Malignant land use/cover expansion in human communities

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Abstract

While there are various pathognomonic characteristics of malignant processes, the most important of these is growth without restraint. Some exceptions have occurred with the occasional disappearance of human communities, but the general trend over the past several thousand years has been for human communities to persist over millennia and to continue expanding in land use by conversion of surrounding areas of natural or cultivated ecosystems to urban space. There is no evidence or example of successful conscious restraint of such growth in any part of the globe. Modern GIS and satellite imagery provide tools for the documentation of urban expansion that accompanies population growth within communities. High rates of population growth and physical expansion of urban space have been heavily documented on all continents. Brasilia, founded in 1956, expanded for decades at rates of up to 13% per year. Serial satellite photographs of the Brazilian Amazon show systematic replacement of pristine rain forest by the fishbone pattern of deforestation and incipient urbanization. Houston, the only major CMSA in the United States without zoning or land use restrictions, has expanded its area at the rate of up to 5% per year since 1974 accompanied by population growth rates of up to 8% per year. The Washington/Baltimore urban agglomeration is expanding at the rate of 22 square kilometers per year. This phenomenon has been documented from Uzbekistan to Belize. As the global urban population reaches 50%, the process of urban expansion appears to be inexorable, uncontrolled, and uncontrollable.

Introduction

The three most important features of cancer in an organism are uncontrolled growth, invasion of adjacent tissues, and spread (metastasis) to other tissues and organs (Anderson, 1961; Hanahan, 2000; Perez-Tamayo, 1961; Ruddon, 1987; Tannock, 1992). Nearly all human communities display these characteristics with respect to their local environments at the present time. It is possible to find evidence from Neolithic times and more recently (such as in Central America and southwestern North America) of communities and settlements being abandoned permanently due to climatic conditions, among others (Tainter, 1988; Redman, 1999). But in general, cultural adaptations that draw energy, food, and water from outside communities result in permanent settlements – cities – that grow and expand without limits. Modern technology allows communities to overcome environmental limits that once meant collapse.

Observations

A principal characteristic of modern cities, especially new ones, is rapid growth and extension into surrounding areas by invasion or distant colonization. Outlying communities are engulfed and absorbed by an expanding central city (Frankhauser, 1998, p. 141). Villages and settlements once remote from the urban center are now surrounded by new urban development (Friess, 2008).

New settlements and urbanizations begin by occupying previously undisturbed ecosystems and gradually (or quickly) replacing them with gardens, deforestation, or structures. Satellite images allow us to witness this process in real time. In the Brazilian Amazon, deforestation along feeder roads is an antecedent to and a sign of incipient urbanization (Lambin and Geist, 2007; Lambin, et al, 2001). (Fig. 1)

