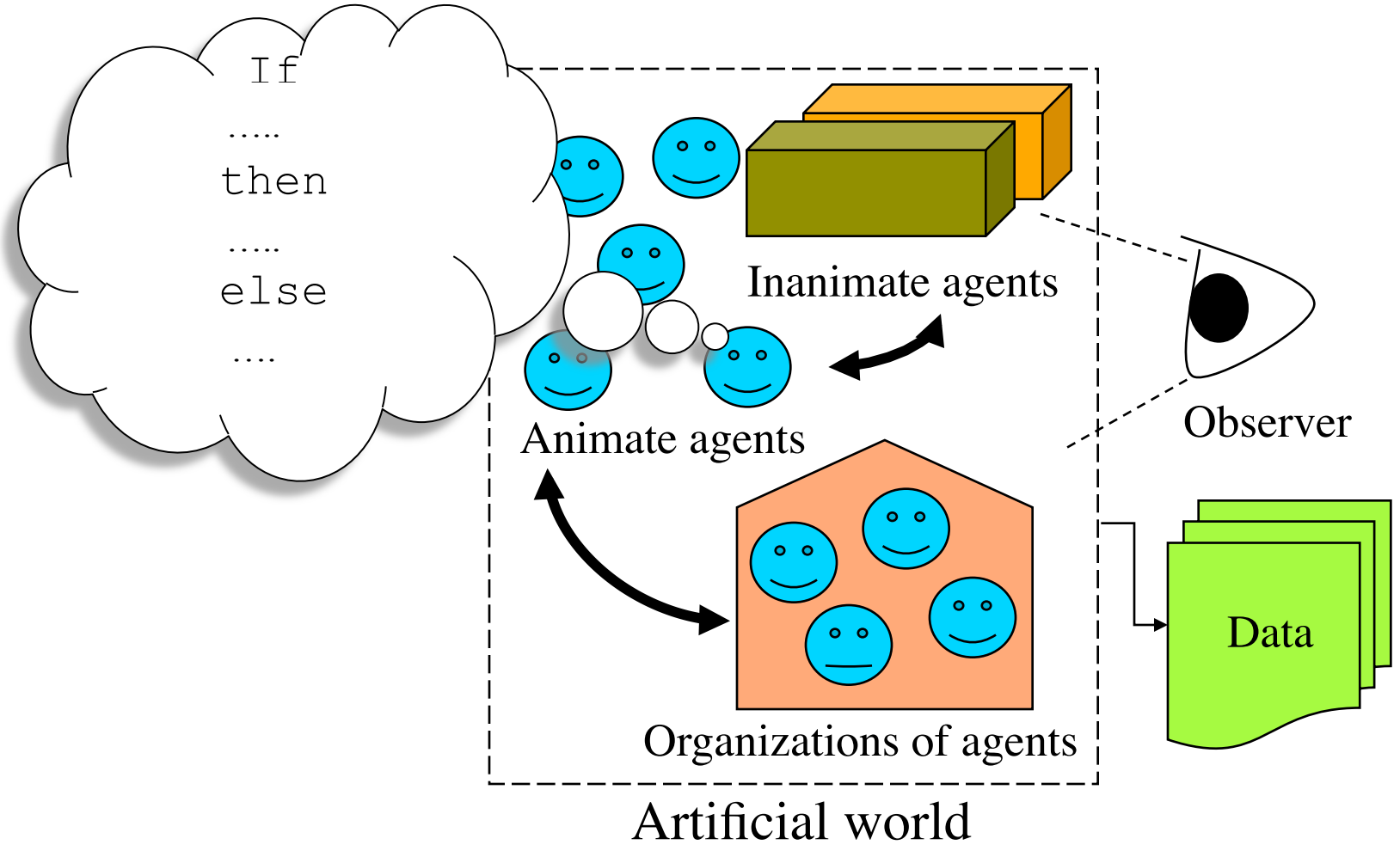


Schelling's Segregation Model

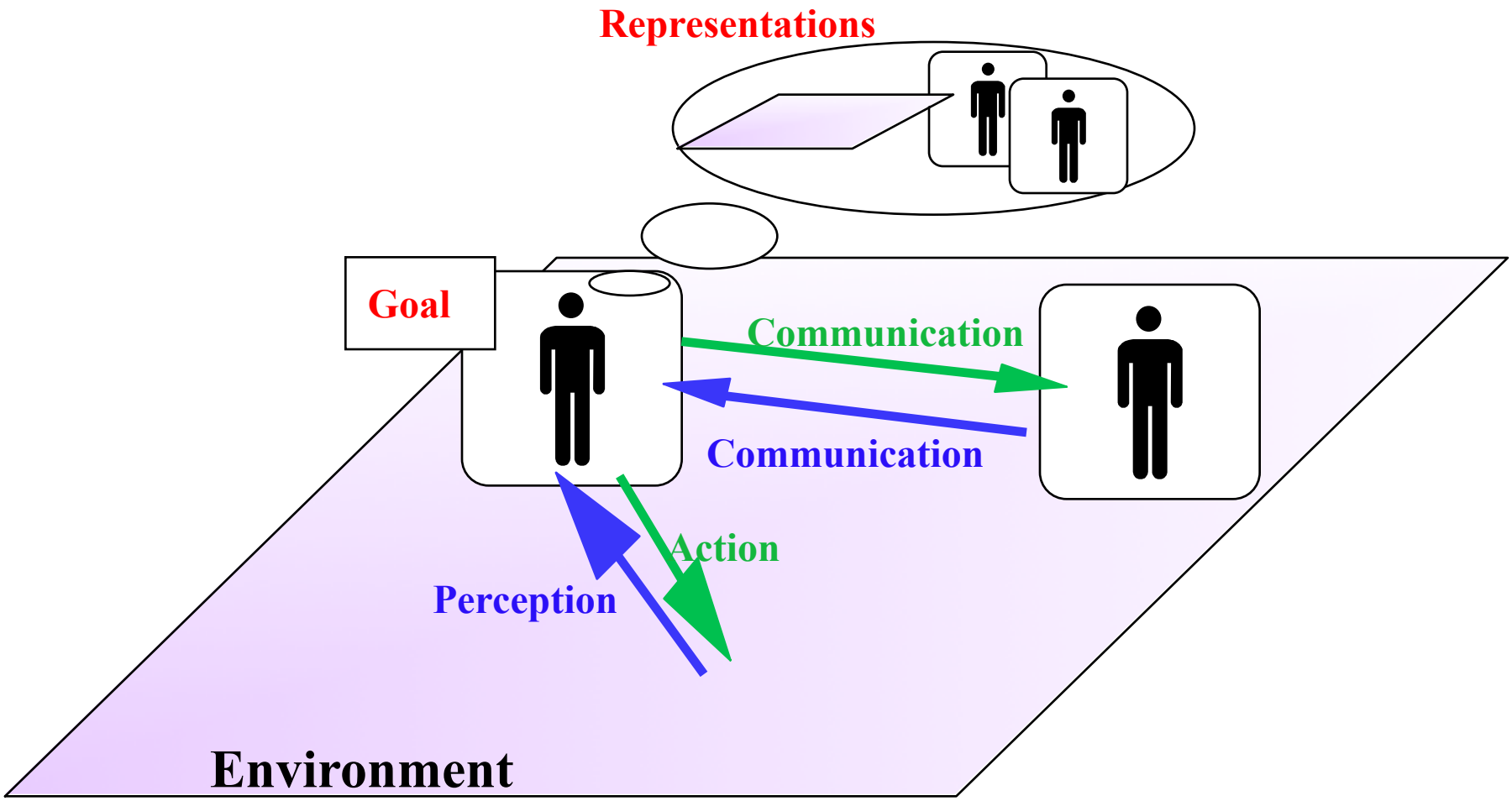
At Equilibrium



Agent-based modeling is a way to study the interactions of large numbers of agents and the macro-level consequences of these interactions.



Agent-based modeling



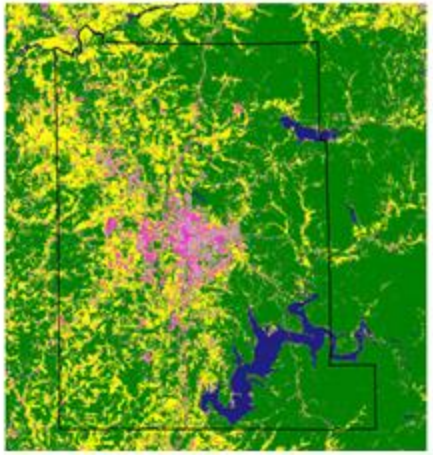
Platforms for ABM

- Many platforms available to model cellular automata and agent-based models
- http://www.openabm.org/site/frameworks
- Ascape 5; Breve; Cormas; DEVSJAVA; Ecolab; Matsim; Mason; MASS; MobiDyc; Net Logo; Repast; Sesam; SOARS; Open Starlogo; Starlogo; Swarm

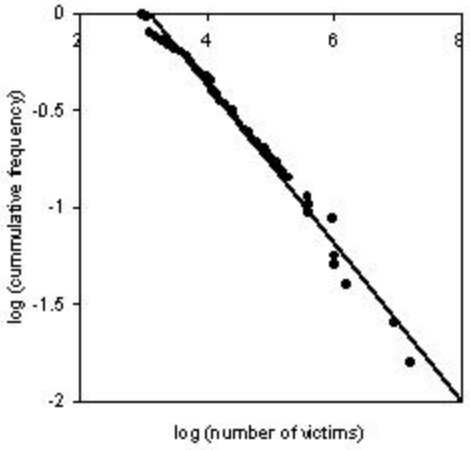
Discussion- Janssen and Ostrom (2006)

