Using Agent-Based Models to Fight Global Warming

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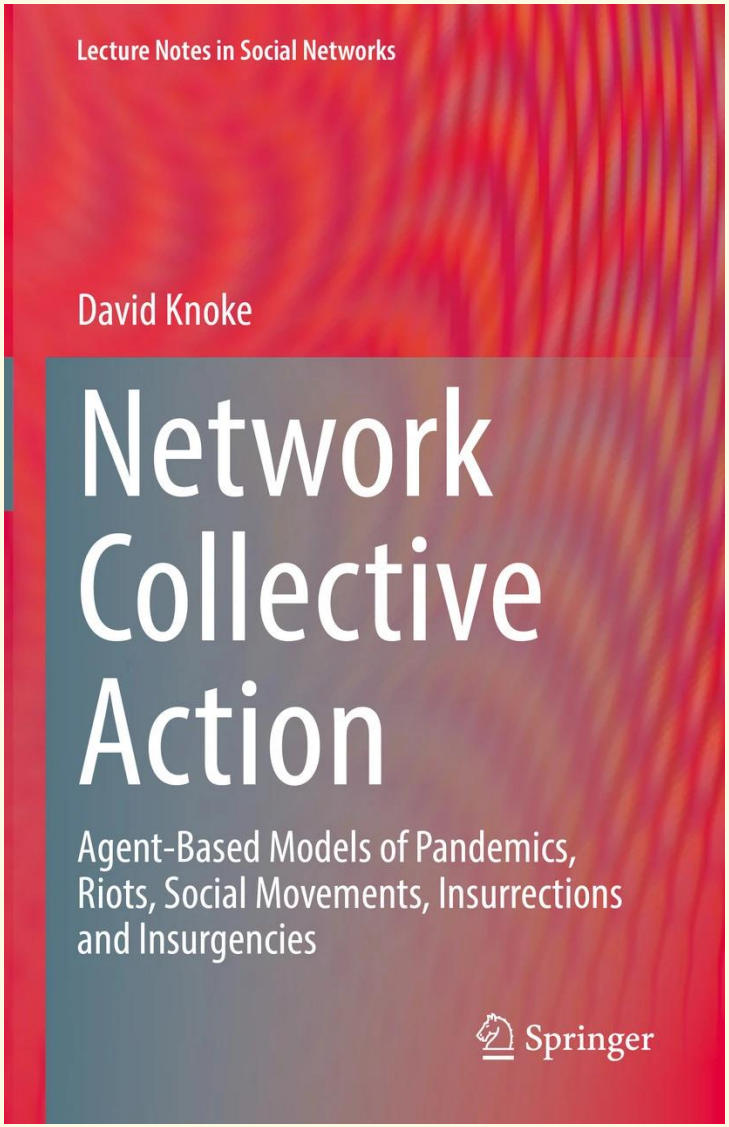
Network Collective Action (2025)



Preface

This book is a product of the Covid-19 global pandemic. When the virus reached the University of Minnesota in the middle of Spring Semester 2020, faculty were told they had one week to convert their courses from in-classroom to on-line zoom instruction. That experience was equivalent to learning to swim by being tossed into the deep end of the pool. Fortunately, I received a sabbatical for the following academic year and was spared additional trauma.

…

[Inspired by the pandemic & the Trump-fomented Capitol Hill insurrection,] I set about learning how to write NetLogo computer codes. Over the next three years my sabbatical project morphed into the half-dozen agent-based models of network collective action that comprise the core chapters of this book.

Definitions of Collective Action

Brooklyn, New York, June 2020

Portland, Oregon, May 2020

Mark Granovetter (1978:1423): No formal definition. Focus is "the formal model and not the substantive question of riot behavior."

James Coleman (1990:198): It involves people carrying out same or similar actions at the same time. Their actions are transient or continually changing (not in equilibrium). Some type of dependence exists among actions – actors aren't acting independently.

Clark McPhail & Ronald Wohlstein (1983:580-81): **Collective behavior** is "two or more persons engaged in one or more behaviors (e.g. orientation, locomotion, gesticulation, tactile manipulation, and/or vocalization) that can be judged common or convergent on one or more dimensions (e.g. direction, velocity, tempo, and/or substantive content)."

Collective Action Spectrum

Collective actions span a range from unplanned to highly institutionalized. Typology displays three ideal types' attributes. See examples on next slide ➔

Spontaneous Actions	Collective Actions	Collective Decisions
• Spontaneous assembly	• Leaders or coordinators	• Legal public institutions
• No leaders, coordinators	• Formal and informal organizations	• Actors have authority to make binding decisions
• Nonextant network ties	• Seeks the redress of political grievances	• Best-of-***n*** social choices
• Imitation of behaviors observed in a vicinity	• Membership recruitment via social network ties	• Voting rule to choose
• Threshold of perceived low-risk acting	• Tactical training	• Production of both public goods & private benefits
• Provocation or triggering event	• Scheduled events	• Coercive enforcement mechanisms
• No/low presence of suppressive authorities	• Event permits required by authorities	• Limited jurisdictions, balance-of-power

Unorganized Actions: Fads-and-fashions, public opinion, gossiping, rumor spreading, unrest, disturbance, gathering, victory celebration, milling, singing, chanting, brawling, rioting, looting, lynching, panicking, stampeding, bullying, mobbing, bank run, workplace shooting (going postal), …

Collective Actions: Flash mob, pop-up meeting, petition, social movement, social movement organization, civil disobedience, demonstration, protest, march, parade, occupation, sit-in, teach-in, rally, vigil, boycott, hunger strike, counterprotest, machine-breaking, sabotage, mutiny, rebellion, insurgency, …

Collective Decisions: Voting, lobby coalition, caucus, jury verdict, court ruling, regulatory rule-making, committee report, legislative act, executive order, …

Agent-Based Models

Agent-based models of complex systems consist of a set of simple rules for individual agent behaviors, interactions, and influences that may produce emergent properties that are not programmed into models. ABMs provide a micro-level foundation of relations among agents that seeks to explain macro-level population patterns. They're better suited to systems lacking central coordination (bottoms up) than authority-imposed top-down systems.

