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A synthesis of data and methods across scales to connect local policy decisions to regional environmental conditions: the case of the Cascadia Scorecard.

Abstract
In some parts of the world, the availability of geospatial data has grown enormously in recent years. Remotely sensed imagery is increasingly available in multiple spectra, inter-seasonally and in multiple resolutions. Coupled with the prevalence of various software packages that facilitate the use of these data, this is a powerful phenomenon for those concerned with the changing state of the earth's natural systems. As the use of these information sources has increased among researchers, so too has it attracted the attention of community groups and conservation organizations. To many of these groups, environmental monitoring done using remote sensing tools and data conveys sophistication and accuracy. Commen Space works closely and frequently with conservation groups whose efforts connect local politics to regional environmental conditions. From these efforts some persistent questions arise repeatedly: What issues lend themselves to exploration through broad scale remote sensing and geographic analysis methodologies? How can the results of these be meaningful among various "readers" who aren't conversant in the data and methods used to produce the analyses? And how can phenomena, visible at the broad geographic and short temporal scales that remote sensing excels at addressing, be linked to decisions and actions carried out on a daily basis at the local scale?

This paper explores these questions through the experience of the Cascadia Scorecard. The Scorecard is an index or set of indicators that focus on seven key trends that environmental and community groups in the Pacific Northwest region of North America have committed to monitoring in an effort to gauge the sustainability of the region's growth. It is under the direction of the Northwest Environment Watch and draws on landscape and socio-demographic analyses conducted by Commen Space. This paper details how the approach to one of the indicators - the rate of urban sprawl in the region's major metropolitan centers - synthesizes multiple data types across several geographic and temporal scales to produce information that is meaningful in a local decision-making context. It presents the rationale for using remote sensing methods in an analysis that crosses international borders. It also addresses the need to supplement this effort with additional analyses at the local scale. In this case, urban sprawl analyses at the regional scale were augmented by studies of building-permit patterns that drove urban growth in three metropolitan centers. The result is a study that exposed the ties between local decisions carried out at the neighborhood scale and their cumulative effect at the regional scale.

Introduction:
In the US, urban sprawl is a much discussed though poorly defined phenomena. More often it's described qualitatively rather than defined quantitatively. Sprawl is usually characterized by auto-centered, low density communities that consume large amount of space per capita. It brings with it new road development and the infrastructure that attends even low density residential development. Because it's driven by economic development trends, it's also often associated with franchise development, uniform growth patterns and a lack of local character. Among its ecological costs are increased congestion, open space fragmentation, and elevated water and air pollution. For an economy, the impacts of sprawl are measured in terms of a declining urban tax base, and the costs of road and water infrastructure. Most basically sprawl represents the conversion of rural, open or wild lands into lands for human uses including transportation, residencies or commercialization. More sprawl means less open land available for wildlife, ecological process or non-residential/commercial human use.

Numerous attempts have been made to develop comparative metrics of sprawl at the national scale in the U.S. The breadth of methods and inconsistency of findings testifies to the difficulty of surmounting challenges of data comparability, appropriate scale of analysis and temporal change. For instance, a recent report of the Brookings Institution purporting to analyze “density trends in every metropolitan area in the United States between 1982 and 1997” and found most cities in the U.S. were sprawling; that is they were adding urbanized land to their metropolitan cores faster than they were adding population.[1] Researchers compared the change in urban land area reported in the quinquennial National Resources Survey with changes in population density for coincident areas as reported by US Census Data. By this method, the Brookings report labels the "rust belt" cities of Ohio and Pennsylvania as the worst sprawlers.

A study by researchers at USA Today agreed with the Brookings report assessment that the majority of US cities sprawl. However over a nearly identical timeline, it finds the majority of the worst offenders in the Southeast of the US. Eschewing the NRS urban areas, the USA Today report measured population density change in the Census-defined urban areas, which only partly explains the disparate results.[2]

There are numerous potential explanations for the disparate results obtained from multiple studies using similar and in some cases identical data over comparable timescales. But neither study explores the relevance of scale of analysis on the resultant findings. Wilbanks, Kates and others provide abundant evidence of the need to consider and incorporate scale in order to truly understand environmental change.[3] Citing a variety of examples, Wilbanks suggests how a "top down" methodology may arrive at different conclusions than a "bottom up" approach.[4] Confirmation of this may be seen in Theobold's critique of sprawl studies that rely heavily on geographically broad and spatially discrete urban areas defined by agencies like the Census Bureau (as do both of the studies cited here). They are likely to be blind to land use change at the exurban and rural fringe where new, low density development may be growing at the fastest rate. To remedy what could be a significant source of uncertainty in broad scale analyses of sprawl rates, he outlines the significance of analyzing this fine scale of land use change to better characterize local land consumption rates.[5]

In the Pacific Northwest region of North America, a growing number of advocacy groups argue that urban sprawl is a principal force responsible for the fragmentation of open space and working lands; for the degradation of fresh water systems; and for a decline in the overall liveability of the region. In the hope of understanding the nature of sprawl in the Pacific Northwest, a Seattle based non-governmental organization, Northwest Environment Watch, is has implemented a sprawl measure in its Cascadia Scorecard. The Scorecard is an initiative intended to develop indicators of the region's overall sustainability. The sprawl indicator is one of seven and the approach to measuring it was developed by researchers at Commen Space, also a non-profit organization providing geographic analyses resources to the regional NGO community.

The team immediately confronted the problem of defining the phenomenon in order to develop a measurement approach. In the Pacific Northwest, the low density growth that signifies sprawl brings very clear consequences. It means forest loss where timber companies, having harvested the full value from their lots, now find it more profitable to sell off the worked lands to developers. It also means the conversion of agricultural lands, family farms that have provided the region and in some cases, the world, food and other agricultural products for decades. When broad economic forces that make traditional use of these lands unprofitable combine with the pressures of a burgeoning population a powerful incentive for land conversion emerges.

In the Pacific Northwest region of North America, the ingredients for precisely this recipe have been gathering for years. Since 1990, regional population grew at twice the national rate[6]. Along the corridor formed by Interstate 5 connecting each of the region's major cities along the west coast, the total population of the major cities doubled since 1965. How does this population growth lead to sprawl? The influx of new residents brings with it an obvious need for increased housing capacity, new schools, and transportation systems that can efficiently move people around. The conversion of forested and agricultural lands offers the cheapest solution to meeting this growing demand.

