Weighing Sprawl Factors in Large U.S. Cities

A report on the nearly equal roles played by population growth and land use choices in the loss of farmland and natural habitat to urbanization

Analysis of U.S. Bureau of the Census Data on the 100 Largest Urbanized Areas of the United States

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by Leon Kolankiewicz and Roy Beck

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Executive Summary

Over a 20-year period, the 100 largest Urbanized Areas examined in this study sprawled out over an additional 14,545 square miles. That was more than 9 million acres of natural habitats, farmland and other rural space that were covered over by the asphalt, buildings and sub-divisions of suburbia. And that was just for the half of Americans who live in those 100 cities.

Americans have become increasingly alarmed, making urban sprawl one of the nation's hottest political issues.

A major controversy in the efforts to halt the rural land loss is whether land-use and consumption decisions are the primary engines of urban sprawl, or whether it is the nation's continuing population boom providing most of the power driving the expansion.

A careful analysis of U.S. Census Bureau data found that the two sprawl factors share equally in the blame:

(1) Per Capita Sprawl: About half the sprawl nationwide appears to be related to the land-use and consumption choices that lead to an increase in the average amount of urban land per resident.

(2) Population Growth: The other half of sprawl is related to the increase in the number of residents within those 100 Urbanized Areas.

On average, there are more of us, and each of us is using more urban land, and therein lie the two halves of the problem. Those and other findings in U.S. Census Bureau data on Urbanized Areas lead the authors to the following conclusions:

- The toll of urban sprawl on ecosystems, farmland and scenic open spaces cannot be substantially halted unless anti-sprawl efforts include a two-pronged attack using both land-use/consumption tools and population tools.
- Anyone advocating U.S. population stabilization who derides the importance of consumption and planning controls is ignoring half the story of American sprawl.
- Similarly, any Smart Growth advocate who relegates population growth to a side issue is turning a blind eye to half the problem and, thus, approximately half the solution which is population stabilization.
- Although the circumstances of each city are different, the power of both sprawl factors is potentially the same in each. Every city that wishes to restrain its land expansion will need to continually keep in mind the impacts on sprawl of both growth factors. Cities with no recent per capita land consumption growth should not throw away land-use tools, lest Per Capita Sprawl resume. And cities with no recent population growth will still need to be reminded regularly of the role population can play in sprawl, lest they thoughtlessly create incentives to promote population growth in the future.
- The forces driving overall national population growth cannot be ignored as contributors to sprawl, since national population growth manifests itself as growth in local communities.

TERMS

This study uses three terms exten- sively and precisely (see pages 24 and 55 for further description).

Sprawl – the rural acres lost as an Urbanized Area spreads outward over a period of time.

Percent Sprawl – the percentage increase of total acres of land in an Urbanized Area over a period of time.

Urbanized Area – a central city and its contiguously developed suburbs, as meticulously calculated by the Census Bureau.

Those conclusions pose a challenge to most anti-sprawl efforts that focus on only one or the other of the two sprawl factors. And of the two, population is the factor most often ignored, according to a literature search. It found that

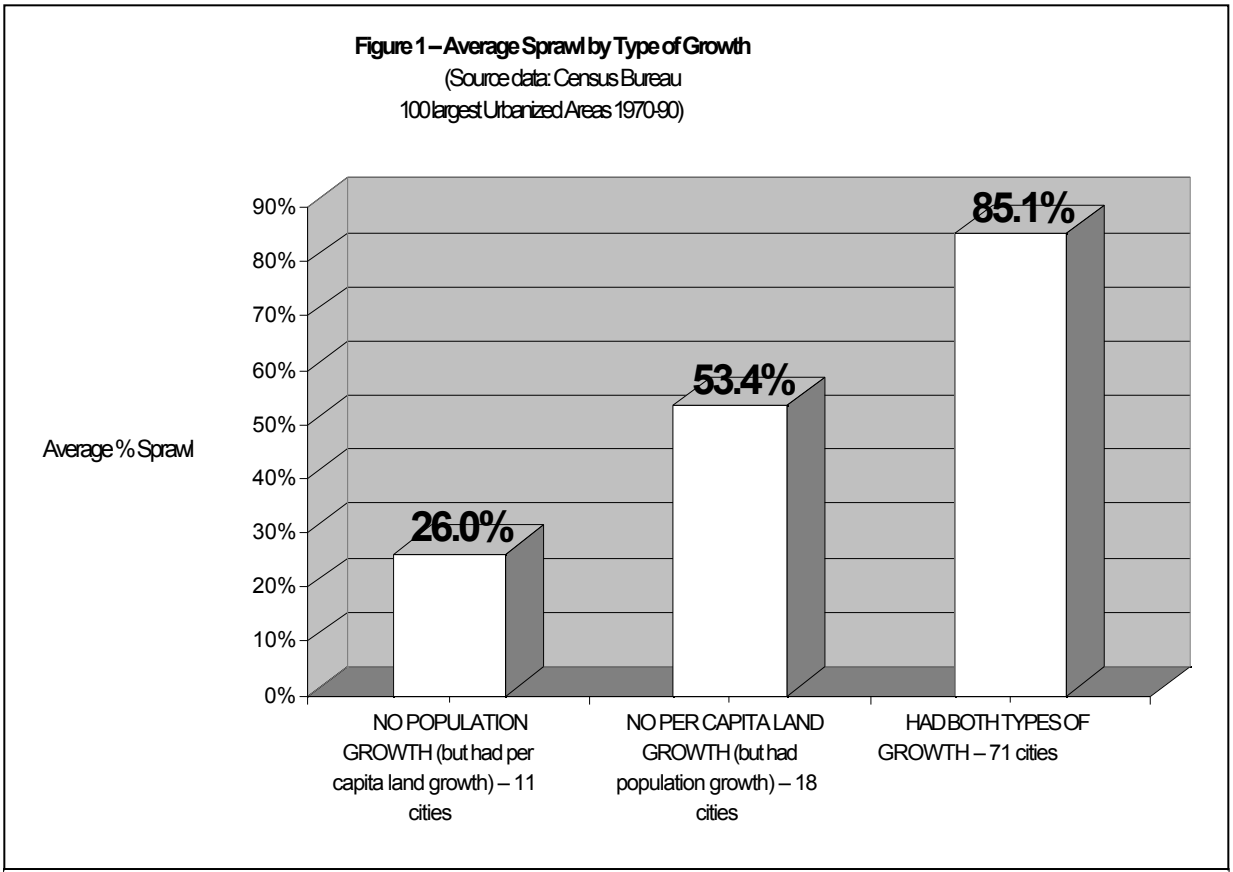
media stories, advocacy programs, governmental reports and plans, and political statements about controlling sprawl rarely suggested that substantially reducing population growth is a necessary anti-sprawl tool. Our analysis of Census data indicates that anti-sprawl efforts that deal almost exclusively with land-use decisions are properly focused to deal with around half the nation's sprawl problem; it also indicates, however, that if continued without a population-stabilization component, those efforts are destined to fall far short of protecting the agricultural land and natural habitats surrounding cities.

WHAT ABOUT DETROIT?

According to the literature search, many have resisted making the reduction of population growth a co-goal of anti-sprawl efforts because of doubts raised by cities where population already has stopped growing. A common comment has been something like this: "But what about Detroit? Clearly, population growth is not a key factor – or a national factor – in sprawl when you consider that Detroit had no population growth whatsoever between 1970 and 1990, but it still was swimming in sprawl – 28.4%." Indeed, others have added, what about Pittsburgh, Milwaukee, Dayton, Akron or Flint? There was no population growth in any of them, but all had sprawl. The average sprawl (percentage increase in total urban land) for the 11 Urbanized Areas with no population growth was 26%.

Our analysis of the Census data, however, provides a context in which those cities appear to reinforce – not contradict – the conclusion that population growth is a powerful determinant of sprawl. **Figure 1** shows that compared to the Detroits and Pittsburghs of the country that had no population growth:

- Average sprawl was twice as high (53.4%) for those Urbanized Areas that had population growth even though they had stopped per capita land consumption growth (the middle bar).



DESCRIPTION: Cities that had either no growth in population or had no growth in per capita land consumption still had sprawl. But cities that had both types of growth had far higher sprawl.

- Average sprawl was more than three times as high (85.1%) for those that had population growth while also continuing per capita land consumption growth (the bar on the right).

Thus, rather than proving that population-stabilization is a minor or secondary goal in anti-sprawl efforts, Detroit indicates just the opposite. When considered in the context of all 100 largest Urbanized Areas, the answer to the question, "What about Detroit?" might be: If it had not had a population decline, its sprawl likely would have been far greater.

Such a finding also reinforces the primary conclusion of the study: Unless a city fights both sprawl factors, it likely will continue to have lots of sprawl. The bars on the left and the middle of Figure 1 illustrate that well.

CHOOSING HOW TO MEASURE

This study measures sprawl in terms of the actual amount of rural land that is lost to urbanization. There are other ways to measure. Often, urban planning institutions focus more on the style of the conversion of rural land to urban use than on the amount of the conversion. Organizations whose chief concerns involve urban planning goals may tend to emphasize the qualitative attributes of sprawl – such as attractiveness, pedestrian-friendliness, and compactness.

But for those who are most concerned about the effect of sprawl on the natural environment and agricultural resources, the more important overall measure of sprawl is the actual amount of land that has been urbanized. Knowing the actual square miles of urban expansion provides a key, but not the only, indicator of the threat to the natural environment and to the nation's agricultural production.

Both the urban planning and environmental approaches to sprawl are valid ones for achieving sometimes differing, though not necessarily competing, goals. Here, however, we concentrate on the environment.

THE IMPORTANCE OF 'PER CAPITA SPRAWL'

The amount of land covered by an Urbanized Area is equal to the average amount of urban land per resident multiplied by the number of residents:

Total Urbanized Land = Per Capita Land Use * Urban Population

Despite the considerable complexity of sprawl in an urban area, nearly all of the complexity can be boiled down to this: Overall Sprawl is the growth in the total amount of land of an Urbanized Area; that overall change is caused by the combination of the changes in per capita land consumption and the changes in population. The Census Bureau provides data to calculate all of that information.

The concept of per capita land consumption is essential to the analysis in this study and, we would contend, to any clear analysis of sprawl. That statistic tidies up the effects of all decisions that affect consumption, such as urban planning, development, transportation, taxing, affluence, business and consumer preferences. We usually cannot know the specific effect of any one of those decisions, but we can know the combined effects of all of them by looking at the single statistic that tells us how much urban land is used on average for each resident to satisfy housing, transportation, work, recreation and commercial needs. In most of the 100 cities, per capita land consumption in 1990 was between one-sixth and one-half acre. (See Appendix E for how this is calculated.)

When per capita land consumption increases, we call that "Per Capita Sprawl."

If the population of a city remains stable, but the land use for the average resident increases, that Per Capita Sprawl will cause the urbanization of surrounding rural land. (Detroit and Pittsburgh were examples of this phenomenon.) Most current anti-sprawl efforts, particularly those under the name of "smart growth," focus on stopping Per Capita Sprawl.

This study has calculated the Per Capita Sprawl percentage for each of the 100 largest Urbanized Areas and displays those in Appendix A.

CALCULATING EACH FACTOR'S 'SHARE' OF SPRAWL

By placing the Per Capita Sprawl percentage next to the Population Growth percentage for each Area, we can visually and immediately gain a fairly clear idea about which factor has played a larger role in the equation that has produced an Urbanized Area's sprawl.

Table 1 allows us to do that for the 10 Urbanized Areas that are ranked here for having had the most square miles of sprawl. Looking at New York City and Philadelphia, we immediately notice that Per Capita Sprawl was a much greater factor than Population Growth. The two factors are quite similar in Washington D.C. and Minneapolis. In the other six, Population Growth is the obvious primary change factor in their Overall Sprawl.

With percentages for the two growth factors available, it is possible to look at their ratio to each other. We used a standard method of calculating those ratios to allow us to figure "shares of sprawl" for each factor. That allowed us, for example, to state that Population Growth was related to 63.5% of the Overall Sprawl in Atlanta, the nation's top sprawler. And Per Capita Sprawl was related to 36.5% of the sprawl.

Table 1 – Per Capita Sprawl Compared with Population Growth in USA's Ten Largest Sprawlers (1970-1990)

Urbanized Area	% Growth in Per Capita Land Consumption	% Growth in Population
1. Atlanta, GA	42%	84%
2. Houston, TX	26%	73%
3. New York City, NY-NJ	24%	- 1%
4. Washington, DC-MD-VA	41%	36%
5. Philadelphia, PA-NJ	48%	5%
6. Los Angeles, CA	- 8%	37%
7. Dallas-Fort Worth, TX	- 15%	59%
8. Tampa-St. Petersburg-Clearwater, FL	13%	98%
9. Phoenix, AZ	- 18%	132%
10. Minneapolis-St. Paul,MN	21%	22%

Source: U.S. Census Bureau data

When using the population and land figures for all 100 Areas, the calculation method found that 50.9% of the sprawl was related to growth in population, and 49.1% was related to growth in per capita land consumption (see Figure 8 on the back cover).

The usefulness of proportioning exercises is not in the mathematical precision of such an equation but in general approximations. Whether Population Growth's share of the nation's sprawl was 50.9%, 50.6% or 45% or 55%, it is obvious that Population Growth and Per Capita Sprawl played roughly equal roles in the rapid expansion of cities over surrounding rural areas.

We applied the results of the apportioning method to the total square miles of sprawl by the 100 largest Urbanized Areas during the most recent 20 years for which data are available. The results are illustrated in Figure 3 (on page 15): Per Capita Sprawl was related to 7,141 square miles of sprawl, and Population Growth was related to 7,403 square miles of sprawl.

To ignore either growth factor, for sure, would be to ignore a vast amount of lost natural habitats, farmland and other rural space.

RESULTS CONSISTENT WITH OTHER STUDIES

The finding of general parity between the two sprawl-inducing factors in 100 large Urbanized Areas between 1970 and 1990 is consistent with several other studies of somewhat different time periods and number of cities:

- Daniel McGrath of the University of Illinois Great Cities Institute studied the most populated 20 coastal regions from 1950 to 1990. He concluded that just over half the urban land expansion was determined by population growth while just under half was determined by other factors such as affluence and technology.[1]

[1] Press Release, "Predicting urban sprawl in top 20 U.S. coastal cities," December 5, 2000, Illinois-Indiana Sea Grant.

- The U.S. Department of Housing and Urban Development studied the nation's cities in the very recent 1994-97 period and declared that urban areas were expanding at about twice the rate of population. As is explained later, that is another way of saying that Population Growth and Per Capita Sprawl were roughly equal.[2]

- The U.S. Department of Agriculture surveyed the development of all rural land (minus Alaska) from 1982 to 1997.[3] We applied the apportioning method to those results (released in January 2001) and found: 49.7% of the transformation of rural land into developed land was related to population growth, and 50.3% was related to per capita land consumption growth.

- Oft-quoted urban planning consultant David Rusk studied the expansion of 213 Urbanized Areas between 1960 and 1990. He found that population increased by 47% while the total land use expanded by 107%. When placed in the apportioning method, the Rusk results showed that 54% of Overall Sprawl had been related to Population Growth, while 46% of sprawl had been related to Per Capita Sprawl.[4]

TWO-PRONGED ATTACK NEEDED NATIONALLY,
NOT JUST IN SOME REGIONS

The relative roles of the two sprawl factors differ widely from region to region, and within the regions. This raises the possibility that the two-pronged attack suggested by aggregate national sprawl data may not be appropriate or necessary in all regions of the country. Part of the public debate among anti-sprawl advocates has been whether population is primarily a problem in just a few regions, thus arguing against a relatively uniform national anti-sprawl campaign that is similar in all regions.

To test that possibility, we sorted the 100 Urbanized Areas into 12 geographic regions. Because of their size and exceptionally high levels of sprawl, the states of California, Texas and Florida were each considered a region unto themselves.

We then calculated the "shares of sprawl" for the average Urbanized Area in each region, allowing us to place each region into one of five categories based on quintiles of shares of sprawl:

Category I: (no regions fit this criteria)
Per Capita Sprawl was the overwhelming factor (81-100%) in Overall Sprawl
Population Growth was a minor factor (0-19%) in Overall Sprawl

Category II: Northeast, Border States, Great Lakes
Per Capita Sprawl was the primary factor (61-80%) in Overall Sprawl
Population Growth was a significant factor (20-39%) in Overall Sprawl

Category III: Plains, Old South, Chesapeake Bay Watershed
Per Capita Sprawl was a primary factor (40-60%) in Overall Sprawl
Population Growth was a primary factor (40-60%) in Overall Sprawl

Category IV: Pacific Northwest, Texas
Per Capita Sprawl was a significant factor (20-39%) in Overall Sprawl
Population Growth the primary factor (61-80%) in Overall Sprawl

Category V: California, Desert Southwest, Mountain West, Florida
Per Capita Sprawl was a minor factor (0-19%) in Overall Sprawl

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[2] "A Complex Relationship: Population Growth and Suburban Sprawl," viewed Feb. 10, 2001, on the Sierra Club website, based on "The State of the Cities 2000," U.S. Department of Housing and Urban Development, 2000.
[3] Calculated by the U.S. Department of Agriculture; these data concern development both near and far from urban areas in the 49 states excluding Alaska. USDA Natural Resources Conservation Service. 2000. *Summary Report 1997 National Resources Inventory*. Table 1, p. 11.
[4] See note 2, "The Debate on Theories of David Rusk," The Regionalist, Fall 1997.

