Sprawl in California

A report on quantifying the role of the state's population boom

Presented at CAPS 2000 Conference—*Waking from the Dream: Population and the Environment at the Millennial Edge*

August 13, 2000
University of Southern California

by Leon Kolankiewicz and Roy Beck

About the Authors

Leon Kolankiewicz and Roy Beck are co-authors of

"The Environmental Movement's Retreat from Advocating U.S. Population Stabilization (1970-1998): A First Draft of History," *Journal of Policy History*, Vol.12, No.1, 2000 (Pennsylvania State University Press).

LEON KOLANKIEWICZ is a national environmental/natural resource planner and a former planner with the Orange County (CA) Environmental Management Agency. He has a B.S. in forestry and wildlife management from Virginia Tech and an M.S. in environmental planning and natural resources management from the University of British Columbia. He has worked as an environmental professional for more than two decades, including stints with the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Alaska Department of Environmental Conservation, Alaska Department of Fish and Game, University of Washington, University of New Mexico, and as a national parks technical advisor with the Peace Corps in Central America. He has written more than 70 articles and reports and is the author of *Where the Salmon Come to Die: An Autumn on Alaska's Raincoast* (Boulder, Colorado: Pruett, 1993).

ROY BECK is a Washington D.C. public policy analyst and the director of NumbersUSA.com, an Internet organization that tracks the role of each Member of Congress in forcing or reducing U.S. population growth. He is the author of four books on U.S. population, the environment, ethics and politics. His articles have appeared in scores of academic books and publications such as the *Atlantic Monthly*. A graduate of the University of Missouri School of Journalism, he was one of the nation's first environment-beat newspaper reporters in the 1960s. As Chief Washington Correspondent of the Booth Newspapers chain in the 1980s, he covered some of the decisions by Congress to speed up U.S. population growth. For the past decade, U.S. population issues have been his primary focus of research, writing, and speaking.

Table of Contents

Sprawl in California

Executive Summary

KEY OVERALL FINDINGS

While there has been scattered debate about whether rising consumption or population growth is primarily responsible for California's urban sprawl, this study breaks new ground by actually attempting to quantify the role of each.

The study found that:

- California's population boom has been the No. 1 factor in the state's relentless urban sprawl, even though most anti-sprawl efforts exclusively target consumption factors.

- The supposedly gluttonous appetite of California citizens for more and more urban space per resident has in fact played little role in the sprawl. In most Urbanized Areas, land per resident did not grow at all – and it usually shrank in both the central city and in the suburbs. Thus, the average Californian was consuming land in an increasingly environmentally responsible way; but there were so many more Californians each year that sprawl marched ever outward.

- The volatile growth of California's population far outweighed the sprawl effect of all other factors combined.

[The period of study was the most recent two decades for which comprehensive government data are available (1970-90).]

WHY THIS STUDY IS IMPORTANT

As governmental agencies, public officials, think tanks, corporations and advocacy groups devote more and more resources to taming California's sprawl, the success of their efforts depends on their accurately assessing why the state's sprawl occurs.

The authors embarked upon this study after a literature search found that media stories, advocacy programs, governmental reports and political statements about sprawl (1) have rarely stated that California's population growth is a significant factor in sprawl and (2) have virtually ignored the possibility that slowing – or stopping – population growth might be an important tool in combating sprawl.

Thus, the finding by this study that population growth was the overwhelming factor in the state's sprawl challenges the strategy of the anti-sprawl movement. And it points anti-sprawl advocates toward a new tool that if wielded successfully, would help their efforts to be more effective.

Effectively taming sprawl is of utmost importance to the future of California's natural environment and human quality of life. For most urban Californians, continuing sprawl results in a direct personal cost of ever-worsening traffic congestion and gridlock. Aggravated traffic congestion alone has the potential to make Californians miserable enough to consider fleeing the state for some semblance of "greener pastures" in other less crowded western states. The greener pastures of Oregon, Washington and Colorado, and the brown deserts of Nevada and Arizona, are rapidly being paved over to accommodate the crush of ex-Californians.

Inside California, the population build-up not only makes life more miserable for human residents but it is having a devastating effect on the state's natural resources. The "ecological footprint" of each Californian includes not only the rural land on the edges of cities that gets urbanized but also far-removed rural lands and habitats that provide for each new Californian's food, fiber, minerals, energy and other resources. Thus, the urban sprawl and spreading ecological footprints of millions of additional Californians have turned the state into one of the Earth's "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 associated with Californians' vast numbers and colossal consumption.[1]

WHAT WAS MEASURED

Sprawl occurs when cities and suburbs expand beyond their boundaries and urbanize rural land at their edges. Each recent decade, California sprawl has degraded hundreds of square miles of some of the most scenic, fertile and biologically rich land in the country.

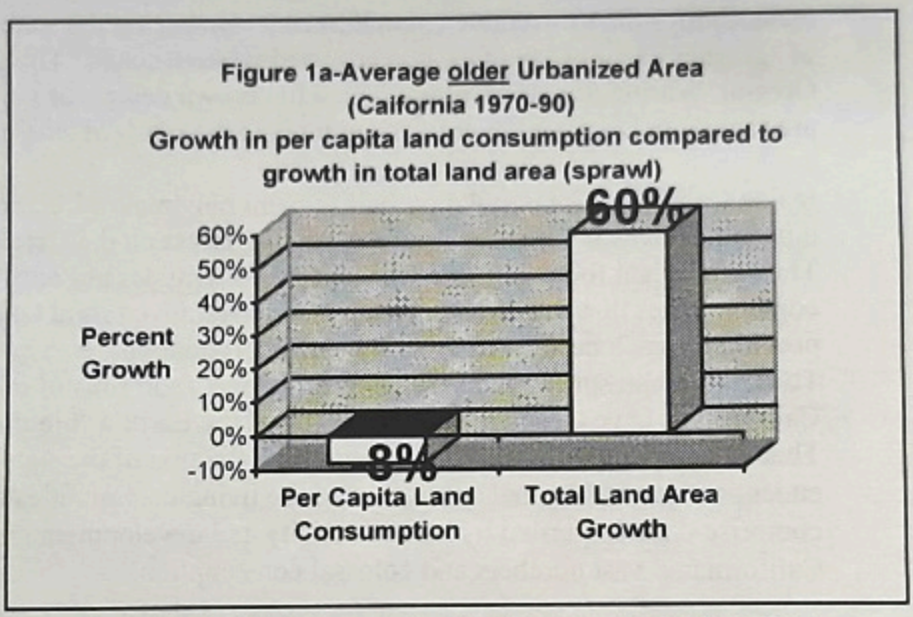
To determine how that has happened, the authors solely relied on the U.S. Bureau of Census's painstaking calculations for each Urbanized Area of more than 50,000 residents. This is done only once a decade, a couple of years after the national census.

This study – a part of a larger national study that will be released later this year – examined the 28 Urbanized Areas in California for which there were at least 10 years of data.

In each case, the study divided the overall sprawl between that which was related to growth in per capita land consumption and that which was related to population growth.

PER CAPITA CONSUMPTION FACTORS CAN'T EXPLAIN OVERALL SPRAWL

The study first checked to see if the data support the apparent assumption of most anti-sprawl efforts that per capita consumption factors are responsible for all or most sprawl.



The combined effect of all urban planning, development, transportation, business and consumer decisions that influence consumption shows up in the statistic that tells us how much urban land is used on average for each resident. If that amount of land grows, a city has "Per Capita Sprawl." A city can have no population growth at all, and still have considerable Overall Sprawl if the amount of land per resident is growing.

If Per Capita Sprawl were the sole factor in Overall Sprawl in California, the percentage growth of one would be the same for the other; for example, if per capita land consumption grew by 13%, total land consumption would also grow by 13%. Or if per capita land consumption growth were the overwhelming factor, its percentage growth would at least be close to that of Overall Sprawl.

