CHAPTER 5

A Synthesis of Data and Methods across Scales to Connect Local Policy Decisions to Regional Environmental Conditions

The Case of the Cascadia Scorecard

Chris Davis

Worldwide, the expansion of urban development poses a growing challenge to the goals of sustainable development. The transformation of land and ecological processes resulting from development is a driving force behind the lost ecological services that concern the Millennium Ecosystem Assessment. A quick glance at just a few global trends suggests why urbanization has quickly become an issue in need of deeper understanding.

Whereas less than 30 percent of the global population lived in urban settings in 1950, nearly 50 percent does so today. For the first time in history, more global residents live in urban areas than not. In the United States, 80 percent of citizens live in urban and suburban areas (Blair 2004). More than half live in coastal counties, where 27 million additional inhabitants are expected in only the next fifteen years (Beach 2002). In South America, 84 percent of all residents are expected to live in urban settings by 2010, completing a remarkable transition that will put the distribution of urban residents on a level equal to that of Northern Europe (Population Reference Bureau 2004).

Challenges posed by geographic and temporal scale underlie the problems researchers face in measuring this dramatic trend of urbanization. Measuring urban sprawl is a highly scale dependent undertaking. Whether or not a region sprawls very much depends on the extent, scale, and resolution of the analysis. An adequate policy response has been slow in coming because complicated scale questions muddy our understanding of how, and in response to what forces, urbanization occurs. Some scale questions are technical: can we isolate patterns of sprawl, to distinguish them from other forms of urban growth and to assess their rate of change? Others focus on determining an appropriate unit of analysis. For instance, development can transform the landscape by parcel and tract, or it may happen by subdivision and by river valley when roads are punched in through native vegetation; it may also occur at the level of an entire forested drainage being cleared for development.

Still other scale questions involve social relations: the benefits of development may be legally protected and transferable among individuals or corporations while the costs accrue across space and time, such as when a forest is clearcut to make room for new homes produces excessive erosion and flooding problems over years in downstream communities.

This chapter attempts to characterize the influence of geographic and temporal scale in measuring urban sprawl effectively. It summarizes the findings of a regional assessment at multiple scales of analysis, with a focus on the influence of geographic scale on an analysis of urbanization in the fast-growing metropolitan centers of the U.S. Pacific Northwest and southwestern Canada. The analysis used three separate methods to quantifiably measure sprawl. Each method was then evaluated and compared to the others to determine how it improves understanding of the patterns of urbanization in the region and how it overcomes challenges posed by geographic and temporal scale.

Background: The Challenge Posed by Scale in Urbanization Studies

The impact of urban growth on the landscape—in particular, the impact of its most corrosive form, urban sprawl—is the subject of a large and growing body of literature (Chin 2002; Gustafson 1998). Yet, little consensus regarding definitions and measurement methodologies is evident. Geographers and other researchers of urban form have not arrived at a widely accepted means of measuring the effects of these trends on the physical environment (Davis and Schaub 2005; Chin 2002; Theobold 2001; Fulton et al. 2001; Torrens and Alberti 2000; Daniels 1998).

Some studies have defined sprawl in terms of the relationship between population growth and built surface as mapped from remotely sensed imagery

(Sudhira, Ramachandra, and Jagadish 2003; Beach 2002; Imhoff et al. 2000). Others rely heavily on census data, comparing population growth to the extent of census-defined urban areas (UAs) (Kolankiewicz and Beck 2001).

Of the considerable number of sprawl analyses that appear in the literature, few explicitly consider geographic scale and its influence on results. But scale is clearly an influential factor, particularly in comparative studies that attempt to assess the performance of one metropolitan area to another. In studies using remotely sensed imagery, low-resolution data may be blind to scattered development, while high-resolution imagery may produce excessive "noise" problems created by the natural heterogeneity that characterizes the spectral signature of built surfaces. Data resolution is also critical to understanding scale-related influences. Bian (1997), for instance, showed that the r^2 value of a regression between biomass and elevation changed by an order of magnitude when the resolution of the input imagery went from one to seventy-five pixels.

Many sprawl studies have relied on changes in population density, focusing on the relationship between population growth and the associated expansion of the urban footprint delineated from one of any number of methods (Sudhira, Ramachandra, and Jagadish 2003; Beach 2002; Fulton et al. 2001; Imhoff et al. 2000). A scale problem arises here because a measurement of density clearly implies explicit reference to a standard spatial unit. And the scale of that unit—a city block, census tract, city, or UA—has a clear impact on results: can neighborhoods sprawl while the larger metro region contains growth? If density—the relationship between the number of residents and the quantity of land required to accommodate them—is a useful metric, what is the appropriate scale of aggregation for comparing metropolitan regions, especially in transboundary regions? Research has made clear that the unit of aggregation may alter results, but no single geographic scale has emerged as the most accepted unit for measuring urban sprawl using population density (Torrens and Alberti 2000).

To make the point more explicitly, Theobold (2001) demonstrates how studies that utilize census-defined UAs and consider population change may aggregate population at too coarse a scale to measure development at the rural fringe. This presents a crucial problem since it is often at this fringe that low-density development—the common denominator in most urban sprawl definitions—occurs at the fastest rate in many global, midsized cities (Montgomery et al. 2003).

Measuring sprawl strictly through changes in population density leads to an additional problem. Sprawling cities, defined as those growing less dense over the study period, may not be major consumers of new land. Instead, population density may be declining in certain areas or at the scale of an entire metropolitan center due to outmigration. Constraining the geographic scale of analysis to a static and potentially arbitrary spatial unit in a time change analysis may lead to the undesirable conclusion that many shrinking towns are actively sprawling. This is the case in several midwestern cities that ranked as major sprawlers in some studies, despite their comparatively low growth rates over the study period (Fulton et al. 2001).

Research Questions: Multimethod, MultiScale Approach

Since scale- and resolution-related issues have affected the results of much sprawl-focused research, an overarching goal of this study was to determine whether multiple analysis methods characterized by different strengths and weaknesses could offer a more nuanced understanding of urbanization patterns than could be obtained from a single method.

In the words of Zermoglio et al. (2005), would the research improve the definition of the problem and offer "improved understanding of scale-dependent processes"? Would the use of several methods shed light on the challenge of determining an appropriate unit of analysis—one that captures growth in the suburban-rural fringe and is indifferent to national and local jurisdictional boundaries?

Less technically, can multiple methods help address the question Wilbanks raises in chapter 2 of this volume: is the scale of decisions linked to the scale at which processes appear to transform the landscape? Ecologists and geographers have argued that a common ingredient in many global environmental problems is the disconnect between the scale of analyses that reveal the problem and the scale of decision making that affects it (Hobbs 1998; Lee 1993). Therefore, an additional goal of this research was to explore how more or less granularity and resolution may illuminate the connections between day-to-day policy setting: would it provide a better understanding of causality, as Zermoglio et al. (2005) argue is possible with multiscale analyses?

