

Forest Conversion Risk Assessment



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Executive Summary

Why Washington's Forests Matter and Why They Are Disappearing

Washington's privately owned working forests (lands managed primarily for timber revenues that also provide public benefits) function as a first line of infrastructure for the state. Their trees slow down stormwater surges, recharge groundwater, shade rivers for salmon, capture atmospheric carbon, shelter wildlife, and anchor a wood-products economy worth roughly \$6 billion a year. When those forests are replaced by houses, roads, and other hard infrastructure communities lose more than scenery: they forfeit a bundle of "green utilities" that would cost millions to replicate with concrete pipes, water-treatment plants, levees, or carbon-capture devices.

Unfortunately, forest loss is accelerating. Between 2007 and 2019 Washington recorded a net decline of $\approx 394,000$ forested acres (about 30,000 acres every 12 months). Small-parcel owners (families, tribes, and small companies that each hold fewer than 5,000 acres) alone shed 103,000 acres, with proportional losses slightly steeper east of the Cascades, even as the absolute acreage drop was larger in the west. Every new cul-de-sac erodes the state's capacity to provide clean water, outdoor recreation, pollinator habitats, cultural heritage sites, and long-term carbon storage.

Four overarching forces explain most of that loss:

- **Urban Pressure.** Population growth and soaring land prices give forest owners record-high pay-outs if they sell to developers. When the price of a buildable lot triples in a decade, cash-strapped families often choose a lump-sum sale over decades of modest timber harvests.
- **Climate Stress.** Longer fire seasons, deeper droughts, and region-wide insect outbreaks raise the risks and insurance premiums for keeping trees standing. After a stand-replacing fire, liquidation and subdivision can look easier than replanting.
- **Demographics.** Washington's forest-owning cohort is aging: the median owner is in their late fifties. Many heirs live out of state and lack the expertise to manage forests under complex regulations.
- **Policy Blind Spots.** Some conservation programs work brilliantly in tidal wetlands or on salmon estuaries but do not reach inland headwaters, even when those upstream parcels carry equal ecological weight.

Left unchecked, these drivers would grind away roughly **half a million additional acres** by the end of this decade, placing salmon recovery goals at risk, inflating flood-control budgets, and shrinking the state's rural job base.

A Single Map that Turns Raw Data into Fast Decisions

In early 2024, the Washington Department of Natural Resources (DNR) concluded that ad-hoc spreadsheets and decade-old map layers were no longer enough. The agency issued a request for a “living” decision aid that could reveal where conversion is most likely, what public values would disappear, and which financial tools could keep forests intact. In June 2024 DNR awarded the contract to Greene Economics in partnership with Spatial Informatics Group (SIG).

Project Evolution “From Two Maps to One Chessboard”

The original work plan called for two separate suites of map products—one for Eastern Washington, one for the west. As the research effort evolved in partnership with DNR policy staff, agency partners, county planners, tribal staff, and land trusts, a consensus emerged: users did not want to jump back and forth across digital silos. They wanted to “see the whole chessboard” on one screen.

Accordingly, the team collapsed all outputs into a single statewide dashboard that lives in a web browser. At the heart of that dashboard is a PLSS section grid. A collection of one-square-mile units used on every property deed in the state. Click any section and three tiers of information pop up:

- **Probability of Conversion.** Section-level scores show the chance (as a percentage) that the land will leave forest use within ten years.
- **Overlays of What’s at Stake.** Eight color-coded layers rank each section on a 1–10 scale for salmon habitat, drinking-water importance, outdoor-recreation potential, carbon storage, rare ecosystems, commercial timber value, climate-change resilience, and wildfire exposure.
- **Policy & Funding Filters.** Thirteen toggles flag whether a parcel is eligible for grants, tax incentives, or easements including:
 - Aquatic Lands Enhancement Program (ALEA) – shoreline conservation grants.
 - Business-and-Occupation (B&O) Forest Tax Credit – a state tax reduction for lands that remain in working forest.
 - Forest Riparian Easement Program (FREP) – long-term stream-side protection with compensation to the owner.
 - Estuary & Salmon Restoration Program (ESRP) – coastal habitat funding.