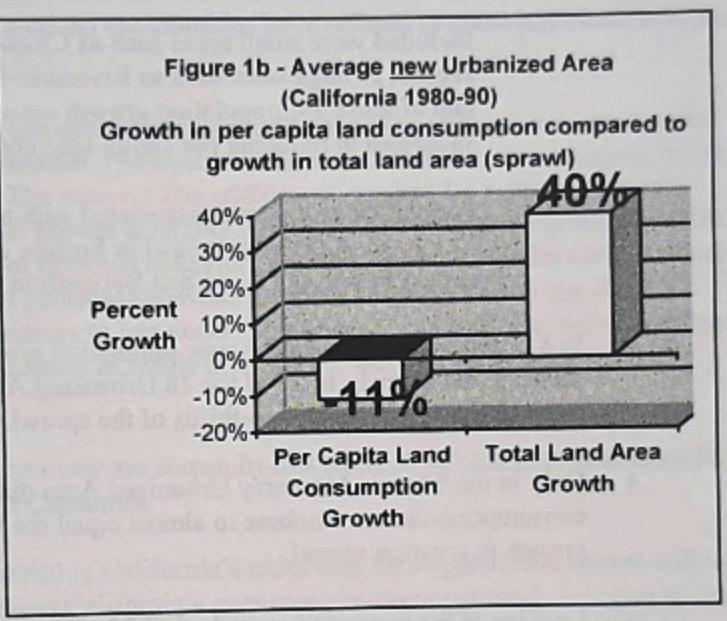
But when we found these two percentages in Census Bureau data and placed them side by side [see Tables 1a and 1b], we learned:

- Not a single one of California's 28 Urbanized Areas had a Per Capita Sprawl percentage that was even close to being as high as the Overall Sprawl percentage.

- On average, the older Urbanized Areas had no per capita consumption growth. Per capita land consumption actually declined by 8%. Despite that, the average older area sprawled (increased its total land area) by 60% over the two decades of study. [See Figure 1a.]

- The average new Urbanized Area also reduced the amount of land per resident (by 11%) while the total land area expanded by 40% over a single decade. [See Figure 1b.]

This simple comparison of U.S. Census Bureau data starkly reveals why Smart Growth efforts in California are likely to fail to stop sprawl if they focus virtually entirely on factors that cause per capita land consumption growth.



It is not that Smart Growth efforts are focused on the wrong factors but that many of them are focused too narrowly. Obviously, there is another factor involved in sprawl, and that factor is population growth.

SPRAWL AND 28 CALIFORNIA URBANIZED AREAS

When we compared population growth with growth in per capita land consumption in each Urbanized Area, we discovered the following:

- In 19 of the 28 Urbanized Areas of the state, growth in per capita land consumption did not appear to be related to *any* of the sprawl – because there *was* no growth in consumption by the average resident. It was population growth that propelled the sprawl.

    - For example, average land consumption in the San Diego Urbanized Area fell from 0.203 acre (about one-fifth of an acre) to 0.188 acre (about one-sixth of an acre) per resident. But San

Diego still devoured another 309.5 square miles of adjoining rural land as it added 1.1 million residents.

- Although residents of Palm Springs remained some of the largest urban land consumers in the nation, average land consumption plummeted from 0.607 acre in 1970 to 0.445 acre in 1990. Nonetheless, Palm Springs still sprawled by more than 40% — because of a burgeoning population.

- With no growth in per capita consumption, population growth was the factor related to 100% of the sprawl in those 19 Urbanized Areas.

  - Included were small areas such as Chico, to medium ones such as Fresno, to large ones such as Riverside-San Bernardino. In every one of those 19, population growth outweighed all Smart Growth successes in reducing per capita land consumption.

  - Population growth was associated with all of the 29% sprawl in Chico, all of the 68% sprawl in Fresno, and all of the nearly 50% sprawl in Riverside and San Bernardino.

- In 8 of the other Urbanized Areas, population growth was the dominant factor in the sprawl. In 27 of the 28 Urbanized Areas, population growth was related to more than two-thirds of the sprawl.

- Only in the Seaside-Monterey Urbanized Area did the some two dozen consumption factors combine to almost equal the influence of population growth in creating sprawl.

- Looking at the combined sprawl of all 28 of the California Urbanized Areas, the standard apportioning formula we used indicated that 95% of the sprawl was related to population growth.

  Only 5% of the sprawl was related to growth in the per capita land consumption which is the focus of nearly all anti-sprawl efforts.

IMPLICATIONS

That population growth is correlated with 100% of sprawl for so many California cities is a sign of some victory in the pursuit of the "densification" goals of conventional anti-sprawl efforts. It means that, for whatever reason, every one of those Urbanized Areas succeeded in stopping increases in per capita land consumption.

Of course, it is theoretically possible for a while to have population growth and no sprawl by forcing all new and old residents to remain within the confines of current urban land boundaries. But no American community anywhere has shown an inclination to do that.

Exhibit A of the limits to how far Americans will go in cramming additional people into their neighborhoods is Los Angeles. No city in America may be a better model of the Smart Growth goal of attempting to restrain sprawl by channeling population growth into ever-denser urban settlements. Between 1970 and 1990, per capita land consumption fell until the Los Angeles Urbanized Area was the most densely populated in the country. No other urban area provided so little land per resident (0.110 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. California's population growth is largely a function of federal immigration policies and national patterns of personal behavior, including fertility. Under current trends in federal policies and personal behavior, California is projected to rise from its current 35 million residents to just under 50 million in 2025. At that point, California will be as densely populated as China is now, and with no end in sight to rapid population growth.[2]

These population phenomena are shown by this study to be central to understanding the future of sprawl in California.

Nothing that has occurred in California's cities thus far suggests that sprawl will not continue its march across California's ever-more beleaguered rural and open spaces. In the process, the state's environment and quality of life for residents will pay an ever-higher price for the nation's unwillingness to stabilize its population.

This study has provided quantitative evidence in support of the common sense perception: Population growth is a significant factor in California's deplorable sprawl problem.

Studies and plans from state commissions, think tanks, universities and advocacy groups that purport to offer blueprints for combating sprawl without dealing with population growth look either naïve, foolish or deceptive in light of the findings of this study.

Sprawl in California

A report on quantifying the role of the state's population boom

1. INTRODUCTION

Urban sprawl in California continues to destroy and threaten some of the most important ecological, agricultural and scenic land in the world.

In recent decades, the state's urbanized areas burst outward in an explosion of sprawl that consumed countryside at a breakneck pace. Thousands of square miles of orchards, rangeland, farmland and natural habitats were covered by concrete, asphalt and the structures they underlie.

This has occurred at the same time California's population has expanded from around 10 million in 1950, to 20 million in 1970, to 30 million in 1990, to 35 million in 2000, with no end in sight.

Were the two California phenomena – massive population growth and massive sprawl – related? Or was it primarily coincidental that they have occurred at the same time?

Coincidental, say many anti-sprawl enthusiasts. They argue that it is the increasingly gluttonous appetite of individual Californians for bigger houses, bigger lots, more cars, more parking lots and more roads that is the main culprit behind the sprawl.

Others argue that simple common sense suggests that population is a major factor in sprawl. After all, those new subdivisions spreading like wildfire across much of California are not being built just for the heck of it but to house more people – roughly half a million additional people each year and five million each decade.

1.1. Biodiversity hotspot

Regardless of the cause, urban sprawl has made California one of the Earth's "biodiversity hotspots." A frighteningly 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 associated with Californians' vast numbers and colossal consumption.[3]

Despite some of the nation's strongest efforts to tame sprawl, hundreds of additional square miles of the state's rural land are churned under by the forces of urbanization each decade. The ecological as well as the quality-of-life future of California depends on efforts to protect the state's land resources.

1.2. Anti-sprawl effectiveness depends on correct targeting

But to be effective, anti-sprawl efforts must be targeted at the factors that are most responsible for the encroachment on open spaces, natural habitats and farmland.

Approximately two dozen major factors have been suggested as culprits in sprawl:

1. One factor is population growth.
2. All the other factors combine to create growth in per capita land consumption – in other words, an increase in the average amount of urbanized land used by each resident of a city.

The relative contributions of the population factor and the combined consumption factors must be understood if anti-sprawl resources are to be used efficiently and effectively. And understanding is difficult without quantification.

The present report attempts to quantify the relative contributions of items (1) and (2) during the most recent 20-year period for which reliable and comprehensive data are available (1970-90).

1.3. No need for abstract debate

The authors embarked upon this study after a literature search found that media stories, advocacy programs and political statements about sprawl in the last few years have contained very few references to population growth as a significant factor. Nearly all public anti-sprawl efforts have been aimed at the factors that increase per capita land consumption.