Figure 5.1
The Pacific Corridor, including major cities, Puget Sound, the Georgia Strait, and the Cascade Mountains.

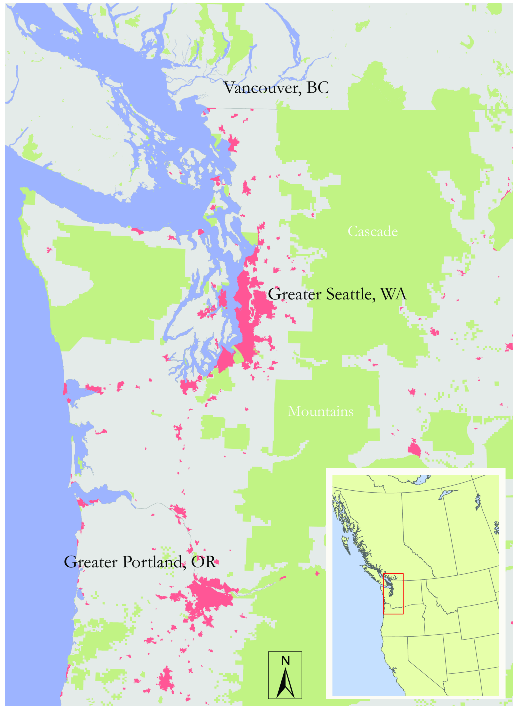


Figure 5.2
New impervious surface in the Puget Sound region, 1988–99.

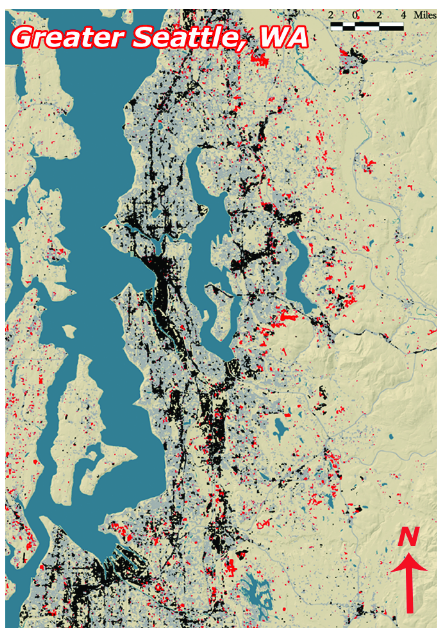


Figure 5.3.
New impervious surface in the Portland metro region, 1989–99.

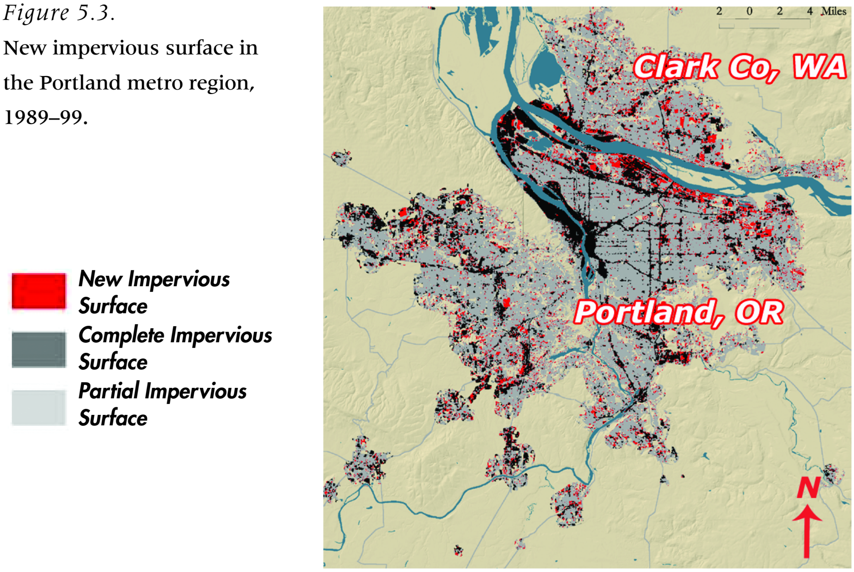
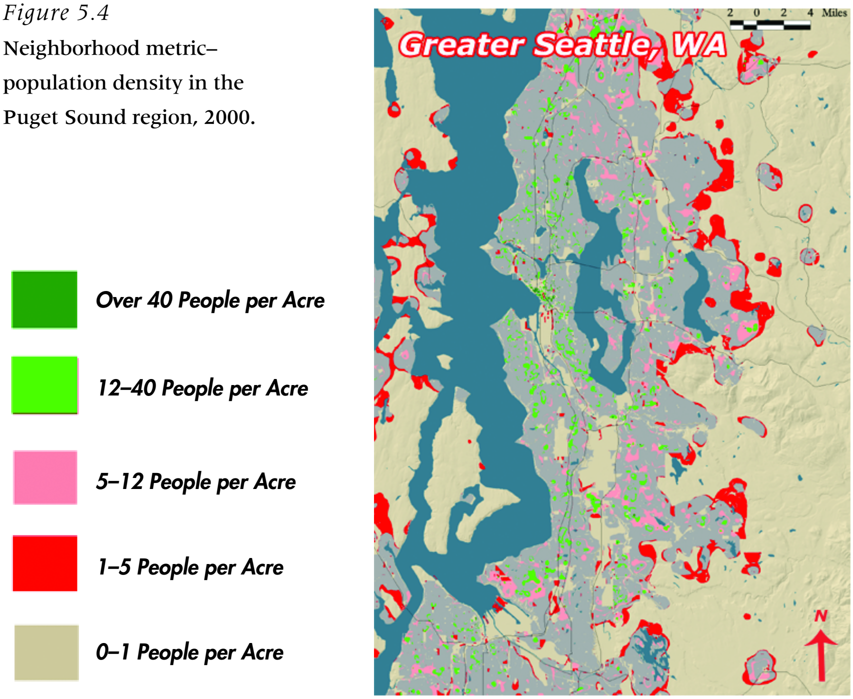


Figure 5.4
Neighborhood metric–population density in the Puget Sound region, 2000.



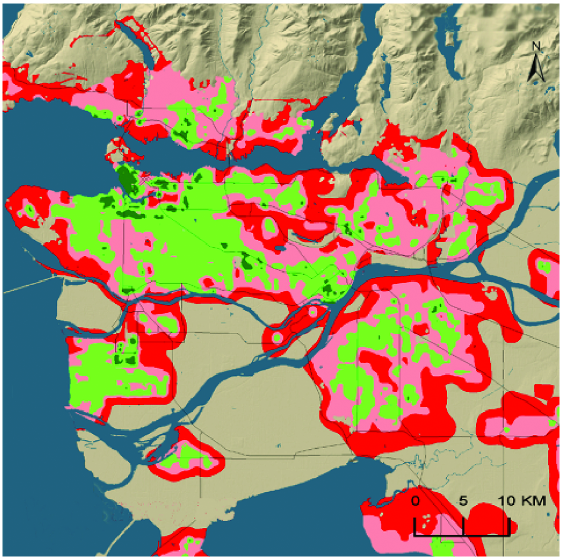


Figure 5.5
Neighborhood metric–population density for Vancouver, British Columbia, 1996.