Approach:

In 2002, Northwest Environment Watch and Commen Space collaborated in an effort to understand how sprawl was altering the regional landscape and to isolate the policy issues that were driving it. Using the qualified definition of sprawl outlined above, methods and data were evaluated in an effort to identify an approach to creating a sprawl metric that could be applied to each of the region's major and secondary metropolitan areas. Several issues were influential in the design of the analysis. Northwest Environment Watch is primarily an educational and advocacy organization that accomplishes its mission via the publication of scientifically conducted but highly accessible research. The analysis needed to be clearly explicable to a lay audience but grounded in methods established in the scientific literature. With constituencies throughout the region, the analysis had to address the issue uniformly in each metro area so that comparisons could be made. The time change nature of the analysis added extra complexity to the data task: if comparable raw data were available to develop a sprawl metric in each of the metro areas, are the data available over comparable timeframes and at similar intervals? The organization's commitment to publishing future updates of the analyses as new residents arrive led to the need to consider the future availability of data.

From these guiding issues, several criteria against which methods and data could be considered emerged. The following questions guided the design of the analysis and the choice of data:

1. Can comparable data be obtained at various analysis scales for each of the seven metropolitan regions, keeping in mind this includes two countries and three state/provincial governments?

2. Are data available at the appropriate temporal scale to support the analyses?

3. Does the method illuminate the connections between day to day policy setting and the physical effects on the landscape?

4. Is it reasonable to assume these data will be reliably available for future analyses of these trends?

These questions proved to be useful guides in subsequent research and offer a framework for thinking about the spatial and temporal scale of a given analysis and the appropriateness of available data to the analysis question.

The Methods

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. Combined, they addressed each of the criteria questions; individually, none was sufficient to meet them all. Each approach relied on distinct methods and data, but the objective was always to characterize and measure urban sprawl in each of the distinct metropolitan areas of the region. The three methods are summarized below and compared in the following table.

Impervious Metric - This approach started from the assumption that urban sprawl is fundamentally defined as a relationship between population and the built environment. Common to nearly all of the definitions of sprawl reviewed in the literature is the notion of low density development; that is, a limited number of residents occupying an ever larger amount of land for residential and commercial use. Most metropolitan regions in North America are supported or abutted by lower density communities. They may be suburban in character or agricultural; they may simply be formally rural areas that were once out of the geographic sphere of their metropolitan neighbors but are now, due to the expansion of transportation corridors or economic ties, considered a peripheral part of the urban core. To be sure, they are not, by definition, all sprawling. Urban sprawl is concerned with the expansion of these areas as a percentage of the geographic region occupied by a metropolitan center. Sprawl occurs when the proportion of these areas increases at a greater rate than population growth, indicating that the consumption of previously lesser or undeveloped land per capita is on the rise.

By mapping the change in impervious surface using remote sensing techniques and multi-spectral imagery and comparing population density changes over the same time scale, the impervious metric measures sprawl by calculating the change in the amount of built surface per capita.

Neighborhood Metric - Sprawling communities are car dependent communities. This too is an often re-occurring theme in the various definitions of urban sprawl in North America. Because they are often characterized by rigidly separated residential and commercial areas rather than by neighborhoods with amenities in walking distance, residents of sprawling communities have a higher reliance on automobiles. The neighborhood metric draws upon research on the population density at which mass transit becomes economically viable.[7] This research establishes thresholds at which communities become sufficiently dense to support local commercial services like groceries and cleaners. At less than 1 person per acre, few or no services can be expected within walking range and cars are required for any necessity from shopping to working or attending school. From 1 to 12 people per acre, public transportation is still not viable and residents are presumed to be car dependent. Above 12 people per acre, public transit becomes more widespread and residents enjoy a greater density of services. Dense urban centers are characterized by population densities greater than 40 people per acre. At this level, individual auto ownership declines and alternative modes of transportation abound.

Permit Metric - 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 annual number of residential building permits for new construction. Specifically it monitors the percentage of those occurring outside established UGBs as a way of gauging whether growth is leading to sprawl or the infill of existing developed lands. 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.

While the three metrics are highly complementary, they have distinct advantages and disadvantages. Table 1 evaluates each metric against the four evaluation criteria established at the outset of the methods review. Green indicates the metric is well suited to address the criteria; yellow indicates method presents some limitations; red indicates the metric may not satisfactorily meet that evaluation criteria.

Methods/ Evaluation Criteria	Comparable Data	Timescale & Interval	Decision Maker Link	Future Availability
Impervious Metric	Consistent spectral signature across region; ignores international border	Error in imagery analysis makes time change over small intervals difficult	Impervious surface isn't regulated the same; abstract concept	Availability of uniform data sources is high; platforms/tech always evolving
Neighborhood Metric	Population density metric easily calculated from data available in both countries;	Census schedule varies, as does modeling of inter-decadal updates	Limited connection between population density patterns and policy decisions; trans classes aren't well known	Census data are reliably updated and provisions made for time sequence analyses
Permit Metric	Locally collected data in variety of formats, various attributes, timescales, levels of reliability	Theoretically, could provide "real-time" monitoring; limited by bureaucratic practice, budgets, comparability problem .	Directly related to decisions and local policies of planning departments and regional leadership	Data are vulnerable to budgets, local politics

Table 1 - Sprawl Metrics and Evaluation Criteria

The table demonstrates that, with respect to the proposed criteria, the three methods balance each other out. It highlights where each method excels and falls short. Because the entire study area lies within a reasonably uniform ecotone characterized by similar vegetation and precipitation patterns, the spectral signatures of various land classes used to classify impervious surface is consistent. Focusing the analysis on the physical transformation of the landscape in response to population growth exploits the principal strength of satellite imagery. It ignores international borders, so it is a strategic choice in a study area that covers multiple political jurisdictions. Unfortunately few local governments make the regulation of impervious surface a component of their planning and regulatory framework. So while measuring the growth of impervious surface provides a connection between growth patterns and ecological systems that are impaired by pavement, it may not provide decision makers a clear strategy for action. Further, impervious surface is a notoriously difficult landscape feature to measure with remote sensing methods. For future updates at frequent intervals, considerable analytical effort is required to ensure that marginal increases in impervious surface from one year to another are accurately distinguished from other forms of land use change and from other sources of error.

By contrast, the neighborhood metric relies heavily on calculating change in population density and using density thresholds as a proxy for land consumption. The thresholds are set at levels that characterize how well suited a neighborhood is to support mass transit. In this case, the assumption is that a growth in the percentage of a metropolitan center that can not support transit is a growth of car dependent neighborhoods, a tell-tale characteristic of urban sprawl. The method benefits 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. Some limitations emerge in conducting the analyses across international borders in two countries with different census schedules and modeling methods. However these are largely surmountable and don't necessarily have a significant impact on the comparability of results across borders. Like the impervious metric, the neighborhood metric is limited in its direct impact on daily decision making. Population density changes are fluid and difficult to monitor over short temporal scales. This approach relies on transit related thresholds which are a fairly new concept and not one that has apparently influenced urban planning efforts or the monitoring of growth management planning.