Population Growth was the overwhelming factor (81-100%) in Overall Sprawl

Per Capita Sprawl was a significant factor of 20% or more in 8 of the 12 regions. It was a minor factor of 19% or less in 4 regions. It was not the overwhelming factor in any of the regions.

It is much more obvious that Population Growth is truly a national factor; it was a significant factor of 20% or more in all 12 regions. Of those, it was a primary factor in 9 of them, including 4 in which it was the overwhelming factor of 81% or more.

Thus, there is no apparent reason to de-emphasize Population Growth in any of the regions, as many have suggested. And, as no major anti-sprawl leaders have suggested de-emphasizing Per Capita Sprawl in the four regions where it was a minor factor, we do not suggest it either. We cannot find a convincing justification, for example, for withholding land-use information from the Urbanized Areas of San Diego, Phoenix and Orlando just because each had less than 10% of their sprawl related to Per Capita Sprawl – which points again to a primary conclusion of the study: Every community should be helped to understand the sprawl power of both Population Growth and Per Capita Sprawl as they design their local programs according to their own unique circumstances.

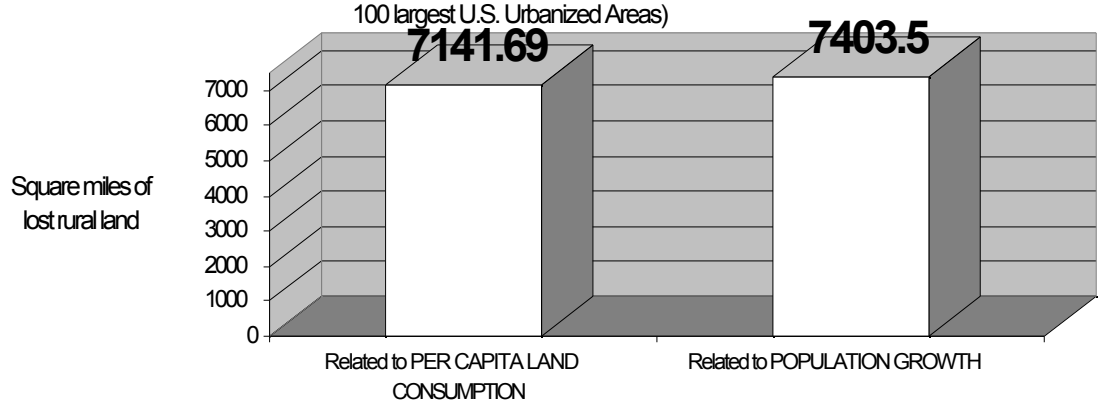
DATA UNDERLYING THIS STUDY
OFTEN HAVE BEEN MISUNDERSTOOD

To some, the conclusions of this study may seem like little more than common sense. As noted above, they do not contradict a number of other studies that are well-known to those who are working to control sprawl.

Yet, our literature search found very little among anti-sprawl efforts that works toward restraining population growth. That is in sharp contrast to this study's conclusion that real and sustainable controls on sprawl are not practicable without vigorous national and local efforts to attack half the source of sprawl by moving toward population stabilization.

Because it is difficult to believe that people who are seriously concerned about sprawl would deliberately choose to ignore or minimize something that is half the problem – or that journalists would intentionally mislead their readers so often in that way – the explanation appears to be that there has been a massive misunderstanding of the data that the Census Bureau provides.

Figure 3 – Rural land loss (sprawl) as related to each growth factor (1970-90)
(Source data: Census Bureau 100 largest U.S. Urbanized Areas)



DESCRIPTION: When the growth percentages of the two major factors in national sprawl are run through the Holdren apportioning method, they show that Per Capita Sprawl was related to 49.1%, and population growth was related to 50.9%, of Overall Sprawl. When those percentages are applied to the total sprawl of the 100 Areas, they yield the square miles of sprawl illustrated above.

Perhaps the most consequential has been the misuse of "doubling" statistics. We have found repeated instances where the role of population growth was dismissed as only a minor factor because the urban area was expanding at double the rate of population.

Charlotte, North Carolina, is such an Urbanized Area. It's population grew by 63% while the total urban area grew by twice as much – 128.7%. Was Population Growth a minor player in that sprawl? To answer the question, it helps to know what the other sprawl factor was doing. In fact, Charlotte's per capita land consumption was growing by 40.3% while the population was growing by 63%. Not only was Population Growth a significant factor, it was the majority factor.

To understand the role that semantics may play in how policies get formed and executed, consider the difference between "urban areas are expanding at double the rate of the population" and "population growth is the primary sprawl factor and accounts for more than half of urban sprawl." Technically, both statements state the same information, but only the latter apparently communicates a clear message to most people.

POPULATION GROWTH WITHOUT SPRAWL APPARENTLY NOT PRACTICABLE

The virtual void of population-stabilization plans within the anti-sprawl programs around the country is related to a belief that population growth can be accommodated without causing sprawl.

Theoretically, that is possible – for awhile: All new residents would have to move into the existing urban area, and none of the previous residents could move to the edge of the city. Such an occurrence over any period of time could happen only through the continual demolition of existing housing to make room for higher-density cluster houses, condominiums or apartment buildings; the demolition of apartment buildings to build higher apartment buildings; higher occupancy rates in existing structures, including some structures not intended for residential use such as garages, and building on any remaining vacant land.

Even if Americans were to accept the escalating governmental regulations that would be required to handle each year's population growth within existing boundaries, such a success would not ease the massive "ecological footprint" on the rural areas of the country.

It is important to recognize that the per-capita-land-consumption figure upon which nearly all conventional anti-sprawl efforts focus includes only the land consumed by an average resident inside his/her own Urbanized Area. It does not include all the rural land in other parts of the country that is required to obtain the food, fiber, minerals and energy for that resident, and to dispose of that resident's wastes – termed the ecological footprint of the Area.

This study failed to find any American community that has shown an inclination to adopt the regulations and make the personal behavior changes that would counteract the effects of population growth for even a few years, let alone in perpetuity – which essentially is what would be required if current national population policies stay in place.

Los Angeles is a prime example of the limits to how far Americans will go in packing additional people into their neighborhoods. No city in America may be a better model of the goal of attempting to restrain sprawl by channeling population growth into ever-denser settlements, both in the urban core and throughout the suburbs. Between 1970 and 1990, per capita land consumption fell until the L.A. Urbanized Area was the most densely populated in the country. Many people find this hard to believe because of Manhattan's skyline. But New York's suburbs are only 60% as dense as those of Los Angeles. No other Urbanized Area provided so little land per resident as Los Angeles (0.11 acre). Most American communities have refused to come anywhere near the L.A. densities.

Yet despite accepting the densest living conditions in the country, the Los Angeles Area sprawled across another 394 square miles of orchards, farmland, natural habitat and other rural land. The reason? The addition of another 3.1 million residents.

STUDY RESULTS PROVIDE MEASURE FOR SERIOUSNESS OF FUTURE ANTI-SPRAWL EFFORTS

The failure of Los Angeles and any others among the 100 largest Urbanized Areas to substantially control sprawl in the face of population growth suggests that those who would attempt to save surrounding environmental habitat and farmland will certainly need to address (a) local incentives that entice more people to move into particular cities, (b) state policies that attract residents from other states, and (c) federal policies that add population to the nation.

Population policies, phenomena and trends – along with the land-use/consumption ingredients in Per Capita Sprawl – are central to understanding the future of sprawl in American cities and how to prevent it. The findings of this study suggest that plans and programs from governmental agencies, think tanks, universities and advocacy groups must tackle both population growth and land-use factors if they are to help the nation find a sustainable solution to the sprawl that is devouring thousands of square miles of natural habitat and farmland each decade.

Weighing Sprawl Factors In Large U.S. Cities

A report on the nearly equal roles played by population growth and land use choices in the loss of farmland and natural habitat to urbanization

1. INTRODUCTION

Considerable controversy has arisen over whether land-use and consumption decisions are the primary engines of urban sprawl, or whether the nation's continuing population boom might provide most of the power driving the expansion of cities into the countryside. Understanding the relative contributions of those factors appears to be essential if cities, states, and the nation as a whole are to devise plans that will provide for sustainable restraints on sprawl.

This study has sought to move beyond the abstract assertions and non-contextual anecdotes that have dominated the debate thus far. It attempts to quantify the roles of the major sprawl factors and to analyze some of the comparative statistical evidence.

1.1. Sprawl claims thousands of square miles each decade

Efficient use of anti-sprawl resources is especially important because sprawl foes are challenging formidable forces. Economic, cultural, demographic and political forces between 1982 and 1997, for example, converted approximately 39,000 square miles (or 25 million acres) of rural land into subdivisions, malls, workplaces, roads, parking lots, resorts, and the like.[5]

- The rural area lost to development between 1982 and 1997 is about equal to the entire land mass of Maine and New Hampshire combined.

- The rate of rural land lost to development in the 1990s was about 2.2 million acres per year. If this rate continues to the year 2050 – when today's toddlers are middle-aged – the United States will have lost an additional 110 million acres of rural countryside. That's about equal to the combined areas of Connecticut, Massachusetts, Rhode Island, Vermont, Delaware, Pennsylvania, New York, New Jersey, and Virginia.

- Added to the loss of an area equivalent to Maine and New Hampshire, the losses by 2050 will amount to much of the Eastern Seaboard. Anyone who has flown at night from New York to Florida and seen the vast clusters of lights below sweeping away as far as the eye can see knows just how far advanced this process of mass urbanization already is – and how strained is the myth of limitless American open spaces.

[5] See note 3.

This study focuses on one part of the rural land loss – the development surrounding what are called Urbanized Areas (entities defined by the Census Bureau as central cities and the contiguous development of their suburbs). Examined are the factors in the sprawl of the 100 largest Urbanized Areas. In those 100 alone, more than 14,000 square miles of the surrounding rural land were lost to urbanization during the most recent 20 years of Census research (1970-90).[6]

Although rates (percentage increases) of sprawl are significant to know, the most important environmental fact about a city's sprawl is the actual number of square miles of rural land that have been urbanized.

Table 2 lists the 10 Urbanized Areas which eliminated the most rural land over the two decades. Paving and building over hundreds of square miles of woods, wetlands, prairies, desertscape and fields, they truly earned the dubious distinction as the nation's "Top Sprawlers," representing many regions, from the Southwest and Texas to the Northern Plains, the Southeast and the Mid-Atlantic.

Table 2 – USA's Top Sprawlers – Urbanized Areas with Greatest Sprawl (1970 to 1990)

Urbanized Area	Sprawl (sq. miles)
1. Atlanta, GA	701.7
2. Houston, TX	638.7
3. New York City, NY-NJ	541.3
4. Washington, DC-MD-VA	450.1
5. Philadelphia, PA-NJ	412.4
6. Los Angeles, CA	393.8
7. Dallas-Fort Worth, TX	372.4
8. Tampa-St. Petersburg-Clearwater, FL	358.7
9. Phoenix, AZ	353.6
10. Minneapolis-Saint Paul, MN	341.6

Source: U.S. Census Bureau data

1.2. Sprawl as sign of economic vitality or ecological threat?

Many organizations and media commentators defend the ever-shrinking rural inventory as a sign of the vitality of the economy and say that it should be embraced and even encouraged. [7] The country's reservoir of farmland and other open space is too vast to worry about how much is being paved each year, they say.

That is not the view of most Americans, however, according to polls which find that "sprawl is among their greatest concerns."[8]

This study does not attempt to resolve that difference of opinion, but the authors' sentiments clearly lie with those who are troubled by the signs of ecological damage from sprawl and other human intervention. Sprawl has contributed directly to the degradation and decline and fragmentation of natural habitats such as wetlands and woodlands, and this "habitat encroachment" is also implicated in the demise of hundreds of species of wildlife now listed as threatened or endangered by the federal and state governments.

Ecological health is especially precarious in the coastal regions:

- Water quality in the East Coast's most important estuary, the Chesapeake Bay, is threatened by the sheer spread of pavement and other impervious surfaces within its 64,000-square-mile watershed. By 1990, some 11,480 square miles had already been developed, and analysis of satellite imagery and other ground-based data indicates that in the 1990s an additional acre was being developed every 6-10 minutes.

[6] The U.S. Census Bureau data sources used in this study are: *1990 Census of Population and Housing, Summary Population and Housing Characteristics – United States,* Table 8 - Land Area and Population Density; *1980 Census of Population, Number of Inhabitants, United States Summary,* Table 34 - Population, Land Area, and Population Density of Urbanized Areas: 1980; *1970 Census of Population, Volume 1Characteristics of the Population, Part 1, United States Summary* (issued June 1973), Table 20 - Population and Land Area of Urbanized Areas: 1970 and 1960). All of these are available from the Statistical Information Office (Population Division) of the U.S. Department of Commerce's Bureau of the Census in Maryland (301-457-2422).

[7] See, for example: Daniel T. Griswold. 2000. "FAIR Ads Unfairly Blame Immigrants for Urban Sprawl, Traffic Jams." CATO Today's Commentary, October 5. Distributed nationally on the Knight-Ridder news wire.

[8] See, for example: "Straight Talk From Americans – 2000." National Survey for the Pew Center for Civic Journalism, conducted by Princeton Survey Research Associates. Released February 15, 2000. Available on the Internet at http://www.pewcenter.org/doingcj/research/r_ST2000nat1.html. Also see polls of Maryland and Virginia voters released in September, 2000 by Negative Population Growth, Inc. that showed significant majorities concerned about the effects of sprawl on the environment and quality of life. Available at www.npg.org.

Residential and related land development degrades local streams and sends "water-fouling" nutrients into the bay, which threaten to overwhelm hard-won, costly reductions in these "loadings."[9]

- In Florida, 68 species of flora and fauna are federally listed[10] and 99 are state listed[11] as threatened or endangered by the explosive expansion of cities that 30 years ago were little more than sleepy southern towns. More than 40% of the state's natural habitats already have been converted to urban or agricultural uses.

- California's fabled suburban expansion has converted the state from one of the ecological wonders of the world into what the scientific journal *Nature* magazine has labeled one of the world's 25 "biodiversity hotspots." That is, comparatively speaking, a very high fraction of the state's unique and endemic plant and animal species – and the living communities and ecosystems they comprise – are imperiled by human activity and development.[12]

Versions of those dramatic impending environmental tragedies can be found in local ecosystems scattered around the country. Urban sprawl is not the only cause, but the expansion of cities is especially powerful because it tends to blot out nearly all ecological and agricultural qualities of the land it converts.

1.3. Paving the world's breadbasket

Like 19th century American cornucopians who could not imagine how human activity could seriously threaten the existence of the seemingly limitless passenger pigeons and buffalo, many commentators and leaders today say they can't imagine any limits to America's supply of farmland. Technological progress that increases the yield per acre can easily stay ahead of the loss of acreage due to urban expansion, they claim.

That technological progress will have to move quickly. The U.S. Department of Agriculture estimates that in just the five years between 1992 and 1997 the nation lost 12.8 million acres of agricultural land: cropland (5.3 million acres), pastureland (6.1 million acres), rangeland (1.4 million acres).

Agricultural land also succumbs to forces other than urban development. Arable land is subject to manmade and natural phenomena such as soil erosion, salinization, and waterlogging that can rob its productivity and eventually force its abandonment. Much of these losses are due to over-exploitation by intensive agricultural practices needed to constantly raise agricultural productivity (yield per acre) in order to provide ever more food for America's and the world's growing populations.

Thus, the potent combination of relentless development and land degradation from overexploitation is reducing America's productive agricultural land base even as the food demands on that same land base from a growing population are increasing. If the rates of agricultural land loss that have prevailed in recent years continue to 2050, the nation will have lost over 55 million of its remaining 375 million acres of cropland, or 15% of it, even as the U.S. population is projected to grow by more than 40% from 283 million to 404 million.[13]

Continuing onto 2100, the discrepancy widens even further. The Census Bureau's medium projection is 571 million, more than a doubling of today's U.S. population. If the same rate of cropland loss were to continue that occurred from 1992-97, then the United States would lose approximately 110 million acres (about 30%) of its remaining 375 million acres of cropland.

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[9] Karl Blankenship. 2000. "Bay partners split on policy for land conversion." Bay Journal. Vol. 10, No. 1.
[10] The White House, Office of the Vice President. 1999. "Vice President Gore Announces Comprehensive Strategy to Restore Species in Florida Everglades." News Release.
[11] Florida Conservation Foundation. No date. Accessed on the World Wide Web at http://sundial.sundial.net/~florida/page47.html.
[12] Norman Myers, et al. 2000. "Biodiversity hotspots for conservation priorities." *Nature*, vol. 403, p. 853. 24 February; R.P.Cincotta, et al. 2000. "Human population in the biodiversity hotpots." *Nature*, vol. 404 p. 990, 27 April. California is one of the world's 25 biodiversity hotspots and one of the most heavily populated ones at that.
[13] U.S. Census Bureau. 2000. "Annual Projections of the Total Resident Population as of July 1: Middle, Lowest, Highest and Zero International Migration Series, 1999 to 2000." Middle Range Projection.