Does growth in per capita land use explain virtually all of California's sprawl, as conventional anti-sprawl efforts suggest? Or, rather, is population growth a significant – even dominant – factor?

While there has been little public discussion of this question, acrimonious debate has sometimes ensued when the question has been raised. Arguments on all sides have tended to involve either abstract assertions or non-contextual anecdotes.

This kind of debate is needless, for it is quite possible to quantify the relative roles of population growth and of the combined per capita consumption factors.

2. DEFINING AND MEASURING 'OVERALL SPRAWL'

To begin this process of quantification, we must know what we are measuring when we speak of sprawl.

2.1. Quality vs. Quantity Measurements

Sprawl can be measured for both quality and quantity (amount). Measures for the quality of urban expansion include:

1) its low-density character, in contrast to compact urban cores;
2) its chaotic, or unplanned nature;
3) its dependence on the automobile; and
4) its connection with the decay of inner cities.

This study of California's urban areas, though, limits itself to measuring the amount of urban sprawl.

We use the term "Overall Sprawl" to refer to the increase of the total size of the land area of a city and its suburbs. If an urban area covered 10 square miles previously and now covers 12 square miles, we say that the city and its suburbs over that period of time have "sprawled 2 square miles."

Overall Sprawl is the loss of rural land at the periphery of a city. This involves the conversion of open space or rural land into built-up, developed, or urbanized land over time, no matter the quality of that conversion.

We believe this measurement by amount most closely resembles the common American understanding of sprawl. If 25 square miles of open spaces around a city are urbanized, most Americans would consider that to be 25 square miles of sprawl, regardless of whether it was developed tastefully or not. They might be more offended by the sprawl if it included ugly development, but the amount of sprawl – and the number of rural acres lost – would be the same. Thus, using this measure, it is possible to have well-planned sprawl or chaotic sprawl, to have high-density or low-density sprawl, to have auto-dependent or mass-transit-oriented sprawl. But regardless of the quality of the sprawl, the amount of sprawl is measured by the square miles of rural land eliminated by urban development.

2.2. Census Bureau's 'Urbanized Areas'

Fortunately, it is easy to measure the amount of Overall Sprawl because of a painstaking process conducted by the U.S. Bureau of the Census for a half-century.

Our study relies solely on Census data on Urbanized Areas of the United States to measure Overall Sprawl.[4]

The Census Bureau 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.

The Bureau introduced the Urbanized Area concept in the 1950 Census as part of its efforts to differentiate the urban and rural portions of the nation's population. It recognized 405 Urbanized Areas in the United States as of the 1990 Census.

[For further explanations of the Census Bureau's methods in measuring Urbanized Areas, see Appendix B]

Nearly every organization that addresses sprawl relies on these Urbanized Area data as the foundation of any quantification of total sprawl. What they haven't done is use those same data to quantify the relative roles of population growth and land consumption in generation of that sprawl.

As of 1990, there were 37 Urbanized Areas in California. Of those:

- 9 were designated for the first time in the 1990 Census. Prior to that, none of them met the Census Bureau's minimum threshold of 50,000 population. Because they were not Urbanized Areas during previous censuses and thus had no previously quantified land mass for comparison purposes, they were not included in this study.

- 12 became Urbanized Areas in 1980, when they first had enough population to qualify. [We call these "new Urbanized Areas."]

- 16 already were Urbanized Areas in 1970 at the beginning of the period examined by this study. [We call these "older Urbanized Areas."]

This study looks at all 28 of California's Urbanized Areas for which at least one decade of data exists.

2.3. Period of study

This study measures sprawl over the most recent two decades for which comprehensive government data are available (1970-90). But 12 of the 1980

Urbanized Areas were not large enough in 1970 to be counted as such. The data for those 12 cover only the 1980 to 1990 period.

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. An exception would be a regular land survey by the Natural Resources Conservation Service of the U.S. Department of Agriculture which is expected to report again in early 2001 for development from 1992 through 1997. This survey— the National Resources Inventory—does not look at specific Urbanized Areas but surveys the conversion of rural land into development throughout whole states, providing a useful comparison for the urban-only data of the Census Bureau. We will include this data in subsequent reports, including a forthcoming one that looks at sprawl nationwide.

3. 'PER CAPITA SPRAWL' ALONE CANNOT EXPLAIN OVERALL SPRAWL

3.1. Many reasons for Per Capita Sprawl

Per capita urban land consumption is not limited to the size of a person's house lot or to a person's proportion of the land covered by an apartment complex. It also includes a portion of all the other land that has been converted from rural to urban use to provide for jobs, recreation and entertainment, shopping, parking, transportation, storage, government services, religious and cultural opportunities, waste handling, and education.

So the level of per capita land consumption is based both on direct individual decisions and behavior, and on collective decisions made through the government and the marketplace. The effect of all urban planning, development and transportation decisions shows up in the per capita land consumption figure.

In the end, per capita land consumption is calculated by dividing the total urban land area by the total number of residents. The resulting per capita figure provides a net result view of at least two dozen major factors that have been suggested as causes of consumption changes.

[See Appendix C for more on calculating per capita land consumption.]

For several decades, per capita land consumption in most U.S. cities has been growing. At least two dozen factors have been advanced as being among the reasons more and more urban land is required for each resident. The factors include:

- price of gasoline,
- inadequate urban planning and zoning,
- local and federal tax incentives and subsidies,
- crime and quality of schools in the central cities,
- mortgage interest tax deductions,
- racial and ethnic tensions,
- the Interstate Highway system and other transportation decisions,
- developer preferences,
- declining size of households caused by factors such as increased divorce rate, lowered marriage rate, later marriages, increased independence of young adults, increased longevity for women,
- consumer preferences for larger houses and yards, and
- affluence.

A nationwide "Smart Growth" movement has emerged to fight sprawl by going after some of those many causes of Per Capita Sprawl. It is composed of a broad-based collection of urban planners, environmentalists, charitable foundations, historic preservationists, "new urbanists," affordable housing advocates, local, state and federal government agencies and elected officials, churches, local growth control activists, and even some of the home building industry. Many variations can be found among their proposals but all advocate tools that would stop the increase in per capita land consumption.

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 the average amount of urban land per resident in an Urbanized Area. If that per capita land consumption figure goes up markedly, then we know that Smart Growth efforts related to the above factors 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 factors are collectively moving in the direction desired by the anti-sprawl leaders. It is difficult to know whether their efforts made the difference, but we do know in such cases that per capita land consumption patterns are being brought under control.

The per capita consumption figure is a crucial gauge of the nature of sprawl in any Urbanized Area.

3.2. Per capita land consumption growth falls far short of total land growth percentage

When we look at Per Capita Sprawl figures for California's cities, we find that – for whatever reasons – the goal of anti-sprawl programs to stop per capita growth has been substantially met. Most Urbanized Areas had no per capita consumption growth at all.

But Overall Sprawl in California's Urbanized Areas continued at a raging pace – consuming more than 1,600 square miles of rural land during the period of study.

It appears that anti-Per Capita Sprawl efforts in California have been largely successful. But anti-Overall Sprawl efforts have been an abysmal failure.

If Per Capita Sprawl were the sole cause of Overall Sprawl, the percentage growth would be the same for both. For example, if per capita land consumption grew by 38%, total land consumption would also grow by 38%.

But in the Seaside-Monterrey Urbanized Area, per capita land consumption grew by 38% while the total land in the urban area grew by the far larger 97%. Where there was Per Capita Sprawl in California, it usually explained very little of the Overall Sprawl:

- The average older Urbanized Area had an 8% decrease in per capita land consumption but had Overall Sprawl of 60% (1970-90).

- The average new Urbanized Area had an 11% decrease in per capita land consumption but had Overall Sprawl of 40% (1980-90).

- Not a single one of California's 28 Urbanized Areas had a Per Capita Sprawl percentage that was even close to the Overall Sprawl percentage.

These facts starkly reveal why nearly all Smart Growth efforts are failing – and will continue to fail – to stop sprawl as long as they focus virtually entirely on factors that cause per capita land consumption growth.