Over 40 People per Acre
12–40 People per Acre
5–12 People per Acre
1–5 People per Acre
0–1 People per Acre

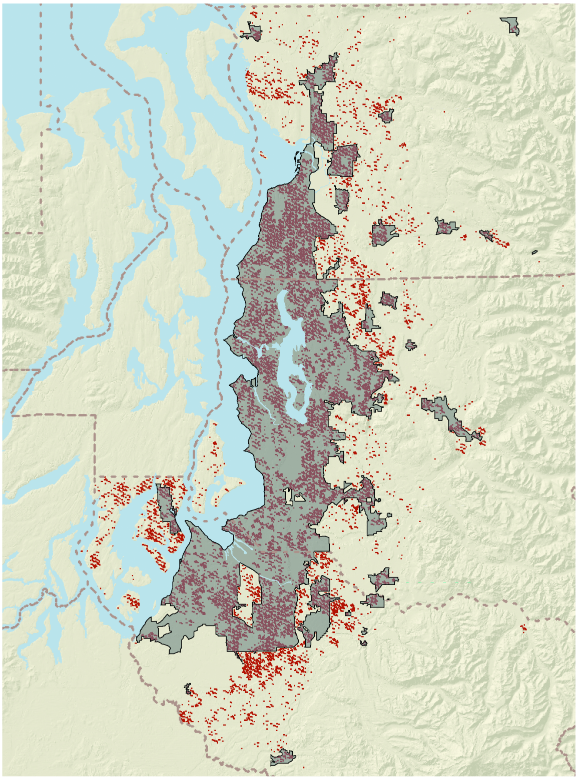
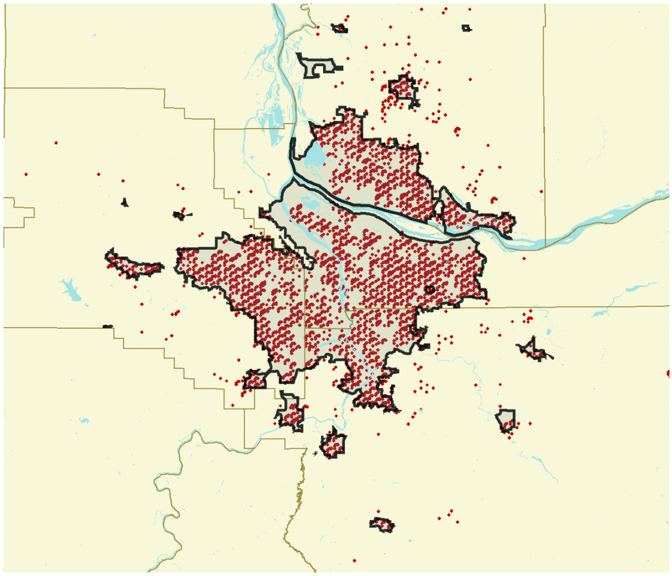


Figure 5.6
Results of permit metric analysis, Puget Sound, 1991–2001.

One Dot per Permit, inside UGB
One Dot per Permit, outside UGB
Water

Figure 5.7

Results of permit metric analysis, Greater Portland, 1995–2001.



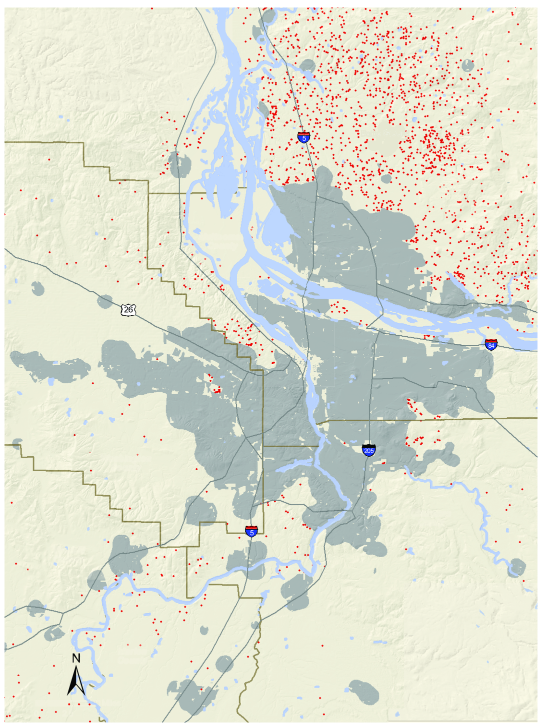
One Dot per Permit, inside UGB

One Dot per Permit, outside UGB

Water

Figure 5.10

Low-density development outside Portland's urban growth boundaries and in rural Clark County. One dot equals ten new people between 1990 and 2000.

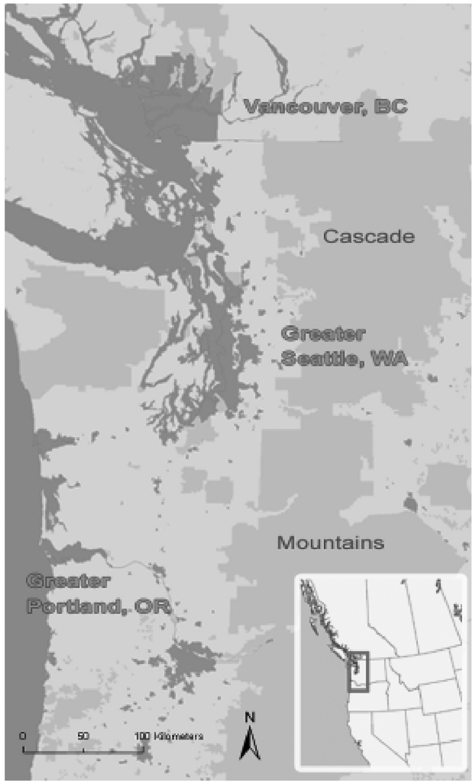


Rural Metropolitan Portland

Urban Metropolitan Portland

Water

Figure 5.1
The Pacific Corridor, including major cities, Puget Sound, the Georgia Strait, and the Cascade Mountains.



Study Area: North American Transboundary Region

The challenges identified in the background section above influenced the methods chosen for this analysis. The research was aided by the fact that the three metropolitan areas are comparable in population size. Other attributes, however, made a comparative sprawl analysis difficult. The transboundary region of Puget Sound and the Georgia Basin in the Pacific Northwest of the United States and southwestern Canada spans two nations, three state or provincial governments, and dozens of cities (figure 5.1; see also color insert). Thousands of kilometers of unincorporated land connect the region's major cities—Portland, Oregon; Seattle, Washington; and Vancouver, British Columbia—along 450 kilometers of inner coastline. About fourteen and a half million people make their home in the region (Lewis 2001).