Because all three streams of information live in one pop-up, users can zoom, filter, and act in minutes rather than weeks.

How the Numbers Were Generated

- **Building the Parcel Database.** Two million private tax parcels were merged with zoning rules, road density, home prices, slope and soil data, wildfire probability, and 2020 census demographics.
- **Identifying Key Drivers.** A literature review plus thirty interviews with agency experts, tribal representatives, and forest-owner associations confirmed four dominant risk drivers (urban, climate, demographics, policy gaps) and ruled out others such as short-term mill closures.
- **Dual Risk Models.** The team built two complementary algorithms:
- A **rare-events logistic regression**: a statistical technique designed when the “yes” outcome is uncommon. In simple terms, the model asks: *How do dozens of parcel attributes combine to push the odds of conversion up or down?*
- A **classification decision tree**: a branch-and-leaf flow chart that repeatedly splits the data into “high risk” or “low risk” buckets. Decision trees excel at capturing non-linear thresholds such as *“distance to city center less than 5 miles”* or *“slope under 15 percent.”*
- Averaging both models’ predictions boosts overall accuracy to roughly 85 percent, because each model corrects the other’s blind spots.

Scoring What’s at Stake. For each PLSS section, the team overlaid eight publicly maintained datasets (e.g., Washington Department of Fish and Wildlife’s *Priority Habitats and Species* layer, the Department of Ecology’s drinking-water importance scores, the Recreation and Conservation Office’s trail density index). Values were normalized to a 1–10 scale, where 1 means “statewide lowest” and 10 means “statewide highest.”

Demonstration of Use

Open the dashboard, set Risk ≥ 6 (top 40 percent of risk scores) and Salmon ≥ 6 , turn on the ALEA funding filter, and the map instantly highlights shoreline parcels that are both ecologically urgent and grant-eligible. In a real trial in Thurston County, the workflow trimmed 14,000 parcels down to 275 high-priority candidates for field visits in under five minutes.

What the Map Reveals

- **Hot-Spot Counties.** Snohomish, Thurston, King, Whatcom, Pierce, Lewis, Spokane, and Skagit contain the largest absolute numbers of high-risk parcels. When adjusted for land area, Island, Kitsap, San Juan, and Clark surge to the top—small counties where even modest raw losses translate into large percentage losses.

- **The I-5 Shadow Effect.** More than **60 percent** of top-decile risk parcels lie within a 30-kilometre band of the I-5 corridor, underscoring the gravitational pull of Puget Sound’s housing market.
- **Climate Cross-Hairs.** Eastern Washington parcels score higher for wildfire exposure; western parcels face emerging drought-induced die-off of western red-cedar. Both phenomena raise management costs and nudge owners toward liquidation.
- **What’s at Stake.** Ten of twelve focus counties register outdoor-recreation scores above 6. Salmon importance peaks in Snohomish, while high drinking-water importance (> 6) clusters in Clark, Lewis, and Skagit.
- **Policy Alignment Gaps.** Not one high-risk inland parcel currently qualifies for ESRP grants. By contrast, **Aquatic Lands Enhancement** eligibility extends to > 60 percent of hot-spot parcels, and the **B&O forest tax credit** theoretically covers about 98 percent, though its small dollar value limits behavioral impact.

Strategic Implications

- **Corridor Strategies.** Stitch together shoreline easements and community-forest acquisitions along lower river valleys (e.g., the Stillaguamish, Chehalis, and Nisqually). Doing so locks in salmon habitat, flood-plain buffering, recreation, and carbon benefits in one package.
- **Modernize Salmon Funding.** Expand ESRP eligibility inland or create a companion “upland buffer” grant so that headwater streams feeding salmon runs can tap the same dollars as tidal marshes.
- **Bundle Wildfire and Easements.** Couple **Service Forestry** fuel-reduction grants (federal cost-share for thinning and pruning) with 40-year **riparian easements** to prevent post-fire liquidation and lower insurance premiums.
- **Quick-Strike Revolving Fund.** Establish a low-interest loan pool that lets land trusts make rapid offers before speculative buyers close. Fast capital is often the difference between conservation and conversion.