It is not that Smart Growth efforts are focused on the wrong factors but that they are focused too narrowly. Obviously, there is another factor involved in sprawl. Without addressing that factor, Smart Growth programs as currently envisioned are designed to fall short of protecting the agricultural land and natural habitats surrounding cities.

4. THE POPULATION GROWTH FACTOR AND LIMITS OF FORCED DENSITY

For some reason, many otherwise intelligent observers seem to have a mental block that keeps them from understanding that the other factor in sprawl is population growth. The only factor that can make Overall Sprawl grow at a faster rate than the increase in per capita land consumption is population growth.

Despite the considerable complexity of sprawl in an urban area, nearly all of the complexity can be boiled down into what end up being two rather simple factors in an equation: The amount of Overall Sprawl in an area is equal to the change in per

Table 1a – Older Urbanized Areas in California Growth in Population, Per Capita Land Consumption, and Total Land Area (1970 to 1990) *

Urbanized Area	% Growth in Population	% Growth in Per Capita Land Consumption	% Growth in Land Area (Sprawl)
Bakersfield	72%	0%	72%
Fresno	72%	-3%	68%
Los Angeles	37%	- 8%	25%
Modesto	117%	-30%	52%
Oxnard-Ventura	96%	-28%	41%
Riverside-San Bernardino	101%	-26%	49%
Sacramento	73%	-21%	42%
Salinas	96%	18%	131%
San Diego	96%	-7%	81%
San Francisco-Oakland	21%	6%	28%
San Jose	40%	-13%	22%
Santa Barbara	40%	-6%	32%
Santa Rosa	159%	-32%	76%
Seaside-Monterrey	43%	38%	97%
Simi Valley	125%	-16%	89%
Stockton	63%	-3%	58%
**Mean of percentages ** **	**78%**	**-8%**	**60%**
Weighted average***	**46%**	**-6%**	**38%**

** The Census Bureau classified these as Urbanized Areas in 1970 or earlier.*

*** Mean of the percentages.*

**** For "% Growth in Population," is the % change in total population of all 16 cities; "% Growth in Per Capita Land Consumption," is the % change in total area of all 16 cities divided by the total population; "% Growth in Total Land Area" is the % change in the sum of all land areas between 1970 and 1990.*

capita land consumption multiplied by the change in population. In most American cities, growth has occurred in both factors.

4.1. Comparing population growth with per capita consumption growth

We can learn a lot about the relative importance of each of these factors in California's sprawl by lining up the growth percentages side by side. Fortunately, both the per capita land consumption change and the population change for each California Urbanized Area are readily available from the Census Bureau.

An observer doesn't have to be a mathematician to see that population growth has been a far greater factor in California's Urbanized Areas than has been per capita land consumption growth.

Table 1b –New Urbanized Areas in California Growth in Population, Per Capita Land Consumption, and Total Land Area (1980 to 1990) *

Urbanized Area	% Growth in Population	% Growth in Per Capita Land Consumption	% Growth in Land Area (Sprawl)
Antioch-Pittsburg	78%	33%	137%
Chico	38%	-6%	30%
Fairfield	44%	- 12%	27%
Hemet-San Jacinto	64%	-5%	56%
Lancaster-Palmdale	232%	-45%	84%
Napa	15%	-4%	11%
Palm Springs	94%	-27%	42%
Redding	48%	-8%	37%
Santa Cruz	24%	8%	33%
Santa Maria	55%	-29%	10%
Visalia	42%	-22%	10%
Yuba City	26%	-16%	7%
Mean of percentages	**63%**	**-11%**	**40%**
Weighted average**	**60%**	**-11%**	**42%**

** The Census Bureau classified these as Urbanized Areas in 1980.*

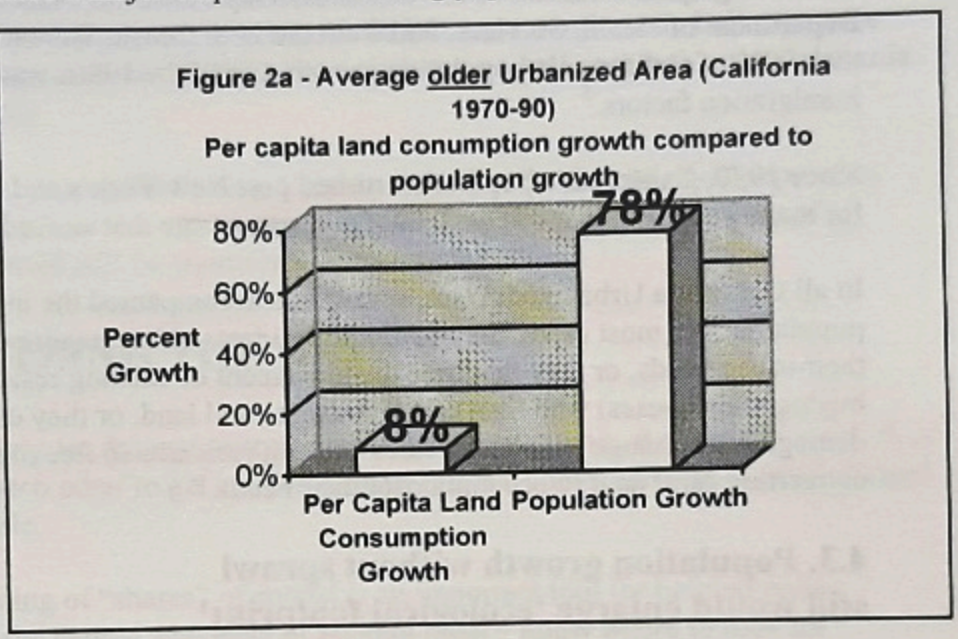
*** Mean of the percentages.*

**** For "% Growth in Population," is the % change in total population of all 12 towns; "% Growth in Per Capita Land Consumption," is the % change in total area of all 12 towns divided by the total population; "% Growth in Total Land Area" is the % change in the sum of all land areas between 1980 and 1990.*

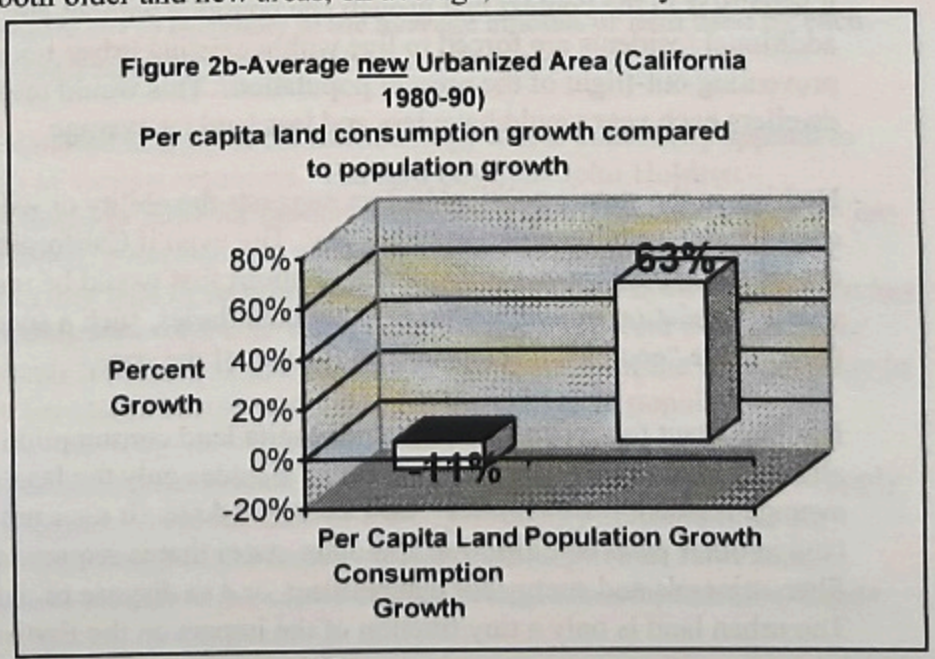
In Tables 1a and 1b, we can compare the growth in the left column (population) with the growth in the middle column (per capita consumption) and see the huge disparity between the two in all but Seaside-Monterrey where the two factors contributing to Overall Sprawl are roughly equal.