Cropland per capita, that is, the acreage of land to grow grains and other crops for each U.S. resident, would decline by two-thirds, from 1.4 acres in 1997 to 0.46 acre in 2100. If this actually occurs, biotechnology will have to truly work magic in raising yields per acre in order to maintain the sort of diet Americans have come to expect – let alone to continue to export any food to the large number of countries that currently depend on American surpluses. Such intensification of agricultural use must also assume no significant increase in the impacts of agriculture to ground and surface water, soil loss, biodiversity, etc.

2. THE FACTORS IN SPRAWL

Approximately two dozen major factors have been suggested as culprits in the urban land expansion depicted above:

1. One factor is population growth.
2. All the other factors combine to create growth in per capita land consumption.

This study examines the relative importance of those two.

2.1. Population growth

A city's population grows based on personal behavior and on local and national governmental actions.

On the personal behavior level, fertility rates can be the major cause of population growth in a city – as was the case during the 1946-64 Baby Boom in this country. That no longer is true, however, as the nation's fertility rate has been just below replacement level for nearly three decades. In only a few places – with most of California being the one large exception – is the fertility rate contributing to long-term population growth.

An urban area's population growth today is much more likely to be the result of enticing residents from elsewhere. Local and state governments can create many incentives that encourage people to move into a city. These include aggressive campaigns to persuade industries to move their jobs from another location, public subsidies for the infrastructure that supports businesses, new housing developments and new residents, and general public relations that increase the attractiveness of a city to outsiders. Even without trying, a city can attract new residents just by maintaining a high quality of life, especially if the nation's population is growing significantly as continues to be the case today. Most U.S. population growth is now the result of federal actions that over the last four decades have quadrupled annual numbers of residents moving into U.S. cities from other countries.[14] The Census Bureau states that if the government continues these current levels, America's communities will have to expand to accommodate nearly 300 million additional people this century.

2.2. Per capita land consumption

The statistic on per capita land consumption is a useful way to understand the combined power of numerous land-use and consumption choices that lead to urban sprawl. [See Appendix B for the per capita numbers for all 100 Urbanized Areas and Appendix D for how the statistic is calculated.]

When Census Bureau data show that per capita land consumption in Houston is 0.259 acre, that means it takes just about one-quarter of an acre to provide the average Houston resident with space for housing, work, retail, transportation, education, religious and other private assembly, government, recreation and other urban needs.

[14] New immigrants and births to immigrants during the 1990s were equal to around two-thirds of all U.S. population growth. The rest of the nation's growth was due to the daughters of the earlier Baby Boom moving through their fertility years. Even though their fertility level is below replacement, there still is short-term growth from their births because there are so many more women in this child-bearing generation than in the previous generation. (The immigrant birth information is based on an analysis of the March 2000 Current Population Survey of the Census Bureau as found in "Immigrants in the United States - 2000: A Snapshot of America's Foreign-born Population," by Steven A. Camarota, Center for Immigration Studies, Washington, D.C., January, 2001, http://www.cis.org.)

Table 3 shows the variation of per capita land use among the nation's top 10 sprawlers. The average Los Angeles resident has barely more than a tenth of an acre, while the average Atlanta resident has more than three times that much space, with one-third of an acre.

The increase in per capita land consumption (Per Capita Sprawl) is a major cause of Overall Sprawl of an urban area. Census data on the nation's Urbanized Areas allow us to track the change in per capita land consumption from decade to decade.

The per capita land consumption figure reflects the combined results of all the following choices, and more:

- development
  - consumer preferences for size of housing and yards
  - developer preferences for constructing housing, offices and retail facilities
  - governmental subsidies that encourage land consumption, and fees and taxes that discourage consumption
  - the quality of urban planning and zoning
  - the level of affluence
- transportation
  - governmental subsidies and programs for highways, streets and mass transit
  - consumer preferences
  - the price of gasoline
- quality of existing communities and ability to hold their residents
  - the quality of schools
  - perceptions about crime and safety
  - ethnic and cultural tensions or harmony
  - the quality of government leadership
  - job opportunities
  - levels of pollution
  - quality of parks and infrastructure
- number of people per household
  - marriage rate and average age for marriage
  - divorce rate
  - recent fertility rate
  - level of independence of young adults
  - level of affluence enabling single people to live separately

Table 3 – Per Capita Land Consumption in the USA's Top Sprawlers (1990)

Urbanized Area	Fraction of Acre Per Resident
1. Atlanta, GA	0.337
2. Houston, TX	0.259
3. New York City, NY-NJ	0.118
4. Washington, DC-MD-VA	0.180
5. Philadelphia, PA-NJ	0.177
6. Los Angeles, CA	0.110
7. Dallas-Fort Worth, TX	0.289
8. Tampa-Saint Petersburg-Clearwater, FL	0.243
9. Phoenix, AZ	0.237
10. Minneapolis-St. Paul, MN	0.327

Source: U.S. Census Bureau data

A nationwide Smart Growth movement has emerged to fight sprawl by going after some of those many causes of Per Capita Sprawl. Because of the number of variables to control, it is very difficult to measure precise effects of trying to change each of the planning, consumption and other behavioral factors mentioned above. But we can know the overall effect of all those factors together by looking at the simple statistic of per capita land consumption.

If that per capita consumption figure goes up markedly in a city, then we know that Smart Growth efforts are failing to achieve their desired result. But if the per capita figure grows only slightly, or remains the same, and especially if it goes down, the above bulleted factors collectively are moving in the direction desired by the anti-sprawl leaders.

2.3. Measuring Overall Sprawl

The word "sprawl" is not a precise term. But we use the term "Overall Sprawl" in a precise way in this study.

Fortunately, it is easy to measure the amount of Overall Sprawl because of a painstaking process conducted by the Census Bureau for a half-century. It uses a rather complicated but consistent set of conditions to measure the spread of cities into surrounding rural land. The Bureau calls the contiguous developed land of the central city and its suburbs an "Urbanized Area." It is possible to measure sprawl from decade to decade by noting the change in overall acreage of a specific Urbanized Area.

Defining sprawl by the Census standards has some limitations that are discussed in Appendix C (along with a description of the difference between an Urbanized Area and a Metropolitan Statistical Area). But this definition is unequalled as a standard quantitative measure of rural urbanization by cities in all regions of the country. Most organizations that measure sprawl rely heavily on Urbanized Areas data.

2.4. Period of study

This study measures sprawl over the most recent two decades for which comprehensive government data are available (1970-90). Urbanized Area data are calculated only once every 10 years. Thus, our study can assess the march of sprawl only through 1990. The calculations from the 2000 Census will not be available for a couple of years, at which time we will update this report.

Although it may be tempting to try to estimate sprawl for the 1990s, the authors feel the Census Bureau's Urbanized Area data are so superior to all other sources that the use of other sources to estimate sprawl would compromise the reliability of this study.

3. WHAT ABOUT DETROIT? WHAT ABOUT LOS ANGELES?

It has not been uncommon the last couple of years to see people quoted in the news media as questioning whether one or the other of the two major factors in sprawl is really that important. The cause for doubt generally comes from the observation that a particular city that has no Population Growth – or that has no Per Capita Sprawl – still has major Overall Sprawl.

One example of these comments boils down to something like this: "What about Detroit? Clearly, Population Growth is not the key factor in sprawl when you consider that Detroit had no Population Growth whatsoever between 1970 and 1990, but it still was swimming in sprawl – 28.4%."

Another example would be: "What about Los Angeles? What's the use of pursuing all those Smart Growth objectives to reduce the amount of land consumption per resident when you look at the sprawling mess Los Angeles created? L.A. had no Per Capita Sprawl between 1970 and 1990; all growth in per capita consumption was stopped. Yet, L.A. was sprawling all over the place – 25.1%."

Anybody who was in Detroit or Los Angeles during that period knows that a 28% or 25% sprawl rate is large and is noticeable in one's daily quality of life. So what are we to learn from Urbanized Areas like these?

3.1. What about Detroit?
Cities where population growth stopped, but sprawl continued

Indeed, what about Pittsburgh, which not only stopped population growth but reduced its population by 9.1%? It still had 30.5% Overall Sprawl.

Something similar happened in Milwaukee, Dayton, New York City, Scranton-Wilkes-Barre, Youngstown-Warren, Akron, Flint, and Buffalo-Niagara Falls. All of them halted population growth but also had sprawl – lots of sprawl, in several cases. The average sprawl for the 11 Urbanized Areas with no population growth was 26%.

What do these cities teach us? First, that stabilizing population alone obviously will not stop sprawl. Second, we learn the power of per capita land consumption growth; all of these cities had a lot of it. While these cities prove that population growth is not the only factor in sprawl, they raise the question of whether population growth is a

significant factor at all. One way to test is to compare Urbanized Areas of no population growth with those where population did grow.

Figure 2 — Average SPRAWL of cities grouped by percentage population growth

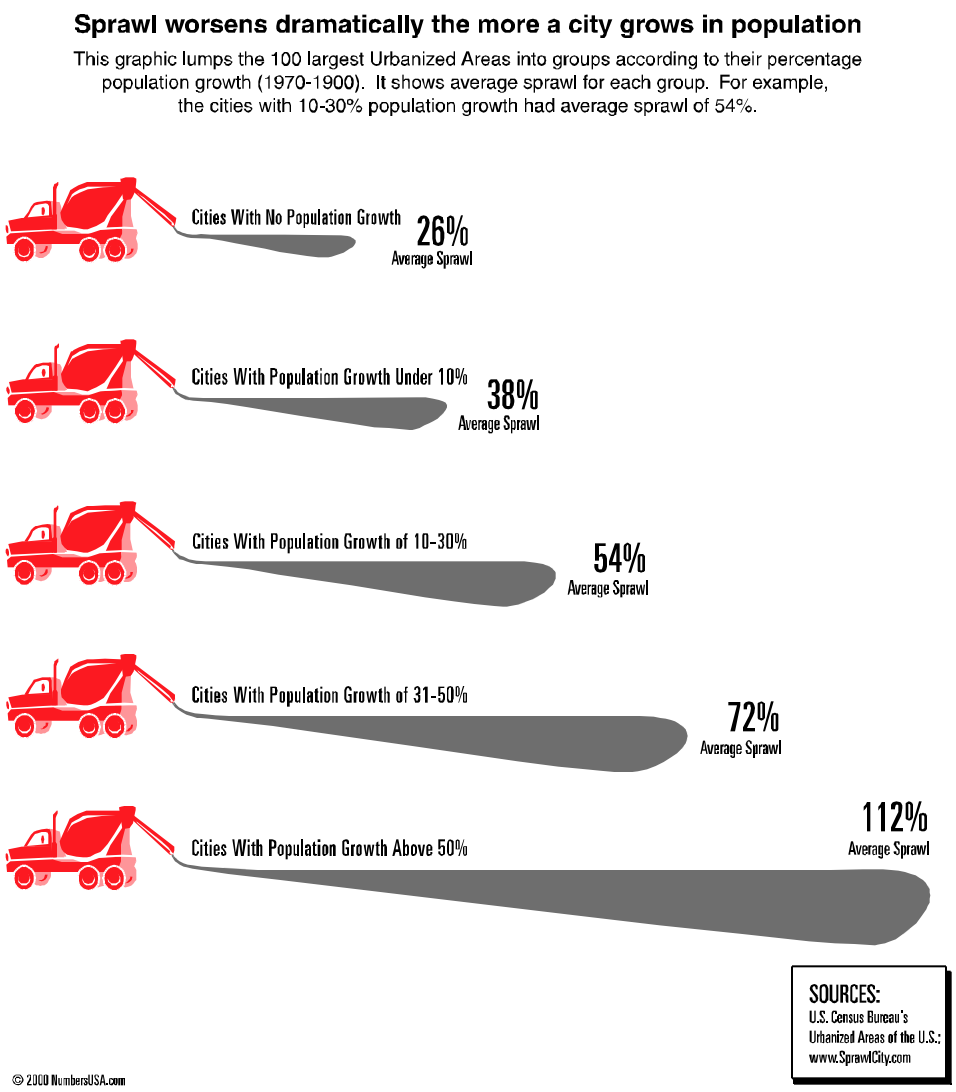


Figure 2 (on the left) groups the 100 Urbanized Areas by their percentage population growth. The results dramatically illustrate how the Areas sprawled by much higher amounts as their population growth rates increased. At the top is an illustration of the 26% average Overall Sprawl for the Areas that had no population growth. But the next strand of concrete poured from the cement truck shows that Areas with moderate population growth below 10% had significantly more sprawl – 38%. And each successive group of Areas with higher population growth had progressively worse sprawl up to the 112% average for Areas with more than 50% population growth.

These statistical comparisons provide fairly strong evidence that, on average, the higher a city's population growth, the higher the rate of sprawl.

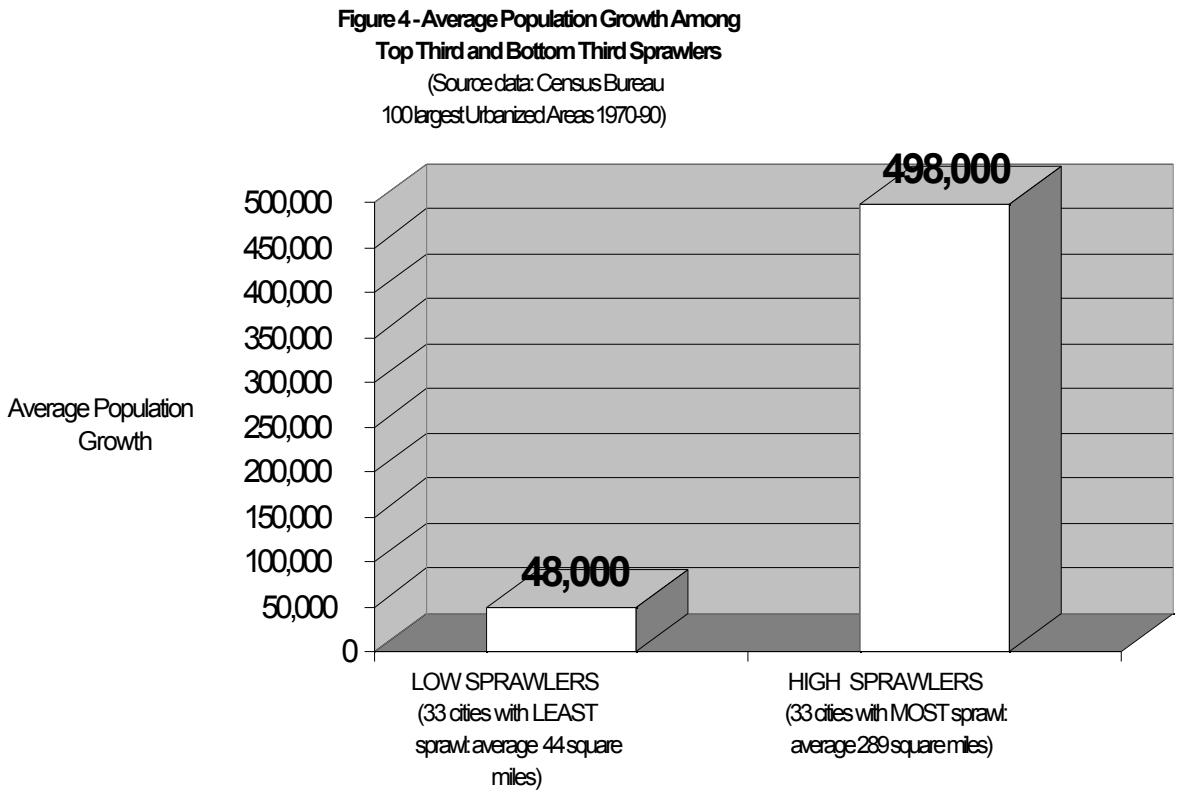
As bad as residents of Detroit may have found the sprawl there during a time of no population growth, they might feel some consolation in the fact that their sprawl of 28.4% was far less than the average sprawl of 75% for the 89 Urbanized Areas where the population did grow.

Thus, rather than proving that population-stabilization is an insignificant goal in anti-sprawl efforts, Detroit seems to suggest just the opposite. When considered in the context of all Urbanized Areas, the answer to the question, "What about Detroit?" might be: If its population growth had not stopped, its sprawl likely would have been far greater.

That may be an important message to hear in such cities, lest their governments inadvertently spur increased sprawl by adopting policies that entice population growth.

Figure 4 provides another way of testing the effect of a city adding population; it uses actual numbers rather than percentages. It looks at the one-third of Urbanized Areas that had the worst sprawl – an average of 289 square miles each. Those Areas averaged population growth of nearly a half-million.