Many subjects

Field studies



Stylized facts



Context

Generalization

Role games

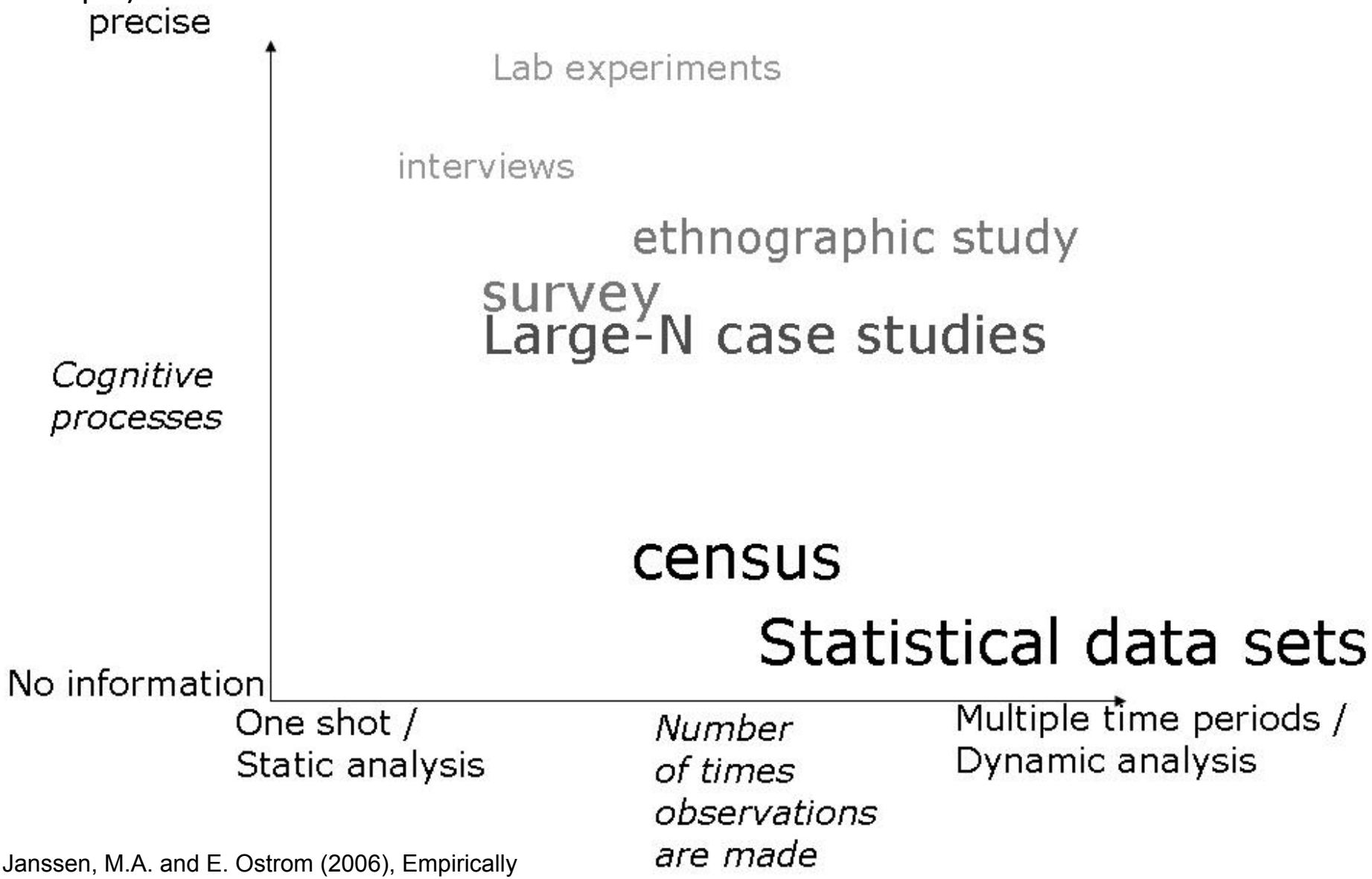
Controlled experiments

Few subjects

Social-Hydrological Risk in the Mexico City Basin

Adapted from Janssen and Ostrom (2006)

How do ABM differ from other social science methods (case studies or large N surveys, for example)?



Janssen, M.A. and E. Ostrom (2006), Empirically based agent-based modelling, Ecology and Society 11(2): 37. [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art37/

What types of social science questions is ABM best used for? Do you know of any examples?

What is the rational actor or *homo economicus* model of human behavior? According to Janssen and Ostrom (2006) why might that not be a good assumption?

What do you think of this statement from Janssen and Ostrom (2006), given what we have already read in this class?

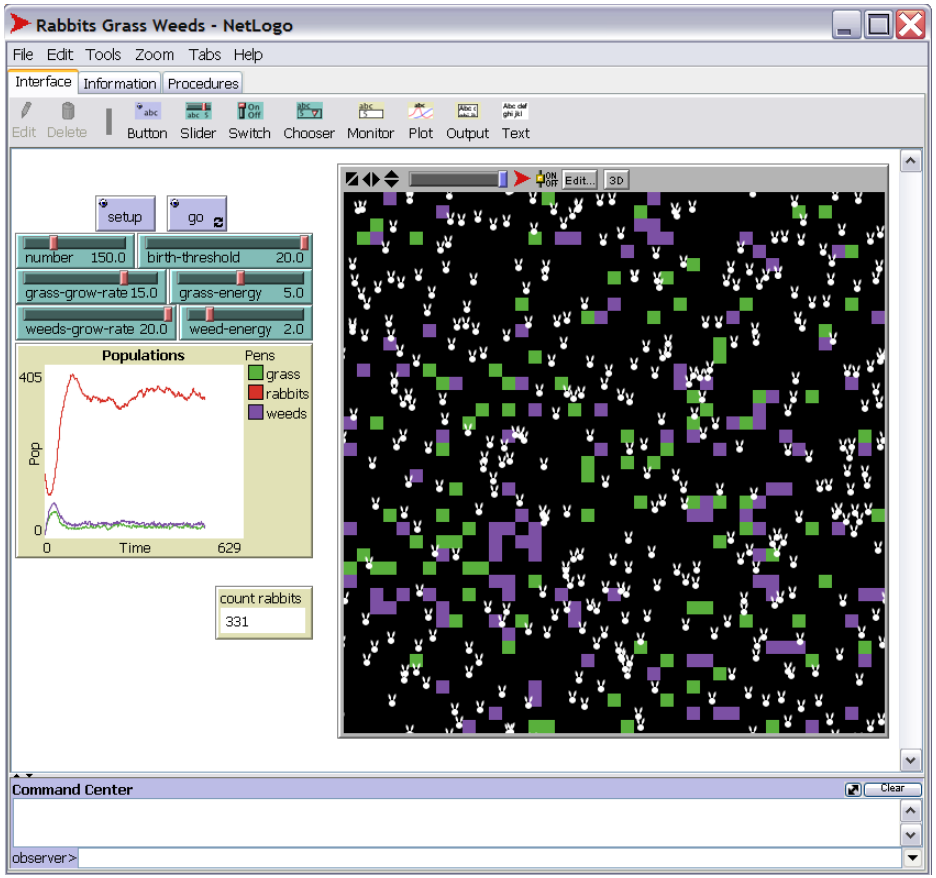
Can social dynamics that matter in resilience, vulnerability, and transformation be meaningfully assessed with ABM?

> *What are meaningful stylized facts to test ABMs in social systems? The various ways empirical techniques are used show the two main challenges: how to develop models that are generalizable and still applicable in specific cases, and how to scale up the processes of interactions of a few agents to interactions among many agents?*

Janssen, M.A. and E. Ostrom (2006), Empirically based agent-based modelling, Ecology and Society 11(2): 37 [online] URL: http://www.ecologyandsociety.org/vol11/iss2/art37/

Netlogo

http://ccl.northwestern.edu/netlogo/



What is NetLogo?
Modeling complex systems

- **programmable modeling environment for simulating natural and social phenomena**
- - well suited for modeling complex systems evolving over time
- - hundreds or thousands of independent agents operating concurrently
- - exploring the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals

What is NetLogo?
Modeling complex systems

- **easy-to-use application development environment**

- - opening simulations and playing with them
- - creating custom models: quickly testing hypotheses about self-organized systems
- - models library: large collection of pre-written simulations in natural and social sciences that can be used and modified
- - simple scripting language
- - user-friendly graphical interface