When comparing the two growth factors, it becomes apparent that any successful effort in California to reduce the percentage growth in the right column (Overall Sprawl) must place a major emphasis on slowing population growth.

Figures 2a and 2b look at the average older and new Urbanized Area in terms of the two factors that combine to cause Overall Sprawl. By themselves, the planning, zoning and all other ingredients that affect the amount of urban land per resident should not have created any Overall Sprawl. Per capita land consumption in both older and new areas, on average, declined – by 8% and 11% respectively.



But the population in the average older Urbanized Area grew by 78% over two decades. Population grew by 63% over a single decade in the average new area.



4.2. California's extraordinary population growth

The primary causes of population growth in a state are (1) native increase [resulting from an excess of births over deaths among natives and from domestic migration which is a net flow of people moving from other states], and (2) immigration [new immigrants and an excess of births over deaths among the foreign-born]. Data from the Demographic Division of the California Department of Finance and the Department of Health Services, and from the U.S. Census Bureau indicate that more than 90% of California's population growth during the 1990s was due to immigration factors.[5]

Since 1970, California's population rushed past New York's and even Canada's and for many years expanded at an annual percentage rate that exceeded India's.

In all California Urbanized Areas, sprawl has accompanied the increase in population. In most cases, the additional residents either require extra rural land for their urban needs, or they facilitate the movement of existing residents (e.g., by buying their houses) who then urbanize more rural land, or they create rapid demographic change which motivates existing residents to flee to the urban edges, converting rural land to accommodate their needs.

4.3. Population growth without sprawl still would enlarge 'ecological footprint'

Few anti-sprawl efforts include suggestions for slowing or stopping California's population growth as a way to control sprawl. When population growth is addressed, it usually is in the context that growth can continue without any urban sprawl if all additional residents are forced to live within existing urban boundaries, while preventing out-flight of the present population. This would mean that California city dwellers each year would have less and less land on average.

Nothing in the state's political history suggests the ability or willingness to do this even for one year, let alone in perpetuity. But even if California's citizens 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 rest of the state.

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 California and other states 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

Californian 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.[6] This impacted area is roughly 25-70 times greater than the built-up space (i.e. developed or urbanized land) of one-sixth to one-half acre inside the California Urbanized Areas.

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

5. ANALYZING THE DATA

With percentages for the two overall growth factors available, it is possible to look at their ratio to each other to get an idea of their relative contribution to Overall Sprawl on a 100% scale.

This apportioning of "shares" of sprawl is an important tool for helping policy makers – and the people who elect or appoint them – know where to look for solutions.

Over time, as sprawl spreads outward across the landscape, the shares of this expansion attributable to (1) increases in the average amount of land used by each resident and to (2) increase in population can be calculated.

We have used a standard mathematical methodology 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 methodology.[7] 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 apportioning formula has enabled analysts to apportion shares of the total increase to (1) the change in per capita energy use and to (2) the change in population.

The unique contribution of the present study is that it appears to be the first to apply these methods 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 D for further description.]

6. CALIFORNIA FINDINGS

We applied the apportioning methodology to the 28 California Urbanized Areas identified by the Census Bureau before 1990.

In the table that follows, the first and second columns of figures show how much rural land was consumed and converted into urban land during the period studied.

[Cities with data in the 1980-1990 column were designated Urbanized Areas for the first time in 1980. The fact that there are two different lengths of study does not alter the comparisons of percentages in the two right-hand columns. And where the Census Bureau combined Urbanized Areas during the period of the study, data were adjusted so that comparisons are accurate.]

Read the table like this, using the first line of the table as an example:

(1) The total Antioch-Pittsburgh Urbanized Area sprawled out during the 10-year period covered by Census figures and consumed 35.5 square miles of rural land, converting it into urban land.

(2) 67% of that 35.5–square-mile Overall Sprawl was related to the population growth in the Urbanized Area.

(3) 33% of that 35.5–square-mile Overall Sprawl was related to Per Capita Sprawl (growth in per capita land consumption).

The actual percentages of population growth and of Per Capita Sprawl are not included in this table. [Find them in Tables 1a and 1b.]

6.1. Population growth related to 100% of sprawl in most cities

The results of the comparisons are dramatic. Far from being an insignificant factor in California's mass sprawl, population growth is related to the overwhelming majority of that sprawl.

The unadjusted analysis showed the population growth share of sprawl to be 100% in 22 of the 28 Urbanized Areas. What this means is that in those cases, between 1970-90 or 1980-90, there was no increase in per capita land consumption in the Urbanized Area as a whole. [In Table 2, we adjusted three of the 22 to lower proportions for reasons explained in Appendix E, so that after adjustment, 19 Urbanized Areas display 100% shares of sprawl related to population growth.]

Table 2

Urbanized Area	Sprawl in Square Miles		% of Total Sprawl related to POPULATION GROWTH was	% of Total Sprawl related to GROWTH IN PER CAPITA LAND CONSUMPTION was
	1970-1990	1980-1990		
Antioch-Pittsburg		35.5	67%	33%
Bakersfield	41.1		99%	1%
Chico		7.6	100%	0%
Fairfield		8.7	100%	0%
Fresno	53.6		100%	0%
Hemet-San Jacinto		15.6	100%	0%
Lancaster-Palmdale		37.9	100%	0%
Los Angeles[1]	393.8		100%	0%
Modesto	17.8		100%	0%
Napa		2.0	70%[6]	30%
Oxnard – Ventura	45.6		100%	0%
Palm Springs		26.7	100%	0%
Redding		16.5	100%	0%
Riverside – San Bernardino	150.4		100%	0%
Sacramento[2]	89.7		100%	0%
Salinas	19.7		80%	20%
San Diego[3]	309.5		100%	0%
San Francisco-Oakland[4]	193.1		78%	22%
San Jose[5]	61.2		100%	0%
Santa Barbara	11.7		78%[6]	22%
Santa Cruz		24.7	74%	26%
Santa Maria		2.3	100%	0%
Santa Rosa	29.0		100%	0%
Seaside-Monterey	23.4		52%	48%
Simi Valley	22.1		100%	0%
Stockton	27.0		84%[6]	16%
Visalia		2.6	100%	0%
Yuba City		1.7	100%	0%
Total	**1,670.5**		**95%**	**5%**

Data sources: 1970 Census of Population, Volume 1 – Characteristics of the Population, Part 1 – United States Summary, Table 20 – Population and Land Area of Urbanized Areas, 1970 and1960 (issued June, 1973); 1980 Census of Population, Number of Inhabitants, United States Summary, Table 34 – Population, Land Area, and Population Density of Urbanized Areas: 1980; 1990 Census of Population and Housing, Summary Population and Housing Characteristics, United States, Table 8 – Land Area and Population Density: 1990.

[1] Includes Anaheim, Burbank, Long Beach, Pasadena, Pomona, and Santa Ana.

[2] Roseville added to Urbanized Area in 1990.

[3] Escondido added to Urbanized Area in 1990.

[4] Includes Vallejo; Berkeley and Livermore added to Urbanized Area in 1990.

[5] Palo Alto added to Urbanized Area in 1990.

[6] Adjusted down from 100%; see explanation in Appendix B.

Vast amounts of some of the most scenic, fertile and biologically diverse land in the country were urbanized in those 19 areas. Nonetheless, that population growth is related to 100% of sprawl for so many California cities is a sign of some success in meeting Smart Growth "densification" goals, in that it means every one of those 19 Urbanized Areas succeeded in stopping increases in the per capita consumption of land. In most cases, the per capita consumption of land not only stopped growing but was reduced. Thus, an increase in per capita land use did not account for any sprawl.

Those 19 areas are stark reminders of the limitation of current anti-sprawl and Smart Growth efforts. Their tools for fighting sprawl are woefully inadequate because they do not address population growth. Although they met their goal of stopping Per Capita Sprawl, Overall Sprawl has been rampant in most of those cities. For example, Simi Valley encroached on another 22 square miles of rural land between 1970 and 1990. The losses were 45 square miles in Oxnard-Ventura, 53 in Fresno, 61 in San Jose, and 89 in Sacramento. Palm Springs paved over nearly 27 square miles in the 1980s alone.

For some smaller Urbanized Areas, the Overall Sprawl in actual square miles may look relatively insignificant compared to that of the large cities. But the percentage sprawl in most of those was quite large, usually running well over 25 percent.