ABM key assumptions (Macy and Willer 2002:146)

- Autonomy – agents make decisions within programmed behavioral rules (self-organizing, not imposed by institutions)
- Interdependency – agents influence one another; choices depend in part on the actions of others (persuasion, sanctioning, imitation, …)
- Simple rule-following – norms, conventions, protocols, heuristics – can generate complex global behaviors of explanatory interest
- Heterogeneity – variation among agents and environmental components
- Adaptive & backward-looking feedback – past outcomes can influence future responses; agent & population learning
- Stochasticity – random probabilities assigned to actions or decisions

Kathleen Carley (1999:4) developed a “socio-cognitive quantum mechanics“ for “understanding social action from the ground up.“ Her framework is a changing network of agents having mental models of the system, embedded in an ecology of social networks. CONSTRUCT and ORGAHEAD simulations plots the changing probability of interactions among dyads of six actors. System trends toward stability over time.

Robert Axelrod (2006:1566) argued that ABMs can address questions common to many fields, promote interdisciplinary collaborations, “provide a useful multidisciplinary tool where the math is intractable, and reveal unity across disciplines.“ He gave examples from his own work on iterated Prisoner’s Dilemma games and other topics, including biological evolution & military alliances in WW2. “ABM can be a hard sell“ to convince academics who work with math and statistics.

ABM Tutorial

Charles Macal & Michael North (2014) provided a brief introduction to ABM and simulation (see also Macal 2016). They sought to show that ABMs are useful, usable, and used. Described key concepts and requirements. Listed ABM software and toolkits, including NetLogo, Repast Simphony, MATLAB. Suggested a pathway for independently becoming an AB modeler (p. 15).

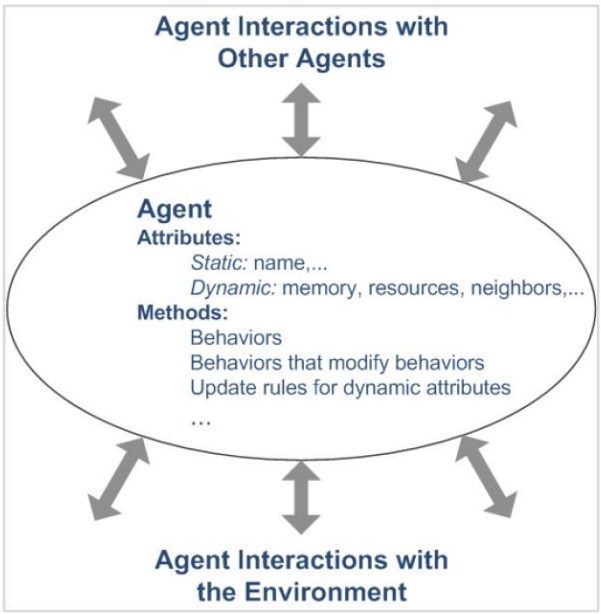


Figure 1: A typical agent.

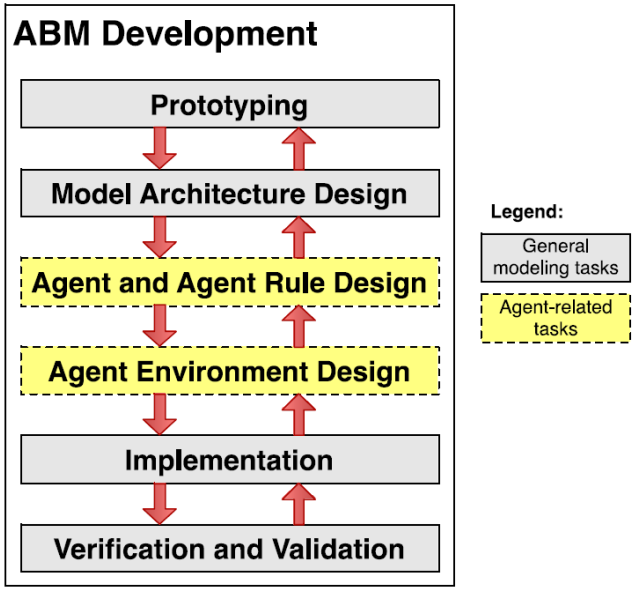
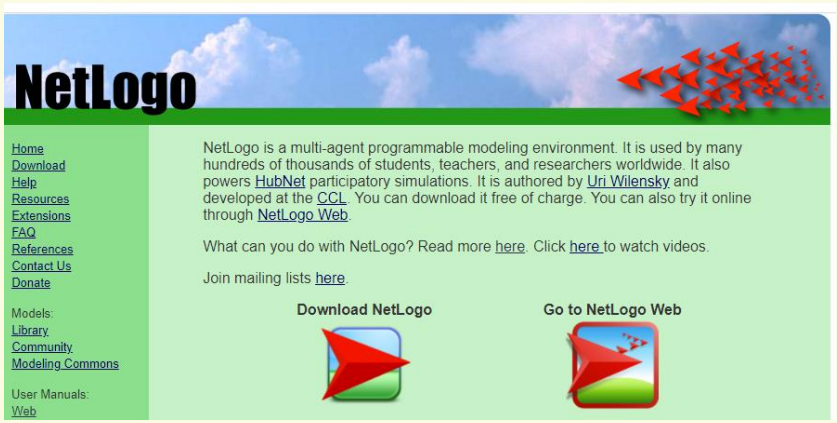


Figure 2: Agent –based model development process.

NetLogo software

NetLogo is a programming language for ABMs, aimed at school children and domain experts without computer skills. It was designed in 1999 by Uri Wilensky at Northwestern University. The library contains numerous sample models spanning the sciences, art, philosophy, and social sciences.



NetLogo calls its agents “turtles“ (after a turtle-shaped lab robot) and environment “patches“ are the cells in a square grid across which agents move and interact with one another.

Program allows creation of a variety of switches, sliders, choosers that enable an “observer“ to vary parameters and plot changes over time in the sizes of turtle subpopulations (e.g., infected, recovered, immune, dead).

Capitol Hill Attack – Mob, Riot, Insurrection, … ?

The 1/6/21 participants were not “tourists“ visiting the nation’s capital. Planning and coordination brought them & their weapons to Washington. Trump urged them to the Capitol to disrupt the Electoral College vote certification, and social media spread The Big Lie about the stolen 2020 election.

Clusters of military, patriot, and QAnon users spread disinformation on the Parler network (Ng et al. 2021).

“The early detection of coordinated effort to organize riots and political violence online may present the possibility of stopping that violence in the real world“ (p. 9).