The world of Netlogo

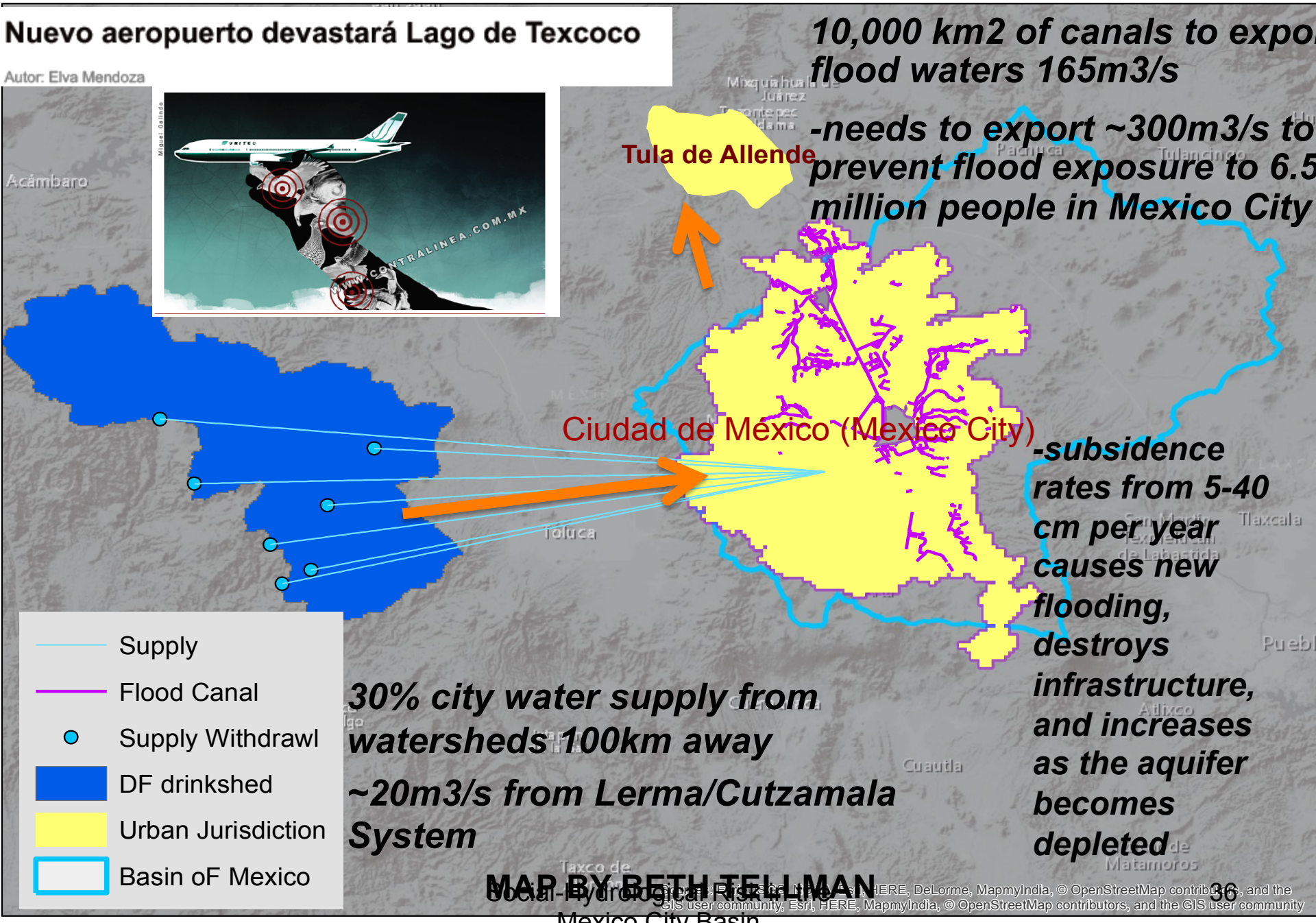
- **NetLogo is a 2-D world made of 4 kinds of agents:**
- - ***patches*** –make up the background or "landscape"
- - ***turtles*** – move around on top of the patches
- - ***links*** – links between turtles
- ***-the observer*** – oversees everything going on in the world

First- Try the Schelling Model

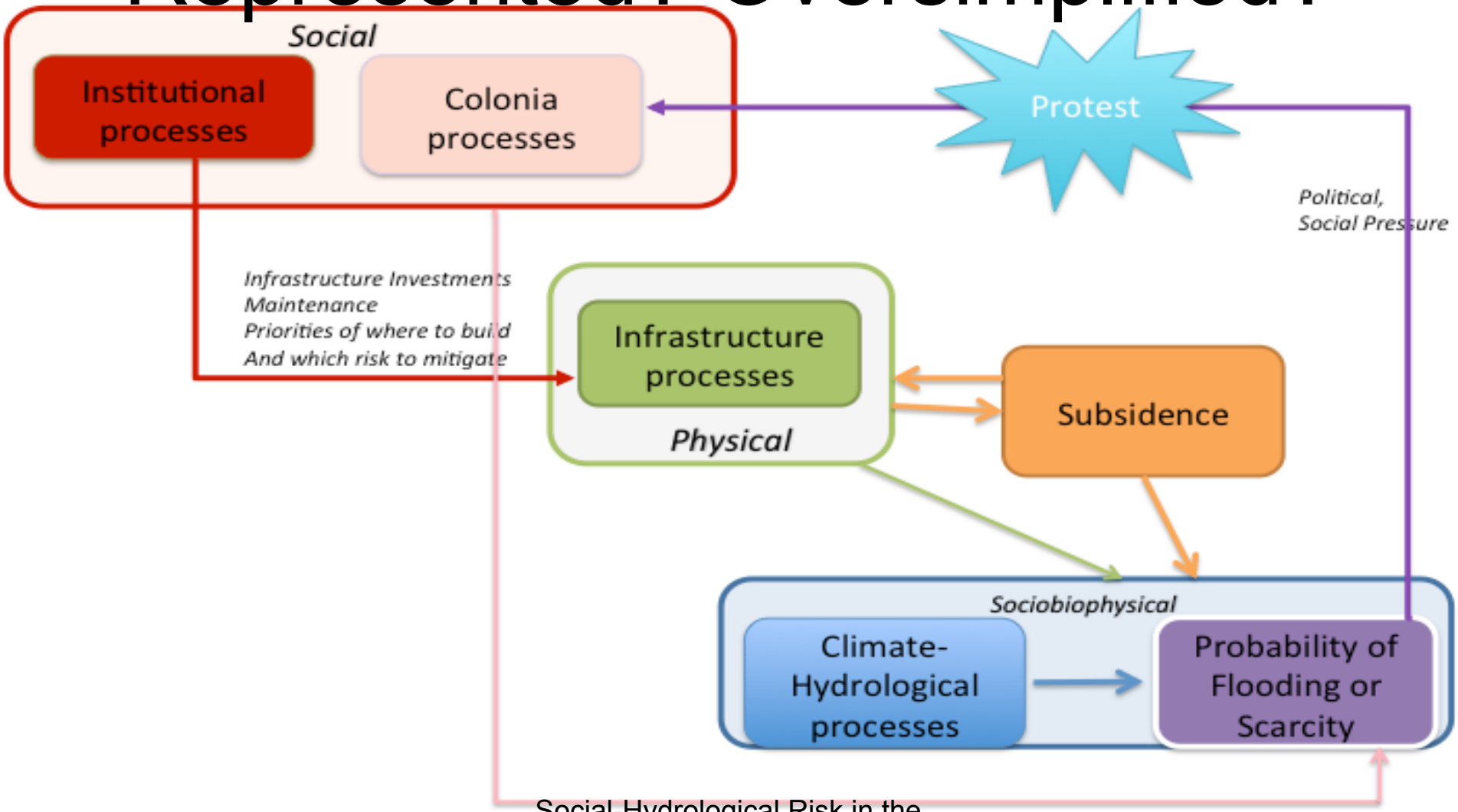
- File-> Model Library-> sample model -> social model ->segregation
- Tour Nlogo
- Press setup and go.
- Slide the similar wanted bar and the number bar to see how it affects outcomes