Whether the sprawl was 19 miles (as in Salinas), or 41 miles (as in Bakersfield), or 150 miles (as in Riverside-San Bernardino), some of the finest agricultural land in the world was lost forever under the asphalt and concrete of the expanding cities.

Those 19 Urbanized Areas provide conclusive evidence that simply stopping the growth in per capita land consumption will not stop sprawl.

6.2. Los Angeles suggests limits of 'the denser the better' approach

To stop sprawl in the face of continuing population growth, a city would have to force major increases in density on its residents. But no city has shown anywhere near the political will to regiment and restrict its inhabitants sufficiently to accommodate population growth without sprawl.

One of the chief examples of failure is the de facto champion of "densification" – Los Angeles. The designation of Los Angeles as a kind of Smart-Growth model may seem incongruous to many because of its reputation as the "sultan of sprawl" and "suburbs in search of a city." For many Americans, Los Angeles is a sprawling model of what they don't want their city to become. But, indeed, the Los Angeles Urbanized Area earned quantitative Smart Growth honors between 1970 and 1990.

One of the chief ideas behind Smart Growth initiatives is that denser is better. Nearly all Smart Growth policies are based on the concept that a city's population can continue to grow indefinitely without creating a lot of sprawl. That can happen in only one way: by confining more and more people into existing urbanized areas. You know that Smart Growth efforts are reaching one of their major goals when you see density increasing. The city that packs the most people into each square mile gets the prize.

Under those measures, the champion model of Smart Growth in the entire nation since 1970 was none other than Los Angeles.

Smart Growth Honor No. 1: Unlike most American Urbanized Areas (but similar to most in California), Los Angeles stopped all *individual sprawl*. That is, the land per resident did not expand. In fact, the urban land per resident shrank by 8%. That means the density increased. From 5,313 residents per square mile in 1970, Los Angeles squeezed in another 500 people per square mile by 1990. Moreover, Smart Growth was achieving its goal throughout the Urbanized Area; density increased in both the core city and in the suburbs.

Smart Growth Honor No. 2: By 1990, land consumption per L.A. resident had dropped to 0.11 acre. That made Los Angeles the most densely populated Urbanized Area in America. No other urban area — not even New York — provided so little land per resident.[8] This is a model that Smart Growth planners apparently would wish for all Americans, certainly if the U.S. population continues to grow.

The fact that Los Angeles on paper deserves Smart Growth accolades raises two important questions: (1) Has the increased density improved the quality of life of those who live there? (2) Has the increased density stopped sprawl?

The first question is a complex one that is outside the scope of this study. Certainly, though, there are indicators that the increased density is related to several major causes of social stress and frustration in Los Angeles, such as overcrowded schools and traffic snarls. Retrofitting a city to accommodate high-density living is very difficult and expensive at best and probably impossible in reality. An example would be the massive problems and expense associated with recent attempts to build a subway to serve even a tiny fraction of Los Angeles. Often, increased density results in a more congested quality of life. And congestion is a result no one is seeking.

The second question is easy to answer; Census Bureau calculations show that increasing the density in Los Angeles did not stop sprawl. Between 1970 and 1990, urban Los Angeles sprawled across an extra 394 square miles (252,160 acres). This was *in addition to* the 1,572 square miles it already occupied in 1970. Only five

other Urbanized Areas in the entire country sprawled more than Los Angeles during this time period. That's hardly a model of success in combating the sprawl problem.

What accounted for this sprawl? Population growth, pure and simple. Between 1970 and 1990, the L.A. Urbanized Area grew by 3.1 million residents – largely because of the federal program of increased immigration levels and the inadequacy of federal efforts to curb illegal immigration. All those additional people had to live, work, play, commute, and be educated somewhere. Although they and the existing residents were willing and able to crowd more closely together than in the past, they did not choose to live together all in the existing urban area. That would have increased the density another 37% over what already were the densest living conditions that Americans in any Urbanized Area were willing to accept.

The unwillingness to further crowd themselves into an ever-denser Los Angeles may have been related to the non-linear nature of congestion once density reaches a certain level. For example, once freeways are near their capacities, increasing the number of cars on the road by, say, 37% can increase waiting times, traffic jams, etc., by much more than 37%.

For whatever reasons that residents refused to increase their density enough to accommodate 3.1 million additional residents, the result was the loss of another 394 square miles of orchards, farmland, natural habitat and other open and rural spaces.

Thus, just as Los Angeles is one model for meeting the Smart Growth goal of high-density living, it also is a model of how Smart Growth initiatives are likely to fail to stop sprawl under current federal policies that generate population growth.

Other models of increasing density but continuing major sprawl were Riverside-San Bernardino, which converted another 150 square miles of rural land into urbanized land, and San Diego, which consumed 309 additional square miles.

Only five California Urbanized Areas exhibited the overall American tendency to increase the urban land required for each resident. Per Capita Sprawl was related to 20% of Overall Sprawl in Salinas, 22% in San Francisco-Oakland, 26% in Santa Cruz, 33% in Antioch-Pittsburg, and 48% in Seaside-Monterey.

7. CONCLUSION

Summing the entire area of Overall Sprawl from the 28 Urbanized Areas, one finds 1,670.5 square miles of rural land lost to sprawl. The average share of sprawl in California Urbanized Areas explained by population growth was about 95%.

California's cities, for the most part, stopped the trend of increasing per capita urban land use. Population growth in most California cities is now the only sprawl-inducing factor that is increasing.

More than any other ingredient, it is the overall growth of U.S. population that is most responsible for the population growth driving sprawl in California's Urbanized Areas. Between 1950 and 2000, the population of the United States rose from about 150 million to 275 million. A disproportionate part of that growth occurred in California, which tripled its population during that period.

Between 1970 and 1990, the period of analysis, California's population rose from 20 to 30 million, accounting for 10 million of the 45-million national increase.

According to the Census Bureau, if current trends of American fertility rates and federal immigration policies continue, California is on a course to hit 50 million residents in 2025. At that point, Californians will be living more densely than today's residents of China.

Nothing that has occurred in California's cities thus far suggests that – if federal policies driving national population growth continue – sprawl will not continue its march across California's ever-more beleaguered rural and open spaces well beyond the year 2025. In the process, the state's environment and quality of life for residents will pay an ever-higher price for the nation's unwillingness to stabilize its population.

These population policies, phenomena and trends – as has been shown by this study – are central to understanding the future of sprawl in California. Studies and plans from state commissions, think tanks, universities and advocacy groups that purport to offer blueprints for combating sprawl without talking about dealing with population growth look either naïve, foolish or deceptive in light of the findings of this study.

We began this investigation to test whether a common sense perception (that California's population explosion is a major factor in its rampant sprawl) could be quantified as true. That perception had been thrown into doubt by the treatment of population growth as a non-factor in sprawl by myriad activists, journalists, planners and politicians.

This study has provided the quantitative evidence in support of the common sense perception: Population growth obviously is the No. 1 factor related to California's deplorable sprawl problem.

APPENDIX A

California Urbanized Areas Raw Data

Table 3a

1970-1990 California Urbanized Areas Raw Data
Population, per capita land use and total land area
from 1970 and1990 U.S. Census Bureau reports

Urbanized Area	1970 Population	1990 Population	1970 Per Capita Land Use (acres/person)	1990 Per Capita Land Use (acres/person)	1970 Total Land Area (sq. miles)	1990 Total Land Area (sq. miles)
Bakersfield	176,155	302,605	0.2078	0.2079	57.2	98.3
Fresno	262,908	453,388	0.1926	0.1873	79.1	132.7
Los Angeles[1]	8,351,266	11,402,946	0.1205	0.1103	1571.9	1965.7
Modesto	106,107	230,609	0.2069	0.1446	34.3	52.1
Oxnard – Ventura	244,653	480,482	0.2917	0.2093	111.5	157.1
Riverside – San Bernardino	583,597	1,170,196	0.3396	0.2516	309.7	460.1
Sacramento[2]	633,732	1,097,005	0.2466	0.1948	244.2	333.9
Salinas	62,456	122,225	0.1537	0.1817	15.0	34.7
San Diego[3]	1,198,323	2,348,417	0.2033	0.1881	380.7	690.2
San Francisco-Oakland[4]	2,987,850	3,629,516	0.1459	0.1541	681.0	874.1
San Jose[5]	1,025,273	1,435,019	0.1730	0.1509	277.2	338.4
Santa Barbara	129,774	182,163	0.1830	0.1715	37.1	48.8
Santa Rosa	75,083	194,560	0.3256	0.2211	38.2	67.2
Seaside-Monterey	93,284	133,188	0.1653	0.2282	24.1	47.5
Simi Valley	56,936	128,043	0.2788	0.2344	24.8	46.9
Stockton	160,373	262,046	0.1868	0.1802	46.8	73.8

Data sources: 1970 Census of Population, Volume 1 – Characteristics of the Population, Part 1 – United States Summary, Table 20 – Population and Land Area of Urbanized Areas, 1970 and1960 (issued June, 1973); 1990 Census of Population and Housing, Summary Population and Housing Characteristics, United States, Table 8 – Land Area and Population Density: 1990.