Roadmap for the Future

- **Ground-Truthing.** Field-check the highest-risk parcels in Snohomish and Thurston by Q3 2025 so that model predictions evolve with real-world observations.
- **Data Refresh Cycle.** Update both risk models every two years to absorb new zoning ordinances, census counts, property-sale records, and wildfire scars.
- **Economic Valuation.** Quantify avoided flood-control costs, reduced water-treatment expenses, and potential carbon-offset revenues to strengthen budget requests.

- **Equity Overlay.** Add census-tract vulnerability scores so that conservation dollars also advance **environmental-justice** goals—steering investments toward communities with fewer parks and higher flood risk.
- **Toolbox Expansion.** Integrate USDA Farm-Bill programs (e.g., the Healthy Forests Reserve Program) and private “green bond” financing to widen the funding menu beyond the initial thirteen tools.
- **User Community.** Host quarterly **user clinics** and maintain a public **changelog** so county planners, tribes, and NGOs can see what has improved and suggest new features.

Plain-Language Takeaway

Washington is losing forests at a pace that would turn the map noticeably grayer by 2030. The new statewide dashboard gives planners an “X-ray” view of where that grayness will creep next, what priceless natural assets stand in its path, and which pots of money can still keep our forests rooted. By collapsing risk scores, ecological overlays, and funding filters into a single pop-up, the tool transforms scattered data into ready-made investment blueprints. Forests may be the first infrastructure, but equipped with timely intelligence, they need not be the first to go.

1. Introduction

Forests in Washington are managed to provide for a wide variety of ecological, social, cultural, and economic benefits.

Working forests (typically defined as “forest land that is managed to provide a steady, renewable, supply of wood for lumber, energy, paper, packaging and other uses”¹) are a key component of the cultural identity and economic vitality of Washington communities and are an essential part of Washington’s economy, representing the third largest manufacturing industry in the state.² Working forests provide over 100,000 direct and indirect jobs and generate nearly \$6 billion in wage income annually.³

Working forests also sequester carbon, provide critical habitat for fish and wildlife, and contribute to improved water quality. They support the offset of nearly 35 percent of our state’s carbon emissions.⁴ They also support healthy streams and wetlands and play a significant role in the water cycle.⁵

Forest lands in the Pacific Northwest are under threat of conversion as a result of urbanization and agricultural conversion. Climate change also influences the risk of forest conversion- primarily as a result of increased risk and uncertainty associated with disease and wildfire. Loss of forest land can result in significant impacts to the availability and quality of surface waters, flood flow regulation, groundwater recharge, biodiversity, recreation, fisheries, pollination, storage of carbon, and many other ecosystem goods and services.

Urbanization comes with new stresses to the landscape, including increased impervious surface, traffic volume, pollution, and heat.

Low density urban development is common in many transitioning forest lands. While this type of development may appear relatively benign, it fragments forests, particularly due to the extensive road network needed to serve residences. As forests fragment, formerly contiguous forest areas are broken up into smaller, discontinuous components that are widely and unevenly distributed. Fragmentation reduces the size and quality of habitat patches, which in turn significantly impacts wildlife. Fragmentation is also deleterious to the forest industry, because long-term forestland investors are generally only interested in larger (i.e., > 5000 acre) patches of contiguous forest land (Thorne 2000). The impervious area that comes with forest fragmentation also increases non-point source pollution, deteriorating water quality and

¹ National Alliance of Forest Owners, “Working Forests.” Available [here](#).

² Washington Forest Products Association, “Healthy Working Forests Are Essential to Jobs and Washington’s Economy.” Available [here](#)

³ Contribution of Working Forests to the Washington State Economy. Mason Bruce and Girard. Inc. 2021. Available [here](#).

⁴ Washington Forest Protection Association. Available [here](#).

⁵ Wheeling, Kate. How Forests Structure Influences the Water Cycle. Eos. 2019. Available [here](#).

aquatic habitats. While the planning requirements of the Growth Management and Shoreline Management Acts⁶ and Critical Areas and Natural Resource Lands Requirements support long range planning and go a long way towards supporting land use controls that encourage the conservation of productive forest lands⁷, conversion pressure still exists.