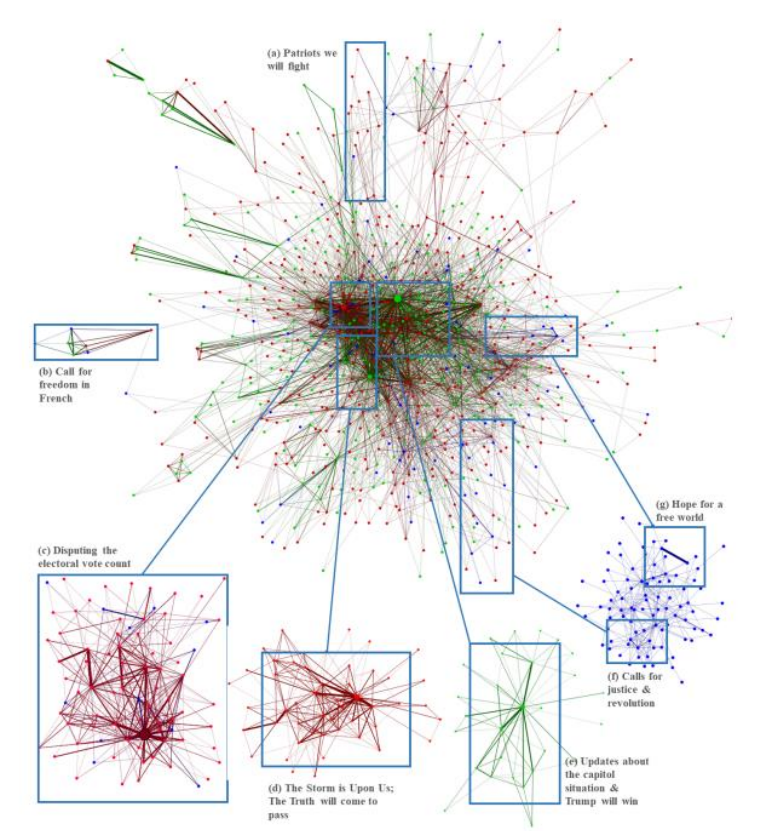
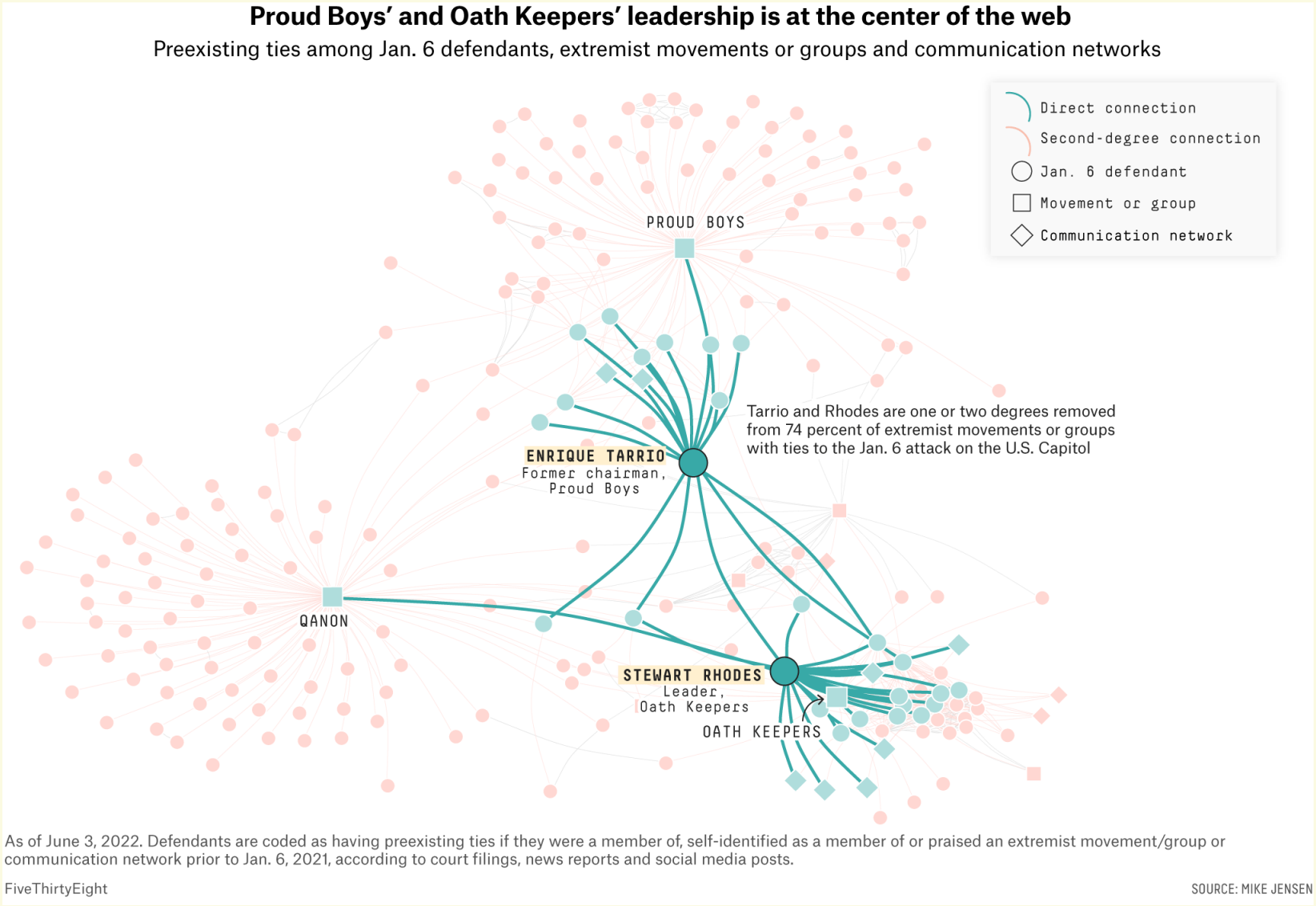
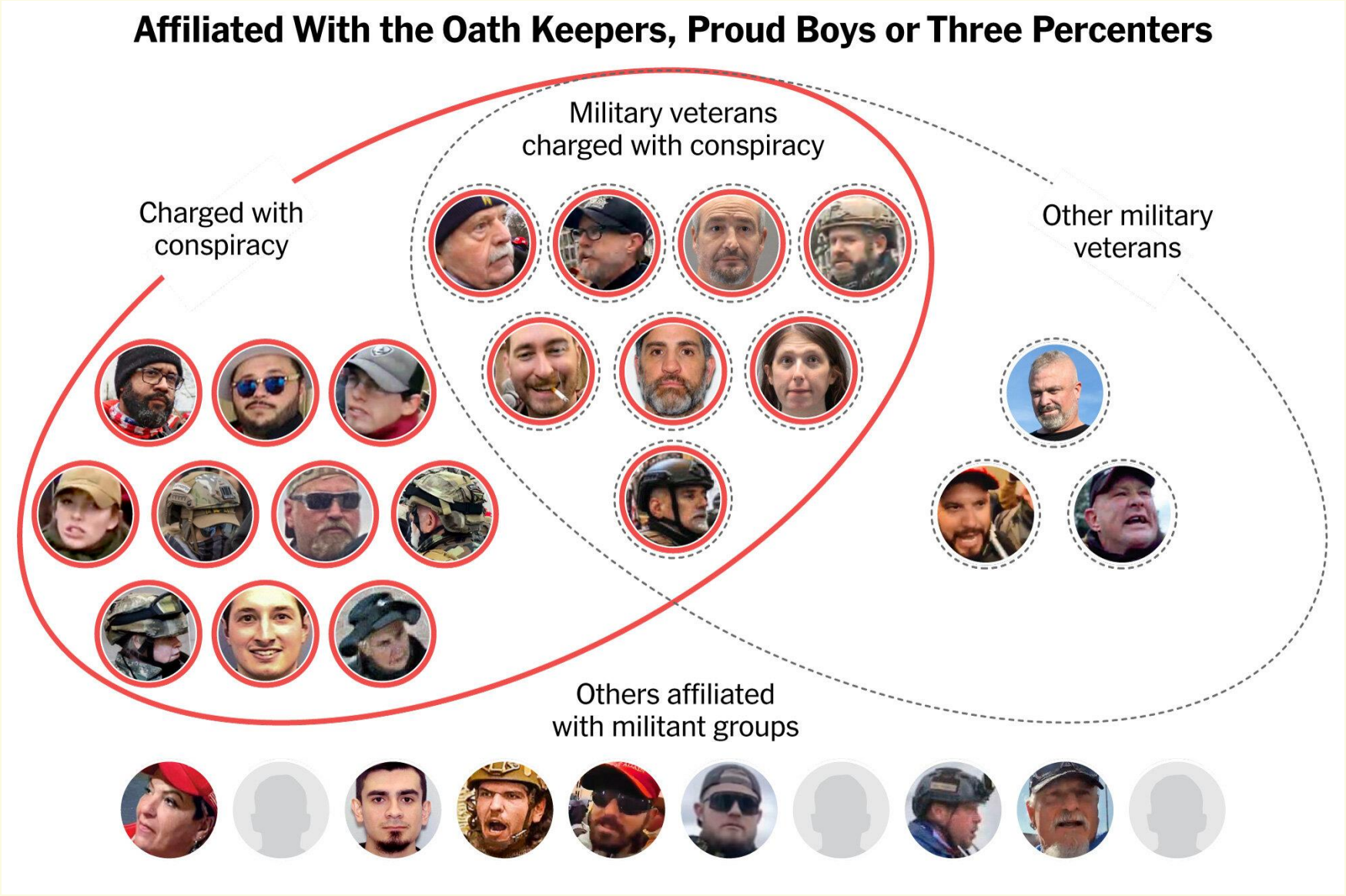