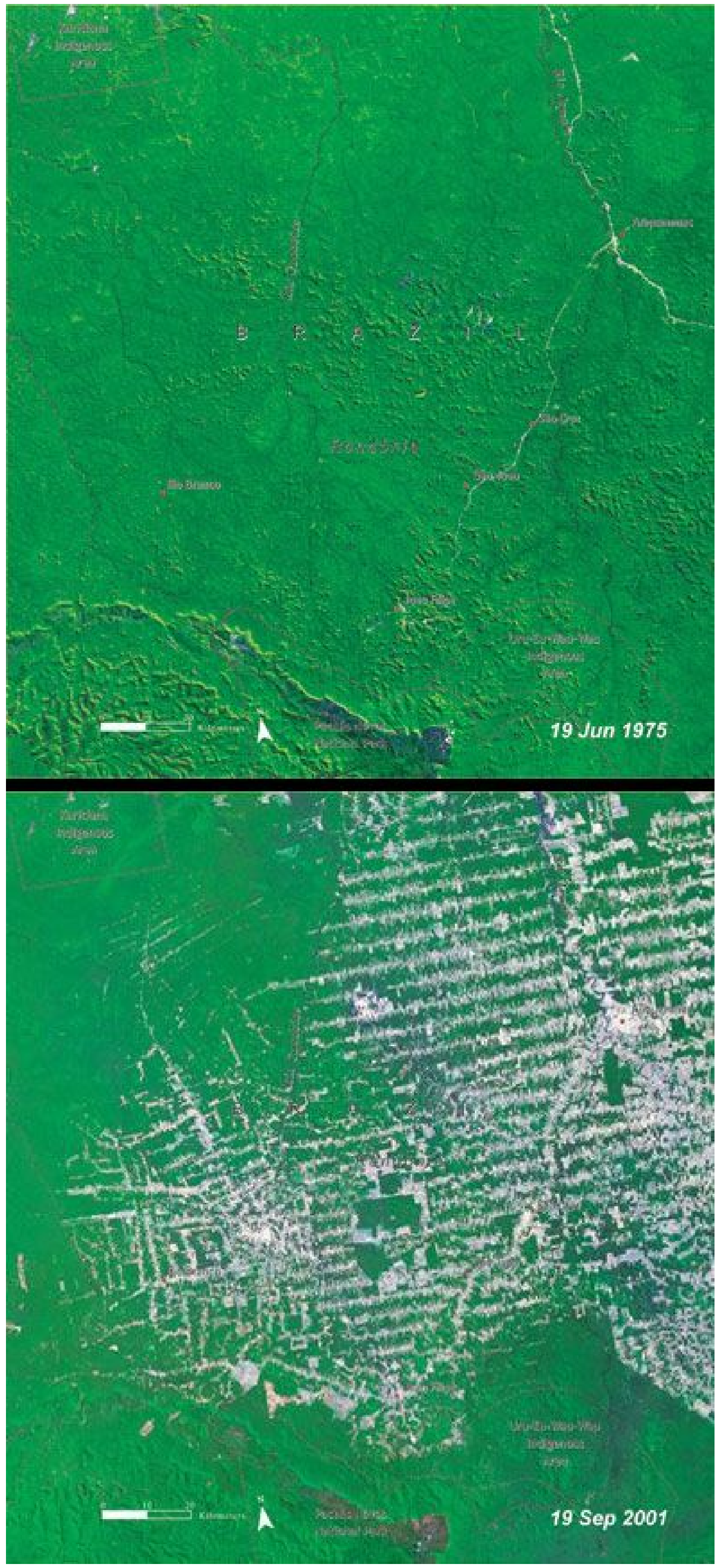

Fig. 1 Brazilian deforestation and incipient urbanization.
From UNEP, Atlas of Our Changing Environment

A study of LandSat photographs by Masek, et al (2000; Foresman, 2000) showed that the Washington-Baltimore metropolitan area was expanding at the rate of 22 square kilometers per year from 1973 through 1996. Figure 2 shows the expansion of land use/land cover of Baltimore from 1792 through 1992. This is clearly the pattern of malignant growth.