In 2005 and 2007 the Washington State Legislature appropriated over \$1 million for the College of Forest Resources at the University of Washington to conduct a detailed analysis to understand the conversion risks and pressures facing working forest owners and managers and to develop recommendations for responding to and mitigating those risk pressures. Their analysis found that the landscape of forest ownership was (and is still today) changing rapidly, as forest assets held and managed by private land managers are increasingly being replaced by real estate investment trusts or institutional investor managers.⁸ As the population ages, and land values increase, there is growing incentive for heirs to cash out their forest holdings to take advantage of rising land prices. In 2009, they estimated that nearly 1 million acres of private working forest land were at “high risk” of conversion to non-forest uses (see Figure 1).⁹

⁶ Municipal Research and Services Center (MRSC). Growth Management Act. Available [here](#).

⁷ Natural Resource Lands. Washington Department of Commerce. Available [here](#).

⁸ Retention of High-Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State. University of Washington, College of Forest Resources. March 2009. Pg. 3. Available [here](#).

⁹ Retention of High-Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State. University of Washington, College of Forest Resources. March 2009. Available [here](#).

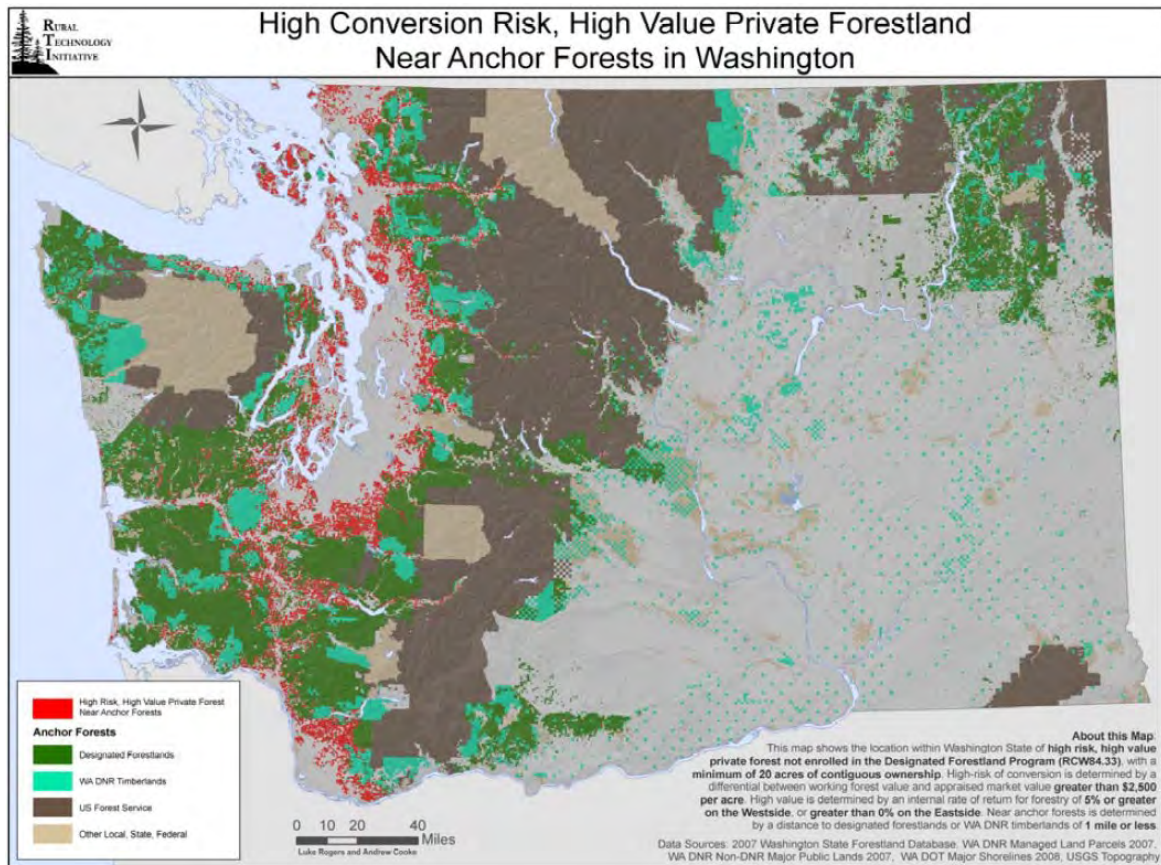


Figure 1. High Risk, High Value Private Forest Land Near Anchor Forests, 2009

Since 2009 these trends have continued, albeit after slowing slightly in the wake of the 2008 housing and financial crisis. The Office of Financial Management projects that by 2050 the state's population will have increased by 28 percent.¹⁰ In Western Washington, by 2050 the population is projected to reach 9.9 million people, up from 7.7 million in 2020.¹¹