Finally, the permit metric marks a significant shift in the scale of analysis. While still covering the same geographic extent, the unit of analysis moves from the pixel or the abstractly defined neighborhood of the first two methods to the individual parcel where sprawl takes its incremental steps. The permit metric presents decision makers with direct evidence of the impacts of their day to day actions and, when combined with UGBs, incontrovertible evidence of their success meeting anti-sprawl policy objectives. In this extraordinary detail however, lies the shortcoming of the permit method. Building permit records are a common data set that any metropolitan planning agency in any North American city maintains. However multiple problems arise in implementing a multi-city 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 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 re-models that don't result in the consumption of open space? Are the permits accurately georeferenced or can they be from accompanying data? Future analyses using this method are contingent upon satisfactory answers to these questions as well as the hope that budgets and other bureaucratic whims do not affect the future availability of similar data. For this study for instance, the Portland Metro Regional Government altered its data distribution policy shortly after providing its permit data. They turned over custodianship of the data to a private commercial entity, dramatically increasing the price of future data sets from the nominal "media fee" that was required for the original data.

Findings

From the three analyses, a staggering amount of data can be assembled. The obvious way to evaluate the findings is to assess how well they answer the main questions posed by Northwest Environment Watch for the Scorecard: which areas are sprawling the worst, to what effect and why? With data to answer these questions, a comparison of the answers provided by each metric may be undertaken to understand the usefulness of answering these questions with the approaches taken here.

Understanding how the region is growing is an exercise in scale. 32% of the residents in the three metropolitan centers of Northwest North America now live in compact neighborhoods, up from 27% in 1990. Measured by this "Neighborhood Metric" and at this broad scale, one may conclude that improvement in the efficient use of land is the norm. But taking of the advantages of each of the metrics to look at the findings at the scale of each metro region and its constituent cities reveals considerable complexity.

Neighborhood Metric:
Using the transportation oriented population bins that are the basis of the Neighborhood Metric, relative sprawl would be measured by focusing on the change in low density development. The worst offender would be the metropolitan area with the greatest share of its people living in communities less than 12 people per acre. Puget Sound, Portland and Vancouver saw relatively similar, though extraordinary, rates of population growth (19%, 27% and 26%, respectively). Table 2shows this growth, recording Vancouver's growth since 1985 because of a different census schedule in Canada. Data are included because the dramatic wave of population growth that drove sprawl during the timeframe studied here began in the mid-eighties.

In Puget Sound, a comparison of density maps from 1990 and 2000 reveals that, 55% of the new growth or 253,000 new residents settled in low density areas with fewer than 12 people per acre. Map 1 reveals a picture of scattered, low density development punctuated by 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, though this represents an improvement from 1990 when the number was one in five. In 1990, this was enough to give Seattle a higher percentage of residents living in compact neighborhoods. But by 2000, Portland narrowly surpassed its larger neighbor.

By contrast, Vancouver British Columbia managed its astounding 50% population growth over the 15 years considered here with notably different results. Map 2 confirms that Vancouver's 2 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% of the city's inhabitants lived in transit friendly areas.

In the Portland metro, similarly rapid growth re-shaped the landscape. Like Vancouver, it experienced population growth that put it near the top of the list of world cities in rate of expansion. Growth in compact neighborhoods in Portland doubled that in Seattle, leading to its surpassing Puget Sound on this score, as mentioned above. (See Map 3). Again, it is revealing to further disaggregate the data on the Portland region to put its performance in context. The Portland metro 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 they data above demonstrate, Portland grew more efficiently than the Puget Sound, in spite of growing at a much faster rate. Significant portions of that new growth were accepted by Clark County however, as shown in Table 3. Moreover, Clark County, with its less restrictive regulatory environment, sprawled to accommodate Portland's growth as shown by the data in Map 4. Not only did it 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, as Map 4 clearly illustrates. While Portland attained admirable achievements between 1990, channeling most of a 2.1% annual growth rate into compact neighborhoods, it might have performed far better but for Clark County's per performance. Disaggregating the metro data to the constituent counties is essential to understanding the policy impact on land use efficiency in the Portland metro.

Table 4provides a final summary of the findings of the Neighborhood Metric in the three metro regions. It makes clear that by the yardstick of transit friendly development, the Puget Sound region fell short of its regional counterparts in limiting sprawl through the nineties.

Impervious Metric
The impervious metric seeks a measurable association between population growth and new built structures. Impervious surface has been implicated in a variety of ecological ills, including the degradation of stream habitat, the pollution of surface waters and the raising of air and water temperature. Sprawling communities, by definition, consume more land per capita than compact ones, converting open space and farmland to roads, buildings and parking lots at rates that are disproportionate to their population growth.

Impervious surfaces are notoriously difficult to measure using remote sensing techniques. They lack a consistently distinct spectral signature. Some surfaces are easily confused with permeable materials such as cleared or bare earth. Roads are important contributors to total impervious areas but their narrow, linear nature is not always discernible within the resolution of commonly utilized satellite imagery. Detecting change in impervious surfaces presents additional technical challenges.

Given these obstacles, the approach relied on spectral mixing analysis (SMA) to calculate change in impervious surfaces in the three metro regions between approximately 1990 and 2000. SMA provides the means to estimate the proportion of a pixel composed of materials that match the chosen spectral signature of impervious surface. The analysis binned pixels in three categories:

- No impervious material
- 15-80% impervious material
- More than 80% impervious material

Puget Sound, the metro region with the largest developed "footprint", converted 156 square kilometers of undeveloped land to some level of imperviousness. Map 5 reveals the new development that occurred in the region was scattered and disconnected. Some occurred along the fringes of existing developed areas, but much took place in areas which previously showed little sign of development in the early satellite images.

The spatial data provide additional evidence that urban growth in the Puget Sound region is qualitatively different than that which has taken place in the region's other metro centers. The Portland metro region added impervious surface closer to the already compact centers of its urban cores. Map 6. Through the timeframe 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.

Once again, Vancouver British Columbia, set the standard for the region Map 7. Despite taking in the greatest percentage of new residents, Vancouver added the least amount of new impervious surface (67 square kilometers). The vast majority of new impervious surface appeared along the edges of existing urban areas or as infill within those areas. Very little new impervious surface emerged in the less developed and agricultural lands surrounding greater Vancouver.

Table 6 connects the two analyses and summarizes the performance of the three metro areas. It separates new impervious surface into the population bins used to classify population density in the neighborhood metric. In each of the metro areas, the greatest amount of imperviousness was added in areas of low development to begin with. But the comparatively greater amount of new impervious surface in Puget Sound can be seen to be concentrated more intensely in these neighborhoods.