What does this model do?

MEXICO CITY ABM


Nuevo aeropuerto devastará Lago de Texcoco
Autor: Elva Mendoza
WWW.CONTRALINEA.COM.MX
10,000 km2 of canals to expo
flood waters 165m3/s
-needs to export ~300m3/s to
prevent flood exposure to 6.5
million people in Mexico City
Tula de Allende
Ciudad de México (Mexico City)
-subsidence rates from 5-40 cm per year causes new flooding, destroys infrastructure, and increases as the aquifer becomes depleted
30% city water supply from watersheds 100km away
~20m3/s from Lerma/Cutzamala System
Supply
Flood Canal
Supply Withdrawl
DF drinkshed
Urban Jurisdiction
Basin oF Mexico
Acámbaro
Toluca
Tlaxcala
Cuautla
Taxco de
Social-Hydrological Risk in the
Mexico City Basin
MAP BY BETH TELLMAN
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community
36

What Processes are Represented? Oversimplified?



Social-Hydrological Risk in the Mexico City Basin

Figure by Beth Tellman

Follow Handouts- Lets play!

Variable	Description	Predictions	After 730 ticks	After 5000 ticks or 15 mins
New infra:	count of new infrastructure built			
Pozos:	running count of wells			
Infrastructure:	running count of pipes and wells (report drains and supply only here)			
Median, max, min water:	shows daily water supply per household over time for colonias. (report all three)			
Subsidence:	tracks mean, max, and min subsidence over time (report all three)			
#colonias protesting:	cumulative number of neighborhoods in protest			
# at risk:	number of current colonias protesting for scarcity vs. flood risk. (report maximum number of both)			

Social-Hydrological Risk in the Mexico City Basin

Discuss!

- Do you notice a relationship with the rainfall pattern and the season? How does this influence protest dynamics?
- Were your predictions different from your outcomes? From the outcomes reported on graphs in pages 7-16 of the white paper?

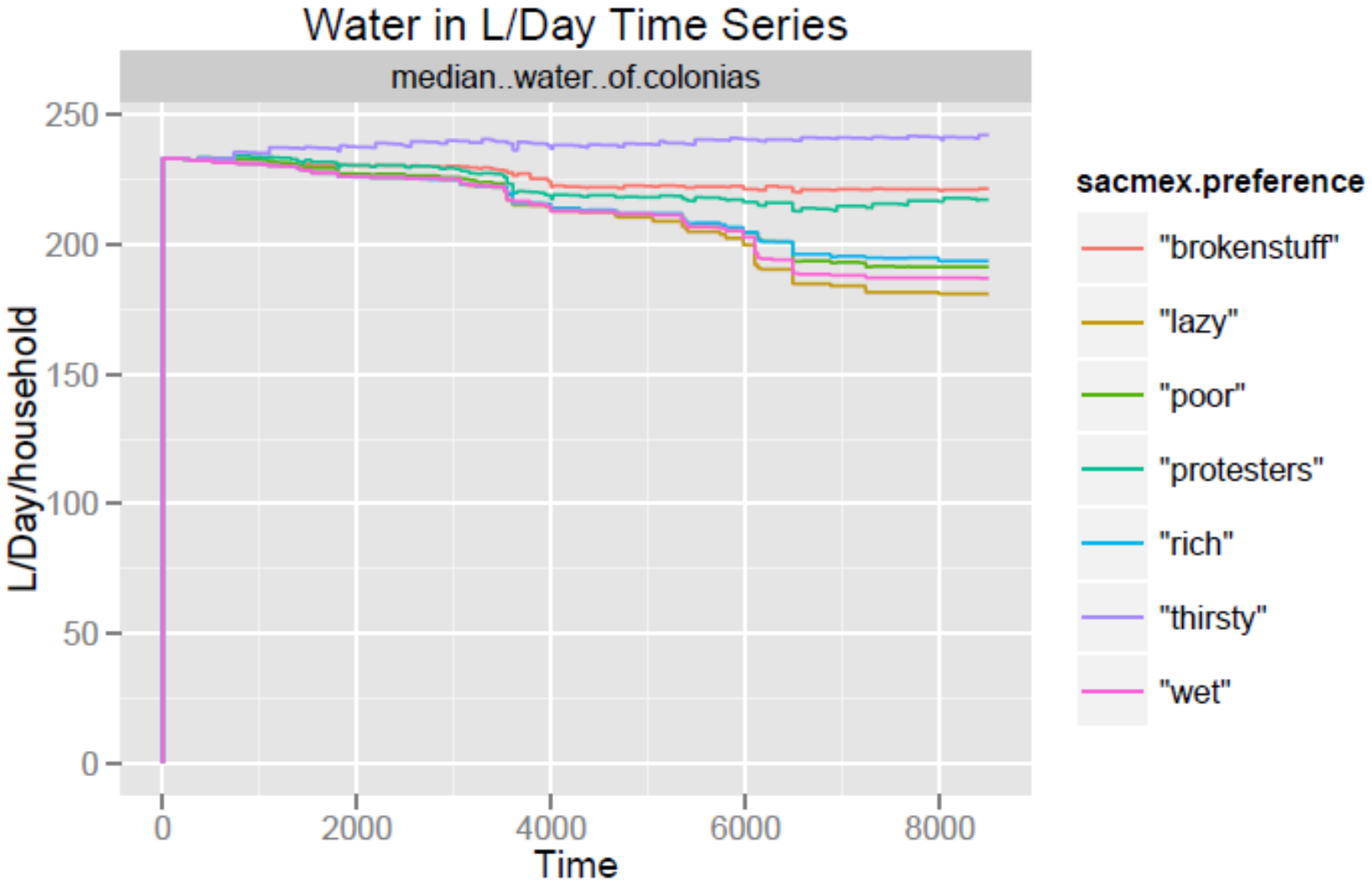
- Looking at table 3 in the white paper, which strategy would you choose if you were governing Mexico City as a “benevolent dictator”? As a politician trying to get elected? If you were trying to save money? If you just wanted to reduce water scarcity as much as possible? Why?