If viewed as a single region, this area was a global leader in population growth in the 1990s. Along the corridor formed by Interstate 5, which connects each of the region's major cities along the west coast, the total population of the major cities doubled since 1965. Puget Sound (referring to Greater Seattle and its surrounding suburbs and cities of Everett, Tacoma, and Olympia, Washington), Portland, and Vancouver saw relatively similar, though extraordinary, rates of population growth: 19, 27, and 26 percent, respectively (Vancouver is measured using data dating to 1985 because of differing census schedules in the United States and Canada). On a global measure, this puts Vancouver and Portland just behind Karachi, Pakistan, and New Delhi, India, and just above Cairo, Egypt, in growth rates of world cities for the same period (Durning et al. 2002).

Geographic constraints exacerbate the land use pressures created by dramatic population growth. From Vancouver, British Columbia, to the southern tip of the Seattle-Tacoma-Olympia metropolis, the region is bounded by Puget Sound and the Georgia Strait, natural barriers that limit growth to the west. To the east, some fifty to eighty kilometers from the urban centers, the Cascade Mountains stretch from British Columbia to Oregon. Comprising mostly public lands and alpine terrain, they form an eastern barrier that helps contain urban growth in the lowland trough.

Methods: Single-scale Assessment with Multiple Scales of Analysis

After considering a variety of analytical approaches, three methods were selected. Each offered different strengths and weaknesses, each posed separate challenges in the area of spatial and temporal scale, and each put particular focus on a separate type of what O'Neill and King (1998) call "grain," the smallest temporal or spatial intervals of an observation set. Combined, they addressed each of the research questions; individually, none was sufficient to overcome all the issues these questions raise. The methods are summarized below.

Impervious Metric

This approach started from the assumption that urban sprawl is fundamentally defined as a relationship between population and the built environment. Human development typically converts native vegetation to impervious surface, which has been implicated in a variety of ecological ills, including the degradation of stream and bird habitat, the pollution of surface waters, and the raising of air and water temperature (Blair 2004; Booth 2000; Booth and Jackson 1997). Ecologically efficient—or nonsprawling—growth would minimize the amount of impervious surface created with the influx of new residents to a region.

Remote sensing analysis is frequently used when calculating landscape metrics, and increasingly in measures of urban sprawl (Sudhira, Ramachandra and Jagadish 2003; Clapham 2003). Use of satellite imagery, in particular, is common because data are available in most areas of the urbanizing world, over common time frames and in highly consistent data formats (Vande Castle 1998). For this study, new impervious surface was compared to change in population as recorded by census data. The goals were (1) to understand the spatial distribution of new impervious surface and (2) to associate this transformation with population change to calculate the amount of built surface per capita. Sprawling regions would be those adding relatively more impervious surface per capita than their counterparts (Davis and Schaub 2005).

Neighborhood Metric

The neighborhood metric was designed to take advantage of the simplicity of population density measurement while avoiding the problems created by selecting an aggregation unit, as outlined above. This was primarily achieved using an analysis technique known as *dasymetric mapping,* an approach that may allow analysts to more accurately "see" the distribution of the mapped phenomena within enumeration units (Holloway, Schumaker, and Redmond 1997; Theobold 2001).

A second analytical step took these more highly resolved population data and used them to calculate changes in density in a way that both overcame the aggregation problem and added policy context. Using spatial analysis tools available in a geographic information system, neighborhoods of predefined density were dynamically delineated. For each grid cell in an urban area, local population density was calculated as the density of the smallest circle that contained at least five hundred residents—a rough proxy for a neighborhood. The number of people per acre was then calculated for that neighborhood, providing a measure of neighborhood density for every location on the map.

The resulting spatial data set was then classified in four categories. The categories were determined by population density thresholds shown to affect the viability of public transit (Newman and Kenworthy 1989). In North America, sprawling communities are car-dependent communities. Therefore, a sprawl measure that reveals the extent and distribution of car-dependent communities was deemed a useful approach to mapping sprawl. In addition to maps that display the change in "transit-friendly" development over time, statistical summaries allowed for an explicit comparison of the major metropolitan regions to determine which are characterized by growth in neighborhoods incapable of supporting public transit. The method also allowed us to report change at a dynamically defined unit of aggregation: the neighborhood as defined by its position in the Newman and Kenworthy (1989) classification scheme, rather than the static census block or tract, which may mask sprawl in low-density areas.

For the neighborhood metric, U.S. and Canadian census data were mapped at the block level and then converted into grid data for subsequent analysis. For the United States, input included data from the decennial censuses 1990 and 2000 for the Seattle-Tacoma region and for the Greater Portland region. In British Columbia, census data were gathered at the block level for 1986, 1991, 1996, and 2001.

Permit Metric

The third approach provides the highest resolution, or finest grain, and consequently the most direct measure of growth. Most of the metropolitan areas in the study area are subject to growth management regulations. Jurisdictions at both the state/provincial level and the local/county level are responsible for setting policy and implementing strategies that contain new growth within established urban growth boundaries (UGBs). UGBs are subject to revision over time but nonetheless provide a distinct geographic reference point for measuring how well growth is being channeled. The permit metric evaluates the percentage of annual residential building permits for new construction authorized outside established UGBs. More than any of the previously described metrics, the permit metric speaks to the impacts of day-to-day decision making and the local scale of neighborhoods and communities.

In both the United States and Canada, building permit data are collected by regulatory agencies at the local level responsible for overseeing construction standards. In the Portland and Seattle regions, permit data were gathered from the Regional Data Center at Metro and from the Puget Sound Regional Council (PSRC), respectively. Attribute data varied from year to year in both regions, but after cleaning data to ensure records accounted only for new home development (as opposed to other permit activities such as remodels) and completed projects (jurisdictions managed the distinction between applied and completed permits in different ways), time series were assembled for each region. In the

Table 5.1

Summary results of each sprawl metric by metropolitan area

Annual Population Growth		**Permit Metric** % New Permits inside UGB		**Neighborhood Metric** % Residents in Compact Communities		**Impervious Metric** Open Space Converted to Development (square km)
		1995	2001	1990	2000	
Puget Sound	1.9%	78%	88%	21%	24%	138
Greater Portland	2.7%	94%	95%	20%	25%	120
Greater Vancouver	2.6%	NA	NA	51%	62%	67

Portland area, permit data from 1995 through 2001 were used; in Puget Sound, PSRC data covered the period from 1991 to 2001.

No unified regional data were available for the Greater Vancouver area. Although the Vancouver Regional District is the analogous regional entity, it does not make a policy of collecting and monitoring the construction activity of its constituent jurisdictions. Time and cost prohibitions precluded collecting data from each of the individual cities in the Greater Vancouver area. Consequently, no permit metric was calculated for Vancouver.