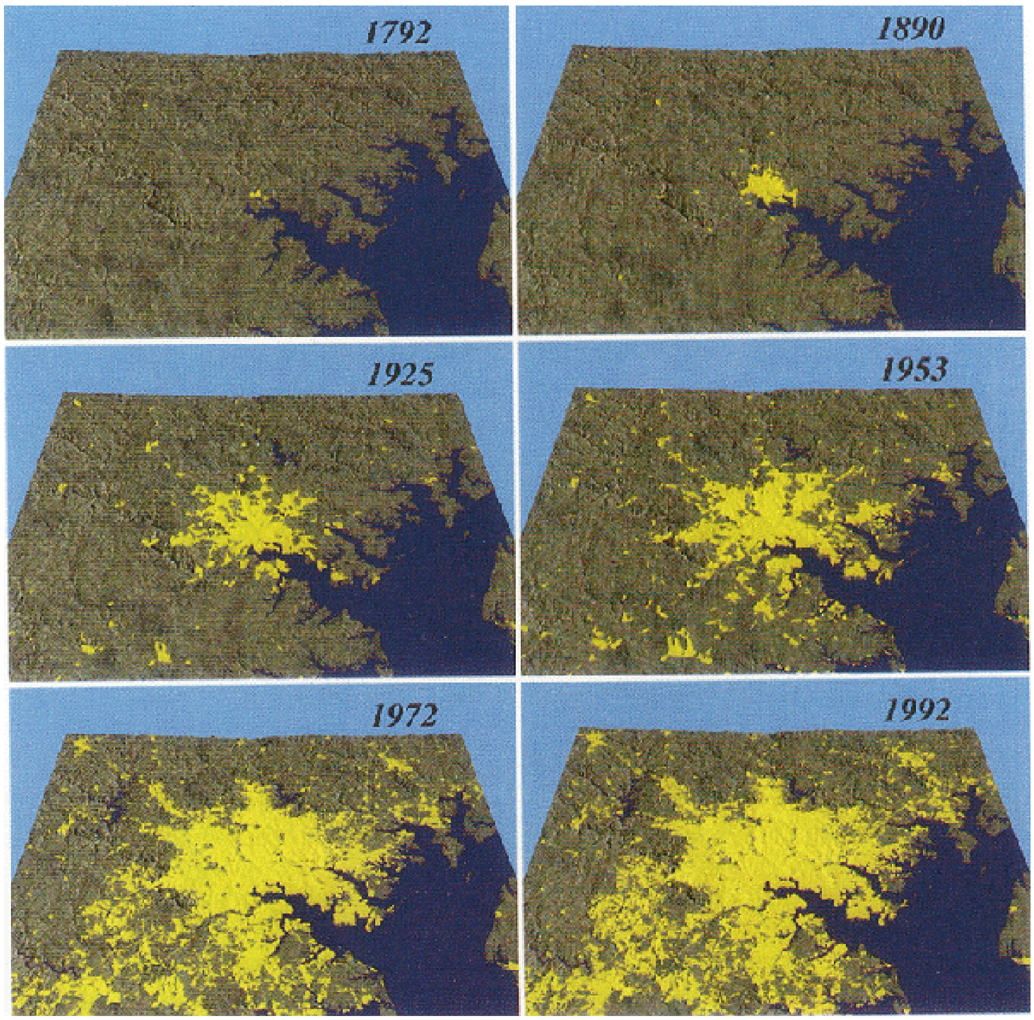

Figure 2. Baltimore simulated forest land cover showing 200 years of urban growth in yellow

Houston, Texas is one of the fastest growing metropolises in the United States. It is the only major CMSA in the United States without zoning or land use restrictions, and it has expanded its area at the rate of up to 5% per year since 1974 accompanied by population growth rates of up to 8% per year (Oguz, 2008; Fig. 3). Oguz used the SLEUTH spatially explicit cellular automata model to simulate future (2002-2030) urban growth in the Houston metropolitan area calibrated with historical data for the period 1974-2002. Without any protection of resource lands, the Houston CMSA will lose an estimated 2,000 km^2 of forest land, about 600 km^2 of agricultural land, and 400 km2 of wetlands by 2030.