Conversely, when we look at the one-third of Areas with the least sprawl – an average of 44 square miles each – we find they were having to handle an average of only 48,000 additional residents. The correlation between high sprawl and high population growth was strong, as was the correlation between low sprawl and low population growth.



DESCRIPTION: The size of population growth was a strong predictor of the amount of sprawl. The 33 cities with the most square miles of sprawl had more than 10 times as much average population growth as the 33 with the least square miles of sprawl.

3.2. What about Los Angeles?
Cities where Per Capita Sprawl stopped, but sprawl continued

In a couple of key aspects, Los Angeles ought to be a poster city for anti-sprawl efforts. Unlike most U.S. Urbanized Areas, Los Angeles stopped all Per Capita Sprawl during the period of study. That is, the land consumption did not increase from the 0.12 acre per resident of 1970. That already was one of the densest living conditions in America.

Most Urbanized Areas that had less than a sixth of an acre per resident in 1970 had significant growth in per capita land consumption by 1990. But Los Angeles reduced its per capita land area by another 8%. Land consumption was falling not only in the urban core but also in the suburbs. By 1990, Los Angeles had achieved the Smart Growth honor of becoming the most densely populated Urbanized Area in America. No other city provided so little land per resident.

Yet, few people in America would think of Los Angeles as a model of Smart Growth. The reason is that Los Angeles continued to sprawl across an extra 394 square miles of orchards, farmland, natural habitat and other open and rural spaces.

Los Angeles was the sixth worst sprawler in the country in actual square miles.

There were other such disappointments, mainly in California and Florida. In all, 18 Urbanized Areas met the goal of stopping growth in per capita land consumption. In fact, all but one (Bakersfield) significantly reduced per capita land consumption. But all had Overall Sprawl. On average, the percentage sprawl of the 18 was 53.4%, twice as bad as that of Los Angeles, and twice as bad as the average for the Urbanized Areas like Detroit that had no Population Growth.

Los Angeles and the other 17 Areas prove that stopping Per Capita Sprawl won't come close to stopping Overall Sprawl if the population is allowed to grow significantly. All 18 had major Population Growth (see **Table 4**).

Table 4 –Urbanized Areas that Stopped Per Capita Sprawl
These areas reduced per capita land consumption
but had much Overall Sprawl (1970-1990)

% Growth in Per Capita Land Consumption	Urbanized Area (alphabetical order)	% Growth in Total Land Area	Population Growth
-5.9%	Corpus Christi, TX	19.3%	26.9%
-15.1%	Dallas-Fort Worth, TX	34.8%	58.7%
-23.6%	Ft. Lauderdale-Hollywood-Pompano, FL	54.1%	101.7%
-2.7%	Fresno, CA	67.8%	72.5%
-15.7%	Honolulu, HI	20.6%	43.0%
-35.3%	Las Vegas, NV	90.7%	194.6%
-8.4%	Los Angeles, CA	25.1%	36.5%
-13.2%	Miami-Hialeah, FL	36.3%	57.0%
-28.3%	Oxnard-Ventura, CA	40.9%	96.4%
-17.7%	Phoenix, AZ	91.3%	132.4%
-25.9%	Riverside-San Bernardino, CA	48.6%	100.5%
-21.0%	Sacramento, CA	36.7%	73.1%
-16.3%	Salt Lake City, UT	37.9%	64.7%
-7.5%	San Diego, CA	81.3%	96.0%
-12.8%	San Jose, CA	22.1%	40.0%
-3.5%	Stockton, CA	57.7%	63.4%
-18.7%	West Palm Beach-Boca Raton, FL	124.8%	176.4%

Source: U.S. Census Bureau Data

Does that mean that anti-sprawl campaigns should de-emphasize the Smart Growth goals of reducing per capita land consumption? Logic once again shows us the error of that suggestion. As bad as their average Overall Sprawl rate was (53.4%), it still was a third lower than the Urbanized Areas that failed to stop either Per Capita Sprawl or Population Growth. If the Population Growth for the 18 had occurred without stopping Per Capita Sprawl, the loss of rural land would have been far worse.

Even though Population Growth is the untamed problem in Los Angeles and the other 17 Areas, it

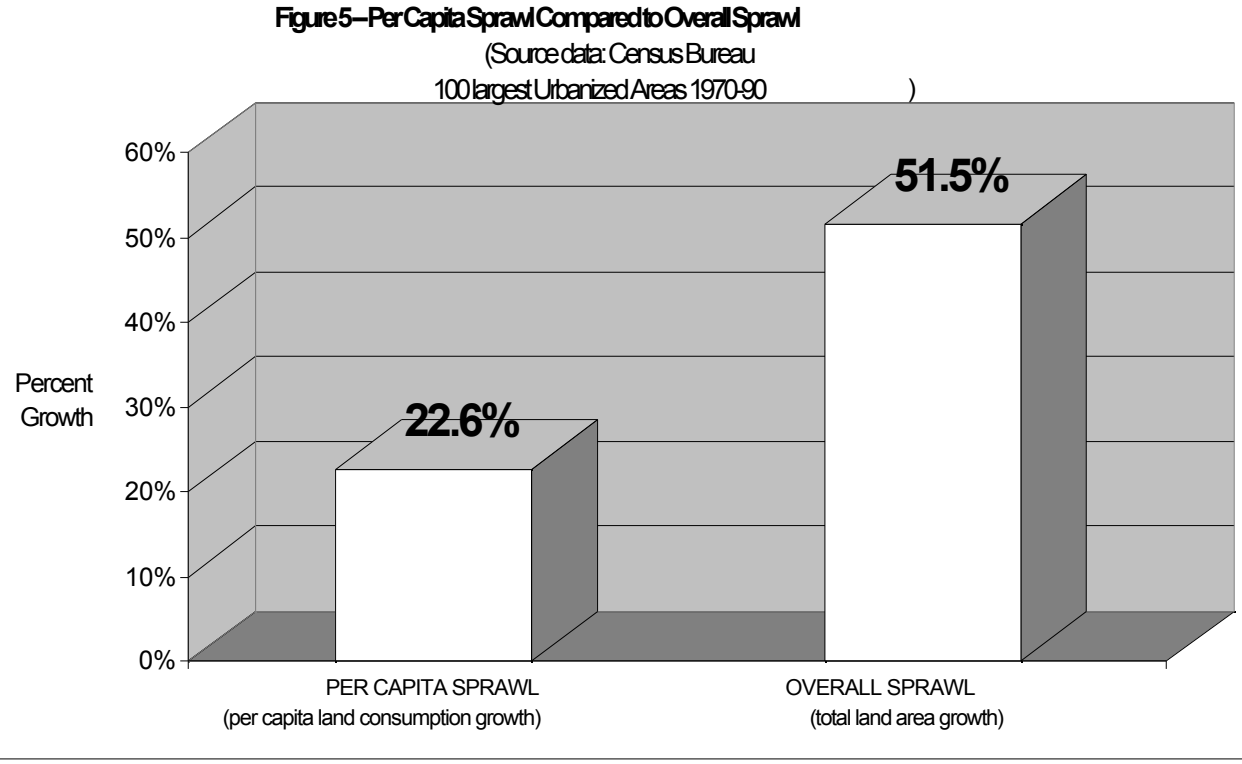
would be a mistake for anti-sprawl campaigns and literature to emphasize only Population Growth and exclude the potential problems of Per Capita Sprawl. Without using Smart Growth tools, per capita land use easily could begin to grow again and multiply the Overall Sprawl in those Urbanized Areas.

4. APPORTIONING RELATIVE CONTRIBUTIONS OF EACH FACTOR TO OVERALL SPRAWL

Despite the considerable complexity of sprawl in an urban area, nearly all of the complexity can be boiled down to what ends up being a rather simple equation:

[The amount of land covered by an Urbanized Area]
is equal to
[the average amount of urban land per resident]
multiplied by
[the number of residents].

Overall Sprawl then is the change in that amount of total urban land and can be calculated using the change in per capita land consumption and the change in population.



DESCRIPTION: The growth in per capita land consumption reflects the combined effects of land use planning, government subsidies, urban policies and consumption decisions. While this Per Capita Sprawl was high, its growth rate was less than half that of Overall Sprawl.

4.1. A sample village illustrates how growth factors work

We can see this equation at work by visualizing a small village with:

- 400 residents
- an average of 0.200 acre land consumption per resident for all housing work, retail, recreational, transportation and other needs
- a fully developed area of the village of 80 acres (400 X 0.200 acre)

Let's say we revisit this village a few years later and find that the fully developed area has expanded 50% to 120 acres. There can be only three types of explanation:

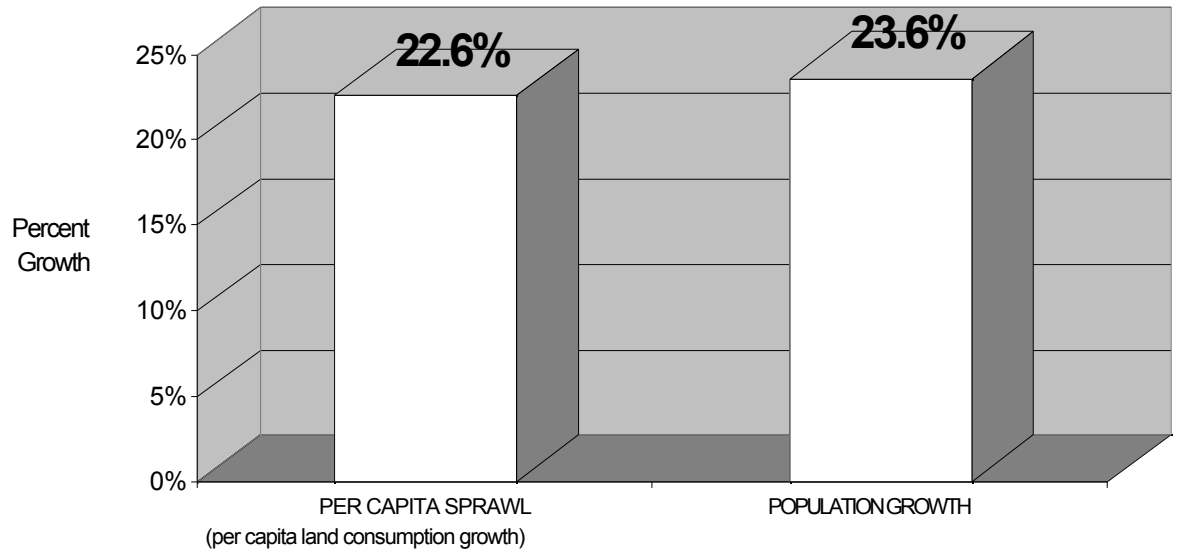
1. The 400 villagers may have expanded their per capita land consumption by 50% from 0.200 acre to 0.300 acre (400 X 0.300 acre = 120 acres). This could have happened by households dividing by divorce or children leaving home and the departees starting new households, by people expanding the size of their houses and yards, by constructing additional public and business buildings, and by abandoning homes and stores within the old boundaries to move just outside those boundaries, perhaps adding a shopping mall and large parking lot on the town's edge.

2. OR the per capita land consumption may not have risen at all while 200 additional people moved into the village, causing a 50% increase in population to 600 (600 X 0.200 acre = 120 acres).

3. OR there may have been some combination of both population growth and per capita land consumption growth. One example would be that population grew 25% to 500 and per capita land use grew 20% to 0.240 acre (500 X 0.240 acre = 120 acres).

Each of the nation's sprawling Urbanized Areas has been expanding in one of those three ways.

Figure 6 – Rate of Per Capita Sprawl Compared to Population Growth
(Source data: Census Bureau
100 largest Urbanized Areas 1970-90)



DESCRIPTION: The rate of the two factors behind Overall Sprawl – per capita land consumption growth and population growth – were nearly identical.

4.2. FINDING: Per Capita Sprawl alone cannot explain Overall Sprawl

Our literature search found that most media stories, advocacy programs, governmental reports and political statements about sprawl have focused almost entirely on the land-use and consumption factors that cause per capita land growth. This would suggest that Per Capita Sprawl explains most, if not all, of the Overall Sprawl in the nation's Urbanized Areas.

One way to determine the accuracy of that supposition is to compare the percentage growth of per capita consumption with the percentage growth of Overall Sprawl. For example, if Per Capita Sprawl were responsible for all of the 50% increase of our sample village above, then Per Capita Sprawl would have to have been at least 50%. When we line up the percentages for those kinds of growth for the 100 largest Urbanized Areas, we find that very few of the Per Capita Sprawl percentages are even close to as high as the Overall Sprawl percentage. [See Table 1on Page 10 and Appendix A.] For example, Chattanooga's per capita consumption rose by 65.7%, but it sprawled by almost twice as much: 120.1%. And the difference in growth rates was far wider in many cities such as Denver, where per capita consumption rose by 8.1% while its overall land consumption rose by 56.7% – seven times as much.

Figure 5 (on page 22) shows that for all the cities, Per Capita Sprawl was a significant 22.6%. But overall land consumption increased by more than twice as much – by 51.5%.

Clearly per capita land consumption growth was a major factor – but not the overwhelming factor – in America's urban sprawl. Though the statistics for some of the Urbanized Areas seem to justify a single-factor anti-sprawl approach dealing with land use issues, most of the cities clearly fit into the third explanation about our sample village in which both Per Capita Sprawl and Population Growth are significant factors of Overall Sprawl.

4.3. FINDING: Comparing the two growth factors reveals national parity

Since all of Overall Sprawl is explained by the combination of population change and per capita consumption change, we can learn much about their relative roles by simply lining up those percentage changes side by side. Those comparisons are available on Table 1 (on page 11) and in Appendix A.

Figure 6 (on the previous page) lumps all 100 Urbanized Areas together and finds that their population change was 23.6% and their per capita land change was 22.6%. Thus, we easily see that the roles of the two growth factors are nearly identical in urban sprawl nationwide.

4.4. FINDING: Calculating ratios with a scientific method reinforces general findings

To test the foregoing very simple exercise, we can run the numbers through a more complex scientific method that is commonly applied to total consumption of various resources. Harvard physicist John Holdren – internationally honored in 2000 for his achievements in environmental science – has particularly developed, described and worked with this method.[15] It can be applied to virtually any type of resource use. Perhaps its best-known application has been in understanding how total U.S. energy use has risen in recent decades. The method has enabled analysts to

[15] John P. Holdren. 1991. "Population and the Energy Problem." *Population and Environment*, Vol. 12, No. 3, Spring 1991. Holdren is Teresa and John Heinz Professor of Environmental Policy and Director of the Program on Science, Technology, and Public Policy at Harvard University's Kennedy School of Government, as well as Professor of Environmental Science and Public Policy in the Department of Earth and Planetary Sciences at Harvard University. Trained in aeronautics/astronautics and plasma physics at MIT and Stanford, he previously co-founded and co-led for 23 years the campus-wide interdisciplinary graduate degree program in energy and resources at the University of California, Berkeley. On April 12, 2000 he was awarded the Tyler Prize for Environmental Achievement at the University of Southern California, which administers the award. The Tyler Prize is the premier international award honoring achievements in environmental science, energy, and medical discoveries of world-wide importance.

apportion shares of the total increase of energy in a country to (1) the change in per capita energy use and (2) the change in population.

A unique contribution of this study is that it appears to be the first to apply this method to sprawl. As in the case of looking at energy consumption, the question here was how much of the increased total consumption of rural land (Overall Sprawl) was related to per capita change in land consumption (Per Capita Sprawl) and how much was related to the increase in number of land consumers (Population Growth). [See Appendix E for further description.]

Table 5 (on the next page) applies the Holdren method to the 10 largest sprawlers. For Atlanta, we see that 36% of Atlanta's Overall Sprawl was related to, or explained by, increases in per capita land consumption – and that 64% was related to Atlanta's massive population growth of the last two decades.

With these proportional percentages, opponents of sprawl in the nation's worst sprawling Urbanized Area, for example, can know that roughly two-thirds of their problem has been the inability to stabilize the Atlanta Area's population. And a very significant minority of the problem (36%) has been the inability to stabilize the per capita land use of the area.

Figure 8 (on the back cover) illustrates the results of applying the Holdren method to the entire population and land area of the 100 largest Urbanized Areas. Of the 14,545.2 square miles of sprawl, 49.1% of the lost rural land was related to the growth in per capita land consumption by the residents of those cities. And 50.9% of the lost rural land was related to the fact that 24.1 million additional people moved into those cities.

For all the sophistication of the Holdren method, with its use of logarithms and the like, it produces results that are little different from a simple equation that one can do on the back of a napkin. A common way to calculate the ratio of any two figures to each other is to add them together to obtain a sum, which can then be divided into each figure to yield a percentage. The two percentages will add up to 100%.

In the case of the Atlanta Urbanized Area, we add the per capita consumption growth percentage of 42 to the population growth percentage of 84, yielding a sum of 126. When we divide 126 into each growth figure we find that:

- per capita land consumption growth is 33.3% of the combined power of the two growth factors, in Atlanta.
- population growth is 66.7% of the combined power of the two growth factors, in Atlanta.