Fig. 1: Core structure of user-to-user graph U' representing textual coordination between groups of users. Military users are colored blue; patriot users red and QAnon users green. The thickness of the links represent the strength of the coordination. Nodes are sized by total degree centrality value.

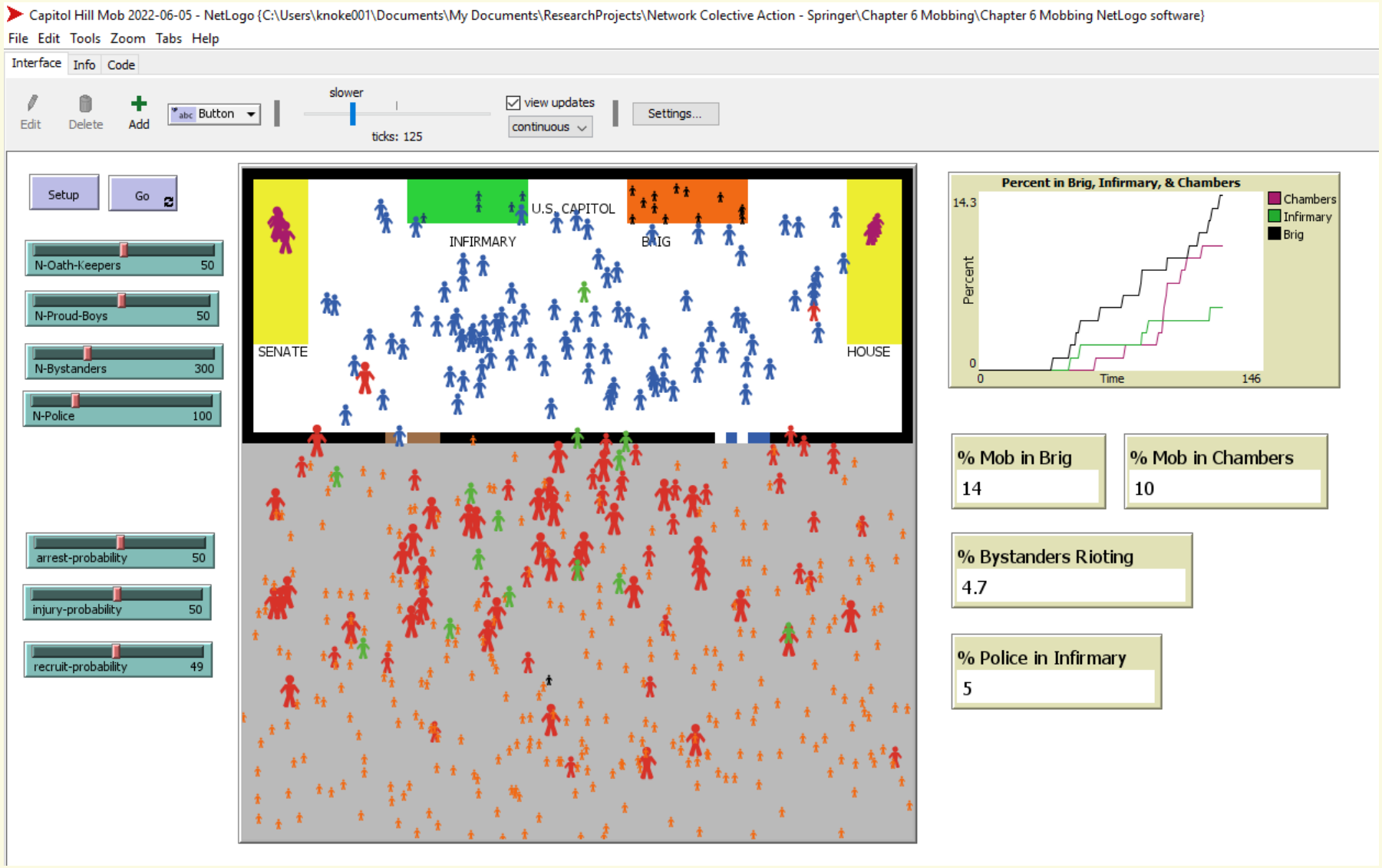
Trials of the Capitol Hill attackers revealed a network of pre-existing communications (Rogers et al. 2022). Stewart Rhodes (Oath Keepers) & Enrique Tarrio (Proud Boys) were within two-steps of 74% of people connected to the attack.