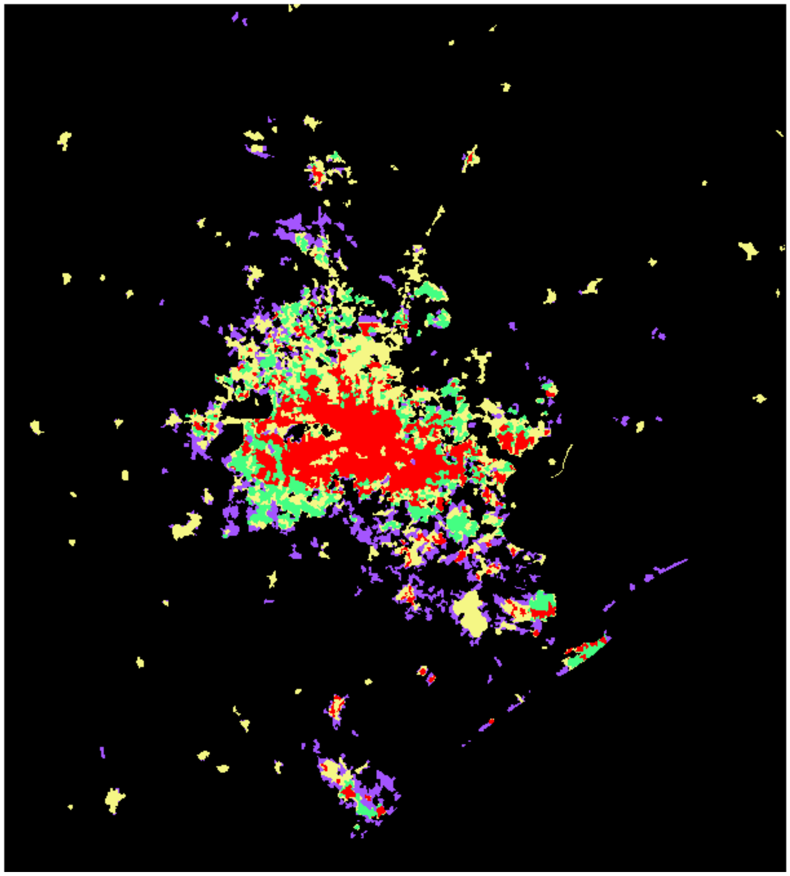

Fig. 3 Houston urban extents 1974-2002 From Oguz, 2008

In Colorado, the Front Range population has increased from 330,000 in 1900 to over 3.5 million in 2000 and is projected to grow to a population of 5.8 million by 2030. An increased demand for natural resources such as air and water, space and pasture for animals, open space, and creation of additional impervious surfaces increases flood risks, higher levels of nutrient loading in water bodies, loss of wetlands, increased air pollution, increased fire risk in the wildland urban interface, and increased traffic congestion (Watts, et al, 2007). (Fig. 4)