[1] Includes Anaheim, Burbank, Long Beach, Pasadena, Pomona, and Santa Ana.
[2] Roseville added to Urbanized Area in 1990.
[3] Escondido added to Urbanized Area in 1990.
[4] Includes Vallejo; Berkeley and Livermore added to Urbanized Area in 1990.
[5] Palo Alto added to Urbanized Area in 1990.

Table 3b

1980-1990 California Urbanized Areas Raw Data

Population, per capita land use and total land area
from 1980 and 1990 U.S. Census Bureau reports

Urbanized Area	1980 Population	1990 Population	1980 Per Capita Land Use (acres/person)	1990 Per Capita Land Use (acres/person)	1980 Total Land Area (sq. miles)	1990 Total Land Area (sq. miles)
Antioch-Pittsburg	86,435	153,768	0.1925	0.2560	26.0	61.5
Chico	51,914	71,831	0.3082	0.2905	25.0	32.6
Fairfield	69,255	99,964	0.2957	0.2606	32.0	40.7
Hemet-San Jacinto	55,377	90,929	0.3236	0.3069	28.0	43.6
Lancaster-Palmdal[2]	56,328	187,190	0.5113	0.2834	45.0	82.9
Napa	59,277	68,049	0.2051	0.1975	19.0	21.0
Palm Springs	66,431	129,025	0.6069	0.4450	63.0	89.7
Redding	52,867	78,364	0.5448	0.5023	45.0	61.5
Santa Cruz	123,226	152,355	0.3843	0.4146	74.0	98.7
Santa Maria	57,237	88,989	0.2572	0.1819	23.0	25.3
Visalia	58,957	83,594	0.2714	0.2113	25.0	27.6
Yuba City	61,107	77,167	0.2723	0.2297	26.0	27.7

1980 Census of Population, Number of Inhabitants, United States Summary, Table 34 – Population, Land Area, and Population Density of Urbanized Areas: 1980; 1990 Census of Population and Housing, Summary Population and Housing Characteristics, United States, Table 8 – Land Area and Population Density: 1990.

To convert from acres to square miles, divide by 640. To convert from square miles to acres, multiply by 640.

APPENDIX B

The Census Bureau's Urbanized Areas Data

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."[9] 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

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.[10] 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 C

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.

Land consumption in most California's Urbanized Areas ranges between one-seventh and one-third of an acre for each resident (see figures in Appendix A).

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 D

The Holdren Apportioning Methodology

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.[11] Although Dr. Holdren's paper dealt specifically with the role of population growth in rising energy consumption, the method can be 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 C, the total land area occupied by the built-up Urbanized Area can be expressed as:

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

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 Δt (e.g., a year or decade), the population grows by an increment ΔP and the per capita land use changes by Δa, the total urbanized land area grows by ΔA which is given by substituting in eqn. (1):

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

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 Δt, yields:

$$\Delta A/A = \Delta P/P + \Delta a/a + (\Delta P/P) \times (\Delta a/a) \qquad (3)$$

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., $100\% \times \Delta A/A$) is the sum of the percentage growth in the population ($100\% \times \Delta P/P$) plus the percentage growth in the per capita land use ($100\% \times \Delta a/a$). 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:

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

The same form applies for per capita land use:

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

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):

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

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:

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

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

$$g_P = (1/t) \ln (P(t)/P_0). \tag{9}$$

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

$$g_A = (1/t) \ln (A(t)/A_0) \tag{10}$$

$$g_a = (1/t) \ln (a(t)/a_0). \tag{11}$$

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

$$g_p + g_a = g_A \tag{12}$$

Substituting the formulae (eqns. 9 thru 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:

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

$$0.1950 + 0.0555 = 0.250 \qquad (15)$$

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 0.250:

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

Performing these divisions yields:

$$0.78 + 0.22 = 1.0 \qquad (17)$$

Thus, we see 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 (19 out of the 28), the results of the Holdren method showed that population growth actually explained more than 100% of the sprawl that occurred, while the per capita land area growth share was less than 0% (i.e., a negative number due to higher population densities or a decrease in land use per capita). 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 throughout a given Urbanized Area (i.e. per capita land consumption went down), so that if there had been no population growth, total urbanized land area taken up by that city and its suburbs would have actually declined. In the table shown in Section 6 of this report (California Findings), a conscious decision was made to limit the calculated share of the total growth rate to only 100% of sprawl for population growth and to report 0% as the growth in land consumption per capita in these cases to avoid the confusion of negative growth rates. (After all, the question is what percentage of a fixed number of square miles of sprawl was caused by population growth. In layman's terms, 100% of those fixed square miles is the highest possible number.) Yet, strictly speaking, this means that in some Urbanized Areas, population growth was so great that it simply overwhelmed the decline in per capita land use, thus leading to positive overall sprawl. Table 4 presents the unadjusted results of the apportioning formula:

Table 4

Urbanized Area	Sprawl in Square Miles		% of Total Sprawl related to POPULATION GROWTH was	% of Total Sprawl related to GROWTH IN PER CAPITA LAND CONSUMPTION was
	1970-1990	1980-1990		
Chico		7.6	122%	-22 %
Fairfield		8.7	153%	-53%
Fresno	53.6		105%	- 5%
Hemet-San Jacinto		15.6	112%	-12%
Lancaster-Palmdale		37.9	197%	-97%
Los Angeles[1]	393.8		139%	-39%
Modesto	17.8		186%	-86%
Oxnard – Ventura	45.6		197%	-97%
Palm Springs		26.7	188%	-88%
Redding		16.5	126%	-26%
Riverside – San Bernardino	150.4		176%	-76%
Sacramento[2]	89.7		175%	-75%
San Diego[3]	309.5		113%	-13%
San Jose[5]	61.2		169%	-69%
Santa Maria		2.3	463%	-363%
Santa Rosa	29.0		169%	-69%
Simi Valley	22.1		127%	-27%
Visalia		2.6	353%	-253%
Yuba City		1.7	368%	-268%

Data sources: 1970 Census of Population, Volume 1 – Characteristics of the Population, Part 1 – United States Summary, Table 20 – Population and Land Area of Urbanized Areas, 1970 and1960 (issued June, 1973); 1980 Census of Population, Number of Inhabitants, United States Summary, Table 34 – Population, Land Area, and Population Density of Urbanized Areas: 1980; 1990 Census of Population and Housing, Summary Population and Housing Characteristics, United States, Table 8 – Land Area and Population Density: 1990.

[1] Includes Anaheim, Burbank, Long Beach, Pasadena, Pomona, and Santa Ana.
[2] Roseville added to Urbanized Area in 1990.
[3] Escondido added to Urbanized Area in 1990.
[4] Includes Vallejo; Berkeley and Livermore added to Urbanized Area in 1990.
[5] Palo Alto added to Urbanized Area in 1990.

Appendix E

Accounting for Distortions by Aggregate Data

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

Hypothetically, it is possible that much or most of an Urbanized Area's population growth occurred on a small fraction of the already built-up central place (i.e. urban core) or older portions of the urban fringe (i.e. inner suburbs) of the Urbanized Land Area, while a small minority of residents building 4,000 sq. ft. single-family dwellings on half-acre lots actually accounted for most of the increase in urban/suburban land. In such a scenario, the population growth would not be directly responsible for much of the sprawl since all of the population growth was occurring in the core of the city – not on the periphery of the suburbs.

