Do cities learn from getting burned?

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Noah C. Goldstein
Department of Geography
University of California at Santa Barbara
Santa Barbara, California 93106
noah@geog.ucsb.edu

Abstract

Human settlements have always been effected by natural disasters. Our awareness of these events is usually that of something "happening" to the city. The fact that the city is changing the *agent* of disaster is left out of that awareness. I argue that many disasters, fire in particular, have co-evolved with cities over time. The perspective I am taking is that the city is an organism that can grow in ideal situations and can shrink in a disaster. Wildfire too can be viewed as an organism, one that usually lies in stasis until the ideal conditions, then quickly grows and dies. Both entities compete for space and resources. One entities' behavior will impact the other, and over time the systems co-evolve. This co-evolution beckons the question, what observable emergent properties emerge from this co-evolution? Does the city learn from the wildfires, and does the fire-adapted landscape change its behavior as a result of city growth? Through the use of modeling we can gain a better understanding of these disasters and the process of urban growth. I propose to examine the use of a coupled urban-wildfire cellular automaton (CA) based model to examine the emergent behavior of the two-process system. Questions of the appropriateness of modeling are explored as well as the possible conclusions that could be drawn from these experiments.

Introduction

Humans are so well adapted to Earth that not only can we live in any ecological niche on (and off) the planet, but we can modify the environment to the extent that we make our own niche. We, as a species, are quite adept at this, exhibiting our dominance over the landscape by literally flattening mountains and creating lakes from rivers, not to mention coating much of the natural landscape with a gray skin of concrete. It is in the city, where we think we can exist uninhibited or unharmed from nature's wrath, and build our habitat as we se fit. But as the adage goes, "never turn your back on the ocean." We forget that cities are perennially vulnerable to disaster, and that many natural disasters are in fact, normal. But does the city, as an organism, forget?

As cities have grown, each has had some sort of natural disaster that has destroyed part or all of it. Some of these disasters are one-time human-induced events, like Nagasaki's atomic destruction or the impending displacement of 2 to 4 million people's homes as a result of China's Three Gorges Dam. The human-induced destruction of urban dwellings will not occur again and those cities can't (and don't need to) plan for another disaster on that temporal and physical scale (especially since the dwellings along the Yellow River will be underwater).

Most cities that have survived one natural disaster can do little to prevent the next disaster, usually by the same agent, from hitting again. In some cases this is due to a missing feedback between then city and the disaster, tsunamis and earthquakes being two pathological cases. However, it can also be because the engine of the disaster, and the city are in fact, co-evolving. Both are changing their behavior as they respond to each other.

I have been focusing my efforts on the co-evolution of wildfires and the cities that they burn. Co-evolution can occur when two entities compete in some way for resources. A brief example of co-evolution is in the relationship between plants and herbivores. Some plants develop toxins in order to discourage their leaves and stems from being eaten. At the same time, herbivores have developed ways of metabolizing the toxins, in order to not go hungry.

Each year, wildfires cause hundreds of millions of dollars of damage in property and infrastructure, in addition to incalculable expenses and losses of the misplaced and newly homeless. The threat of fire is on the increase as cities encroach on natural areas. (Jehl, 2000). Also, each year, millions of acres of fire-adapted landscapes are paved, built on, and destructively managed. Acre for acre, the city is winning the battle with the natural landscape. In this study, the city is viewed as a spatial organism, one that has shape and behavior. I take the perspective that the human dimension of the city is manifested in the size and behavior of the urban area. The city emerges as an object from humans building communities, infrastructure, and homes. The ecological dimensions of wildfire are manifested by fire frequency, behavior and size. The next section will examine some of the dynamics of this two-process system.

