Using agent-based modeling to examine the effects of social connectivity on resilience

Hollis Miller[1,2], J. Daniel Rogers[2]

[1]Department of Anthropology & Sociology, Lafayette College, Easton, PA
[2]Department of Anthropology, Smithsonian Institution, Washington, DC

Introduction

In recent decades, multiple fields including anthropology, economics and ecology, have developed theories of complex adaptive systems to help explain varying processes, from the rise and fall of empires to changes in ecosystem function. What ties these theories together is the idea of resilience, defined as "the capacity of a system to absorb disturbance and still retain its basic structure and function" (Walker and Salt 2006: xiii). Here we examine resiliency in an interdisciplinary setting, drawing from theories in ecology regarding the connectivity of ecosystems and applying them to the social sciences. Does increased connectivity within a social-ecological system lead to increased resiliency as it does in ecosystems? Connectivity, in this sense, refers to the extent to which people rely on and communicate with one another, whether through economic, social or familial structures. To explore this question, we used HouseholdsWorld, an agent-based model that simulates pastoralist society in Inner Asia. We conducted three experiments by manipulating variables that control the propensity of people to share wealth, the strength of kinship ties and the movement of people across the landscape in the model. The data revealed that lessened social connectivity does affect demographic success and thus resiliency, but the direction of that effect depends on the type of connectivity in question. Understanding the dynamics of social-ecological systems is especially pressing now, as the Earth system is currently being tested by humans through environmental degradation and climate change.

HouseholdsWorld

- An agent-based model rooted in historical, ethnographic and climate data
- Households are situated in a 10,000 km² landscape (Figure 1) modeled after the Egiin Gol region in northern Mongolia (Figure 2)

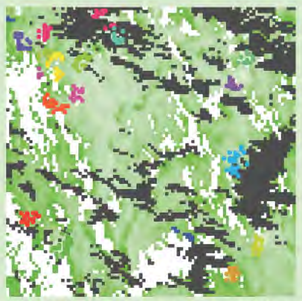

Figure 1: Simulation landscape, colored dots mark the location of households and signify their clan affiliation.

Figure 2: Geographic location of Egiin Gol (Rogers et al. 2012)

- Nomadic pastoralism is the sole way of life within the model
- Social rules dictate the movement of households each day (Figure 3)
- Households belong to camps and also belong to a lineage/clan
- Wealth is measured by herd size and can be displayed using several of the model outputs (Figure 4)
- Weather events, which are either droughts or *zuds* (winter storms) affect the abundance of biomass on the landscape
- The baseline run of the model represents "reality" in terms of weather events and the structure of the society

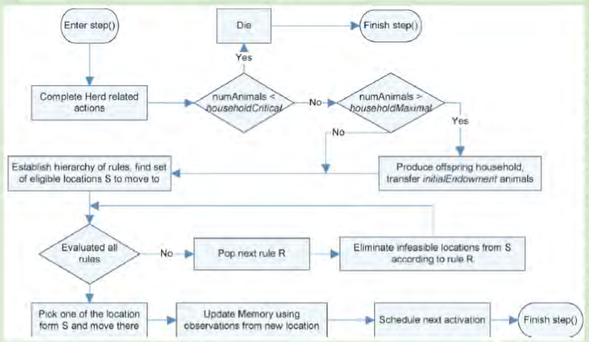

Figure 3: Flowchart describing the computing process that operates for each household, each day. Each household evaluates whether or not it has enough animals left to survive, whether or not it can produce offspring and where it will move on the landscape given the established social rules. The social rules include the local abundance of grazing pasture, camp memory of previous pastures, cohesion of the camp/clan and avoiding alien camps and clans.

Figure 4: Example wealth outputs from HouseholdsWorld. The clan wealth plot on the left displays the minimum, average and maximum number of animals that clans posses on any given day. The household wealth histogram on the right displays the distribution of wealth at the household level for a single day in time. Both plots show fairly standard wealth distributions with a large gap between the wealthy and the poor.

Connectivity Experiments

- Baseline – scenario based on real climate, historical and ethnographic data
- No Bailout – economic connectivity is decreased as households no longer share wealth with kin in times of need
- Alien Distance – kinship ties are weakened and fewer people are recognized as kin
- Social Rules – changed the order of the social rules so households base movement decisions first on the local abundance of grass and then on camp memory of good pasture, this represents decreased communication among camp members

Each of the experiments was run for 330 years in the model. The effects of these experiments on the total population and number of clans are depicted in Figures 5 and 6.

Figure 5: Total population for each of the experiments plotted through the 330 year time frame. The first 250 years of the run are an initialization phase when no extreme weather events occur, hence the fairly stable population during that period. The later section with high variability in the population is the phase when extreme weather events are introduced. These data suggest that connectivity is important to demographic success, as evidenced by the sometimes extreme deviance from the baseline run, especially in the social rules experiment.