Rhodes, Tarrio, & others found guilty of seditious conspiracy, sentenced to prison for 18 years & 22 years, respectively. Trump pardoned all in 2025.



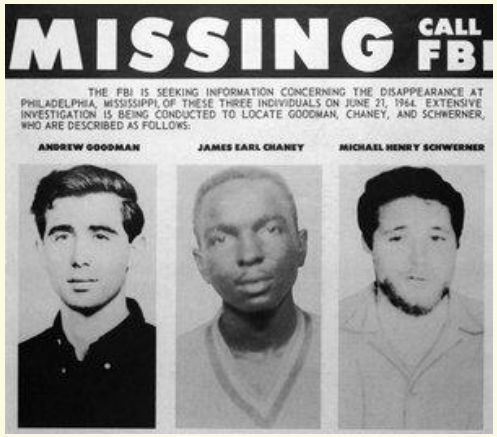
Chief of the Capitol Police claimed they were outnumbered 58 to 1. What might have been the outcome if the numbers were reversed? An agent-based model simulation:



1964 Mississippi Freedom Summer

Doug McAdam's analysis of activists who participated in SNCC's 1964 Mississippi Freedom Summer, a campaign to register black voters, included a social network factor.

Evidence came from the essays written by 961 applicants, describing their backgrounds & reasons for wanting to go.



Compared to 241 applicants who withdrew, the 720 who went to Mississippi had more organizational affiliations, higher levels of past civil rights activity, more extensive and stronger prior ties to other Freedom Summer participants. These stronger social bonds helped sustain them in dangerous situations.

"The differences are especially pronounced in the two strong tie categories, with participants listing more than twice the number of volunteers and nearly three times the number of activists as the withdrawals" (McAdam 1986).