Results: Multimethod, Multiscale Approach

Table 5.1 summarizes the results across each of the metrics for each metropolitan area.

Impervious Metric

The results of the impervious analysis provide a view of new built development in each of the study areas at a high spatial resolution over comparable time scales. The analysis successfully isolated areas of increased built surface, allowing a comparison of development patterns resulting from population growth among metropolitan areas.

Puget Sound, the metro region with the largest developed "footprint," converted 156 square kilometers of undeveloped land to some level of imperviousness. The new development that occurred in the region was scattered and disconnected (figure 5.2; see also color insert). Some occurred along the fringes of existing developed areas, but much took place in previously undeveloped areas of the map.

Figure 5.2
New impervious surface in the Puget Sound region, 1988–99.

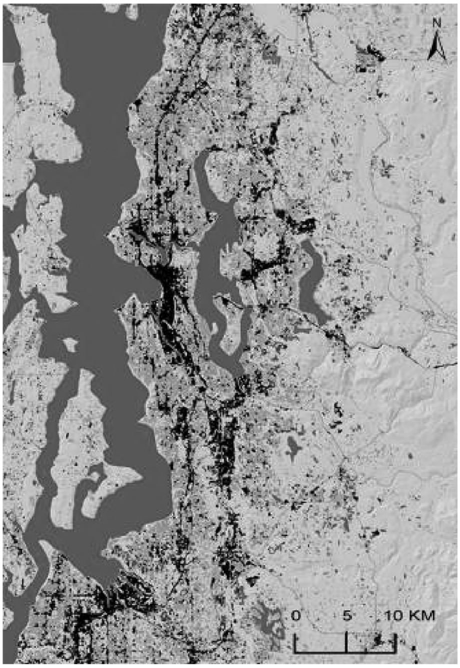


Figure 5.3.
New impervious surface in the Portland metro region, 1989–99.

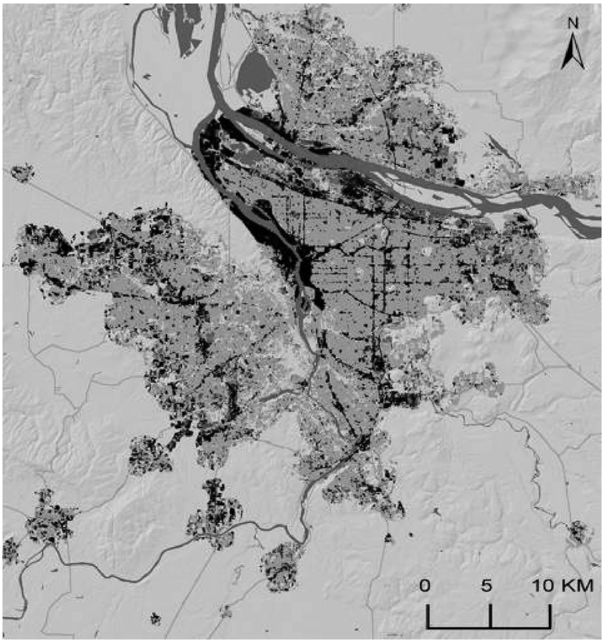
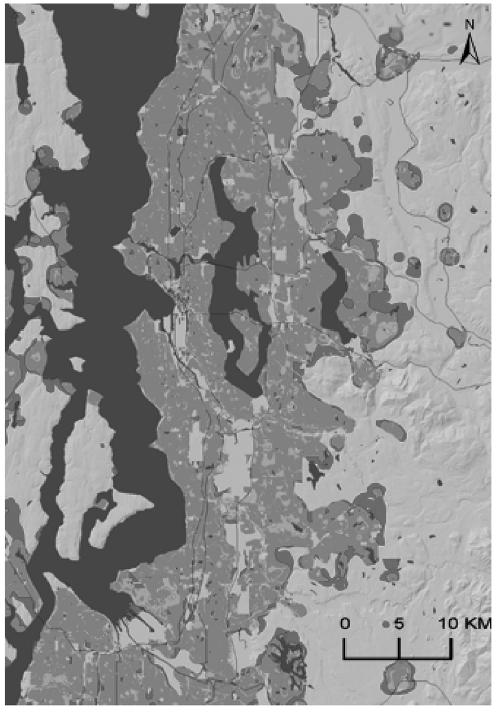


Figure 5.4
Neighborhood metric–population density in the Puget Sound region, 2000.



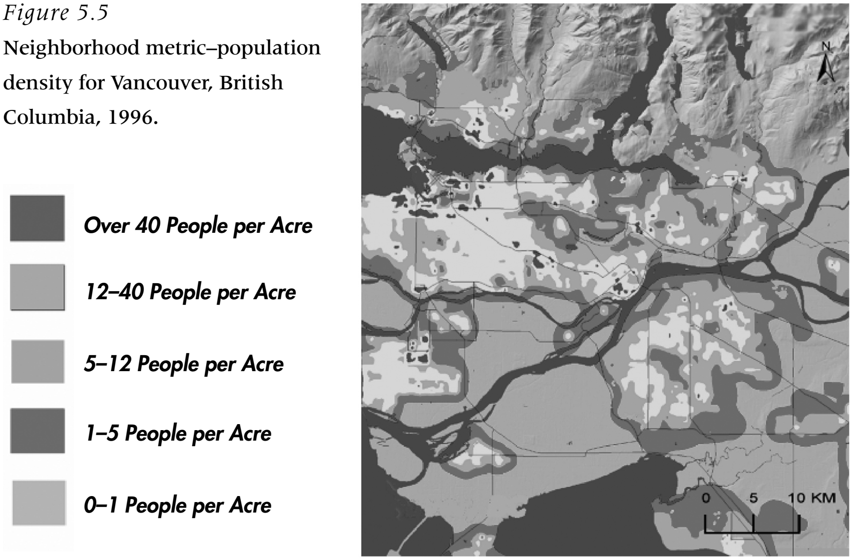
The Portland metro region added impervious surface closer to the already compact centers of its urban cores (figure 5.3; see also color insert). Mapping the resulting data suggests that through the time frame of the study, Portland's suburbs remained separated from one another by largely undeveloped land. Nevertheless, new impervious surface consumed 120 kilometers of open space, most of it within the bounds of the region's defined UGBs.

Based on the spectral mixing analyses (SMAs), Vancouver, British Columbia, set the standard for the region. Despite taking in the greatest percentage of new residents, Vancouver added the least amount of new impervious surface (67 square kilometers).

Neighborhood Metric

In Puget Sound, a comparison of density maps from 1990 and 2000 reveals that 55 percent of the new growth, or 253,000 new residents, settled in low-density areas with fewer than twelve people per acre. Figure 5.4 (also in color insert) reveals a picture of scattered, low-density development punctuated by

Figure 5.5
Neighborhood metric–population density for Vancouver, British Columbia, 1996.



concentrations of residents throughout the nearby suburban and rural lands. By the end of the decade, only one in four Puget Sound residents lived in compact communities.