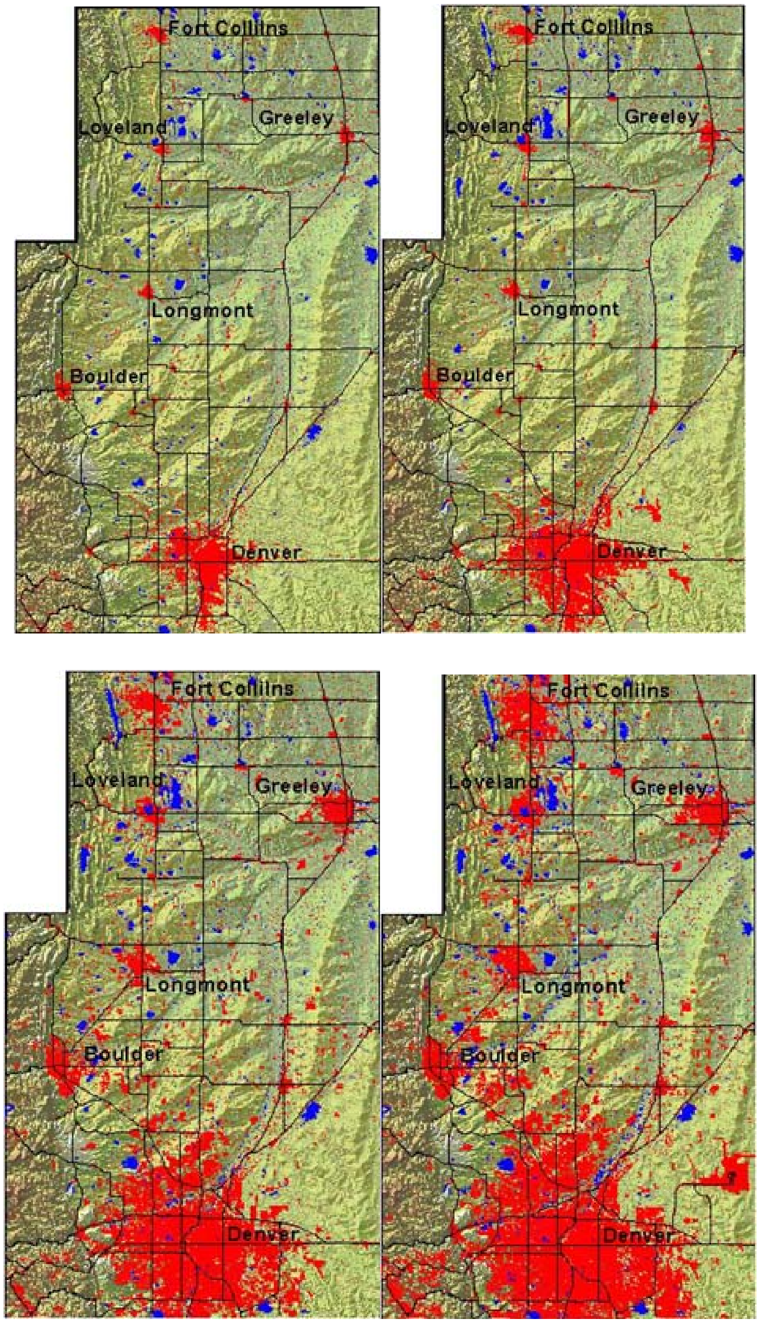

Figure 4. Colorado Front Range Urban Growth Map 1937, 1957, 1977, 1997
From CUES Study of Landscape Dynamics along Colorado Front Range
http://rockyweb.cr.usgs.gov/cues/COcuesHome.html

Changes similar to those seen in Colorado's Front Range are occurring in many U.S. metropolitan areas and are accompanied by increased local and regional Urban Heat Island (UHI) effects. Readings from 366 U.S. Climate Normals stations were analyzed based on Land Use/Land Cover (LULC) extents defined by the US Land Cover Trends Project. Results showed that few significant temperature trends occurred before periods of greatest LULC change, but after the period of greatest LULC change was observed, 95% of stations that exhibited significant trends displayed warming trends (Hale, et al, 2006).

Similar trends are occurring in China. China has experienced rapid urbanization since 1978. From 1978 to 2000, the number of small towns in China increased from 2,176 to 20,312, and the number of cities increased from 190 to 663. During this period, the proportion of urban population in China rose from 18% to 39%. Shenzhen, the fastest-growing city in China, once a small fishing village, was chosen as the site for a new port. It grew from ~ 0.1 million to ~ 7 million from 1978 to 2000. On average, the population of Shenzhen doubled every 3.6 years. The effect of such rapid urbanization in China has been the creation of a larger number of Urban Heat Island (UHI) effects, which have contributed directly to an effect on the average surface temperatures and evidence for a significant effect on climate (Zhou, et al, 2004).

Urban land area in the Beijing-Tianjin-Hebei region expanded by 71% between 1990 and 2000. (Tan, et al, 2005) Different-tier cities had enormous differences in urban development such as speed of urban land expansion and the spread of urban land per capita growth. Of all the new urban land, about 74% was converted from arable land, and there was a general tendency for smaller cities to have higher percentages of such conversion. Urban land is highly correlated with arable land in spatial distribution.

China's urban land increased by 817,000 hectares from 1990-2000, of which 80.8% occurred during the period from 1990-1995 and 19.2% during the period from 1995-2000. (Liu, et al, 2005) China's urban expansion had high spatial and temporal differences in four expansion modes: concentric, leapfrog, linear and multi-nuclei. Case studies of 13 megacities showed that urban expansion had been largely driven by demographic change, economic growth, and changes in land use policies and regulations.

Romero, et al (1999) analyzed land-use change in Santiago, Chile by looking at climatic transformation caused by the rapid transit from natural semiarid surface to urban areas. Santiago is under permanent subsidence inversion layers. The city is located in a closed basin surrounded by mountains. The urban area has Chile's highest population concentration (40% of the national total), 70% of the industries, and many vehicles, the main source of smog. Ozone exceeds air quality standards in the summer at all sites. There is no consideration of local climatic features in the process of urban planning

Veracruz, Mexico's principal port in the Gulf of Mexico, is expanding over a field of dunes, leveling many, surrounding and often obliterating inter-dunal wetlands, and encroaching on wetlands in neighboring floodplains. The metaphor of metabolization is used to enrich the characterization of the process and to highlight its vitality, but the city is still seen by its own planners as "malignant" with respect to adjacent ecosystems (Siemens, et al, 2006).