Figure 6.1 Recruiting Movement Supporters ABM at start

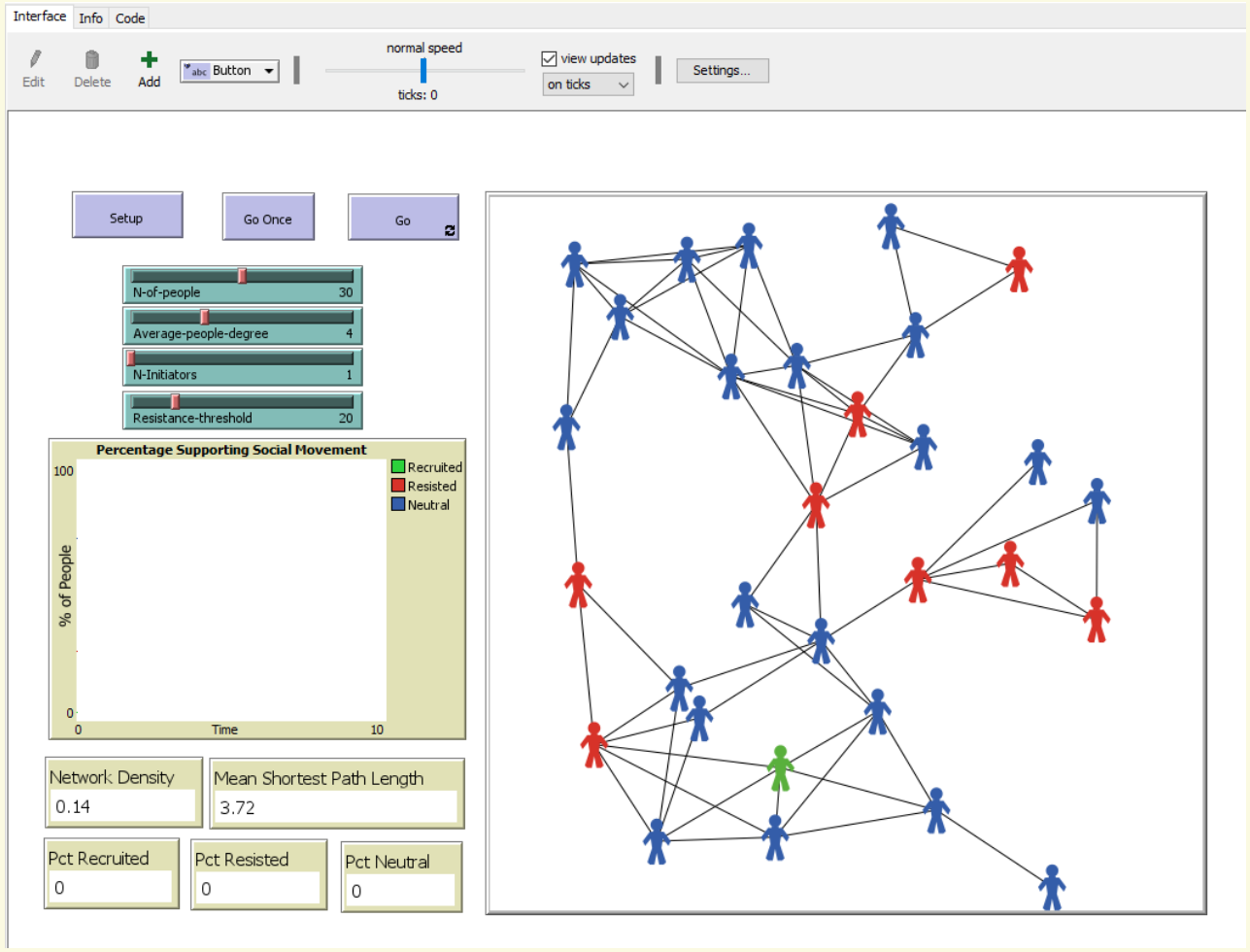


Figure 6.2 Recruiting Movement Supporters ABM at end

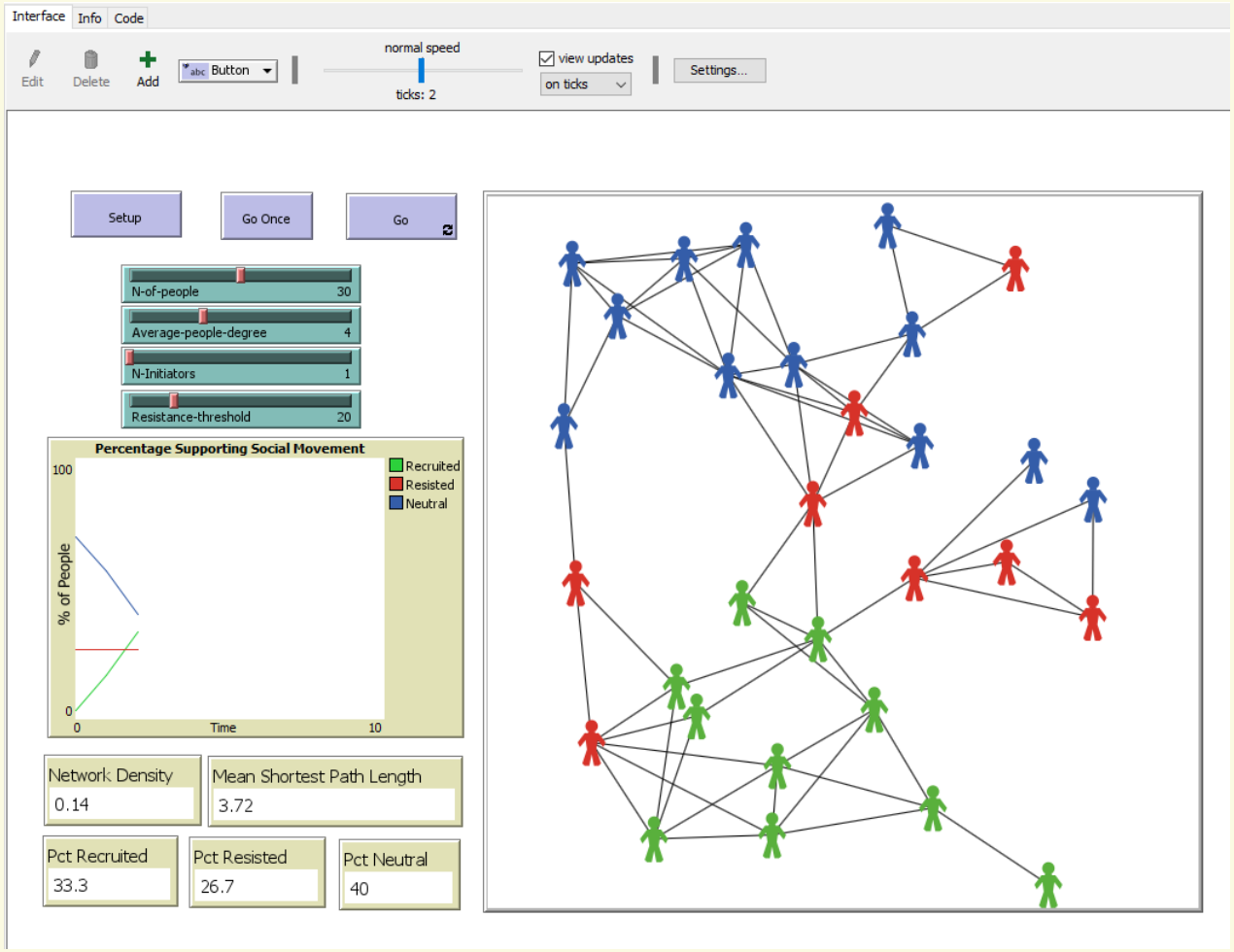


Table 6.1 Two Recruiting Movement Supporters experiments with different network densities

	Model 6.1	Model 6.2
Network size (number of agents)	30	30
Average degree	3	5
Resistance threshold	0.20	0.20
Mean percentage recruited	46.9%	71.3%
Mean percentage resisted	19.9%	20.3%
Mean percentage neutral	30.7%	7.9%
Mean ticks	5.2	5.2
N of experimental runs	200	200

Polycentric Collective Action

Elinor Ostrom, a political scientist at Indiana University, was the first woman to win the Nobel Prize in economics.

She explored how communities could sustainably manage their **common-pool resources** (CPR) – forests, fisheries, grazing land, irrigation systems – by self-governance without privatization or centralized government. What cooperative rules, norms, and actions could be used to avoid the **tragedy of the commons** where numerous individuals, acting rationally in pursuing their own self-interests, deplete or destroy a CPR through over-use?

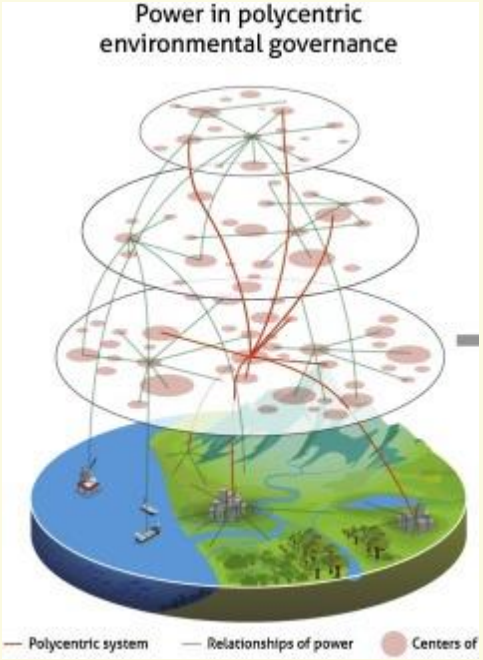
Ostrom's **polycentric governance theory** involves many self-organizing efforts generate local and regional communication, trust-building, policy experimentation, and learning (Ostrom 2009, 2010a, 2010b).