So 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 may be misleading.

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 and found little to indicate that the sprawl our formula has associated with population growth was instead really caused by affluent suburbanites with gluttonous appetites for land.

Our initial analysis relying solely on aggregate data showed the population growth share of sprawl to be 100% in 22 of the 28 Urbanized Areas. What this means is that in those cases, between 1970-90 or 1980-90, the percentage of population growth exceeded the percentage growth in land area. Overall density in the Urbanized Area rose, which means that overall declining density (averaged across the entire UA), by definition, could not have accounted for any sprawl. Yet, it is possible for the urban core density (and population) to rise, while the suburban density falls. In these cases, using only the aggregated population growth and density figures for the entire Urbanized Area would mask the fact that density had declined in the suburbs.

Thus, we examined all those cities in which the mathematical model related 100% of sprawl to population growth at the level of the aggregate Urbanized Area, in order to detect the pattern of change in urban and suburban densities. [We also examined Bakersfield for which 99% of its sprawl was correlated with population growth.] The sign that population growth really wasn't that much of a culprit (i.e. linked to

100% of sprawl) would be the meeting of each of two conditions: (1) an increase in urban density, and (2) a simultaneous decrease in suburban density. Table 5 below shows the results of this analysis:

Table 5

Urbanized Area	Urban Density	Suburban Density
Bakersfield	Increased 5%	Increased 4%
Chico	Decreased 6%	Increased 49%
Fairfield	No change	Increased 108%
Fresno	Decreased 10%	Increased 14%
Hemet-San Jacinto	No change	Increased 29%
Lancaster-Palmdale	Decreased 21%	Increased 198%
Los Angeles	Increased 20%	Increased 4%
Modesto	Decreased 16%	Increased 68%
NAPA	**INCREASED 12%**	**DECREASED 38%**
Oxnard-Ventura	Increased 124%	Increased 12%
Palm Springs	Increased 26%	Increased 54%
Redding	Decreased 10%	Increased 60%
Riverside-San Bernardino	Increased 40%	Increased 36%
Sacramento	Increased 21%	Increased 30%
San Diego	Increased 18%	Increased 1%
San Jose	Increased 19%	Increased 7%
SANTA BARBARA	**INCREASED 35%**	**DECREASED 13%**
Santa Maria	Increased 53%	Increased 17%
Santa Rosa	Increased 9%	Increased 13%
Simi Valley	Increased 24%	Increased 669%
STOCKTON	**INCREASED 11%**	**DECREASED 23%**
Visalia	Increased 36%	Increased 5%
Yuba City	Increased 6%	Increased 200%

Thus, it can be seen that of those Urbanized Areas where the original analysis indicated population's share of sprawl to be 100%, in the case of only three small to moderately large cities – Napa, Santa Barbara, and Stockton – is the result somewhat misleading for the reason just given. Population growth's share of sprawl in these cities was adjusted accordingly. The Findings Table in Section 6 shows the adjusted percentages rather than the original 100% share attributed to population growth.

In each of those three Urbanized Areas, the per capita land consumption of the total Urbanized Area did not increase. Thus, the formula originally assigned 0% of the Overall Sprawl to Per Capita Sprawl. But in each of those cases, a strong decrease in per capita land consumption in the urban core disguised the fact that there was significant Per Capita Sprawl in the suburbs.

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. Thus, overall, 84% of Stockton's total sprawl was due to population growth.

In the case of Napa, the population had a 100% share of the growth in the size of the urban center from 16.0 to 17.4 square miles, but a 0% share in the growth of the urban fringe from 3.0 to 3.6 square miles. To adjust the percentage, we found that the urban core's growth in land area constituted 70% of the total growth in land area. Therefore, because 100% of the sprawl in the urban core was related to population growth, it was determined that population growth comprised 70% of total sprawl in Napa.

Finally, in the case of Santa Barbara, the "central city" or core area actually declined slightly from 1970 to 1990, even as its population and density rose. Thus, it would be inappropriate to assign any of Santa Barbara's sprawl to this central city population increase (although, as stated above, some flight to the suburbs may indeed have been induced by population-related pressures and problems in the urban core, but we can't measure or quantify this readily). Therefore, the share of Santa Barbara's sprawl related to population growth was derived by comparing the change in suburban (i.e. "urban fringe" in Census Bureau terminology) population and land area from 1970-90. Using this technique, Santa Barbara's population share of sprawl was 78%.

In 20 of 23 cases above, suburban density was rising during the study period. Thus, there was no widespread shifting of internal populations that rendered the results of the apportioning tool a distortion of reality. Rising density in the suburbs allows one to rule out the possibility that a rapid rise in density in the core (say, driven by the settlement of poor immigrants at very high densities, as happened in Santa Ana in the 1980s and 1990s) could have been so high as to mask declining density in the suburbs.

Appendix F

Population Growth Without Sprawl

The apportioning formula shows that 100% of the 393 square miles of sprawl in Los Angeles was associated with population growth. But theoretically, Los Angeles could have had no sprawl at all if every one of the 3.1 million additional residents had settled within the existing urban boundary. For example, Los Angeles could have avoided sprawl during the study period if the following had occurred:

(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 3.1 million new residents.

(4) If the leftover business, commerce and entertainment needs plus the residential needs of the extra 3.1 million 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.

(5) If the 3.1 million residents placed no further demands for non-urban recreation, waste disposal, worksites, shopping or roads just beyond the urban boundary.

Those five requirements 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 the most densely populated city in America to increase its density by another 37%. 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 which succeeded in accommodating population growth without sprawl. There were no such successes in the short-term, let alone long-term.

ENDNOTES

[1] 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 hotspots." *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.

[2] U.S. Census Bureau. 1996. "Population Projections for States, by Age, Sex, Race, and Hispanic Origin: 1995 to 2025." *Population Paper Listing #47,* Table: Projections of the Total Population of States: 1995 to 2025.

[3] See note 1.

[4] 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 1 Characteristics 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).

[5] A CAPS Data Report, Jan. 22, 1999, Californians for Population Stabilization, Los Angeles, (213) 387-6454.

[6] 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.

[7] 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.

[8] Because of the skyscraper density in New York City's Manhattan borough, it is difficult for many to believe the Los Angeles Urbanized Area is more dense than the New York Urbanized Area. But the suburbs of Los Angeles are far more dense than New York's.

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

[10] 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.

[11] See note 9.

Sources of California's Sprawl

Urbanized Area	Sprawl in Square Miles		% of Total Sprawl related to POPULATION GROWTH was	% of Total Sprawl related to GROWTH IN PER CAPITA LAND CONSUMPTION was
	1970-1990	1980-1990		
Antioch-Pittsburg		35.5	67%	33%
Bakersfield	41.1		99%	1%
Chico		7.6	100%	0%
Fairfield		8.7	100%	0%
Fresno	53.6		100%	0%
Hemet-San Jacinto		15.6	100%	0%
Lancaster-Palmdale		37.9	100%	0%
Los Angeles[1]	393.8		100%	0%
Modesto	17.8		100%	0%
Napa		2.0	70%[6]	30%
Oxnard – Ventura	45.6		100%	0%
Palm Springs		26.7	100%	0%
Redding		16.5	100%	0%
Riverside – San Bernardino	150.4		100%	0%
Sacramento[2]	89.7		100%	0%
Salinas	19.7		80%	20%
San Diego[3]	309.5		100%	0%
San Francisco-Oakland[4]	193.1		78%	22%
San Jose[5]	61.2		100%	0%
Santa Barbara	11.7		78%[6]	22%
Santa Cruz		24.7	74%	26%
Santa Maria		2.3	100%	0%
Santa Rosa	29.0		100%	0%
Seaside-Monterey	23.4		52%	48%
Simi Valley	22.1		100%	0%
Stockton	27.0		84%[6]	16%
Visalia		2.6	100%	0%
Yuba City		1.7	100%	0%
Total	**1,670.5**		**95%**	**5%**

For reprints, additional information,
or to be placed on a mailing list, contact:

NumbersUSA.com
1601 N. Kent Street
Suite 1100
Arlington, VA 22209
1-877-885-7733
info@numbersusa.com