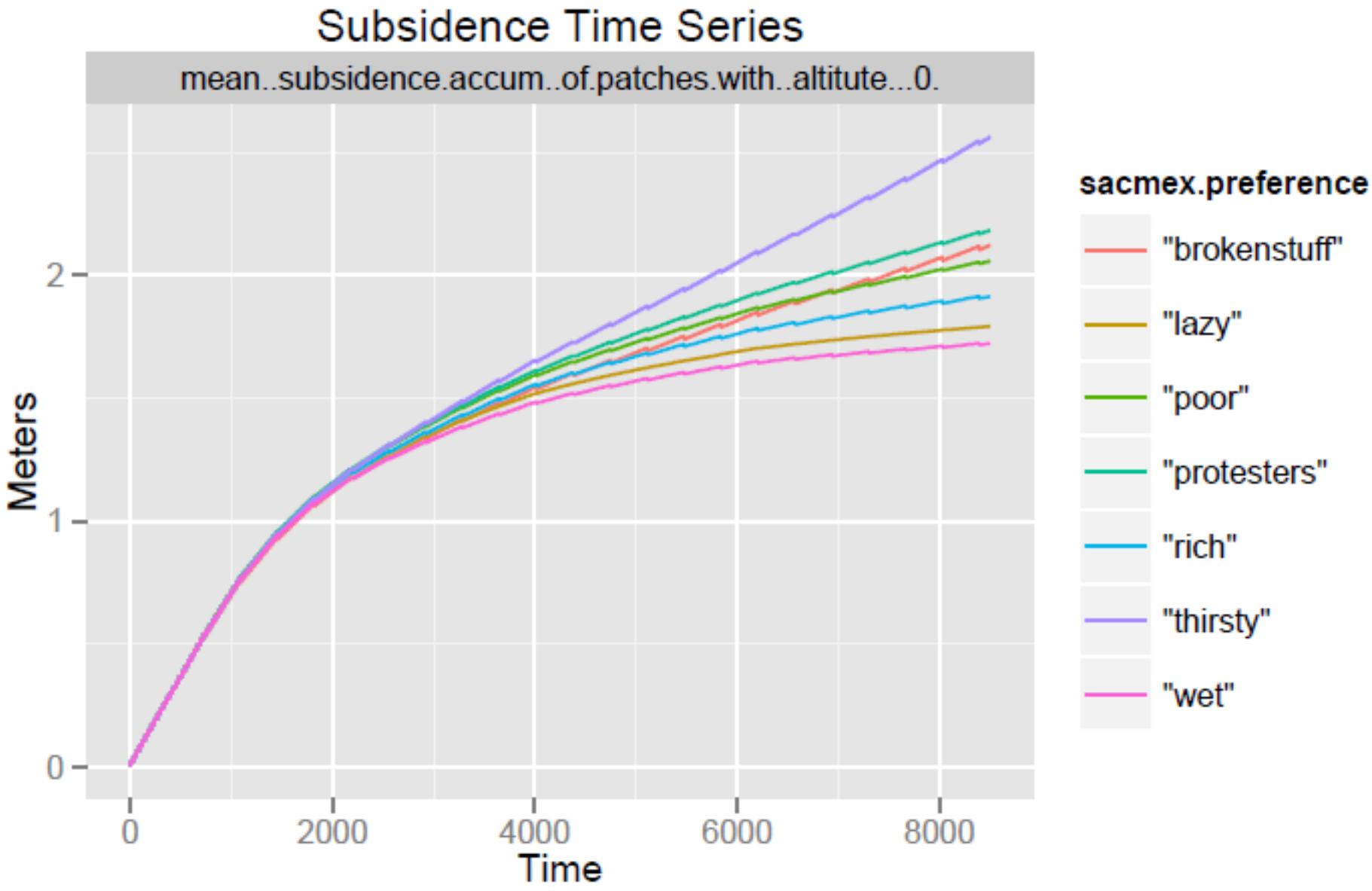
Post Model Run Discussion

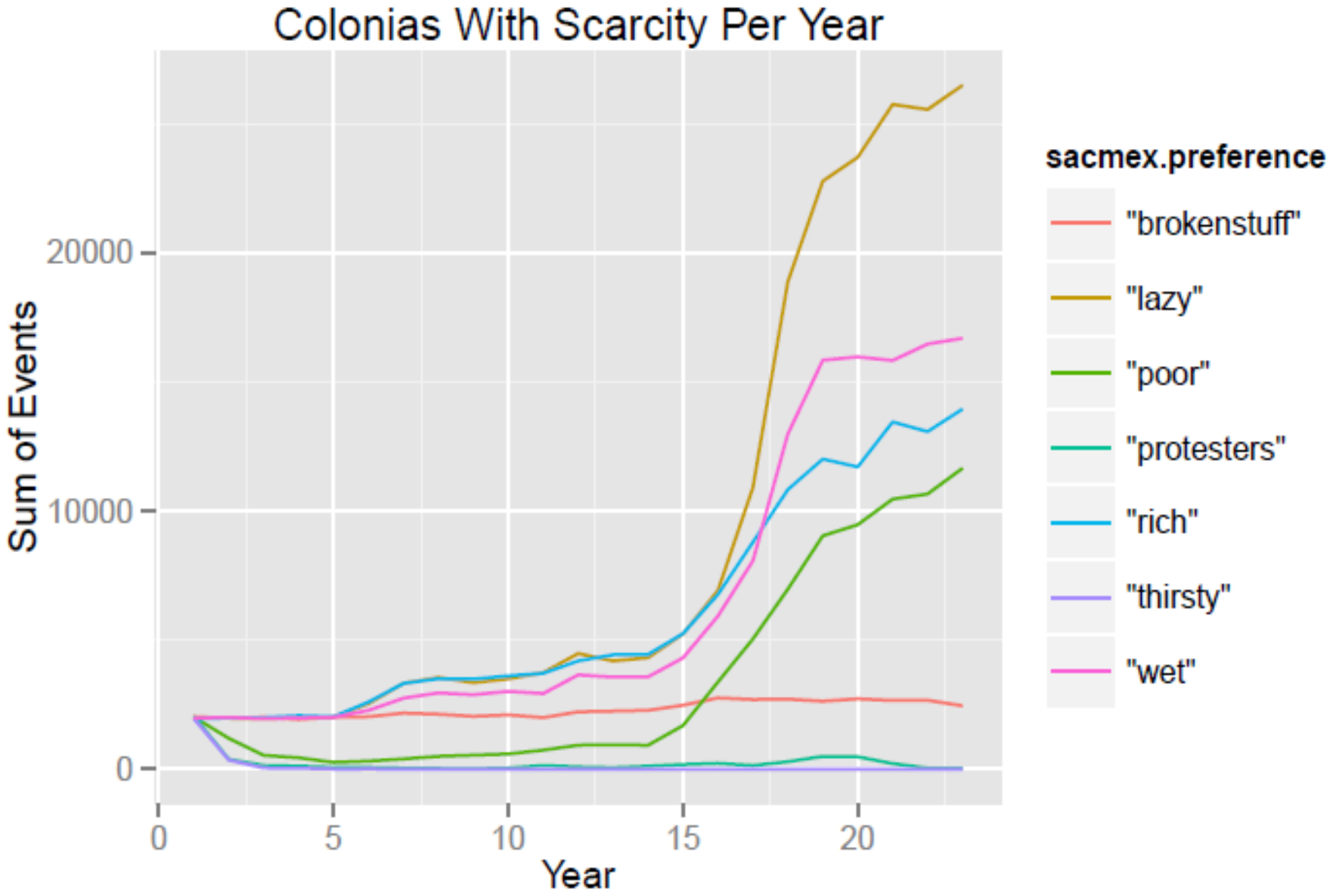
- Do you agree with the author's conclusions on page 16/17 of the model analysis?
- Did the ABM answer the questions hypothesized on page 3?

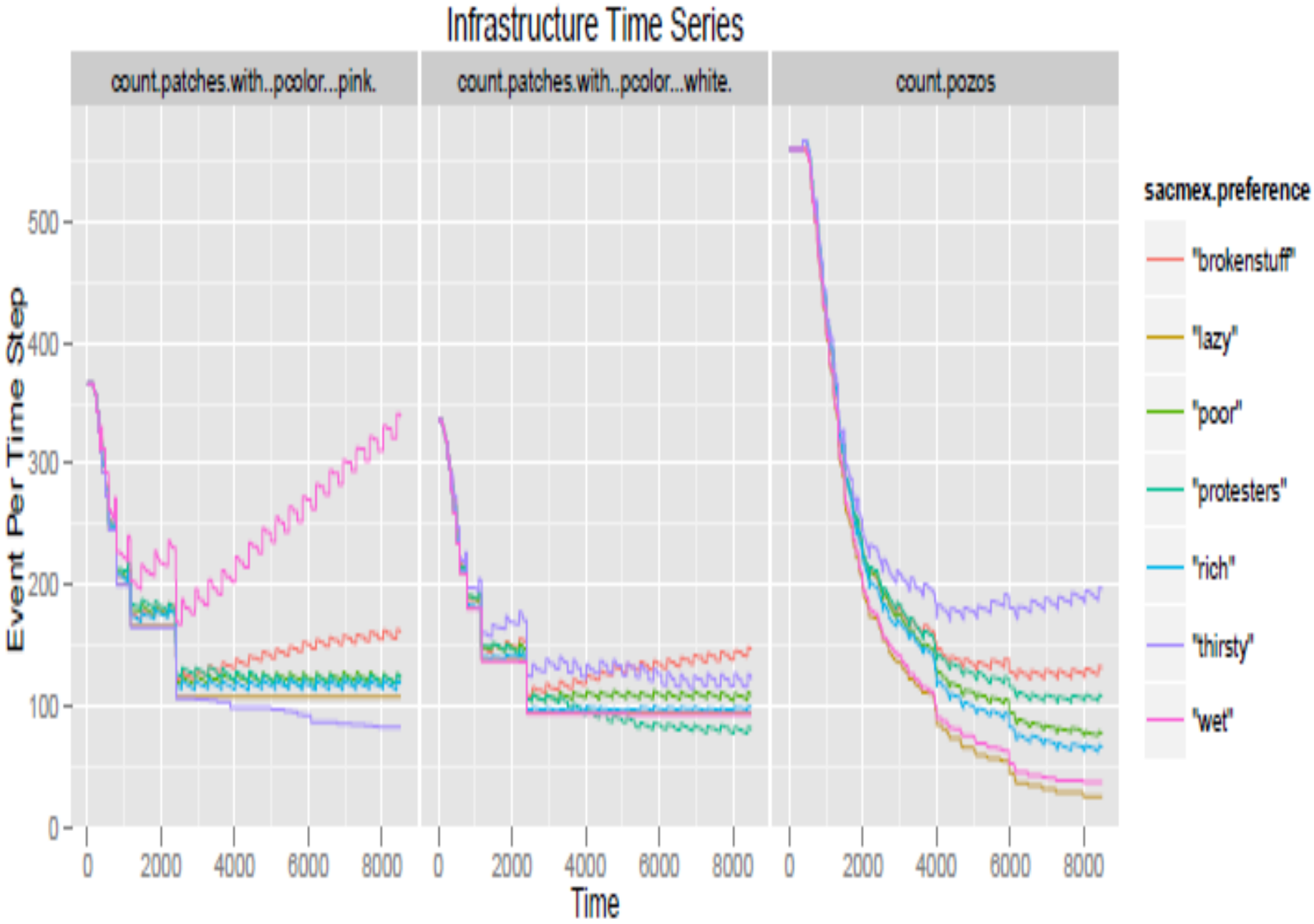
1. Do different preferences to governing water risks (e.g.) scarcity vs. flooding, or communities (poor vs. rich) influence different vulnerability outcomes?
2. Is one type of risk mitigated at the expense of another?
3. Is there a governing preference that mitigates both scarcity and flooding (e.g. can "urban resilience" be achieved)?
4. Does responding to protest demand instead of investing in infrastructure maintenance increase either risk (scarcity or flooding) over the long term?