Important conditions likely to increase cooperation among polycentric entities:

1) reliable information is available about the immediate and long-term costs and benefits of actions
2) individuals involved see the common resource as important for their own achievements and have a long-term time horizon
3) gaining a reputation for being a trustworthy reciprocator is important to those involved
4) individuals can communicate with at least some of the others involved
5) informal monitoring and sanctioning is feasible and considered appropriate
6) social capital and leadership exist, related to previous successes in solving joint problems (Ostrom 2014:104)

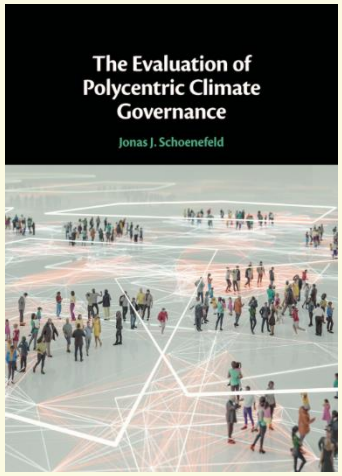
In ***A Polycentric Approach for Coping with Climate Change***, she argued: "Waiting for a single worldwide 'solution' to emerge from global negotiations is also problematic" (Ostrom 2009:3). The decades-long failures of nations to reduce greenhouse gas emissions reveals top-down solutions are impossible.

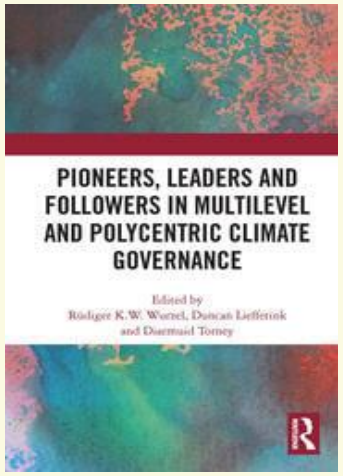
An alternative approach, the "**updated collective action theory** developed in Poteete, Janssen, and Ostrom [2010] is not as pessimistic about the likelihood of diverse organizations at multiple levels finding policies that increase levels of voluntary cooperation or increase compliance with rules established by governmental authorities" (p. 12).

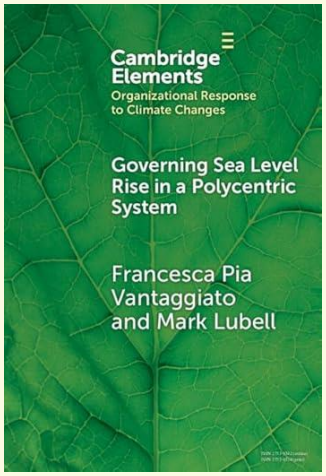


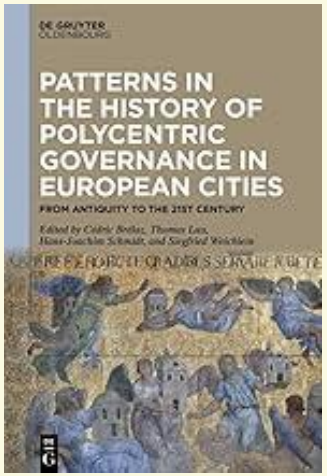
"A strong commitment to finding ways of reducing individual emissions is an important element for coping with climate change. Building such a commitment, and the trust that others are also taking responsibility, can be more effectively undertaken in small- to medium-scale governance units that are linked through information networks and monitoring at all levels" (p. 39).

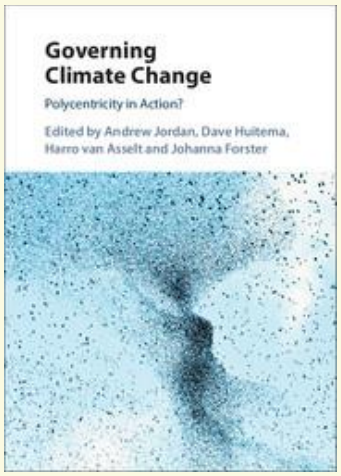
Many books discuss polycentric climate governance