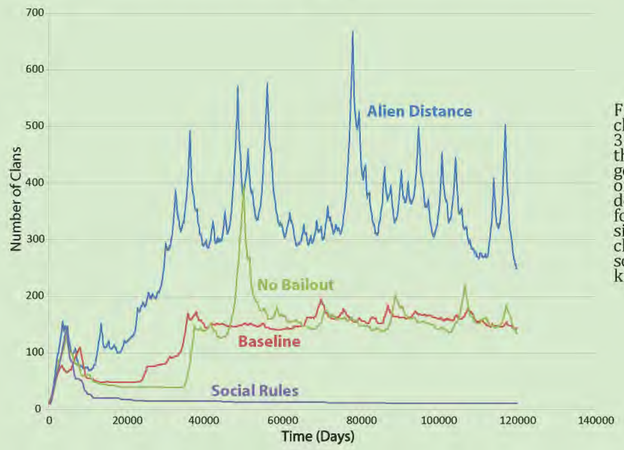

Figure 6: Total number of clans plotted throughout the 330 year model run. While the number of clans does generally rely on the number of households, this plot depicts great variation in clan formation for populations of similar size. This suggests changes in the structure of society and the strength of kinship ties.

Results

No Bailout
- Number of households decreased because there was no social safety net for poor households
- Wealth distribution was standard with strong stratification between the wealthy and the poor
- The society is less resilient without the bailout function

Alien Distance
- Number of households and number of clans increased
- Fewer people are recognized as kin, so households may act more independently, similar to a modern urban society - more available marriage partners
- Clans are less wealthy (Figure 7) and there is a smaller wealth gap
- The society is more resilient when kinship ties are weaker

Social Rules
- Number of households plummeted to well below 500
- Number of clans reaches as low as 11 and clans are very cohesive
- Lack of mobility coupled with lack of genetic diversity leads to the low population as people are not coming into contact with marriageable partners
- Wealth is more evenly distributed, presence of a healthy middle class
- Society is structured differently than in the baseline run and is less resilient

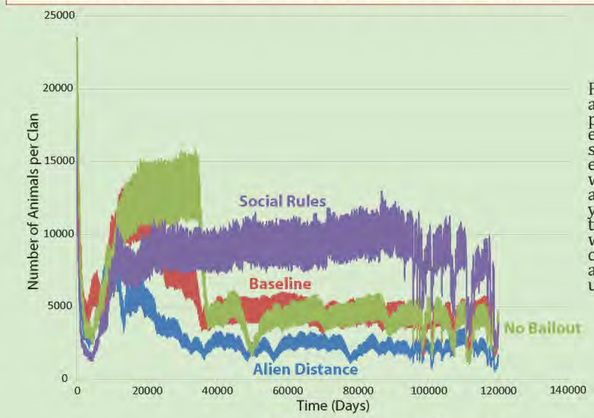

Figure 7: Plot depicting the average number of animals per clan though the 330 year experimental runs. The plot shows that the social rules experiment yielded the wealthiest clans, while the alien distance experiment yielded the poorest. Note that this is an average measure of wealth and there are some clans with over 20,000 animals and others with under 200.

Conclusions

From these experiments using HouseholdsWorld, it is clear that connectivity does have an effect on resilience; however, that effect is not always the same. In two of the three experiments, weakened connectivity led to less resilience, which suggests that, generally, more interconnected societies are more resilient. This runs against some theorists, notably Carole Crumley, who claims that highly interconnected societies become "brittle" (2001). The difference perhaps lies in the fact that Crumley studies complex social systems such as states and empires where hierarchical control is the source of forced connectedness, whereas HouseholdsWorld models a nomadic pastoral society with no formal system of hierarchy. With such a small-scale society in which individual households are making the same choices every day, slight changes to the decision-making process can have huge effects, as evidenced by the social rules experiment. Locating these critical thresholds is incredibly important for any society, but it is especially important now that the world has become so connected and faces the variability that climate change promises. How resilient is the society we live in today?

References:

Cioffi-Revilla, C., J. D. Rogers, and M. Latek. "The MASON HouseholdsWorld Model of Pastoral Nomad Societies." In *Simulating Interacting Agents and Social Phenomena: The Second World Congress on Social Simulation*, edited by K. Takadama, C. Cioffi-Revilla, and G. Deffaunt, 7:193–204. Agent-Based Social Systems. Tokyo: Springer, 2010.

Crumley, C. L. "Communication, Holism, and the Evolution of Sociopolitical Complexity." In *From Leaders to Rulers*, edited by Jonathan Haas, 19–36. New York: Plenum, 2001.

Rogers, J. D., T. Nichols, T. Emmerich, M. Latek, and C. Cioffi-Revilla. "Modeling Scale and Variability in Human-Environmental Interactions in Inner Asia." *Ecological Modelling* 241 (2012): 5–14.

Walker, B. H, and David Salt. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, DC: Island Press, 2006.

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