In 2024 the Department of Natural Resources (DNR) issued a request for a consultant to perform an in-depth mapping exercise providing an updated spatial understanding of geographic areas most at risk of conversion and the ecological, social, economic, and cultural factors that influence conversion risk so that DNR can prioritize conservation and protection opportunities to maintain forestland, protect working forests, and strengthen the health and resilience of Washington forests. DNR identified three key potential drivers of conversion risk (climate change, population growth and supply chain dynamics) that warranted further exploration. DNR also anticipated that these drivers would have differential effects on the eastern and western areas of the state.

¹⁰ Forecast of the State Population. State of Washington. Office of Financial Management. November 2023. Pg. 1. Available [here](#).

¹¹ Puget Sound Regional Council. Vision 2050. Available [here](#).

In June of 2024, Greene Economics was awarded the contract in partnership with Spatial Informatics Group. The original framing of the research effort is depicted in Figure 2 below.



Figure 2. Project Conceptualization

The analysis began with a review of the existing literature related to the identified drivers and engagement with agency and partner stakeholders to better understand the impact of the identified drivers and to identify other drivers not specified in the initial design. These findings are summarized in Chapter 2 and in Appendix A. Concurrently with these efforts the research team conducted a thorough review of existing policies and programs to understand both the availability of resources and the effectiveness of these instruments and resources in mitigating conversion risk. Program effectiveness and availability was also discussed with interviewees during the stakeholder interviews. These results are presented in Chapter 3 and Appendix B. Based on the findings from these activities, the team developed a methodology to characterize conversion risk on both a parcel and at section level.

This information was used to develop a set of interactive maps and overlay features that allow a user to identify geographic areas at high risk of conversion and identify features or attributes that would be at risk if those areas were to be converted out of working forests. The team held two workshops (Appendix B) with DNR staff and partners from other organizations and agencies to validate and refine the prediction models and prioritization tools.

As the research effort evolved in partnership with DNR and other stakeholders, it became clear that the map products and prioritization tools (in the form of overlays and pop-up boxes) could be structured as a single product, eliminating the need to differentiate between eastern and western Washington. A discussion of the development of these tools is provided in Chapters 4, 5 and 6. The resulting dynamic analysis tools are encapsulated in a single map product covering the entire state at the section level. The user can focus on a particular geography and can filter

this map by conversion risk potential, threat of loss, and policy applicability. Working examples of the map products are provided in Chapter 6 and Appendix C includes a user guide.

Chapter 7 provides an example application of these tools to illustrate how they can potentially be used to inform policy decisions and program development. The report concludes with a synthesis of findings, identification of opportunities to develop or strengthen programs and policies and suggestions for further research.

2. Literature and Program Review

Building on the literature review that informed the development of the research plan, the team worked with DNR staff to identify and prioritize over 100 studies, journal articles, white papers and web-based materials related to forest conversion for review. The team also invited stakeholders and workshop participants to suggest materials for consideration. While the body of work on this topic is significant, much of the work is somewhat dated, and there have been several significant events (e.g. COVID) that have occurred or are occurring with greater frequency (e.g. climate driven increases in fire/flood risk & impacts) that are likely not reflected in these materials.

The findings from these reviews are summarized below, and a complete bibliography of materials is included with this report. In addition to reviewing articles, journals, and other scholarly work related to conversion risk, the team conducted a thorough review of historic, existing, and proposed state and federal programs that address conversion risk. These findings are also summarized in this section and a complete compilation of program reviews is included in Appendix D.