Permit Analysis

Attempting to measure 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. Moreover, few jurisdictions have any mechanism for regulating impervious surfaces beyond rules for controlling stormwater at construction sites. But building permit records provide data on new construction activities at very high spatial and temporal resolution.

The challenge with these data, 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. In the U.S., building activities are regulated by cities and counties for unincorporated lands. In Portland and Puget Sound, regional governmental agencies aggregate permit data provided by the individual city and county governments that comprise their metro areas. Whether these data are provided at reliable, regular frequencies and in comparable formats may be a function, in part, of the regulatory power the regional entity holds over the local agencies. In the Portland region, the regional authority (Metro) holds unusual authority. The Puget Sound counterpart - Puget Sound Regional Council - has no regulatory authority; rather it gathers data and publishes research. It has little leverage to exert over local government agencies.

Unfortunately the Greater Vancouver Regional District, which might be considered the analog to these organizations in the U.S, does not have as part of its responsibility the consolidating of building permit data for the metropolitan area. Time and budget constraints precluded contacting each of the local agencies in the Vancouver metro region. Consequently permit analysis was not carried out for greater Vancouver. Similarly, Portland data necessarily excluded permits issued in Clark County which, because it is located in Washington State, is not formally part of Portland's metropolitan government authority. Efforts to acquire and reconcile data directly from the County and other local agencies in Clark County were unsuccessful. Since the other analyses performed in this project clearly demonstrated the important role Clark County plays in absorbing significant portions of Greater Portland's population growth, the exclusion of these data constitutes a meaningful data gap.

In Puget Sound and Portland, building permit data were gathered for the years of 1991 through 2000. Changes in data gathering policies and additional factors precluded evaluation of data older than these. 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.

Map 8 adds context to the pattern of urban sprawl in Puget Sound established in the earlier metrics. 46,000 permits were issued outside the UGBs over the study period. To be fair, the UGBs were only established in 1995 in Puget Sound, but 22,000 of these permits were issued after their creation. Many of these may be the result of "grandfather" clauses, exceptions to the UGB definitions established at the time of the regulation. Looking over the entire time period, the trend in permit issuance favors more constrained growth. By 2001 88% of the permits issued in Puget Sound were inside the UGBs, more than doubling the number in 1991. Still, in 2001 42% of permits were issued in areas of less than 12 people per acre which confirms that when Puget Sound's UGBs were established they included significant amounts of lower density lands to accommodate future growth. And again the importance of further disaggregation is clear, particularly since this analysis can be most closely related to the implementation of growth management policy at the local level. In the Puget Sound metro area, the three counties that permit development outside of the cities managed growth very differently. Table 7 shows that of the three counties comprising the Puget Sound metro, King was far more effective at channeling permitted development into compact neighborhoods than Pierce and Snohomish. Indeed a comparison of the density of permits in Map 8 bears this out.

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 than in Puget Sound. (Table 7). On the other hand, 95% of new residential permits in Portland were issued within the UGBs, compared to the 88% in Puget Sound. Map 9 provides a powerful illustration of the success achieved by Oregon counties managing Portland growth. Again the omission of Clark County data is an important and unquantifiable caveat to these data.

Conclusions

Puget Sound only implemented growth management laws mid-decade. Grandfather clauses, implementation lag and other factors may have contributed to its performance. Conclusions drawn from the shorter, more recent timescale of the permit analysis suggests that the region is at work reversing the trends that are visible in the analyses carried out here.

How can the differences be explained?

Puget Sound "scored" worst in each of the metrics. Lacking any form of regional government, the communities of Puget Sound were only forced to take regulatory measures to address sprawl in the mid nineties. By the permit analysis, we may conclude that the policies have intervened in the trends that are apparent in the impervious surface and neighborhood metrics.

Portland has been widely recognized for the visionary land use and growth management strategies it has had in place in various forms since the 1970s. Mass transit investments have influenced the growth of younger surrounding communities. But influence of nearby Clark County across the river and under the newer, less stringent growth controls of Washington State, can not be overlooked. Portland's economic vitality drives growth across the state border where commuters working in Portland may seek lower property values and more rural living conditions. This analysis showed that Portland's growth fueled a disproportionate amount of land consumption in Clark County which may have acted as an "escape valve" releasing some of the growth pressure that built up on the Oregon side of the Columbia River.

In Vancouver British Columbia, policies have been in place to protect surrounding agricultural lands since the early 1970s. These have successfully constrained the consumption of arable lands for commercial purposes and resulted in a more in-tact rural-agricultural landscape surrounding greater Vancouver. Geography - the constraining realities of mountains and water - have clearly hemmed in development. But equally important and notably distinct from it US counterparts, so has a policy that has shunned the construction of significant highway systems to connect the urban core to far flung communities. Instead a commuter transit system has grown up to support the city's growth and to provide necessary transportation for a large proportion of the communities' needs.