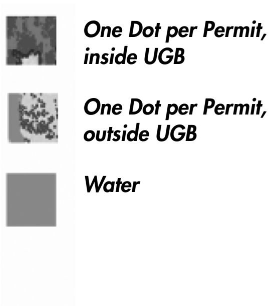
By contrast, Vancouver managed its astounding 50 percent population growth over the fifteen years considered here with notably different results. Figure 5.5 (also in color insert) confirms that Vancouver's two million residents occupy far less land and reside in much more consistently compact neighborhoods than their counterparts in the Puget Sound region. By 2001, more than 60 percent of the city's inhabitants lived in transit-friendly areas.

In the Portland metro area, similarly rapid growth reshaped the landscape. Like Vancouver, it experienced population growth that put it near the top of the list of world cities in rate of expansion. But growth in compact neighborhoods in Portland doubled that in Puget Sound.

Permit Metric

In Puget Sound and Portland, building permit data were gathered for the years of 1991 through 2000. Forty-six thousand permits were issued outside the UGBs in the Puget Sound region over the study period (figure 5.6; see also color insert). Twenty-two thousand new permits were issued outside the boundaries after their establishment, which was ratified by law in 1995,

Figure 5.6
Results of permit metric analysis, Puget Sound, 1991–2001.



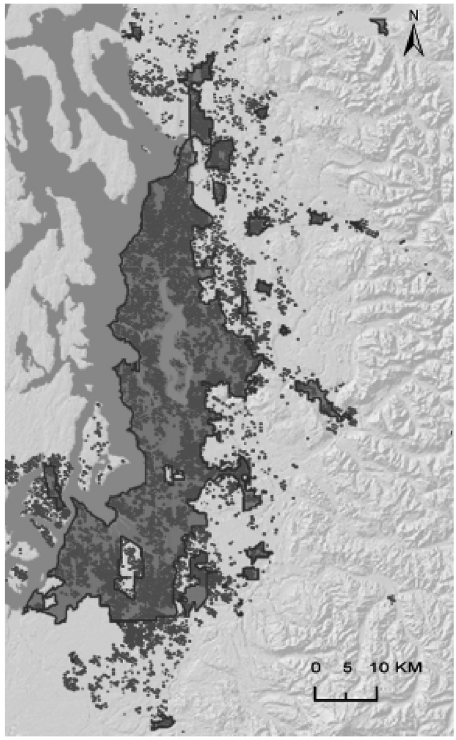
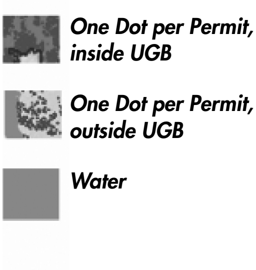
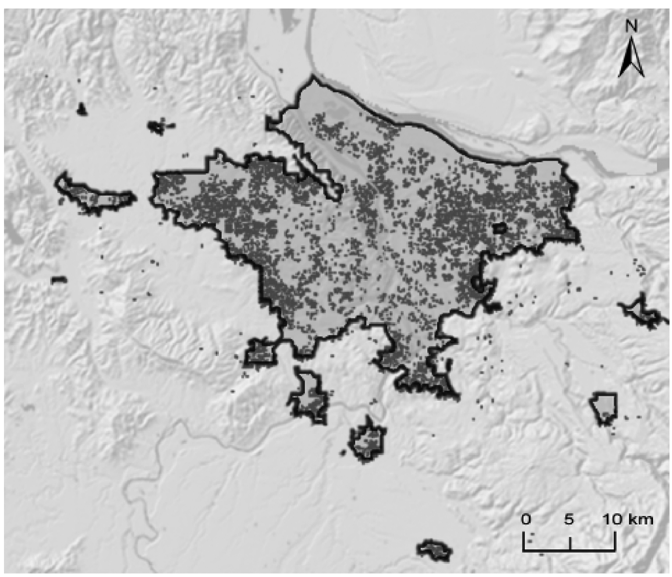


Figure 5.7
Results of permit metric analysis, Greater Portland, 1995–2001.





halfway through the period for which permit data were analyzed. By 2001, 88 percent of the permits issued in Puget Sound were inside the UGBs, more than doubling the number in 1991.

The Portland metro appears to have outperformed the Puget Sound region on this final metric. A lower percentage of permitted development went into low-density, car-dependent communities in the Portland metro area than in Puget Sound. Approximately 95 percent of new residential permits in Portland were issued within the UGBs, compared to the 88 percent in Puget Sound. Figure 5.7 (also in color insert) powerfully illustrates the success achieved by Oregon counties in managing Portland growth. However, data for Clark County, located in Washington State but within the range of the Portland metropolitan region, are lacking. This constitutes a significant problem, as addressed below.

Discussion: Multimethod, Multiscale Approach

The considerable literature on urban sprawl measures suggests that several issues have hindered the emergence of a consistent approach to measuring and monitoring urban sprawl.

- Research has not arrived at a consistent physical description of the sprawling landscape. Consequently, traditional landscape metrics used in landscape ecology to characterize land cover patterns have not been useful in standardizing an approach to measuring sprawl.
- Urban sprawl appears to be a highly scale dependent phenomenon—that is, whether a region is sprawling depends heavily on the scale of observation.
- Because of the limits of the data resolution typically used in many sprawl studies, measurements may be blind to land use changes in areas of low density or in the rural fringe, precisely the areas where development with the attributes of sprawl often occurs.
- Measurement methods focused on landscape form may not illuminate links between policies and their influence on development patterns.

The use of multiple metrics for the three metropolitan centers in the transboundary research completed here provided results that overcame most of these and other related issues while providing data that may help in benchmarking future studies. Findings were relatively consistent across each of the metrics, with each approach ranking the three areas in the same order

Table 5.2

Comparison of each metric's performance against the evaluation criteria

Scale-related Challenges	Characterizing Sprawl	Resolution/Scale Problems	Direct Policy Linkages
Impervious Metric	Consistent spectral signature across region; ignores international border	High resolution captures full heterogeneity of impervious surfaces, making classification and accuracy assessment difficult	Impervious surface is not regulated the same; abstract concept
Neighborhood Metric	Population density metric easily calculated from data available in both countries	Overcomes resolution issues with dasymetric methods and dynamically delineated, density-based neighborhoods instead of relying on census blocks or tracts	Limited connection between population density patterns and policy decisions; transit classes are not well known
Permit Metric	Locally collected data in variety of formats; various attributes, time scales, and levels of reliability	Provides a high spatial resolution if able to georeference and reconcile data from multiple jurisdictions	Directly related to decisions and local policies of planning departments and regional leadership

(excepting the permit metric, which omitted Vancouver, British Columbia). Table 5.2 summarizes some of the major pros and cons of each of the metrics.