Table 5 – Sources of Sprawl in USA's Top Sprawling Urbanized Areas

Urbanized Area	% of Total Sprawl related to GROWTH IN PER CAPITA LAND CONSUMP-TION was:	% of Total Sprawl related to POPULA-TION GROWTH was:
1. Atlanta, GA	36%	64%
2. Houston, TX	30%	70%
3. New York City, NY-NJ	100%	0%
4. Washington, DC-MD-VA	53%	47%
5. Philadelphia, PA-NJ	89%	11%
6. Los Angeles, CA	0%	100%
7. Dallas-Fort Worth, TX	0%	100%
8. Tampa-Saint Petersburg-Clearwater, FL	15%	85%
9. Phoenix, AZ	0%	91% *
10. Minneapolis-St. Paul, MN	49%	51%

Source: U.S. Census Bureau data
**Adjusted from 100%: see Appendix F for explanation.*

These numbers – as all numbers coming from this simple calculation – are quite close to the percentages produced by the Holdren method of 36.5% and 63.5% respectively. The importance of these proportioning exercises is in general approximations, not mathematical precision. The Holdren method – with its more sophisticated accounting of the relationship between factors – tends to move the percentages slightly toward the middle from the figures yielded by the simple ratio calculation.

4.5. FINDING: Other data are consistent with the conclusion that both sprawl factors are roughly equal

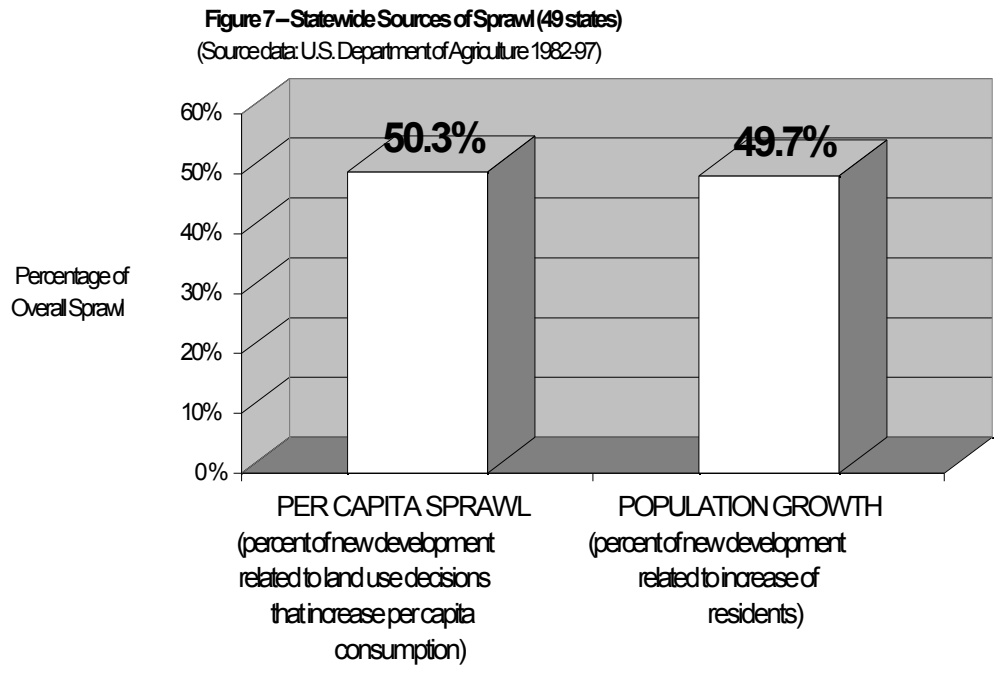
Four other studies on rural land loss provide for conclusions that are consistent with this study's finding that population growth and per capita land growth are nearly equal in their sprawl roles. (The four – by the U.S. Department of Agriculture, the U.S. Department of Housing and Urban Development, the University of Illinois Great Cities Institute and private consultant David Rusk – are described on Page 13.)

While this study relied on the Census Bureau's calculations on rural land loss around the 100 largest Urbanized Areas, the others looked at fewer and larger numbers of Areas. This study covered the 1970 to 1990 period while the others covered 1950-1990, 1960-1990, 1982-1997 and 1994-97.

Interestingly, all five studies provide for the same general conclusion: about half the rural land loss is explained by population growth and about half is explained by growth in per capita land consumption. This suggests a certain consistency to the nature of sprawl among broad regions and over a broad period of time. There appear to be long-standing built-in cultural and economic trends in America that drive a certain amount of Per Capita Sprawl, while a constant high level of Population Growth has typically doubled the overall rural land loss.

The fact that the two most recent studies ending in 1997 provide for about the same aggregate conclusion as ours suggests that the eventual Census data on the 1990s won't show a markedly different national picture than its data for 1970-90.

Of particular importance to this study is the survey by the U.S. Natural Resources Conservation Service (NRCS) of the Department of Agriculture. If the Census Bureau Urbanized Areas data were giving us a false reading on the real pace of sprawl by overstating or undercounting, the NRCS results would likely give us a significantly different figure.



DESCRIPTION: The U.S. Department of Agriculture calculates the conversion of rural land to development in all parts of every state except Alaska. These data indicate that almost exactly half of the loss of rural land nationwide is related to increased developed land per person, and half of the loss is related to population growth.

The NRCS has conducted inventories of the nation's ecologically productive land every five years since 1982. It provides statewide data rather than assigning development to specific cities. The NRCS survey picks up development such as weekend cottages and second homes that are built by city residents far enough into the country that they don't get included in the data on expanding Urbanized Areas. The NRCS survey also notes all the rural land lost each year to the development of recreational areas, resorts, roads, manufacturing, parking areas and sprawling small cities under 50,000 residents.

When we applied the Holdren apportioning method to the NRCS data, the results were nearly identical to those of our study of the 100 largest Urbanized Areas using Census data.

Figure 7 illustrates that 50.3% of the rural land loss nationwide (minus Alaska) was related to increased acres of development per resident – and that 49.7% was related to the nation's population growth.

5. CONCLUSIONS

On average in the nation's 100 largest Urbanized Areas, there are more and more of us, and each of us is using more and more urban land. Therein lie the two halves of the nation's urban sprawl problem. The toll of sprawl on natural habitats, agricultural land and scenic open spaces cannot be substantially halted unless anti-sprawl efforts include a two-pronged attack using both land-use/consumption tools and population tools.

5.1 Correcting misinterpretations of data

The above conclusion poses a challenge to anti-sprawl efforts because most use only a one-pronged tool. It is not that the data supporting the two-pronged conclusion have been unavailable. In fact, our literature search found, the very same data have often been used to oppose the necessity of a two-pronged approach. One contribution of this study may be to help journalists, government officials, advocacy groups and individual citizens to understand how they have been misinterpreting the data.

This study has identified the following misinterpretations as ones that appear to have had significant influence in causing the country's urban sprawl problems to be framed too narrowly by those desiring to resolve them.

5.1.1. Wrong generalizations from too little data

The authors regularly encounter population-stabilization enthusiasts who argue that the nation's population growth is the most significant threat to the quality of life of city inhabitants and of the natural world because of its role in urban sprawl. One of the authors believed at the outset of this study that the results would confirm that claim handily. After all, Census Bureau data showing that an incredible 78 million additional Americans have been added to the country since the first Earth Day in 1970 just seemed to guarantee such a conclusion.

But the population data and personal experiences in fast-growing cities were not sufficiently comprehensive to allow for an accurate conclusion about the nature of sprawl. Once we considered the full data on the 100 largest Urbanized Areas, we found no justification for an approach to the nation's urban sprawl that is decidedly weighted toward efforts at stabilizing the population while minimizing efforts to stop Per Capita Sprawl. As Figure 7 (on page 36) shows, the percentage growth in population and in per capita land consumption are practically the same.

Proper interpretation of that data would seem to require a roughly equal division of resources and attention to both parts of the sprawl problem.

5.1.2. Misunderstanding the data when sprawl is <u>double</u> population growth

A different kind of misunderstanding of the sources of sprawl is found in the comparing of Overall Sprawl rates to Population Growth rates. Sometimes there is an implied suggestion that population growth really isn't that important, as when a columnist recently wrote: "Sprawl is a Virginia specialty; a federal study says the state is developing its land twice as fast as its population is growing." [16] Other times, that type of fact is used to make a direct point, such as a recent letter from a president of a large conservation organization to a donor:

> "[In most states outside of California] the problem is not population increase but population distribution. For example, from 1940 to 1970, the population of the Portland, Oregon urban region doubled but the amount of land occupied by that population quadrupled."

In other words, he was saying, sprawl was double the rate of population growth and, therefore, population growth isn't really the problem.

But that is an erroneous interpretation of accurate facts. This study has shown that when a city is "sprawling at double the rate of population growth," that means the city's population growth is not insignificant but is in fact the primary sprawl factor and more than half the problem – a finding that calls for quite a different response than the one by the writer of the letter. That writer made such a colossal error of interpretation that we don't want to embarrass the illustrious conservation leader by citing his name or that of his organization.

We feel certain that the mistake was entirely an honest one. And we feel such certainty because we have seen the same mistake stated repeatedly by some of the nation's top conservation and anti-sprawl leaders as they use the "sprawling at double the rate of population growth" to make the erroneous case that population growth is not a primary factor in an area's sprawl. The Rusk data cited on page 13 often is misused in this way, for example.

We find it difficult to understand why anybody seriously concerned about sprawl would deliberately choose to ignore or minimize something that is half the problem, or why journalists would so consistently mislead their readers in that way. So this constant misinterpretation of data would appear not to be intended; rather, it seems, most people just don't understand what it means to compare an *independent* variable (like Population Growth) with a *dependent* variable (like Overall Sprawl).

That is why this study's simple exercise of lining up the rates of Population Growth and Per Capita Sprawl side by side is so important. In the mathematical formula, as to a large extent in the real world, those two are both *independent* variables. The most common impression that one gets from looking at the two side by side is generally an accurate one: If the rate for one is a lot bigger than the other, then it can safely be assumed that the bigger factor is a lot bigger part of the Overall Sprawl; if the two are similar in size, it is correct to assume that the two have similar effects on Overall Sprawl.

In addition, this study has modeled ways to apportion the Overall Sprawl to the two *independent* variables so that each represents a certain percentage of the *dependent* variable (Overall Sprawl). Associating a percentage with an *independent* variable communicates far more to the average person than placing that *independent* variable side by side with a *dependent* variable.

In the end, it is how the data are described in everyday language that may be most important to improving understanding of the factors of sprawl. Saying that "population growth is the primary sprawl factor and accounts for more than half of urban sprawl" communicates far more clearly than saying that "urban areas are expanding at double the rate of the population

The reader may wonder why we say that population growth is more than half the problem rather than half the problem if its growth rate is half the rate of Overall Sprawl. Consider Charlotte, North Carolina. Its sprawl rate of 128.7% was just over double the population growth rate of 63%. The Holdren method finds population growth was related to 59.1% of Charlotte's 241.7 square miles of sprawl. That may seem questionable to people who don't routinely work with numbers. But it should make sense to most people once they see that Charlotte's population growth of 63% was significantly higher than its Per Capita Sprawl of 40.3%.

[16] "County Opens Untouched Land to Usual Sprawl," Marc Fisher, *Washington Post*, January 18, 2001.

(What is said about population growth can also be said of Per Capita Sprawl. Little Rock's sprawl of 109% was just over double its Per Capita Sprawl rate of 52.4%. The Holdren method found that 57.1% of Little Rock's sprawl was related to Per Capita Sprawl.)

5.1.3. Misinterpreting the data when sprawl is slower than population growth

What does it mean when a city is sprawling at a slower rate than population growth? Is that cause for celebration? When the authors released an earlier report on a study of all Urbanized Areas in California, some journalists and city officials got quite excited and claimed victory because their cities were shown as having reduced per capita land consumption and as sprawling at a slower rate than their population was growing.

In the process, they missed the point that their cities still were sprawling at high rates. One of them, for example, indeed had reduced per capita land consumption by 45%, a major achievement at controlled growth. But at the same time, the Urbanized Area still had expanded by a whopping 84%, hardly a cause for celebration. By concentrating on increasingly dense development, the city had kept the sprawl from being much worse, but it had continued to threaten large amounts of countryside because it expanded its population by 232%. In the immediate aftermath of our report, there was no sign of any interest by city officials in slowing their rate of population growth and, thus, there appeared to be no chance of taming rampant sprawl of the city.

5.1.4. False assumption that two-pronged approach not needed in many regions

A widely stated assumption holds that population growth exacerbates sprawl in some parts of the country but is only a minor, or even a negligible, factor in much of the country. This assumption has misled many to argue that population stabilization tools are inappropriate for some regions and need not be discussed there.

But this study found that in not a single one of 12 regions was population growth a minor or negligible factor in the average city's sprawl. Rather, population growth was a significant factor in the Overall Sprawl of all 12 regions. Indeed, it was a primary factor in five and the overwhelming factor in four (see page 14).

That finding makes it obvious that anti-sprawl campaigns would need to stress population stabilization in all regions of the country to have a chance for a real and sustainable halt to sprawl.

Nonetheless, it remains important to note that urban planning cannot rely solely on national or regional averages but must take into account the peculiar mix of local circumstances that vary widely in each region.

5.2. Limits to containing population growth within existing urban boundaries

The virtual void of population-stabilization plans within the anti-sprawl programs around the country is also related to a belief that population growth can be accommodated without causing sprawl. Theoretically, that is possible – for awhile.

The findings of the study raise the following issues, however.

5.2.1. Inability to force enough extra density

The Miami Urbanized Area had 94 square miles of sprawl. All of it was associated with population growth because per capita land consumption declined. Miami could have prevented all 94 square miles of sprawl if the 695,000 additional residents had settled within the existing urban boundary. That could have happened:

(1) If all pre-existing residents were forbidden from moving from inside the city to rural land just outside the city. They would have had to remain within the old boundaries of the Urbanized Area or moved inside the boundaries of another city.

(2) If arriving immigrants and residents of other parts of the country were required to settle inside existing city boundaries.

(3) If vacant land inside the urban boundary were used for providing places of work and commerce for the new residents.

(4) If the leftover business, commerce and entertainment needs plus the residential needs of the extra residents were met by a combination of the following: (a) large numbers of pre-existing residents in single-family dwellings would either divide their houses into duplexes or tear down their homes, allow apartment buildings to be built on their land and then move into one of the apartments; (b) the scarce remaining public parks would be converted into apartment complexes; (c) more low-level apartment buildings would be replaced with high-rises; (d) local teens and people in their early 20s on the verge of household formation would continue living with their parents or double up with someone else already living within the old urban boundaries; (e) multiple families and unrelated adults began to share households.

(5) If the new residents placed no further demands for non-urban recreation, waste disposal, worksites, shopping or roads just beyond the urban boundary.

Those five requirements, however, would necessitate a level of government control, personal sacrifice, voluntary lifestyle change, loss of personal freedom, and expense that no city in America has come close to talking about – let alone fulfilling. But something that drastic would be needed to force one of the three most densely populated Urbanized Areas in America to increase its density enough to accommodate 695,000 more residents. And then the Area would have to do all those things again if population growth was allowed to continue any longer.

If one were to design a city from scratch, one would be far more likely to achieve such a density with public approval. But, as is obvious from the above five requirements, it is extremely expensive, disruptive and personally difficult to quickly achieve major density enhancements in already-built areas.
The United States provides no models of Urbanized Areas that succeeded in accommodating population growth without sprawl. Nothing in the political history of the nation's cities suggests the ability or willingness to do this even a few years, let alone in perpetuity.

5.2.2. Portland's lesson of limits

For a glimpse of what might be the best the nation as a whole is likely to be able to achieve in accommodating population growth without forcing urban sprawl, Portland may be the model. No Urbanized Area has received more attention than Portland in its efforts to preserve the natural beauty, quality of life and unbroken vistas of majestic Pacific Northwest landscapes from the concrete and subdivisions of sprawl.

Since most cities have not been able to develop the political support to do even a fraction of what Portland has done, it seems reasonable to consider Portland's experience to be something of the upper limit in how far incentives for increasing density can be pushed in most American cities – at least for the near-future.

In an effort to tame land-devouring sprawl, the state of Oregon, and the Portland metro area in particular, have taken bold steps that have garnered both national scrutiny and acclaim. In 1973 the Oregon legislature passed its landmark urban growth boundary law, requiring each municipality in the state to draw a line in the sand (or through forests and farms, in the case of western Oregon), beyond which urbanization could not march – at least, in theory. Today, each of Oregon's 241 cities is surrounded by an urban growth boundary. Portland's was first established in 1979.

The law does seem to have had a positive effect in reducing sprawl in the state, but certainly not in stopping it cold. Greater Portland not only stayed aesthetically pleasing but also met the Smart Growth goal of increasing density greatly. In the decade prior to the imposition of the Urban Growth Boundary, new population was added at the

density of 2,448 per square mile. In the decade after the imposition of the Boundary, it was added at the density of 3,744 per square mile. That was a 53% increase in the density of new development, a major achievement.