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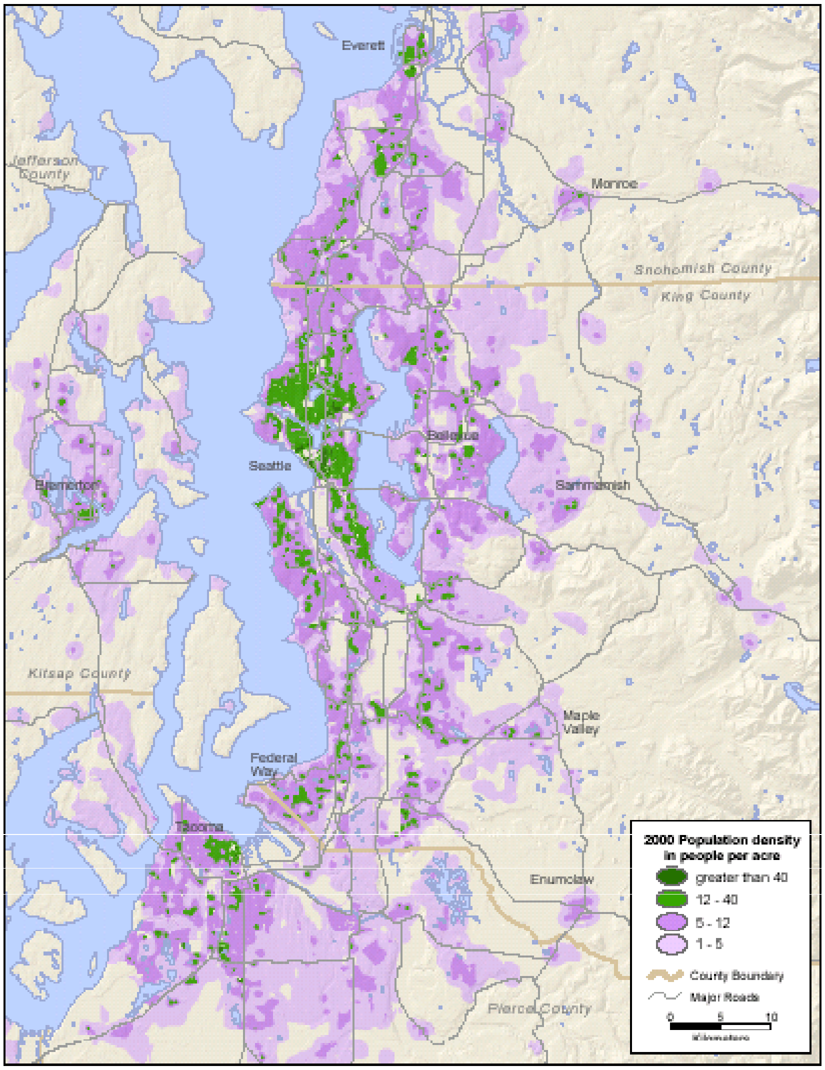
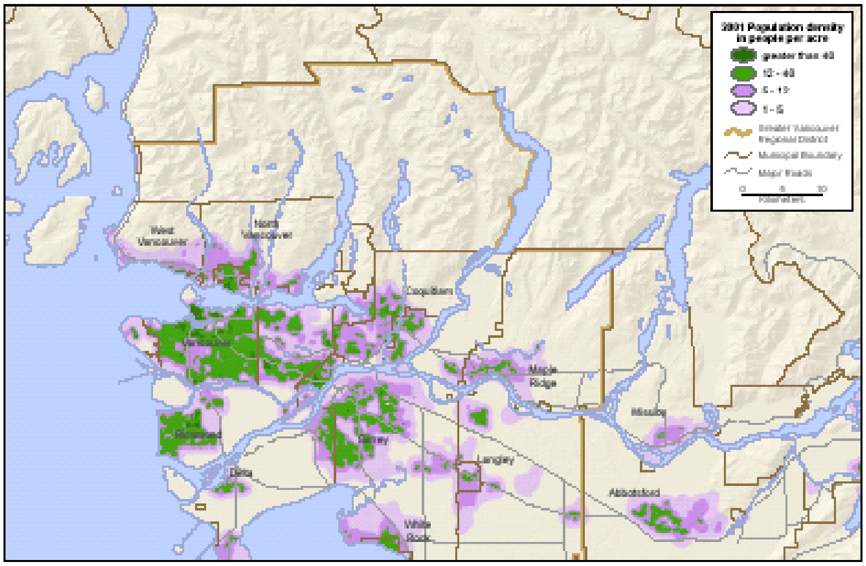
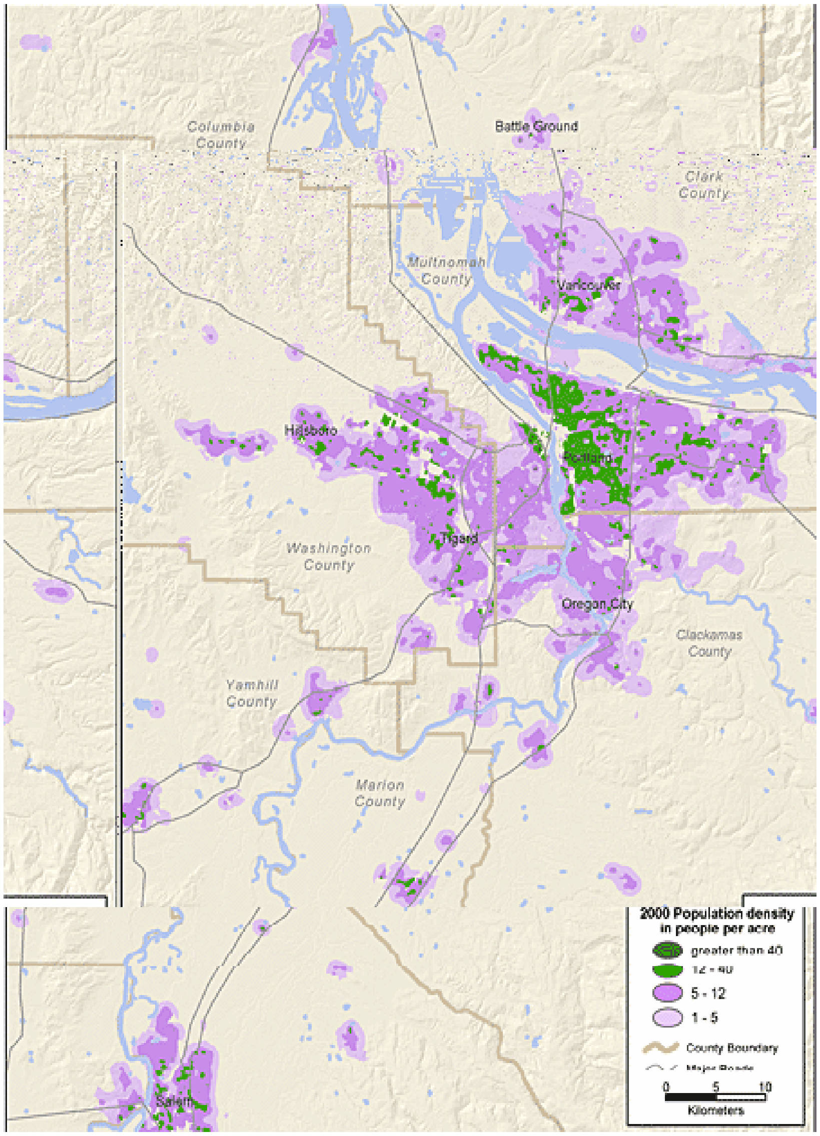