Impervious Metric

The impervious metric offered reasonably high resolution (thirty-meter pixels) in a consistent data format available in each of the study areas. Because the entire study area lies within a reasonably uniform ecotone characterized by similar vegetation and precipitation patterns, the spectral characteristics of various relevant land classes is consistent. Focusing the analysis on the physical transformation of the landscape in response to population growth exploited the principal strength of satellite imagery: the data format ignores international borders, so it is a strategic choice in a study area that covers multiple political jurisdictions.

Somewhat complicating the applicability of this approach is that impervious surface is notoriously difficult to measure with remote sensing methods. The image components that comprise impervious urban landscapes—rooftops, parking lots, streets, and sidewalks—are marked by exceptional spectral variety, making it difficult to consistently define paved surfaces using automated methods. The SMA technique provided considerable help in solving this problem (a complete technical explanation of SMA and its contributions to measuring impervious surface can be found in Davis and Schaub 2005).

The problem of identifying the full variety of impervious surface types that appear in a satellite image is exacerbated by high-resolution imagery that captures greater heterogeneity in the landscape. Given the opportunity to take a measurement every thirty meters, the analyst must still select a scale at which to aggregate the measures of imperviousness to avoid being overwhelmed. The impervious metric successfully related changes in land form to population growth and to patterns formed in and out of designated urban growth areas to answer the scale of analysis problem.

We found that impervious area mapping from satellite imagery is also susceptible to criticism because of low certainty at large geographic scales and the likelihood of misclassification of pixels with similar spectral signatures. Problems with registration of images from multiple years may hamper attempts to capture fine-grained land use change at the fringe of the urban-rural interface.

Neighborhood Metric

The neighborhood metric characterized sprawl in the three regions in a clear, policy-relevant way: by tracking the growth in communities sufficiently dense to support public transit. Areas of low or middle density were not overlooked or masked out by large aggregation units used to summarize the area of development. Instead, the boundaries of the spatial unit of analysis were determined dynamically by the attribute being measured: transit-related population densities. The result was a higher resolution map of the spatial extent of density patterns that explicitly captures the edges between communities where growth is potentially transforming the landscape.

Using the dasymmetric mapping technique also helped ensure that spatial data provided as accurate a representation of the geographic distribution of residents as possible and contributed to the method's strength of capturing population density change at the rural fringe.

Carried out with census data widely available in both countries, the method benefited from its reliance on population density analyses, which are readily understood and easy to calculate. The structure of the data lends itself to time-series analyses, as does the availability of historical data. The processing technique used to dynamically define the neighborhood boundaries also supports future change analyses that might otherwise be complicated by revised census boundary definitions.

Some limitations emerge in conducting the analyses across international borders in two countries with different census schedules and sampling methods. However, these are largely surmountable and do not by necessity significantly affect the comparability of results across borders.

Permit Metric

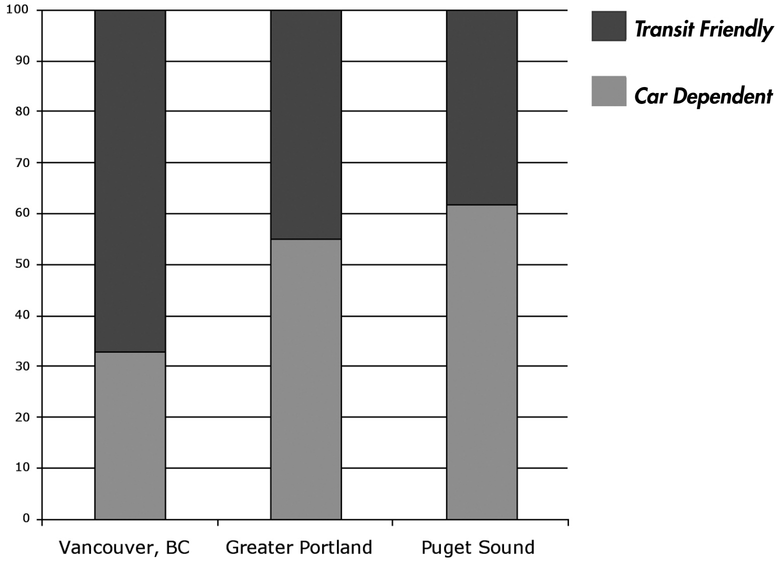
Measuring sprawl by analyzing the spatial distribution of new building permits helps connect the abstract phenomena of land conversion and scattered development to the day-to-day policy decisions that drive them. Population-density patterns may seem out of the control of planners and land use agencies. Similarly, few jurisdictions have any mechanism for regulating impervious surfaces beyond rules for controlling stormwater runoff at construction sites. But building permit records provide data on new construction activities at very high spatial and temporal resolution.

The permit metric sought to identify or corroborate the patterns of sprawl revealed in the prior analyses by (1) tallying the number of permits for new residential units within and outside of UGBs and (2) summarizing the distribution of new residential permits in each of the population density bins used in the neighborhood metric analysis. In doing so, it captured growth in the rural fringe as well as in and outside areas designated for development at high spatial and temporal resolution. It was also useful in disaggregating the patterns of growth to understand how public policy differences across a metropolitan region may influence development patterns.

The challenge with the permit metric approach, as is often the case with high-resolution data, is the task of managing the volumes and varieties of data across the broad geographic extent of the study area. Given the cost of acquiring, managing, and reconciling high-resolution data across multiple jurisdictions, it may be that we often acquire the benefits of higher resolution by sacrificing spatial or temporal extent.

Figure 5.8

Neighborhood metric: proportions of population growth channeled into transit-friendly development, Portland and Puget Sound, 1990–2000, and Vancouver, British Columbia, 1991–2001.



Building permit records are a common data set that most metropolitan planning agencies in North America maintain. However, multiple problems arise in implementing a multicity analysis relying on these data. Local jurisdictions gather varying types of data with permits. The agencies that gather data may not be the same ones responsible for documenting, archiving, and distributing them, leading to erratic gaps between the collection of data and the time that it becomes available for analysis. Additional issues also arise in reconciling the meaning of data from various organizations. Does the existence of a permit confirm the project was actually built? Can new residential and commercial projects be easily and systematically separated from add-ons or remodels that do not consume open space? Are the permits accurately georeferenced, or can they be from accompanying data?

Efficient analysis across many regions depends on the existence of a regional entity that gathers and formats data from local jurisdictions, helping researchers overcome these problems. Unfortunately, this was not the case in Vancouver, British Columbia, where the Greater Vancouver Regional District did not have such a policy in place.

The Power of Synthesis

Each of the methods conferred certain advantages with respect to the scale-related problems outlined above. By combining the results of the different methods, findings that were invisible to any one of them alone emerged.

For instance, figure 5.8 summarizes findings of the neighborhood metric in the three metro regions. It makes clear that by the yardstick of transit-friendly development, Vancouver excelled while the Puget Sound region failed to create communities dense enough to support the widespread public transportation necessary to curb sprawl.