2.1. Identification of Known Key Drivers

Forest conversion refers to the transformation of forested land into non-forest uses, often for residential, commercial, or agricultural development. There are many known drivers of conversion risk. These include:

- urbanization and shifting population growth patterns (and associated changes in land values),
- shifting ownership demographics and changes in ownership patterns and objectives,
- changes in regulations and management requirements,
- changes in climate impacts (including fire risk), and to some extent,
- changes in the economic structure of the forest products industry supply chain.

The literature associated with these drivers is explored in detail in the remainder of this section.

Population Growth

As populations expand, previously undeveloped lands are often cleared to accommodate urban and suburban growth, reducing both relative and absolute forest cover. Population growth, and the associated development pressures it brings, has been cited as a key driver of forest conversion in Washington going back to the late 1990s, when DNR estimated that the state was losing 56 square miles a year (or 100 acres a day) of forestland to non-forest use. Again in 2007, Bradley et.al. identified population pressure as a driver of conversion risk, noting that at that

time Washington had the 10th fastest growing population rate in the nation at 21 percent.¹² A 2009 report, also prepared by the University of Washington's College of Natural Resources, identified population growth as a significant source of conversion risk pressure.¹³

As populations grow, the demand for residential and commercial infrastructure expands, putting undeveloped forested areas at heightened risk of being cleared and converted to accommodate development in response to these demands. In Washington, continued population growth is driven both by in-migration from other areas of the U.S., and relocation of existing populations within the state. This is particularly prevalent in urban or urbanizing areas on the western side, and in key areas around Spokane on the eastern side of the state, which exacerbates the risk of forest land conversion.

As of April 1, 2024, the Washington State population had reached an estimated 8 million people, reflecting a 4.3 percent increase since 2020. Using Office of Financial Management data, the overall annual population growth rate remains around 1.1 percent.¹⁴

In 2006, 20.3 percent of people in Washington moved, but by 2019, this rate had dropped to 16.9 percent.¹⁵ Despite the lower mover rate, Washington still experienced a significant gain in domestic migration, meaning more people moved into the state from other states than left.

In 2019, the state saw 231,956 people move in from other parts of the U.S., while 199,758 left, resulting in a net gain of 32,198 people. This trend has continued in recent years, with the state experiencing an average 4.3 percent annual growth rate in the last decade. By April 2024, the total population of the state was estimated at over 8 million.¹⁶ This demonstrates Washington's attractiveness as a destination for movers, particularly from other states in the Pacific region, which includes California and Oregon. The state's overall trends reflect a nationwide shift in migration patterns, with more people engaging in long-distance moves between states, even as the total number of movers decreased.¹⁷

Data from a 2023 National Movers Study shows that between 2020 and 2023 Washington experienced relatively balanced migration, with roughly the same numbers of people entering and leaving the state as shown in Table 1 below.

¹² Bradley et al., "Study 4: Forest Land Conversion in Washington State," Available [here](#).

¹³ College of Forest Resources, University of Washington, "Retention of High-Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State," March 25, 2009. Available [here](#).

¹⁴ Washington State Office of Financial Management, "2024 Population Trends." Pg.1. Available [here](#).

¹⁵ Ibid.

¹⁶ Washington State Office of Financial Management, "Washington State Tops 8 Million Residents in 2024 | Office of Financial Management." Available [here](#).

¹⁷ Ibid.

Table 1. Migration Trends in Washington State 2020-2023¹⁸

Year	Percent Inbound	Percent Outbound	Percent Change
2020	54.5	45.5	+9
2021	51.5	48.5	+3
2022	50.9	49.1	+1.8
2023	47.8	52.2	-4.4

Net migration, (the difference between the number of immigrants and the number of emigrants divided by the population), was the dominant factor in population growth in Washington in 2024, accounting for 82 percent (69,100 individuals) of the total population increase. Natural change (births minus deaths) accounted for 18 percent of the total growth, contributing to 15,500 individuals.

In Washington specifically, the significant net migration gain—despite its declining mover rate—suggests that the state remains a desirable destination for domestic movers. While the figures above suggest that there may be a shifting trend towards outbound migration, at this time it is unclear whether the shift towards outbound migration observed in 2023 (as noted in the table above) represents an anomaly or a permanent shift. Regardless, historic migration trends in Washington place additional pressure on land use, particularly in regions adjacent to urban centers, where development is most likely to occur.