Map 1 – Puget Sound Population Density



Map 2 - Vancouver, BC Population Density



Map 3 – Portland, OR Population Density

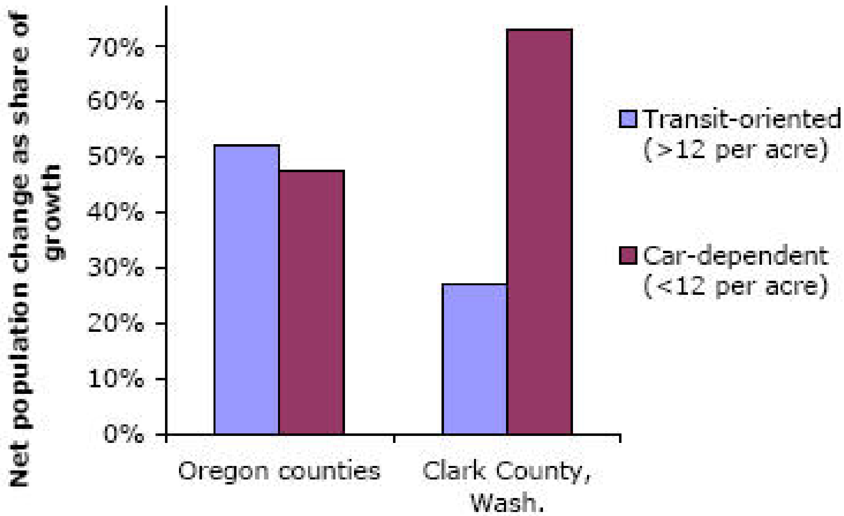


Table 3 – Population Growth in Portland Metro Region

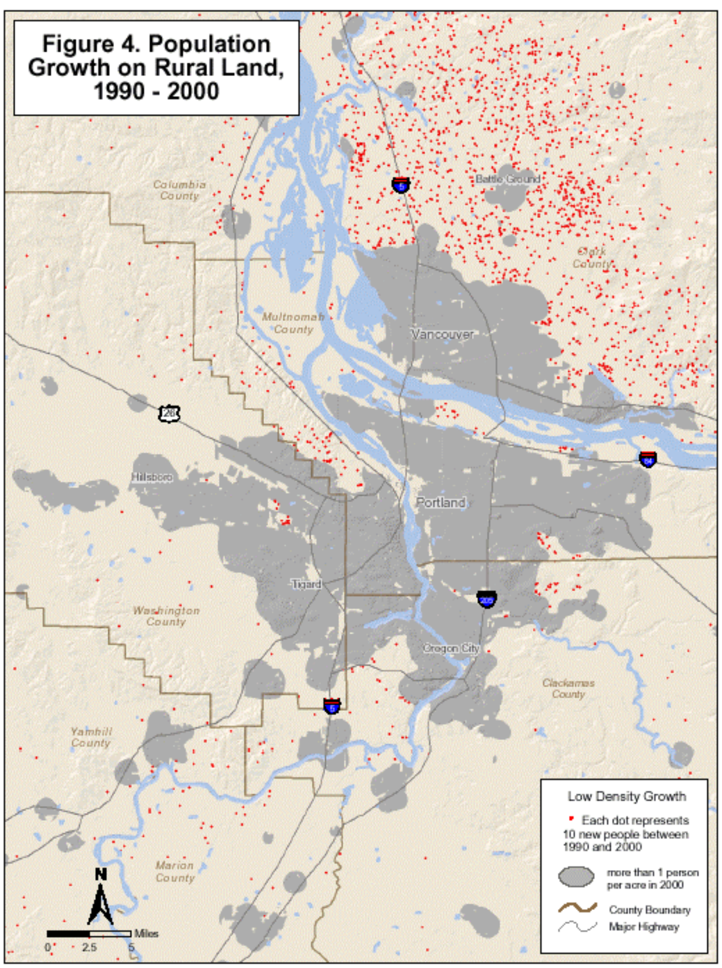


Figure 4. Population Growth on Rural Land, 1990 - 2000

Map 4 – Population growth on Rural Land, Clark County, WA.

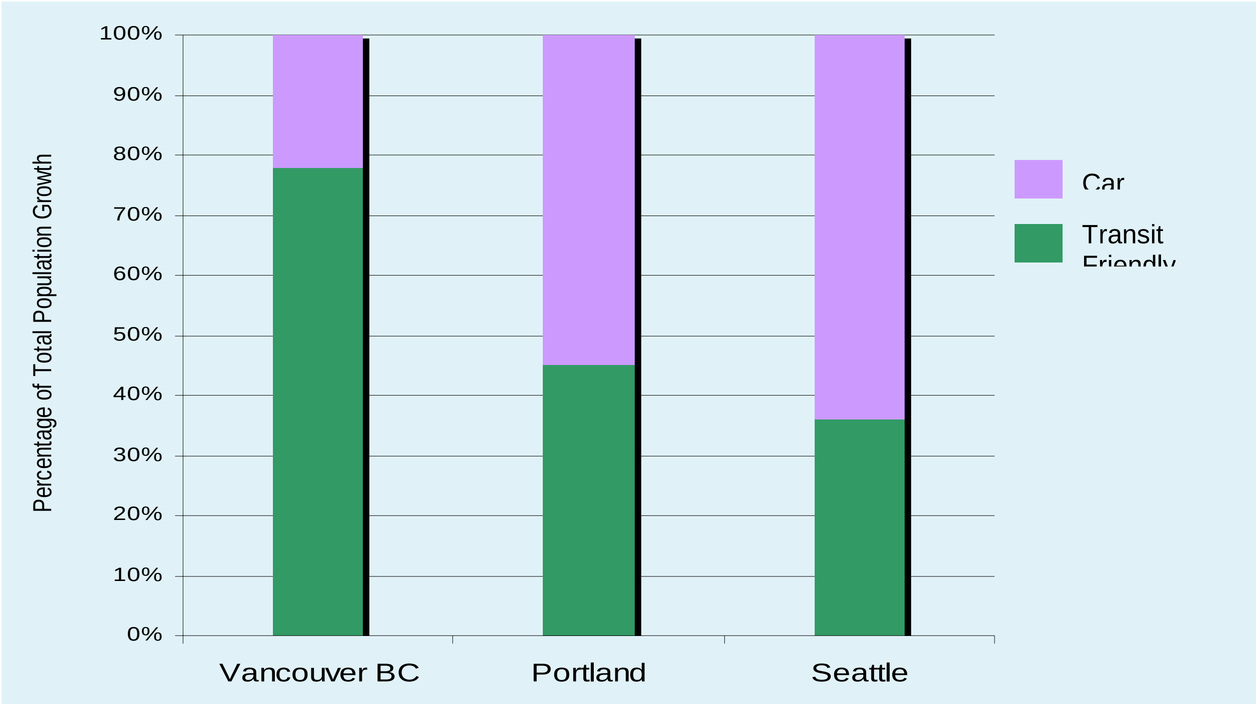
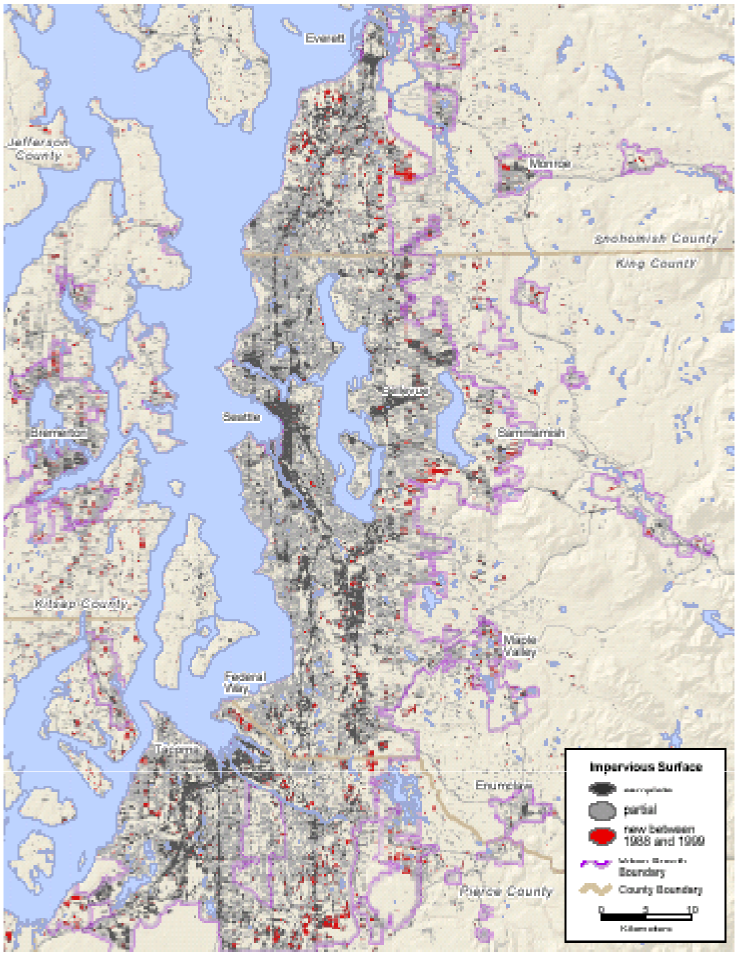
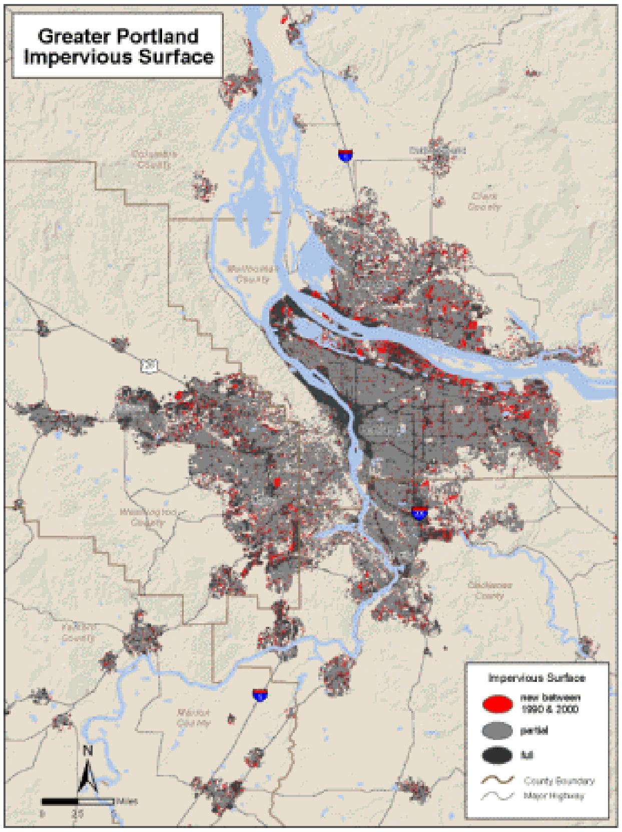