In nearby Belize, urban expansion is one of the major causes of land cover change (Cherrington, 2007). Belize City's area has about doubled between 1980 and 2007. The annual growth rate has been ~106 acres (43 ha.) per year More than 1700 acres (705 ha) that have been cleared have largely been taken from mangrove and other wetlands. From 39,771 inhabitants occupying 1,750 acres in 1980 to approximately 66,422 inhabitants occupying 3,449 acres in 2007, there has been a 67% increase in population but a 102% increase in area occupied. At 5,000 inhabitants per km^2, the population density remains high and comparable to London and Chicago.

Del Mar Lopez, et al (2001) studied the rate and distribution of urban growth on the island of Puerto Rico from 1977 to 1994. In 1977, 11.3% of Puerto Rico was classified as urban. After 17 years, urban areas had increased by 27.4 % and urban growth in soils suitable for agriculture had increased by 41.5%. There was a loss of 6% of potential agricultural lands.

Ciudad Victoria, Tamaulipas grew from 84,000 population in 1970 to 250,000 in 2000, a 200% growth in 30 years (Anderson, et al, 2005). 50 km to the south of Ciudad Victoria is the El Cielo Biosphere Reserve designated by UN in 1987. This ecologically unique 356,872 – acre site stretches from the eastern to western slopes of the Sierra Madre Oriental. The reserve contains biodiversity that is among the highest in the world because the climate is in the transitional zone between North and Central America. It has four distinct ecosystems. The authors ask: Will the growing population of Ciudad Victoria impinge upon resources of this Biosphere Reserve, or will it remain protected from urban expansion and resource exploitation?

Discussion

Urban areas drive environmental change at multiple scales “well beyond their city boundaries” (Grimm, et al, 2008). The material demands of production and human consumption alter land use and affect biodiversity and hydrosystems locally to regionally. Urban population growth has occurred on less than 3% of the global terrestrial surface, yet the impact of urban growth has been global with 78% of carbon emissions, 60% of residential water use, and 75% of wood used for industrial purposes attributed to cities. Even in ancient times, excessive demands of a highly stratified urban elite led to degradation of productive landscapes and the collapse of otherwise successful societies. An example is the salinization of the most fertile soils in the 3rd millennium BCE in Mesopotamia.

Urban areas cause and respond to changes in biogeochemical cycles that are regional and global in nature. Cities are the primary source of greenhouse gas emissions and are therefore critical contributors to global climate change. As previously noted, rapid urbanization and the cumulative impact of urban heat island (UHI) effects occurring in an increasing number of small towns and cities with higher air and surface temperatures than rural surroundings is leading to regional climate change (Zhou et al, 2004).

Conclusion

Even as the “gigalopolis” (USGS, 2007) is one of the defining features of the human occupation of global ecosystems in the 21st century, we find that urban geographers are still puzzled by the challenge of understanding exactly how and why cities grow, what forms they are likely to take or which forms are best, how to define the optimum size of a city in terms of the density of population and activities, and the ways that cities function. The main thing that can be said is that cities are complex systems that mainly grow from the bottom up, and that the size and shape of cities follows well-defined scaling laws that result from intense competition for space (Batty, 2008). A more difficult challenge is determining and recommending policies for managing the growth and form of cities. There do not appear to be any examples of success in controlling the shape or growth of cities aside from a highly-designed and planned city like Brasilia, which lasted in its original form for only a few years. .

In the next 25 years, the world will see the addition of nearly 1 million km^2 of urban area in tens of thousands of cities around the globe, by which time 60% of the world's population will live in cities. Ecologists are now faced less with understanding how undisturbed ecosystems function than how urban form controls energy use, oil security and climate change (McDonald, 2008).

It is the premise of this paper, however, that urban land cover/use expansion, which is the singular characteristic of modern cities and, in fact, all modern human communities, now has all the main characteristics of a malignant process, and can only be understood completely in those terms.

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