The City-Wildfire Relationship

Many of the natural landscapes of the American West, South-West, and Florida include fire as an emergent property of ecological self-organization at many spatial and temporal scales. Fire promotes succession by triggering the seed germination of some species, and clearing the land for pioneer annual plants. The scorching of a forest and chaparral leave some dead wood standing, making new habitat for raptors and small mammals. Historically these fires were triggered by lightning and would burn until they ran out of fuel or they became extinguished by the accompanied rains. Typically each region has a fire regime which operates on a cycle, dependent on the dominant habitat type. The cycle is generally different for the size of the fire as well. For example, large fires in chaparral, the dominant vegetation type of Santa Barbara, California, occur every 10 – 25 years, while small fires (< 1 acre) can occur frequently during the dry months of the year. When a large fire burns, its movement is determined by the winds, fuel load and slope of the surroundings. If the winds are strong enough, spotting, can occur. Fire spotting is the process of an ember, blown by the wind, starting a new fire up to a kilometer away from the "mother" fire.

Humans have changed the natural fire regime. Since we view the natural landscape as an economic resource, our shepherding of nature has been paramount to fire policy. The buildup of kindling and fuel has led to an altered fire regime for most areas. The result of this is a stochastic periodicity and a better fueled fire, with a behavior no less predictive. The prescribed burn policy of government agencies has possibly done some good in re-establishing the natural fire regimes, although there is clearly a lack of deep understanding of the system. This is evidenced by the ignition of fires in weather where they never catch hold, or of the wrong scale (possibly too small). The lack of understanding is further evidenced by the recent fire started in the Bandelier National Monument in New Mexico, which burned hundreds of homes in Los Alamos, including some structures of the Los Alamos National Laboratory (luckily, no buildings where fire is modeled were burned.)

Urbanization is a complex process as well. Urban areas grow in many ways as they age, such as economically, socially and spatially. Spatial urban growth occurs by the construction of urban structures in commercial and residential zones. The spatial distribution of new zones is dependent on the distribution of the existing zones, the economic and social drivers of the region, the geography of the region, as well as the area's topography.

As the acres of the natural landscape become urbanized, there are some neutral and positive feedbacks that create better fire conditions. As cities grow, pockets of non-urbanization remain. Examples include parks, nature preserves, and conservation easements. Urban areas are usually not built on steep slopes, due to building and insurance costs. These small refugia of native habitats are becoming increasingly biologically valuable and the need of fire is retained along with the biota.

The development of infrastructure to support the city can lead to wildfires. Simple observations of ignition points of wildfires correlate to road proximity. A cigarette, a spark from metal-on-concrete, or a forgotten campfire ember can be effective in starting a fire in ideal wildfire conditions. An arsonist from the nearby city can do similar damage. Another example of activities which can promote wildfires is the use of fire-prone landscaping near the urban fringe. The use of these plants (usually non-native) allow a wildfire to easily spread into an urban area.

Most of the behavior change of the urban areas occurs after a fire. The learning comes in the form of human behavior change. This includes the system of fire-fighting, often consisting of volunteers, who gain respect in the community for their actions. As a way of dealing with family separation as a result of the recent Los Alamos fire, a volunteer website was developed which retained a database of rescue shelters and their temporary inhabitants. In the Santa Monica Mountains of California, Los Angeles Department of Fire has started a nursery of fire-resistant and drought-tolerant native plants, handed out free to county residents. There are changes in building and landscaping code and pre-fire “management” techniques put in place. Rarely does the burnt city opt to not rebuild the burnt dwellings and build somewhere else, however. Private landowners' desires and insurance companies' deep pockets facilitate the re-building.

Other disasters can force cities to adapt the behavior of re-building. In coastal areas, insurance companies and federal agencies refuse to pay for building sea walls for cliffside homes. As a result, the houses fall into the sea, or in Isla Vista, California, the houses are destroyed and the cliff is turned into a park. Elsewhere in California, a landslide in La Conchita entombed a handful of homes. The area is condemned and will not be restored.

Modeling the co-evolution

One way of examining the spatial interaction of these two phenomena is through temporal modeling in a Geographic Information System (GIS). The relationship can be better understood through simulating the competing processes of these phenomena. For the urban modeling a CA-based model is employed. The Urban Growth Model (UGM) (Clarke, Hoppen, and Gaydos 1997) calibrates the historical behavior of a city and applies the parameters of calibration to four growth rules which affect the city's response to slope, roads, dispersion, creation of new spreading centers and edge growth.