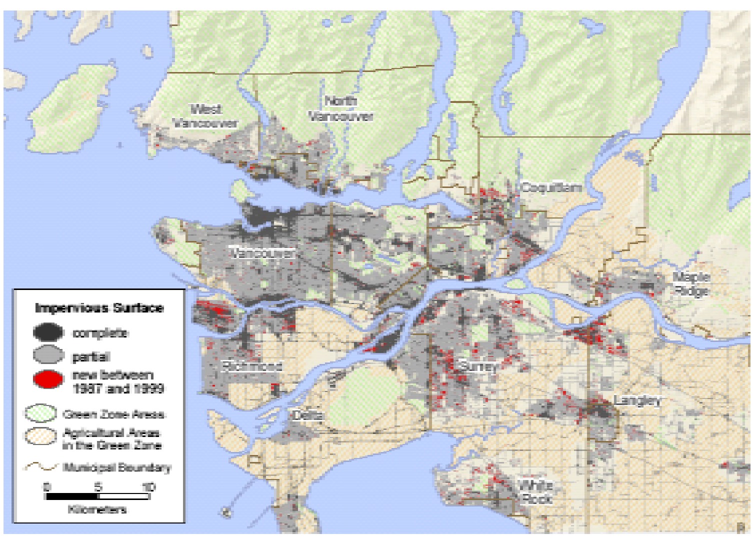
Table 4 – Findings of the Neighborhood Metric