But the discouraging news after all that effort is that the Portland Urbanized Area still sprawled out across 39 additional square miles (25,000 acres) from 1980 to 1990. Thus, in its first decade of vigorously applied Smart Growth techniques, Portland could not stop the urbanization of rural land. The reason? The population grew by 146,000 during the decade. (The official results of the second decade – the 1990s – will not be available until the Census Bureau has a couple of years to work with the 2000 Census data.)

The same disappointing results were to be found in the entire state of Oregon. The U.S. Department of Agriculture survey reveals that hundreds of square miles of open space have been converted to developed land between 1982 and 1997, long after the 1973 state legislative action to stop that from happening. Population growth – much of it from former Californians fleeing the rapidly congesting Golden State – was the explanation. Many are skipping the ever-denser Portland Urbanized Area and settling in the countryside just enough beyond the urban edge to not add to Portland's sprawl per se but to help account for the state's surging rural development.

The experience in Oregon suggests there likely are limits to how far government can curb per capita land use before diminishing returns set in. No matter how tough the regulations to try to force population growth into existing urban areas, they will have to be toughened still more the next year, and more the next, with no end to increasing densities and government restrictions – unless population growth is stopped.

As people continue to pour into Portland and Oregon, development pressures within the "containment vessel" of the Urban Growth Boundaries are intensifying. Indeed, news articles warning of "gaps" and "cracks" in "the Great Wall of Portland" have become legion. And resistance to the ever-higher densities and in-fill development promoted by regional planning authorities as the way to grow without sprawl appears to be spreading even in "Ecotopia." Increasing numbers of Portland residents are decrying the added congestion and surging housing prices that are accompanying efforts to prevent sprawl while having rapid population growth.

If metro Portland's population continues to grow and if the Portland public' s desire for breathing room and reasonably priced housing trumps its desire to contain or slow sprawl, the Portland Experiment of 1980 to 2000 may not be the exemplar of what Americans may be persuaded to adopt. Rather, it may be an example of Smart Growth controls that even one of the most ecologically minded and motivated American communities won't accept over the long run.

The lesson would not be that the Smart Growth efforts of Portland were wrong-headed but that the best-thought plans cannot create a protective wall for nature that will withstand the continuous onslaught of population growth.

5.2.3. The 'ecological footprint' effect of additional population beyond the urban boundaries

Even if it were politically and physically feasible to pack more and more population into existing urban boundaries without sprawl, the rising populations of the city would still create a larger and larger "ecological footprint" in the rural areas beyond the urban area.

It is important to recognize that the per capita land consumption figure upon which all conventional anti-sprawl efforts focus includes only the land consumed by an average resident inside his/her own Urbanized Area. It does not include all the rural land in other parts of the country that is required to obtain the food, fiber, minerals and energy for that resident, and to dispose of that resident's wastes. The urban land is only a tiny fraction of the impact on the Earth that each new American makes. In fact, each person in an urban area has tentacles that extend far outward, pulling in natural resources from a variety of productive lands and waters of the biosphere.

Another way of expressing this is that every person has an ecological footprint, the area of biologically productive land he or she co-opts or exploits to satisfy the above-mentioned demands. The average American has an ecological

footprint of 12.6 acres.[17] This impacted area is roughly 25-75 times greater than the built-up space (i.e. developed or urbanized land) of one-sixth to one-half acre for each resident inside most Urbanized Areas.

Thus, even if we were able to control urban sprawl in the face of rapid population growth, the impact on the states' environment of rapidly growing numbers of Americans would still be enormous.

5.3. The necessity of addressing population growth

All of the above point to the necessity of addressing national policies now destined – according to the Census Bureau – to expand the current population of 281 million (up from 203 million in 1970) to more than a half billion (571 million) this century.

At the same time, cities which value their surrounding rural land and want to stop sprawl will need to address (a) local incentives that entice more people to move into particular cities and (b) state policies that attract residents from other states.

It is difficult, however, to conceive of many cities in America being able to stop their population growth for more than a short period if current demographic trends are allowed to continue and add nearly 300 million people to the nation this century.

Figure 3 (on page 12) shows how many square miles of the 100 largest Urbanized Area's sprawl over a 20-year period was related to the population growth of that time. Even if the cities had succeeded in eliminating all the sprawl related to the land-use and consumption factors behind per capita land growth, that still leaves 7,403 square miles of sprawl that was explained by population growth.

5.4. Future anti-sprawl efforts must tackle both growth factors

Population policies, phenomena and trends – along with the land-use/consumption ingredients in Per Capita Sprawl – are central to understanding the future of sprawl in American cities and how to prevent it. The findings of this study suggest that plans and programs from governmental agencies, think tanks, universities and advocacy groups must tackle – or at least support others who tackle – both population growth and land-use factors if they are to avoid being ineffective, naïve, foolish or deceptive in attempts to stop the urbanization of rural land.

[17] Mathis Wackernagel and William Rees. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, B.C. and Philadelphia, PA: New Society Publishers. The New Catalyst Bioregional Series.

APPENDIX A

Percent Changes in Each of 100 Largest Urbanized Areas (1970-90)

The "sprawl" in the 4th and 5th columns is the increase in the size of the contiguous developed area of each Urbanized Area from 1970 to 1990, as measured by the Census Bureau. The raw data used to calculate those changes and the ones in the 2nd and 3rd columns can be found in Appendix B.

The "sprawl apportionment" in the 6th and 7th columns is the result of applying the "Holdren method" to the Census data. That method is explained on page 31 and in Appendix D.

Read the table like this (using the first line on Akron as an example): From 1970 to 1990, Akron was **79th** largest in terms of the square miles it sprawled over the surrounding countryside. The population of the Akron Urbanized Area declined by **2.7%** while the average amount of urban land for each resident grew by **29.9%**. These two factors combined to cause the urbanization of **53.6** square miles sprawl of previously rural land. That sprawl amounted to a **26.3%** increase (percent sprawl) in the total land covered by the Akron Area. When considering the two sprawl-inducing factors together, we find that **0%** of the **53.6** square miles of sprawl was related to population growth, while **100%** was related to land-use factors that increased per capita land consumption.

Urbanized Area (number is where city ranks in square miles of sprawl)	**Sprawl Factors Percent Growth**		**Overall Sprawl**		**Sprawl Apportionment**	
	Popu-lation	**Per Capita Land Con-sumption**	**% Growth in Land Area**	**Square Miles Growth**	**Population Growth Factor's Portion**	**Per Capita Land Use Factor's Portion**
Akron, OH **(79)**	-2.7%	29.9%	26.3%	53.6	0.0%	100.0%
Albany-Schenec-tady-Troy, NY **(75)**	4.6%	32.5%	38.7%	58.2	13.9%	86.1%
Albuquerque, NM **(44)**	67.1%	18.1%	97.4%	111.4	75.5%	24.5%
Allentown-Bethlehem-Easton, PA **(85)**	12.9%	27.8%	44.3%	43.6	33.1%	66.9%
Atlanta, GA **(1)**	84.0%	42.0%	161.3%	701.7	63.5%	36.5%
Austin, TX **(23)**	112.5%	49.9%	218.4%	187.4	65.1%	34.9%
Bakersfield,CA**(87)**	71.8%	0.0%	71.9%	41.1	99.9%	0.1%
Baltimore, MD**(14)**	19.6%	60.0%	91.4%	282.9	27.6%	72.4%
Baton Rouge, LA **(52)**	46.7%	49.5%	119.3%	100.9	48.8%	51.2%
Birmingham, AL **(27)**	11.5%	59.3%	77.6%	174.2	18.9%	81.1%
Boston, MA **(19)**	4.6%	28.2%	34.1%	226.8	15.4%	84.6%
Bridgeport-Milford, CT**(99)**	0.1%	7.9%	8.0%	11.9	1.6%	98.4%
Buffalo-Niagara Falls, NY **(68)**	-12.2%	52.1%	33.6%	71.8	0.0%	100.0%
Charleston, SC**(32)**	72.5%	46.6%	152.9%	151.7	58.7%	41.3%
Charlotte, NC **(39)**	63.0%	40.3%	128.7%	241.7	59.1%	40.9%
Chattanooga, TN-GA **(37)**	32.8%	65.7%	120.1%	140.1	36.0%	64.0%
Chicago, IL-NW Indiana **(13)**	1.2%	22.6%	24.1%	307.3	5.3%	94.7%
Cincinnati, OH- KY **(25)**	9.2%	39.8%	52.7%	176.6	20.8%	79.2%

Urbanized Area (number is where city ranks in square miles of sprawl)	**Sprawl Factors Percent Growth**		**Overall Sprawl**		**Sprawl Apportionment**	
	Popu-lation	**Per Capita Land Con-sumption**	**% Growth in Land Area**	**Square Miles Growth**	**Population Growth Factor's Portion**	**Per Capita Land Use Factor's Portion**
Cleveland,OH**(100)**	-14.4%	15.0%	-1.6%	-10.2	NA	NA
Colorado Springs, CO **(60)**	72.4%	13.8%	96.2%	86.6	80.8%	19.2%
Columbia, SC **(53)**	35.8%	41.8%	92.5%	95.6	46.7%	53.3%
Columbus, OH**(46)**	19.6%	22.9%	47.1%	110.4	46.5%	53.5%
Corpus Christi, TX **(96)**	26.9%	-5.9%	19.3%	25.2	100.0%	0.0%
Dallas-Fort Worth, TX **(7)**	58.7%	-15.1%	34.8%	372.4	100.0%	0.0%
Dayton, OH **(83)**	-10.6%	36.4%	21.9%	49.2	0.0%	100.0%
Denver, CO **(29)**	44.9%	8.1%	56.7%	166.0	82.6%	17.4%
Des Moines, IA (**82)**	14.8%	27.5%	46.4%	50.6	36.2%	63.8%
Detroit, MI **(18)**	-6.9%	37.9%	28.4%	247.4	0.0%	100.0%
El Paso, TX- NM **(51)**	69.2%	9.1%	84.6%	101.0	63.0%*	37.0%*
Flint, MI **(71)**	-1.2%	72.1%	69.9%	67.4	0.0%	100.0%
Ft. Lauderdale-Hollywood-Pom-pano, FL **(43)**	101.7%	-23.6%	54.1%	114.9	100.0%	0.0%
Fresno, CA **(80)**	72.5%	-2.7%	67.8%	53.6	100.0%	0.0%
Grand Rapids, MI **(65)**	23.7%	23.4%	52.7%	77.0	50.3%	49.7%
Greenville, SC **(64)**	58.0%	32.2%	108.9%	77.2	62.1%	37.9%
Harrisburg, PA**(69)**	21.7%	57.1%	91.1%	71.4	30.3%	69.7%
Hartford-Middle-town,CT **(45)**	17.5%	57.4%	84.9%	110.8	26.2%	73.8%
Honolulu, HI **(97)**	43.0%	-15.7%	20.6%	23.7	100.0%	0.0%
Houston, TX **(2)**	72.9%	26.4%	118.6%	638.7	70.1%	29.9%
Indianapolis,IN**(59)**	11.5%	10.3%	23.0%	87.7	52.7%	47.3%
Jackson, MS **(35)**	52.2%	97.4%	200.4%	144.7	38.2%	61.8%
Jacksonville, FL **(31)**	39.4%	3.6%	44.5%	156.4	90.3%	9.7%
Kansas City, MO-KS **(15)**	15.7%	33.4%	54.5%	268.6	33.6%	66.4%
Knoxville, TN **(40)**	59.8%	59.0%	154.1%	132.7	50.3%	49.7%
Lansing-E.Lansing, MI **(95)**	15.5%	16.4%	34.5%	25.3	48.7%	51.3%
Las Vegas, NV**(47)**	194.6%	-35.3%	90.7%	109.9	100.0%	0.0%
Little Rock-North Little Rock,AR**(50)**	37.2%	52.4%	109.0%	103.9	42.9%	57.1%
Los Angeles,CA**(6)**	36.5%	-8.4%	25.1%	393.8	100.0%	0.0%
Louisville, KY- IN **(67)**	2.1%	31.5%	34.3%	72.2	7.1%	92.9%
McAllen,Edinburg-Mission, TX **(56)**	188.8%	31.6%	280.1%	91.6	79.4%	20.6%
Memphis, TN **(34)**	24.3%	40.4%	74.4%	145.5	39.1%	60.9%
Miami-Hialeah, FL **(54)**	57.0%	-13.2%	36.3%	94.0	100.0%	0.0%
Milwaukee,WI**(76)**	-2.1%	14.6%	12.2%	55.5	0.0%	100.0%

Urbanized Area (number is where city ranks in square miles of sprawl)	**Sprawl Factors Percent Growth**		**Overall Sprawl**		**Sprawl Apportionment**	
	Popu-lation	**Per Capita Land Con-sumption**	**% Growth in Land Area**	**Square Miles Growth**	**Population Growth Factor's Portion**	**Per Capita Land Use Factor's Portion**
Minneapolis-Saint Paul, MN **(10)**	22.0%	20.8%	47.4%	341.6	51.3%	48.7%
Mobile, AL **(74)**	16.7%	16.5%	35.9%	60.5	50.4%	49.6%
Nashville, TN **(38)**	27.8%	10.1%	40.8%	140.0	71.8%	28.2%
New Haven-Meriden, CT **(62)**	29.6%	35.0%	74.9%	80.4	46.4%	53.6%
New Orleans, LA **(61)**	8.2%	35.7%	46.8%	86.1	20.4%	79.6%
New York City-N.E. New Jersey**(3)**	-1.0%	23.6%	22.3%	541.3	0.0%	100.0%
Norfolk-Virginia Beach-Newport News, VA **(20)**	41.3%	6.2%	50.1%	221.4	85.1%	14.9%
Ogden, UT **(55)**	73.1%	44.8%	150.7%	91.9	59.7%	40.3%
Oklahoma City, OK **(12)**	35.3%	41.0%	90.7%	307.7	46.8%	53.2%
Omaha, NE-IA**(86)**	10.7%	15.3%	27.6%	41.8	41.6%	58.4%
Orlando, FL **(17)**	190.4%	3.2%	199.6%	262.9	97.2%	2.8%
Oxnard-Ventura, CA **(84)**	96.4%	-28.3%	40.9%	45.6	100.0%	0.0%
Pensacola, FL **(58)**	52.2%	53.7%	133.9%	88.9	49.4%	50.6%
Philadelphia,PA**(5)**	5.0%	47.5%	54.9%	412.4	11.2%	88.8%
Phoenix, AZ **(9)**	132.4%	-17.7%	91.3%	353.6	92.0%*	8.0%*
Pittsburgh, PA **(24)**	-9.1%	43.5%	30.5%	181.7	0.0%	100.0%
Portland-Vancouver, OR-WA **(42)**	42.1%	2.4%	45.4%	121.2	93.8%	6.2%
Providence-Pawtucket, RI-MA **(77)**	6.4%	15.0%	22.4%	54.6	30.8%	69.2%
Raleigh, NC (**48)**	100.9%	24.2%	149.5%	105.4	76.3%	23.7%
Richmond, VA**(30)**	41.6%	47.8%	109.3%	158.1	47.1%	52.9%
Riverside-San Bernardino, CA **(33)**	100.5%	-25.9%	48.6%	150.4	100.0%	0.0%
Rochester, NY **(66)**	3.0%	46.5%	51.0%	74.3	7.3%	92.7%
Sacramento, CA **(57)**	73.1%	-21.0%	36.7%	89.7	100.0%	0.0%
St. Louis, MO-IL **(16)**	3.4%	52.9%	58.1%	267.6	7.3%	92.7%
Salt Lake City, UT **(70)**	64.7%	-16.3%	37.9%	69.8	100.0%	0.0%
San Antonio, TX **(21)**	46.2%	34.4%	96.5%	215.1	56.2%	43.8%
San Diego, CA **(11)**	96.0%	-7.5%	81.3%	309.5	100.0%	0.0%
San Francisco-Oakland, CA **(22)**	21.5%	5.7%	28.4%	193.1	77.9%	22.1%
San Jose, CA **(73)**	40.0%	-12.8%	22.1%	61.2	100.0%	0.0%
Scranton-Wilkes-Barre, PA **(98)**	-9.1%	22.4%	11.3%	20.4	0.0%	100.0%
Seattle, WA **(26)**	40.9%	1.0%	42.3%	174.8	97.1%	2.9%
Shreveport, LA **(81)**	9.3%	42.1%	55.4%	52.2	20.3%	79.7%
Spokane, WA **(91)**	21.5%	20.2%	46.0%	35.8	51.5%	48.5%

Urbanized Area (number is where city ranks in square miles of sprawl)	**Sprawl Factors Percent Growth**		**Overall Sprawl**		**Sprawl Apportionment**	
	Popu-lation	**Per Capita Land Con-sumption**	**% Growth in Land Area**	**Square Miles Growth**	**Population Growth Factor's Portion**	**Per Capita Land Use Factor's Portion**
Springfield, MA-CT **(72)**	3.6%	22.6%	27.0%	64.1	14.8%	85.2%
Stockton, CA **(94)**	63.4%	-3.5%	57.7%	27.0	84.0%*	16.0%*
Syracuse, NY **(90)**	3.4%	34.3%	38.9%	37.4	10.1%	89.9%
Tacoma, WA **(49)**	49.5%	21.0%	80.5%	104.1	67.9%	32.1%
Tampa- St. Petersburg-Clearwater, FL **(8)**	97.8%	12.9%	123.3%	358.7	84.9%	15.1%
Toledo,OH-MI**(93)**	0.3%	16.5%	16.9%	27.9	1.8%	98.2%
Trenton, NJ-PA **(92)**	8.9%	34.5%	46.5%	30.4	22.4%	77.6%
Tucson, AZ **(36)**	96.9%	19.6%	135.4%	141.8	79.1%	20.9%
Tulsa, OK **(41)**	27.8%	32.3%	69.0%	124.3	46.7%	53.3%
Washington, DC-MD-VA **(4)**	35.5%	40.9%	91.0%	450.1	47.0%	53.0%
West Palm Beach-Boca Raton,FL**(28)**	176.4%	-18.7%	124.8%	170.2	100.0%	0.0%
Wilmington, DE-NJ-MD-PA **(63)**	21.1%	41.2%	71.0%	78.0	35.7%	64.3%
Wichita, KS **(88)**	12.1%	22.7%	37.5%	39.4	35.8%	64.2%
Worcester, MA- CT **(78)**	27.6%	28.8%	64.3%	54.3	49.0%	51.0%
Youngstown-Warren, OH **(89)**	-8.6%	42.3%	30.1%	38.7	0.0%	100.0%
Total Sprawl				**14,545.2**		
Average Urbanized Area (mean)**	**41.7%**	**23.5%**	**69.6%**	**145.5**	**51.3%**	**48.7%**
Aggregate average***	**23.6%**	**22.6%**	**51.5%**		**50.9%**	**49.1%**

* *Adjusted: see Appendix F for explanation* ** *Mean of the percentages in the column*
*** *Raw data on land and population for all cities are calculated together*

APPENDIX B

Raw Data for 100 Largest Urbanized Areas (1970-90)

The following is from the U.S. Census Bureau's Urbanized Areas data.[18] In some cases, an Urbanized Area in 1990 is the result of the Census Bureau having combined two or more Urbanized Areas from 1970 because they grew into each other. In these cases, the 1970 data reflect the combined data from the multiple Areas.