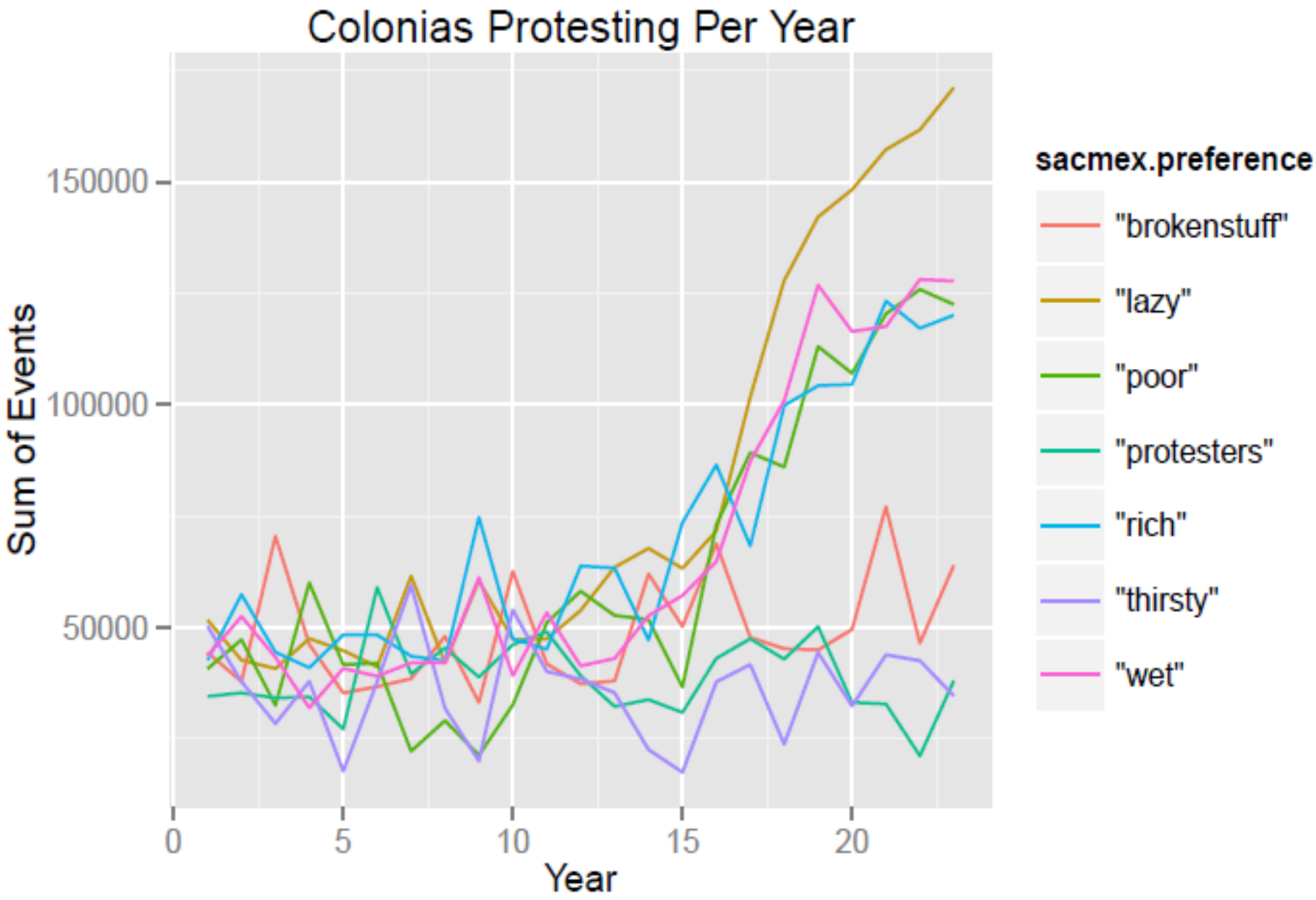
What do the figures tell us?


Water in L/Day Time Series
median..water..of.colonias
250
200
150
100
50
0
L/Day/household
0
2000
4000
6000
8000
Time
sacmex.preference
"brokenstuff"
"lazy"
"poor"
"protesters"
"rich"
"thirsty"
"wet"


Subsidence Time Series
mean..subsidence.accum..of.patches.with..altitute...0.
Meters
0
1
2
0
2000
4000
6000
8000
Time
sacmex.preference
"brokenstuff"
"lazy"
"poor"
"protesters"
"rich"
"thirsty"
"wet"


Colonias With Scarcity Per Year
Sum of Events
20000
10000
0
0
5
10
15
20
Year
sacmex.preference
"brokenstuff"
"lazy"
"poor"
"protesters"
"rich"
"thirsty"
"wet"


Infrastructure Time Series
count.patches.with..pcolor...pink.
count.patches.with..pcolor...white.
count.pozos
Event Per Time Step
Time
0
100
200
300
400
500
0
2000
4000
6000
8000
sacmex.preference
"brokenstuff"
"lazy"
"poor"
"protesters"
"rich"
"thirsty"
"wet"


Colonias Protesting Per Year
Sum of Events
150000
100000
50000
0
5
10
15
20
Year
sacmex.preference
"brokenstuff"
"lazy"
"poor"
"protesters"
"rich"
"thirsty"
"wet"

- What hypotheses do you have about Mexico City you think an ABM could help answer? What data and new submodels might be required to answer that question?
- Any ideas of how to improve the model?