Map 5 – Impervious Surface – Puget Sound



Map 6 – Impervious Surface – Portland, OR



Map 7 – Impervious Surface – Vancouver, BC

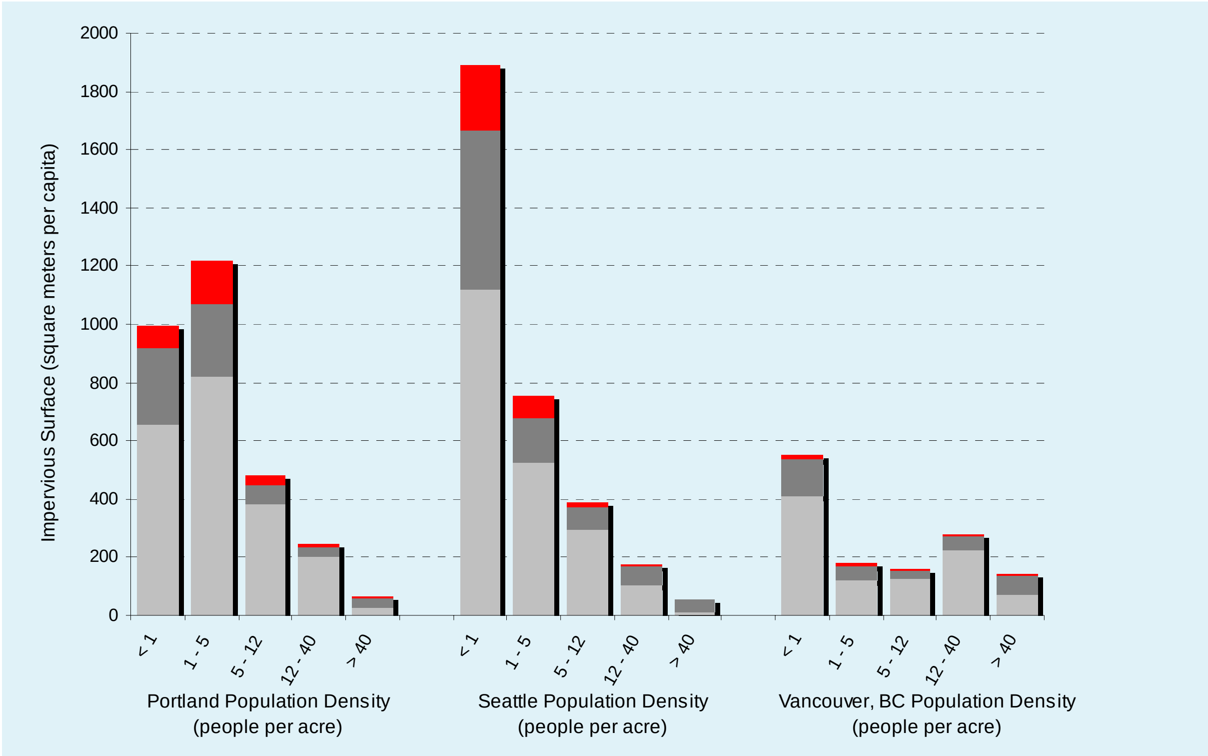
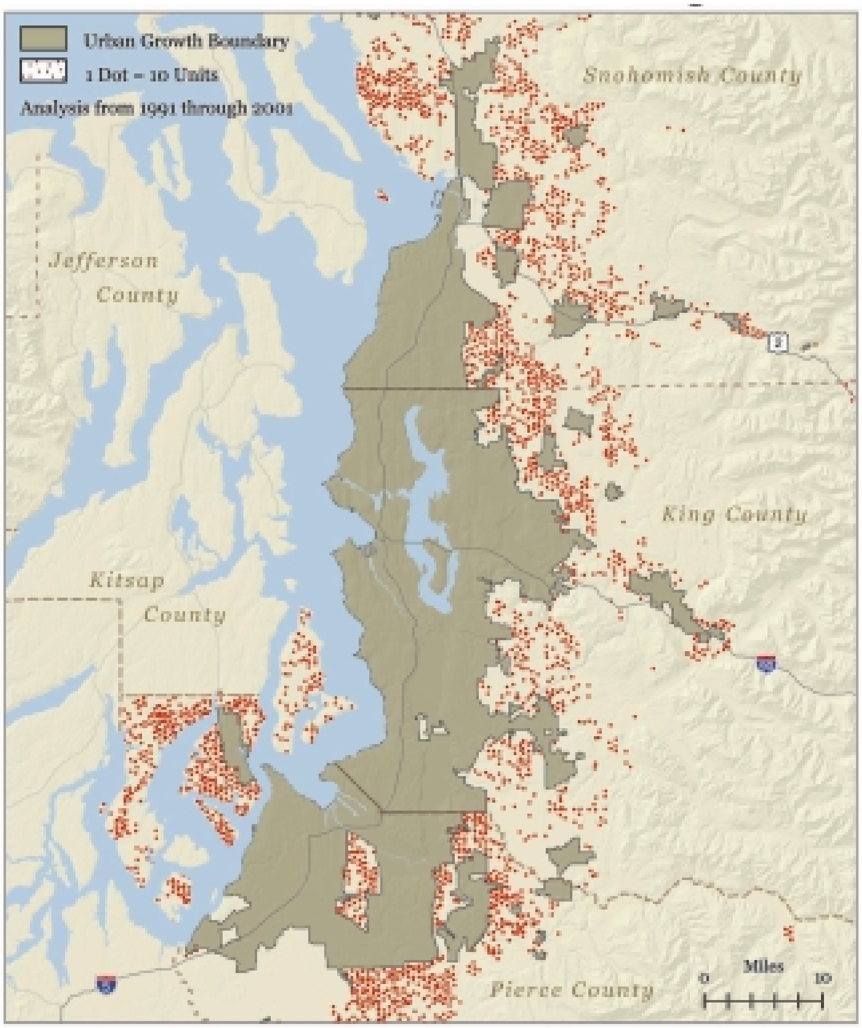


Table 6 – Population Density Change and New Impervious Surface in Three Meto Centers of the PNW

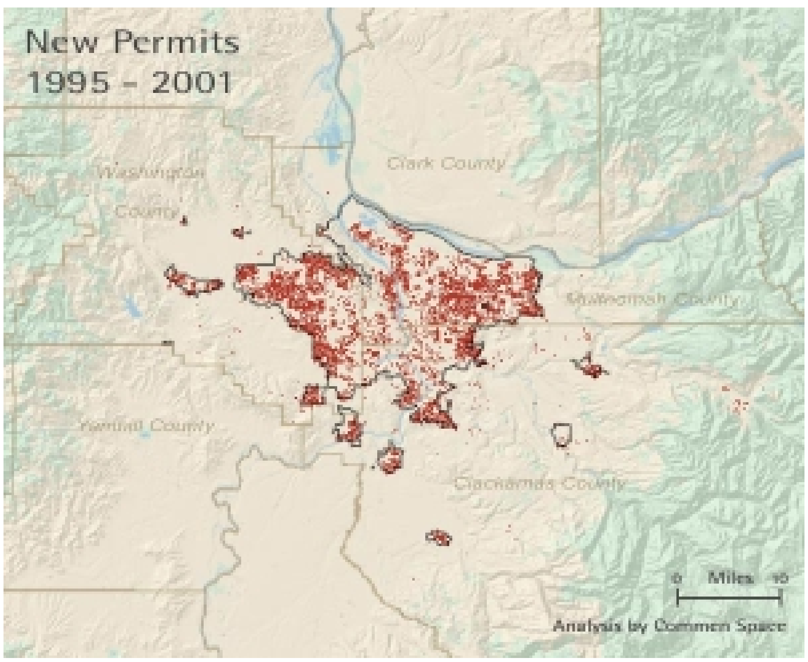


Map 8 – Permits Issued outside UGB, Puget Sound, WA

City/County	Share of new residential housing permits inside UGB 1995 (percent)	Share of new residential housing permits inside UGB 2000 & 2001* (percent)	Share of new residential housing permits in compact neighborhoods 2000-2001 (percent)
Portland (3 OR counties)	94	95	9
Multnomah County	98	99	18
Washington County	97	97	4
Clackamas County	84	87	0
Seattle (3 counties)	78	88	18
King County	89	95	32
Snohomish County	79	84	3
Pierce County	62	73	3

*Average of 2000 and 2001.

Table 7 – comparing permited growth in Portland and Puget Sound



Map 9 – Permited Growth in Portland, Or.