Urbanized Area (number is where city ranks in square miles of sprawl)	**Population**		**Per Capita Land Use** (acres/person)		**Total Land Area** (sq. miles)	
	1970	**1990**	**1970**	**1990**	**1970**	**1990**
Akron, OH **(79)**	542,775	527,863	0.239	0.311	203.5	257.1
Albany-Schenectady-Troy, NY**(75)**	486,525	509,106	0.197	0.262	150.5	208.7
Albuquerque, NM **(44)**	297,451	497,120	0.246	0.290	114.4	225.8
Allentown-Bethlehem-Easton, PA **(85)**	363,517	410,436	0.173	0.221	98.5	142.1
Atlanta, GA **(1)**	1,172,778	2,157,806	0.237	0.337	435.0	1,136.7
Austin, TX **(23)**	264,499	562,008	0.207	0.311	85.8	273.2
Bakersfield, CA **(87)**	176,155	302,605	0.207	0.207	57.2	98.3
Baltimore, MD **(14)**	1,579,781	1,889,873	0.125	0.200	309.6	592.5
Baton Rouge, LA **(52)**	249,463	365,943	0.217	0.324	84.6	185.5
Birmingham, AL**(27)**	558,099	622,074	0.257	0.410	224.6	398.8
Boston, MA **(19)**	2,652,575	2,775,370	0.160	0.205	664.4	891.2
Bridgeport-Milford, CT**(99)**	413,366	413,863	0.230	0.248	148.8	160.7
Buffalo-Niagara Falls, NY **(68)**	1,086,594	954,332	0.125	0.191	213.7	285.5
Charleston, SC **(32)**	228,399	393,956	0.277	0.407	99.2	250.9
Charlotte, NC **(39)**	279,530	455,597	0.242	0.339	105.7	241.7
Chattanooga, TN-GA **(37)**	223,580	296,955	0.334	0.553	116.7	256.8
Chicago, IL-NW Indiana **(13)**	6,714,578	6,792,087	0.121	0.149	1,277.2	1,584.5
Cincinnati, OH-KY **(25)**	1,110,514	1,212,675	0.193	0.270	335.1	511.7
Cleveland, OH **(100)**	1,959,880	1,677,492	0.210	0.242	646.1	635.9
Colorado Springs, CO **(60)**	204,766	352,989	0.281	0.320	90.0	176.6
Columbia, SC **(53)**	241,781	328,349	0.273	0.387	103.3	198.9
Columbus, OH **(46)**	790,019	945,237	0.189	0.233	234.5	344.9
Corpus Christi, TX **(96)**	212,820	270,006	0.391	0.368	130.3	155.5
Dallas-Fort Worth,	2,015,628	3,198,259	0.339	0.288	1,070.6	1,443.0

[18] See note 6.

Urbanized Area (number is where city ranks in square miles of sprawl)	**Population**		**Per Capita Land Use** (acres/person)		**Total Land Area** (sq. miles)	
	1970	**1990**	**1970**	**1990**	**1970**	**1990**
TX **(7)**						
Dayton, OH **(83)**	685,942	613,467	0.209	0.285	224.2	273.4
Denver, CO **(29)**	1,047,311	1,517,977	0.178	0.193	292.8	458.8
Des Moines, IA (**82)**	255,824	293,666	0.272	0.348	109.1	159.7
Detroit, MI **(18)**	3,970,584	3,697,529	0.140	0.193	872.0	1,119.4
El Paso, TX-NM **(51)**	337,471	571,017	0.226	0.247	119.4	220.4
Flint, MI **(71)**	330,128	326,023	0.186	0.321	96.4	163.8
Ft. Lauderdale-Hollywood-Pom-pano, FL **(43)**	262,908	453,388	0.192	0.187	79.1	132.7
Fresno, CA **(80)**	613,797	1,238,134	0.221	0.169	212.2	327.1
Grand Rapids, MI **(65)**	352,703	436,336	0.265	0.327	146.2	223.2
Greenville, SC **(64)**	157,073	248,173	0.288	0.381	70.9	148.1
Harrisburg, PA **(69)**	240,751	292,904	0.208	0.327	78.4	149.8
Hartford-Middle-town, CT **(45)**	465,001	546,198	0.179	0.282	130.5	241.3
Honolulu, HI **(97)**	442,397	632,603	0.166	0.140	115.0	138.7
Houston, TX **(2)**	1,677,863	2,901,851	0.205	0.259	538.6	1,177.3
Indianapolis, IN **(59)**	820,259	914,761	0.297	0.328	381.2	468.9
Jackson, MS **(35)**	190,060	289,285	0.243	0.479	72.2	216.9
Jacksonville, FL **(31)**	529,585	738,413	0.424	0.440	351.3	507.7
Kansas City, MO-KS **(15)**	1,101,787	1,275,317	0.286	0.382	493.2	761.8
Knoxville, TN **(40)**	190,502	304,466	0.289	0.459	86.1	218.8
Lansing-E.Lansing, MI **(95)**	229,518	265,095	0.204	0.238	73.4	98.7
Las Vegas, NV**(47)**	236,681	697,348	0.327	0.212	121.2	231.1
Little Rock-North Little Rock, AR **(50)**	222,616	305,353	0.273	0.417	95.3	199.2
Los Angeles, CA **(6)**	8,351,266	11,402,946	0.120	0.110	1,571.9	1,965.7
Louisville, KY- IN **(67)**	739,396	754,956	0.182	0.239	210.4	282.6
McAllen, Edinburg-Mission, TX **(56)**	91,141	263,192	0.229	0.302	32.7	124.3
Memphis, TN **(34)**	663,976	825,123	0.188	0.264	195.5	341.0
Miami-Hialeah, FL **(54)**	1,219,661	1,914,660	0.135	0.117	258.7	352.7
Milwaukee,WI **(76)**	1,252,457	1,226,293	0.233	0.267	456.5	512.0
Minneapolis-Saint Paul, MN **(10)**	1,704,423	2,079,676	0.270	0.327	721.4	1,063.0
Mobile, AL **(74)**	257,816	300,912	0.418	0.486	168.4	228.9
Nashville, TN **(38)**	448,444	573,294	0.490	0.539	343.5	483.5
New Haven-Meriden, CT**(62)**	348,341	451,486	0.197	0.266	107.3	187.7
New Orleans, LA**(61)**	961,728	1,040,226	0.122	0.166	184.0	270.1

Urbanized Area (number is where city ranks in square miles of sprawl)	**Population**		**Per Capita Land Use** (acres/person)		**Total Land Area** (sq. miles)	
	1970	**1990**	**1970**	**1990**	**1970**	**1990**
New York City-N.E. New Jersey **(3)**	16,206,841	16,044,012	0.0957	0.118	2,425.1	2,966.4
Norfolk-Virginia Beach-Newport News, VA **(20)**	936,522	1,323,098	0.302	0.321	442.3	663.7
Ogden, UT **(55)**	149,727	259,147	0.260	0.377	61.0	152.9
Oklahoma City, OK **(12)**	579,788	784,425	0.374	0.527	339.1	646.8
Omaha, NE-IA **(86)**	491,776	544,292	0.196	0.226	151.2	193.0
Orlando, FL **(17)**	305,479	887,126	0.275	0.284	131.7	394.6
Oxnard-Ventura, CA **(84)**	244,653	480,482	0.291	0.209	111.5	157.1
Pensacola, FL **(58)**	166,619	253,558	0.255	0.391	66.4	155.3
Philadelphia, PA **(5)**	4,021,066	4,222,211	0.119	0.176	751.8	1,164.2
Phoenix, AZ **(9)**	863,357	2,006,239	0.287	0.236	387.5	741.1
Pittsburgh, PA **(24)**	1,846,042	1,678,745	0.206	0.296	596.4	778.1
Portland- Vancouver, OR-WA **(42)**	824,926	1,172,158	0.206	0.211	266.8	388.0
Providence-Pawtucket, RI- MA **(77)**	795,311	846,293	0.196	0.225	244.1	298.7
Raleigh, NC **(48)**	152,289	305,925	0.296	0.367	70.5	175.9
Richmond, VA **(30)**	416,563	589,980	0.222	0.328	144.6	302.7
Riverside- San Bernardino, CA **(33)**	583,597	1,170,196	0.339	0.251	309.7	460.1
Sacramento, CA **(57)**	601,361	619,653	0.155	0.227	145.7	220.0
Rochester, NY **(66)**	633,732	1,097,005	0.246	0.194	244.2	333.9
St. Louis, MO- IL **(16)**	1,882,944	1,946,526	0.156	0.239	460.6	728.2
Salt Lake City, UT **(70)**	479,342	789,447	0.246	0.205	184.3	254.1
San Antonio,TX **(21)**	772,513	1,129,154	0.184	0.248	222.9	438.0
San Diego, CA **(11)**	1,198,323	2,348,417	0.203	0.188	380.7	690.2
San Francisco-Oakland, CA **(22)**	2,987,850	3,629,516	0.145	0.154	681.0	874.1
San Jose, CA **(73)**	1,025,273	1,435,019	0.173	0.150	277.2	338.4
Scranton-Wilkes-Barre, PA **(98)**	427,035	388,225	0.271	0.331	180.9	201.3
Seattle, WA **(26)**	1,238,107	1,744,086	0.213	0.215	413.1	587.9
Shreveport, LA **(81)**	234,564	256,489	0.257	0.365	94.3	146.5
Spokane, WA **(91)**	229,620	279,038	0.216	0.260	77.8	113.6
Springfield, MA-CT **(72)**	514,308	532,747	0.295	0.362	237.8	301.9
Stockton, CA **(94)**	160,373	262,046	0.186	0.180	46.8	73.8
Syracuse, NY **(90)**	376,169	388,918	0.163	0.219	96.2	133.6
Tacoma, WA **(49)**	332,521	497,210	0.247	0.299	128.7	232.8

Urbanized Area (number is where city ranks in square miles of sprawl)	Population		Per Capita Land Use (acres/person)		Total Land Area (sq. miles)	
	1970	**1990**	**1970**	**1990**	**1970**	**1990**
Tampa-St. Peter-sburg-Clearwater, FL **(8)**	863,901	1,708,710	0.215	0.243	291.0	649.7
Toledo, OH- MI **(93)**	487,789	489,155	0.217	0.253	165.5	193.4
Trenton, NJ-PA **(92)**	274,148	298,602	0.152	0.205	65.4	95.8
Tucson, AZ **(36)**	294,184	579,235	0.227	0.272	104.7	246.5
Tulsa, OK **(41)**	371,499	474,668	0.310	0.410	180.1	304.4
Washington, DC-MD-VA **(4)**	2,481,489	3,363,031	0.127	0.179	494.5	944.6
West Palm Beach-Boca Raton, FL**(28)**	287,561	794,848	0.303	0.246	136.4	306.6
Wilmington, DE-NJ-MD-PA **(63)**	302,334	338,789	0.222	0.272	105.1	144.5
Wichita, KS **(88)**	371,267	449,616	0.189	0.267	109.8	187.8
Worcester, MA- CT **(78)**	247,416	315,666	0.218	0.281	84.4	138.7
Youngstown-Warren, OH **(89)**	395,540	361,627	0.208	0.296	128.6	167.3
TOTAL	**102,280,202**	**126,389,399**			**28,245**	**42,791**
AGGREGATE AVERAGE (mean)	**1,022,802**	**1,263,894**	**0.177**	**0.217**	**282**	**428**

APPENDIX C

About the Census Bureau's Urbanized Areas

Generally speaking, an Urbanized Area must exhibit a pattern of continuous development outward from a central core. Although there are special provisions for "jumps," and certain other exceptions, by and large, new areas added every 10 years by the Census Bureau to the adjacent urban fringe must be contiguous to that fringe and must have a population density of at least 1,000 people per square mile.

Difference from MSA designation

Urbanized Areas are smaller in area than the Metropolitan Statistical Areas (MSA) that are mentioned far more commonly in the media and other public discussion. The Census Bureau describes an MSA as "a large population nucleus, together with adjacent communities having a high degree of social and economic integration with that core."[19] The major difference between the Urbanized Area and the MSA is that the latter includes the entire land mass of every county that contains a part of a city and its suburbs. That means the outer parts of an MSA are rural. An Urbanized Area, on the other hand, includes whole counties only if every square mile of them is urbanized. And in the outer counties, only the land that is indeed urbanized is counted.

An MSA often lumps together cities that have substantially grown out toward each other but which may still contain some rural land between them. For example, Los Angeles and its contiguous suburbs in Orange and Los Angeles counties, Simi Valley and its suburbs, Oxnard-Ventura and their suburbs, and San Bernardino and Riverside and *their* suburbs are all classified as a single CMSA (Consolidated Metropolitan Statistical Area). But because there is some rural land remaining between the suburbs of one and the suburbs of another, these places are considered to be four separate Urbanized Areas.

Usefulness as a measuring tool

[19] Found at http://www.census.gov/population/www/estimates/metroareas.html on 7 August 2000.

The 1,000-people-per-square-mile threshold for classification as part of an Urbanized Area is not without its critics. For example, urban expert David Rusk believes that the growth in Urbanized Land Areas since 1950, as documented in successive Census Bureau reports, understates the actual loss of rural environments to sprawl.[20] The 1,000 density threshold (equal to about one dwelling per two acres) is arguably too dense to convey a rural "feel" and allow for unfettered rural livelihoods, like farming. On the other hand, there is still a substantial amount of open space left when there is an average of two acres (about two football fields) for each house. Nonetheless, the practice of designating a given site as either urban or rural, with no intermediate classification, is indeed an over-simplification.

Yet for the purposes of this study, shortcomings of the Census designations have little effect on the outcome. Since this study has defined sprawl as the progressive loss of open space to built-up space – unpaved lands to paved-over ground in other words – the 1,000-per-square-mile criterion is as defensible a threshold between urban and rural zones as any. Moreover, it allows use of the Census Bureau's nationwide, unrivalled stock of information. The strength of the Census Bureau's uniform data set lies in calculating changes from rural to urban areas rather than in precisely defining the line that divides them. The shortcoming of the Census Bureau measurement is in calculating total development, not in calculating change. This study focuses on the change.

APPENDIX D

Calculating Per Capita Land Consumption

The per person land consumption in each Urbanized Area can be expressed as:

$$a = A / P \qquad (1)$$

where:

a = area of urbanized land for the average resident
A = Area of total urbanized land in a city and its suburbs
P = Population of that city and its suburbs

For example, the West Palm Beach Urbanized Area in 1990 had 794,848 residents living on about 196,000 acres. Thus, the per capita land use was around 0.25 acre (one-quarter of an acre) per resident.

Put simply: The land used per person is the total land area divided by the total number of people. This is the inverse of population density, which is the number of people per unit area of land. When per capita land consumption goes up, density goes down; when per capita land consumption goes down, density goes up.