Population growth continues to concentrate in major metropolitan areas, which saw 68 percent of total state population growth in 2023, while smaller counties with populations under 100,000 also saw an increased share of growth relative to previous years.¹⁹ Washington's incorporated cities and towns had a combined population of 5.3 million as of April 2024, an increase of 1.3 percent from the previous year. The cities experiencing the largest population increases included Seattle, which added 18,500 individuals, followed by Vancouver, Tacoma, Redmond, Bellingham, Kent, Arlington, Bothell, SeaTac, and the Spokane Valley.²⁰

While the state's decline in the overall mover rate suggests that fewer people may be relocating to Washington itself, this trend should not be assumed to reduce the risks of forest conversion. In fact, with fewer inter-state moves, the pressure may shift towards intra-state moves with new residents settling in less densely populated, rural, or forested areas, within the state and within a given county where housing availability is less constrained. Nationally, "same-county movers," those who relocated within the same county, consistently represented the largest proportion of movers despite their share falling from 59 percent in 2006 to 55 percent in 2019.

¹⁸ United Van Lines, "2023 National Movers Study | United Van Lines®." Available [here](#).

¹⁹ Ibid.

²⁰ Washington State Office of Financial Management, "Washington State Tops 8 Million Residents in 2024 | Office of Financial Management." Available [here](#).

Looking specifically at the Puget Sound region, between 2014 and 2018 the highest number of transplants into the central Puget Sound region (14 percent) came from the state's other counties.²¹

This migration encourages the expansion of suburban and exurban development in these areas into previously undeveloped forest lands, especially given Washington's growing demand for housing. These incoming residents are likely seeking affordable housing and space, leading to development pressures in forested regions. As urban areas like Seattle, Bellevue, and Tacoma become more congested and housing prices rise, developers may turn to previously untouched forest areas to meet the growing housing demand from new residents.

Suburbanization, Real Estate Markets, and Land Values

Population dynamics affect conversion risk through their influence on urbanization and suburbanization trends and the impacts on associated land values and real estate markets.

Regardless of where movers originate, population influx into areas that are not already densely populated or do not already have significant housing stock drives up demand. The resulting scarcity creates incentives for developers to offer higher prices for land—which has the potential to incentivize conversion, particularly when a landowner weighs the potential for near term financial gain against other factors that may make long term stewardship of a working forest more costly or more complex.

According to the Office of Financial Management, Washington added over 50,000 new housing units in 2024 alone, with more than 70 percent of those occurring in one of the five largest metropolitan counties (King, Pierce, Snohomish, Clark, and Spokane).²²

The most recent research on the relationship between these drivers, their associated impact on financial gain for landowners, and conversion risk suggests that while there is some correlation between these drivers and the risk of forest conversion, they cannot be separated from other aspects of financial returns from forest ownership, particularly for owners of smaller holdings.²³

Changing Landowner Demographics

The demographics of land ownership are a potential driver of conversion risk because different owners may have different land management and financial objectives. As landowners age, their interest and ability to manage lands as working forests may change. Need for ready or emergency cash may pressure a landowner to sell or convert a working forest. Heirs may not be geographically positioned to manage a working forest and may have completely different goals and financial needs, leading to conversion. Studies by Rabotyagov et al., Raymond et al., and

²¹ Puget Sound Regional Council, "Puget Sound Trends." Available [here](#).

²² Washington State Office of Financial Management, "Washington State Tops 8 Million Residents in 2024 | Office of Financial Management." Available [here](#).

²³ Rabotyagov et al., "Washington's Small Forest Landowners in 2020." Available [here](#).

the report "Forest Land Conversion in Washington State" provide an overview of the demographics of forest landowners in the region.

Though the average age of family forest landowners is between 57 and 67 years old,²⁴ Rabotyagov et al. found that many individuals intend to retain their property as they age; therefore, age is not always a reliable predictor of whether landowners will sell their property.²⁵ However, the presence of an immediate financial need, which is difficult to predict, may be a more significant driver of sale than age.²⁶

Demographics may also combine with what Rabotyagov et al. identify as the treadmill effect—trouble keeping up with changing demands of land management or policy—as a reason for selling land.²⁷ As landowners age, their ability or willingness to navigate and stay current with complex regulations and requirements for land management may diminish. As their willingness to comply with complex regulations dwindles, their willingness to sell their forestland increases.