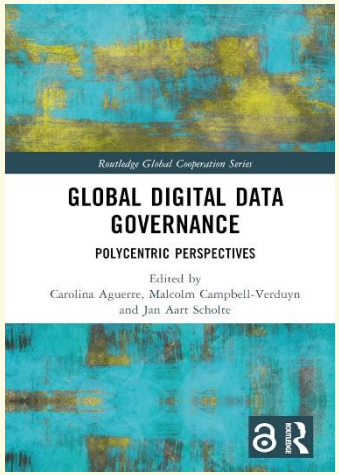


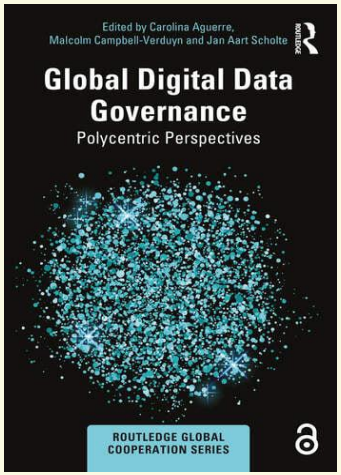


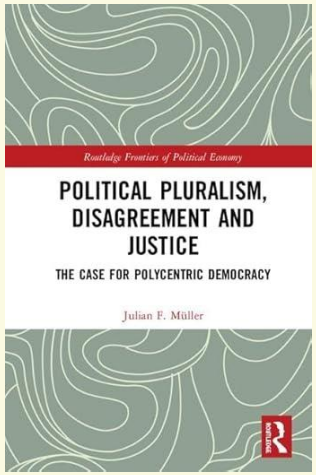


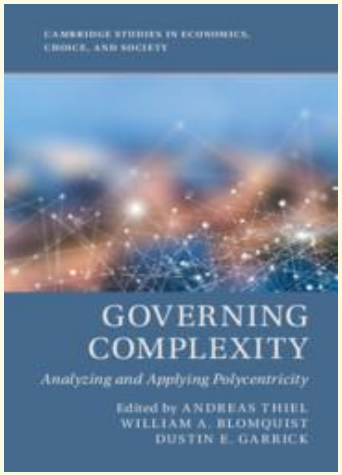


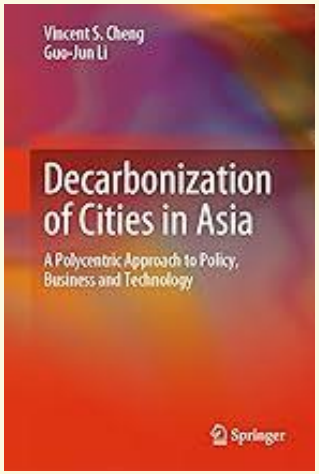






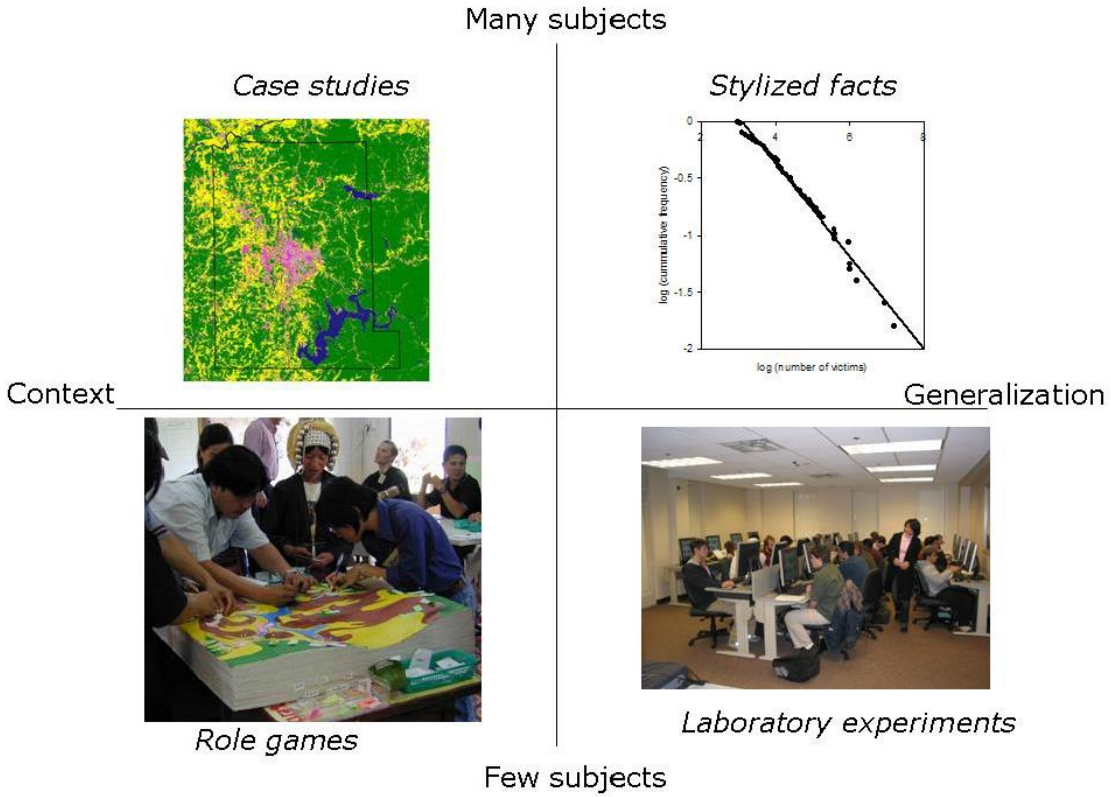






Janssen and Ostrom (2006) proposed using agent-based models to complement empirical field research & laboratory experiments for understanding and improving polycentric governance.

Fig. 2.. The different types of approaches to combine empirical information and agent-based modeling (sources: top-left figure is an adapted version of a remote-sensing image of Monroe County, Indiana, USA created by Cynthia Croissant, Laura Carlson, Glen Green, Tom Evans, Shanon Donnelly, and Charles Winkle; top-right figure is based on Fig. 1 of Cederman (2002); bottom-left photo is provided by Francois Bousquet; and bottom-right photo is provided by James Russell of the Interdisciplinary Experimental Laboratory at Indiana University.)



Prof. Marco Janssen at Arizona State University's School of Sustainability continues to develop ABMs to analyze common-pool resource dilemmas.

Janssen & Baggio (2017) conducted experiments on dilemma situations experienced in irrigation CPRs. "The irrigation dilemma captures situations where farmers at the tail-end or head-end of a system exert different levels of influence on the collective action problems related to the maintenance of the irrigation system and the allocation of water."

"The fundamental problem facing irrigation systems are 1) provisioning for the resource, such as in building and maintaining physical infrastructure, and 2) the asymmetric common-pool resource dilemma, where the relative positions of resource users at the head and tail of the system generate asymmetric access to the resource."

Table 4: Fitness scores for the different null models and treatments

	Unconstrained communication	Constrained communication	Both treatments
Random	0.2604	0.4700	0.3652
Selfish	0.0552	0.0328	0.0440
Cooperative	0.5010	0.2479	0.3745
Mixed model	0.6629 (6% random, 7% selfish, 87% cooperate)	0.6826 (53% random, 4% selfish, 43% cooperative)	0.6160 34% random, 1% selfish, 65% cooperative
Conditional cooperative	0.7328	0.4635	0.5845 (see Table 2*)
Social values	0.6282	0.6820	0.6080 (see Table 3*)

*Note: see Tables 2 and 3 for the parameter combination leading to the fitness presented here.

"Table 4 clearly indicates the inappropriateness of the selfish rational model in explaining results observed in the experiments. The random model seems to perform better when communication is constrained while the cooperative model performs best in the case of unconstrained communication. Both latter models (random and cooperative) outperform the rational selfish model. The mixed model outperforms all other null models."

Ending on a literally playful note, Janssen et al. (2024) used the online **Port of Mars** game to study solutions to collective action problems in uncertain environments. “Initial results suggest that a higher average social value orientation and more communication are the key factors that explain why some groups are more successful“ surviving in Port of Mars.

Fig 1. Illustrations of the five characters in the card game of Port of Mars (source: [31]).

https://doi.org/10.1371/journal.pone.0308363.g001

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