A CA-based fire model is used to model wildfires as well (Clarke, Brass, and Riggan 1995). This model operates on a different time scale (hourly instead of yearly) and takes wind, slope, soil moisture and vegetation type into account. Fires are started from user-defined ignition points and then allowed to burn until they extinguish themselves. The fire organism is generated by the ecological processes which promote fire. Other parameters, fire regime and successional stage for example, are important properties of the ecology and contribute to the expression of wildfire.

Santa Barbara, California , was used as a study site due to its rich historical fire and urban datasets and large amounts of wildfire damage in its history. The infamous Painted Cave fire burned many homes and caused millions of dollars of damage in 1990. The Painted Cave fire was notable for burning lemon groves and jumping US-101, a four-lane highway and a major transportation artery for the South Coast.

In order to examine the relationship of the dynamics of wildfire and urban growth, the systems will be coupled in a number of ways.

1. The first method does not use the fire model. It relies on the urban growth model to fill in the missing temporal urban data with output from the model's calibration stage. These "backcasted" timesteps will be intersected with the historical fire extents, producing the fire-urban spatial intersection from 1929 to 1997. This method will produce the spatial extent and frequency of the urban-wildfire competition. Urban areas which were burned more than once will be identified as well.
2. The second method of linking the two models will be in running UGM in calibration mode, but allowing the historical fires to remove the urban pixels as they are burned. Those pixels will be allowed to re-urbanize, but the effect on the model parameters will be taken into account. The urban predictions can then be run and the difference between the fire-calibrated run and the non-calibrated run can be observed as Santa Barbara grows into the future.
3. In a "alternate future" modeling scenario, the Urban Growth Model can be calibrated with the fires burning Santa Barbara as they occur, but this time, the city will be forced to "learn" - it cannot grow back where it has been burned. The difference between the "intelligent growth" and the present day urban extent can be explored as well as the differences in predictions. In examining an alternate present of Santa Barbara, one that has learned from wildfires, the differences in city shape and behavior can lead to different implications about how cities can behave.
4. Using the fire-calibrated urban parameters, Santa Barbara growth is simulated into the future. In-between each annual time step, the fire model can be applied to the landscape, using the historical ignition points for starting fires. The fire model does not force all fires to start, but is dependant on the environmental conditions. Since climatic conditions and fuel load vary throughout the year, choosing the time of year to seed the ignition points will be an issue. At first, it might be best to use the historical ignition points for dates in the Julian calendar to ignite fires.
5. Currently there is research on developing good fuel models for fire models and fire hazard assessments (Regelbrugge and Conard 1996). Most of this effort has been in determining the differences in fuel loads and moisture contents of different types of plants, native as well as non-native. Little of this effort has included modeling the fuel load of human dwellings. After running a simulation of Santa Barbara urban growth, the new and existing urban areas could be tested for fire danger. The urban pixels could be given surrogates for fuel load and fires could be ignited near the homes. Scenarios could be run with high urban fuel loads - reflecting poor management, or low fuel loads - reflecting intelligent choices of material and landscaping were used. In addition, fires could be started inside the urban boundary, employing the model as an urban fire model as well. The expense of fire would be calculated from the 1997 property values associated in the urban database.

This study in modeling may lead to some insight into the following questions:

1. Can urban-wildfire co-evolution be observed and tested in a spatial setting?
2. Fires change a city's behavior by establishing zoning and building codes, as well as rules for landscaping. Which new emergent properties be detected in the urban-wildfire system? At what spatial and temporal scales is it visible? Is there "collective intelligence" in this co-evolved system?
3. From the use of a coupled urban-wildfire model: Is there a distance effect? Do burned pixels in one area affect the behavior of another urban area in the same city?
4. Can the study of this coupled system lead to observations about each system that are non-observable on their own?
5. How do cities organize themselves in a disaster, with respect to information and disaster management? Which forms of mitigation are effective?

References

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