The total land area occupied by the built-up Urbanized Area can be expressed as:

$$A = P \times a \qquad (2)$$

This can be stated as: the total square miles (or acres) of an Urbanized Area can be simply expressed or "factored" into the product of the Population of the Urbanized Area (*viz*., *P*) multiplied by the per capita urban land consumption (*viz*., a). Equation (2) is the basis for attributing or apportioning the shares of sprawl (viz. growth in *A*) back onto two contributing factors, the growth in *P* and the growth in *a*.

APPENDIX E

The Holdren Apportioning Method

A method for quantifying the respective contributions of population growth and changes in consumption per capita of any type of resource consumption was laid out in a landmark 1991 paper by Harvard physicist Prof. John Holdren.[21] Although Dr. Holdren's paper dealt specifically with the role of population growth in rising energy consumption, the method can be

[20] David Rusk. 1999. Letter to Ms. Georgia Masters, Department of Community Economic Development, State of Pennsylvania, Harrisburg. July 12. Rusk is an independent consultant on urban and suburban policy, the author of *Cities without Suburbs*, and the former mayor of Albuquerque, New Mexico.
[21] See note 15.

applied to many types of population/ resource consumption analyses. In the case of sprawl, the resource under consideration is rural land, namely the expansion over time of the Urbanized Area into rural areas.

As stated in Appendix D, the total land area occupied by the built-up Urbanized Area can be expressed as:

$$A = P \text{ x } a \qquad (1)$$

Where*:*

A = Area of total urbanized land in a city and its suburbs
a = area of urbanized land used by the average resident (per capita land use)
P = Population of that city and its suburbs

Following the logic in Holdren's paper, if over a period of time t (e.g., a year or decade), the population grows by an increment P and the per capita land use changes by a, the total urbanized land area grows by A which is given by substituting in eqn. (1):

$$A + \Delta A = (P + \Delta P) \text{ x } (a + \Delta a) \qquad (2)$$

Subtracting eqn. (1) from eqn. (2) and dividing through by A to compute the relative change (i.e., $\Delta A/A$) in urbanized land area over time interval t yields:

$$\Delta A/A = \Delta P/P + \Delta a/a + (\Delta P/P) \text{ x } (\Delta a/a) \qquad (3)$$

Now eqn. (3) is quite general and makes no assumption about the growth model or time interval. On a year-to-year basis, the percentage increments in P and a are small (i.e., single digit percentages), so the second order term in eqn. (3) can be ignored. Hence following the Holdren paradigm, eqn. (3) states that the percentage growth in urbanized land area (viz., 100% x $\Delta A/A$) is the sum of the percentage growth in the population (100% x $\Delta P/P$) plus the percentage growth in the per capita land use (100% x $\Delta a/a$). Stated in words, eqn. (3) becomes:

Overall percentage land area growth =
Overall percentage population growth + Overall percentage per capita growth (4)

In essence, the Holdren methodology quantifies population growth's share of total land consumption (sprawl) by finding the ratio of the overall percentage change in population over a period of time to the overall percentage change in land area consumed for the same period. This can be expressed as:

$$\textit{Population share of growth} = \frac{(\textit{Overall percentage population growth})}{(\textit{Overall percentage land area growth})} \qquad (5)$$

The same form applies for per capita land use:

$$\textit{Per cap. land use share of growth} = \frac{(\textit{Overall percentage per capita land use growth})}{(\textit{Overall percentage land area growth})} \qquad (6)$$

The above two equations follow the relationship based on Prof. Holdren's eqn. (5) in his 1991 paper. A common growth model follows the form (say for population):

$$P(t) = P_0 \ (1 + g_P)^t \qquad (7)$$

Where $P(t)$ is population at time t, P_0 is the initial population and g_P the growth rate over the interval. Solving for g_P the growth rate yields:

$$\ln (1 + g_P) = (1/t) \ln (P(t)/P_0) \qquad (8)$$

Since ln $(1 + x)$ approximately equals x for small values of x, eqn. (8) can be written as:

$$g_P = (1/t) \ln (P(t)/P_0). \qquad (9)$$

The same form of derivation of growth rates can be written for land area (A) and per capita land use (a)

$$g_A = (1/t) \ln (A(t)/A_0) \quad (10)$$

$$g_a = (1/t) \ln (a(t)/a_0). \quad (11)$$

These three equations for the growth rates allow you to restate the Holdren result of eqn. (4) as:

$$g_P + g_a = g_A \quad (12)$$

Substituting the formulae (eqns. 9 through 11) for the growth rates and relating the initial and final values of the variables P, a and A over the period of interest into eqn. (12), the actual calculational relationship becomes:

ln (*final population / initial population*) +

ln (*final per capita land area / initial per capita land area*) =

ln (*final total land area / initial total land area*) (13)

In other words, the natural logarithm (ln) of the ratio of the final to initial population, plus the logarithm of the ratio of the final to initial per capita land area (i.e., land consumption per resident), equals the logarithm of the final to the initial total land area.

In the case of the San Francisco-Oakland Urbanized Area from 1970 to 1990, this formula would appear as:

ln (*3,629,516 residents / 2,987,850 residents*) +

ln (*0.15413 acre per resident / 0.14587 acre per resident*) =

ln (*874.1 square miles / 681.0 square miles*) (14)

Computing the ratios yields:

ln (1.215) + ln (1.057) = ln (1.284)

0.1950 + 0.0555 = 0.2505 (15)

Then applying eqns. (5) and (6), the percentage contributions of population growth and per capita land area growth are obtained by dividing (i.e., normalizing to 100%) each side by 0.2505:

$$\frac{0.1950}{0.2505} + \frac{0.0555}{0.2505} = \frac{0.2500}{0.2505} \quad (16)$$

Performing these divisions yields:

0.78 + 0.22 = 1.0 (17)

Thus, we note that in the case of the San Francisco-Oakland Urbanized Area from 1970 to 1990, the share of sprawl due to population growth was 78% [100 % x (0.1950 / 0.250)], while declining density (i.e., an increase in land area per capita) accounted for 22% [100% x (0.0555 / 0.250)]. Note that the sum of both percentages equals 100%.

In a number of cases (28 out of the 100), the results of the Holdren method showed that either population growth or growth in per capita land consumption actually explained more than 100% of the sprawl that occurred, while the per capita land area growth (in the case of the former), or population growth (in the case of the latter) share was less than 0% (i.e., a negative number due either to higher population densities or a decline in population throughout the aggregate Urbanized Area). There were 17 cases in which population growth explained more than 100% of sprawl, and 11 cases in which growth in per capita land consumption did the same. Still in these instances, the sum of the percentage numbers – one positive and one negative – adds up to 100%. These are the cases in which overall population density increased, or alternatively, there was an absolute decline in population, throughout a given Urbanized Area. In Table 5 and Appendix A, to avoid confusion created by negative growth rates, the authors limited the calculated share of the total growth rate to no more than 100% and no less than 0% of sprawl. The issue is the percentage of a fixed number of square miles of sprawl that can be explained by one of the two factors. In layman's terms, 100% of those fixed square miles is the highest possible number.

Appendix F

Accounting for Distortions by Aggregate Data

We note that our analysis, when applied at the level of the aggregate Urbanized Area (UA), including one or more central places and an urban fringe, does not capture geographic shifts of population within the boundaries of the UA. This requires additional measurements to ensure that such hypothetical shifts have not distorted the conclusions.

Hypothetically, it is possible that a disproportionately high share of a UA's population growth occurred on a small fraction of the already built-up central place (i.e. urban core) of the UA, while a small minority of residents settling in spacious new single-family dwellings on half-acre lots on the outer fringes of the city actually accounted for most of the overall increase in urban/suburban land. In such a scenario, the population growth would not be *directly* responsible for much or even any of the sprawl since most or all of the UA's net population growth was occurring in the core of the city – not on the periphery of the suburbs where the sprawl is taking place. (*Indirectly*, such densification might indeed facilitate or enable the expansion of peripheral sprawl through several means).[22]

Thus, if an Urbanized Area's population growth is occurring primarily in the urban core, while densities are falling in the suburbs, the proportion of sprawl attributed to population growth from the analysis of aggregate UA data may be misleading. In these cases, using only the aggregated population growth and density figures for the entire UA would mask the fact that density had declined in the suburbs. Fortunately, the Census Bureau provides separate data for the urban cores and the suburban fringes. This makes it possible to test for the hypothetical distortion just stated. We have performed the test on all 100 cities and found nothing to indicate that the share of sprawl our formula has associated with population growth was systematically overstated, although we did find isolated instances of overstatement.

The initial sign that population growth might not be linked to as much sprawl as the aggregate analysis suggests would be the meeting of each of two conditions: (1) an increase in central urban density, and (2) a simultaneous decrease in density in an expanding suburban area. These two conditions were clearly and unequivocally met in six out of the 100 cities studied: El Paso, Mobile, Phoenix, Tacoma, Wilmington, and Stockton. An adjustment procedure was applied to these UA's that consisted of the following: The total growth in land area was apportioned between urban (i.e. central place) and suburban (i.e. urban fringe) shares. Since density rose in the urban share, 100% of this share was assigned to population growth. Then the same Holdren analysis used on aggregate UA data for all 100 cities was applied to the urban fringe share of growth. That is, the percentage growth in both suburban population and suburban land area were calculated in order to derive shares of the suburban land area growth attributable to suburban population growth and rising per capita land consumption (declining density).

In performing this adjustment, the share of sprawl explained by population growth actually rose in three of the six UA's – Mobile, Tacoma and Wilmington. In these cases, the central place land area grew by very little or actually shrank, and population and population density there increased only slightly. Urban fringe population growth was greater and was actually found by the Holdren formula to represent a higher share of urban fringe land increase than the share of overall UA land area increase attributable to population growth. In these three cases, we continued to use the overall aggregate UA figures for Mobile, Tacoma, and Wilmington, rather than adjusting these figures upwards.

[22] The expansion of peripheral sprawl may be facilitated by means such as: 1) a diminished quality of life in the urban core due to crowding, higher crime, or social tensions, pushing out those long-time residents who have the option of leaving; 2) greater demand for inner city/suburban housing, which bids up prices on older or more run-down housing stock, thereby enabling the sale of homes and the departure of their long-term occupants; 3) the availability of more low-cost labor (i.e. associated with the higher numbers of lower-income, urban residents) for new housing and infrastructure construction, landscaping, etc., which effectively lowers expenses for and increases the relative affluence of higher-income consumers, permitting (among other things) the purchase of larger homes on larger lots further away from the central city.

In the three other cases, the initial aggregate UA Holdren analysis indicated that population growth explained 86% of El Paso's sprawl, and 100% of both Phoenix's and Stockton's. These were adjusted downwards to 63% for El Paso, 92% for Phoenix, and 84% for Stockton, respectively, based on the adjustment method described above. Table 6 in Section 4.4 and Appendix A show the adjusted percentages rather than the original 100% share attributed to population growth.

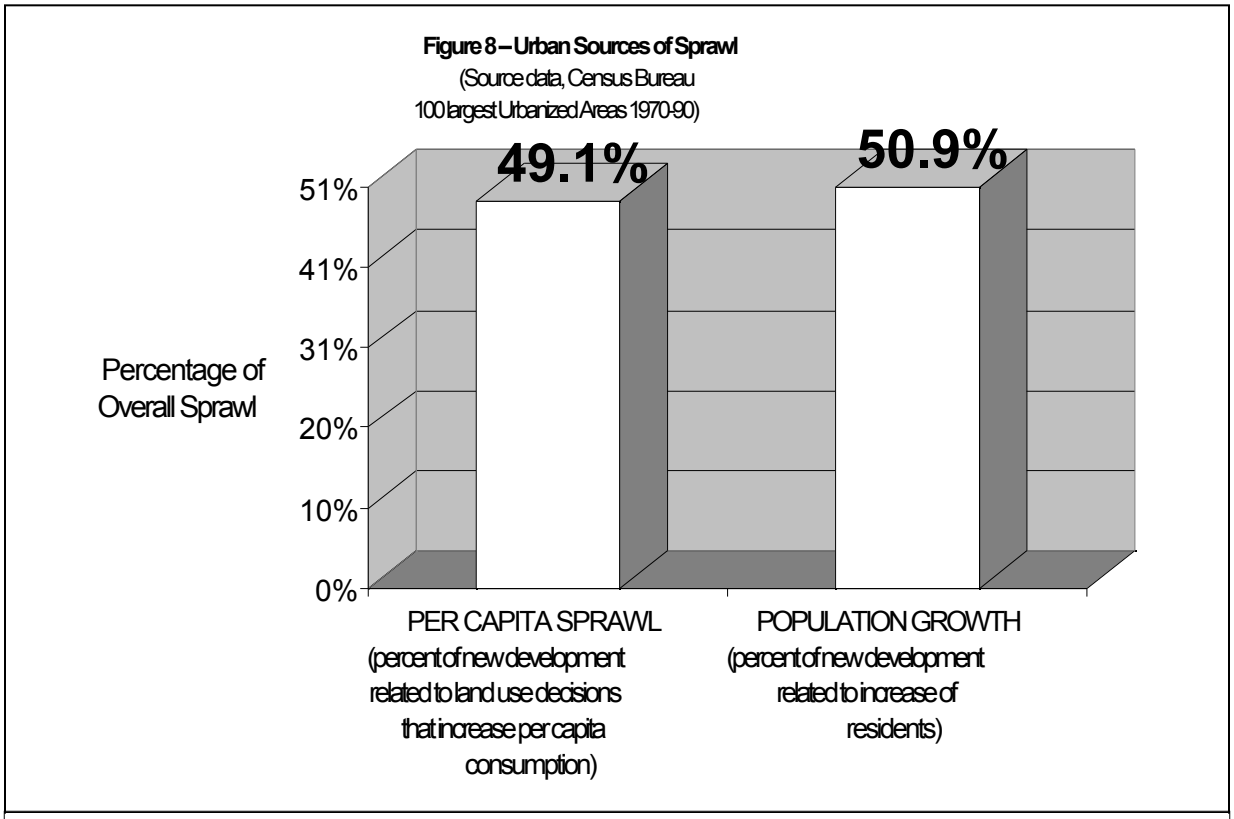
In the case of El Paso, Texas, the central core grew in area from 118.3 to 162.7 square miles from 1970 to 1990, while the fringe or suburbs grew from just 1.1 square miles in 1970 to 57.6 square miles in 1990. The total increase in area of the El Paso UA was 353.6 square miles, 44% of which is attributable to growth in the central place and 56% to growth in the urban fringe. Within the 44% attributable to growth in the central place, population growth had a 100% share of sprawl (reflected in a rising number of residents per square mile). Within the urban fringe (which constituted 56% of the total increase in area), the population grew from 13,827 in 1970 to 55,830 in 1990, an increase of 304%. Urban fringe land area increased by a whopping 5,136%. (The very small, very densely populated 1970 urban fringe area of just 1.1 square miles at a density of 13,827 per square mile, compared to just 2,724 per square mile for the urban core, suggests that in 1970 El Paso was an anomaly.) Applying the Holdren method to the urban fringe alone, 34% of the suburban sprawl is associated with population growth. Thus, 100% of the 44% urban share and 34% of the 56% suburban share of the El Paso UA are related to population growth; putting these together, 63% of the entire UA sprawl is related to population growth.

In the case of Phoenix, Arizona, the central core grew in area from 247.9 to 472.1 square miles from 1970 to 1990, while the fringe or suburbs grew from 139.6 to 269 square miles. The total increase in area of the Phoenix UA was 353.6 square miles, 63.4% of which is attributable to growth in the central place and 36.6% to growth in the urban fringe. Within the 63.4% attributable to growth in the central place, population growth had a 100% share of sprawl (reflected in a rising number of residents per square mile). Within the urban fringe (which constituted 36.6% of the total increase in area), the population grew from 281,795 in 1970 to 469,680 in 1990, an increase of 67%. Urban fringe land area increased 93%. Applying the Holdren method to the urban fringe alone, 78% of the suburban sprawl is associated with population growth. Thus, 100% of the 63.4% urban share and 78% of the 36.6% suburban share of the Phoenix UA are related to population growth; putting these together, 92% of the entire UA sprawl is related to population growth.

Finally, in the case of Stockton, the central core grew in area from 29.9 to 52.6 square miles from 1970 to 1990 (an increase of 76%), while the fringe or suburbs grew only from 16.9 to 21.2 square miles (a 25% increase). Thus, expansion of Stockton's urban core was responsible for 84% of the increase in land area for that California city from 1970 to 1990. Within that 84%, population growth had a 100% share of sprawl; within the 16% of Stockton's total sprawl that was suburban or urban fringe, population growth had a 0% share of sprawl (population actually declined in the urban fringe, although the area grew). Thus, overall, 84% of Stockton's total sprawl was due to population growth.

ENDNOTES

See footnotes



DESCRIPTION: About half of the sprawl in the nation's largest cities was related to the land use and consumption decisions that determine per capita land consumption. And about half the sprawl was related to population growth.

Also available:
Sprawl in California (2000, 42 pp, NumbersUSA)
Sprawl in Florida (2001, 44 pp, NumbersUSA)

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