With the benefit of additional measures that refine the temporal scale of analysis, however, a changing picture emerges. The communities of Puget Sound were forced to take regulatory measures to address sprawl only in the mid-1990s. Consequently, the permit rate within the UGBs increased significantly during the latter half of this study period. The higher temporal resolution of the permit data detected shifts in the development trends that arise from new policies that are invisible to the neighborhood metric, which relies on decennial census data.

This suggests that finer-resolution data would seem to offer an opportunity to isolate the relationship between policy and the landscape. There is, therefore, a compelling interest in disaggregating high-resolution data to the spatial scale of the decision making, wherever possible. Disaggregating high-resolution data to combine it with the results of other metrics is revealing, particularly in the Portland metro region.

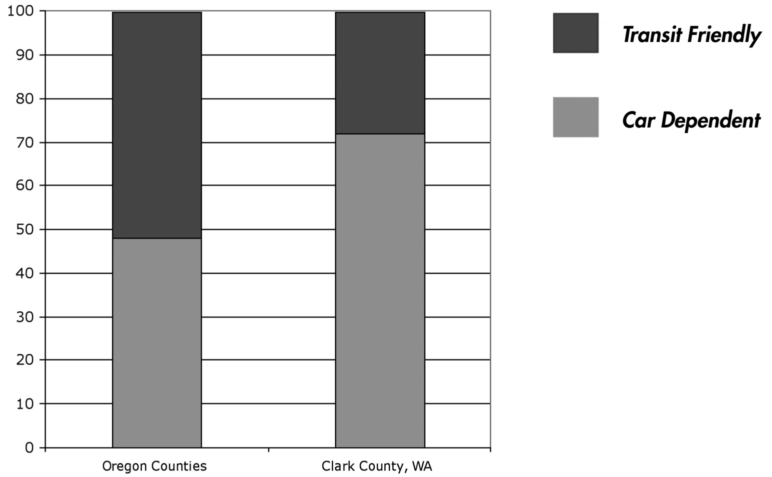
The Portland metro area includes Clark County, Washington, on the north bank of the Columbia River. Unlike the three Oregon counties included in the Portland metro area, Clark County communities are subject to the more recently established and less stringent growth management regulations of Washington State. As the results of each of the metrics suggest, Portland grew more efficiently than Puget Sound, in spite of a faster-expanding population. However, significant portions of that new growth were accepted by Clark County (figure 5.9).

We suspected that Clark County, with its less restrictive regulatory environment, sprawled to accommodate Portland's growth. Permit data were available for the Oregon portion of Greater Portland but proved unreliable for Clark County, so this hypothesis could not be tested using that metric.

Instead, we modified the neighborhood metric data to map one dot per every ten new residents relocating to rural areas of the Portland metro region between 1990 and 2000. Figure 5.10 (also in color insert) shows the results.

Figure 5.9

Neighborhood metric: proportions of population growth channeled into transit-friendly development in Clark County, Washington, and the Oregon counties of the Greater Portland region, 1990–2000.



Not only did Clark County, Washington, accept a disproportionately large share of the Portland metro's new residents, it located them in highly inefficient, low-density communities at a rate that eclipsed rural land consumption on the Oregon side. Although Portland attained admirable achievements between 1990 and 2000, channeling most of a 2.1 percent annual growth rate into compact neighborhoods, the metro region might have performed far better but for Clark County's poor performance. Disaggregating the metro data to the constituent counties is essential to understanding the policy impact on land use efficiency in the Portland metro area. Indeed, it provides stark insights on the policy differences shaping land use across the state boundaries.

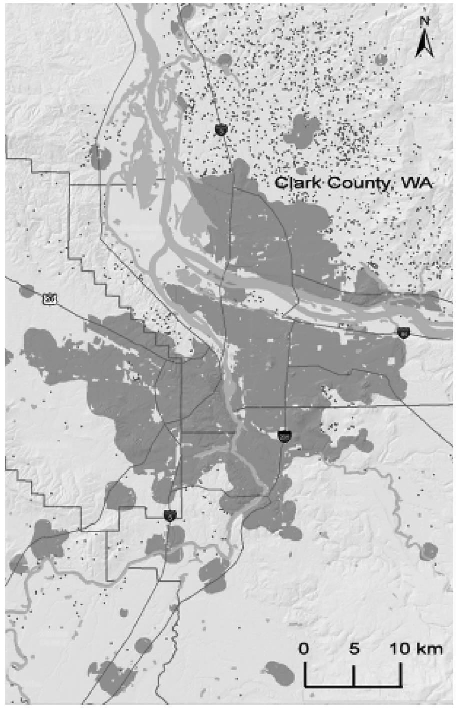
Conclusions

The conversion of natural landscapes to human-focused uses, particularly urban development, is a problem complicated by the need to explicitly consider geographic and temporal scale.

For researchers seeking policy solutions, a disconnect often arises between the scale of analyses that reveal the problem and the scale of decision making that

Figure 5.10

Low-density development outside Portland's urban growth boundaries and in rural Clark County. One dot equals ten new people between 1990 and 2000.



affects it. Ecologists and geographers have been observing this problem for years and interpreting it as a fundamental cause of many environmental problems (Hobbs 1998; Lee 1993). We see urban sprawl transforming lands in the geographies between metropolitan centers. By its nature, this is a problem involving multiple political jurisdictions. We recognize it as a regional phenomenon shaped by the interaction among multiple centers of growth. But more often than not, policy-setting institutions are not set up to facilitate or regulate these relationships.

The findings underscore at least two of the benefits of multiscale assessments identified by Zermoglio et al. (2005). First, they illustrate the improved analysis that can be attained with scale-dependent processes. Urbanization occurs at several spatial scales. Effectively measuring it to inform policy may require multiple scales of analysis aimed at different levels of organization, as the Clark County–Portland example makes clear.

Second, the results provide a better understanding of causality. The impervious metric captures the morphology of urbanization without necessarily isolating the drivers behind it. But governments regulate development.

Increasingly, they mandate density. The metrics used here provide indicators that are sensitive to specific decisions and policies at the local level.

As Kates (2001) and others have pointed out, theories aimed at bringing sustainable development into policy-setting realms must be cognizant of linking definitions of sustainability to explicit scales. Portland, Oregon, is cited ubiquitously for its far-reaching growth management and transportation planning successes. Many hold its record of forward-thinking policy setting as a model for other similarly sized cities to emulate. But as this study clearly shows, Portland's record at the scale of its decision making and its record at the scale of metropolitan growth are two separate things.

As a dynamic landscape form, urban sprawl is like other patterns scrutinized in landscape ecology: its character and shape are highly dependent on the spatial and temporal scale at which it is studied. Using three distinct analytical metrics, this study revealed some examples of how spatial and temporal scale may influence the interpretation of analytical results and the potential of multiple methods to enhance that interpretation.

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