Climate Change

Climate change can be considered an indirect driver of conversion risk, exacerbating the impacts of other known drivers. For non-industrial private landowners holding forest land as an economic investment (which ranked 6th out of 13 ownership objectives among respondents in Rabotyabov et al.)²⁸ anything that impacts that objective has the potential to influence a conversion decision. For example, climate change makes forests more vulnerable to pests and disease which can impact the value of timber harvests- which may lead to a landowner's decision to cash out forest holdings to maximize immediate return and in favor of a less risky investment.²⁹ Conversely, changes in weather patterns (increased temperature and more frequent and more severe storms) can influence migration patterns and housing demand³⁰, increasing land value to the point where sale to developers generates more revenue than sale of timber.

Every region within Washington state has been impacted by climate change, and these effects are expected to continue and accelerate over time.³¹ The severity and type of impacts, however, vary across the state, particularly from east to west.

²⁴ "Forest Land Conversion in Washington State." Available [here](#).

²⁵ Rabotyagov et al., "Washington's Small Forest Landowners in 2020." Available [here](#).

²⁶ Ibid.

²⁷ Ibid.

²⁸ Ibid pg. 86.

²⁹ Yuhan Wang, D. Lewis. Wildfires and climate change have lowered the economic value of western U.S. forests by altering risk expectations. 2024. Journal of Environmental Economics and Management. Available [here](#).

³⁰ Climate Related migration to the Pacific Northwest. 2016. University of Washington Climate Impacts Group. Available [here](#).

³¹ Washington State Department of Ecology, "Washington State Climate Resilience Strategy." Available [here](#).

The Climate Resilience Guidance for Small Forest Landowners in Western Washington document identifies climate change impacts specific to Western Washington.³² The guidance document lists increased temperature as a significant impact, stating that temperatures in Western Washington have increased by 1.7 degrees Fahrenheit over the past 120 years and that this trend will continue in the future, particularly during the summer months.³³ Spring snowpacks have also decreased by 30 percent from 1955 to 2016, which reduces soil moisture and streamflow during spring and summer months. Snowpacks in the Cascade and Olympic Mountains are projected to further decrease, reducing soil moisture, which supports tree growth.³⁴ Increased severity in storms may lead to an increase in landslides, which uproot and disrupt forest health. Finally, warmer temperatures and changes in precipitation may create suitable habitat for new pests and diseases that may affect the health of Western Washington forests.³⁵ These impacts have led to the die back of western red cedar and will continue to manipulate the ranges of tree species across the region.

The [20-Year Forest Health Strategic Plan for Eastern Washington](#) identifies wildfires, summer droughts and insect/disease outbreaks as significant stressors for forest health on the Eastern half of the state.³⁶ Wildfires are a serious concern when it comes to forest conversion. In 2015, wildfires across the state broke many records, and there are predictions that the Pacific Northwest may experience four times as many acres burned annually in the late 2000s as compared to the median annual burned area from 1916 to 2006.³⁷

Disease and insect damage, like those already inflicted from the mountain pine beetle, are predicted to increase over the upcoming decades. The National Insect and Disease Risk Map estimates that over 2.5 million acres of Washington state forestland are at risk of suffering severe damage from insects and disease.³⁸ The Forest Health Strategic Plan stated that the number of trees killed or damaged in Eastern Washington from 2000 to 2010 was 150 percent greater than the 1990s and 200 percent greater than the 1980s.

Supply Chain Dynamics

In addition to climate change and population growth the initial research question also identified supply chain dynamics as potentially having an influence on conversion risk (Figure 1). The literature on supply chain dynamics and conversion risk addresses the issue from two

³² Raymond et al., "A Climate Resilience Guide for Small Forest Landowners in Western Washington." Available [here](#).

³³ Ibid.

³⁴ Ibid.

³⁵ Ibid.

³⁶ Washington Department of Natural Resources, "20-Year Forest Health Strategic Plan: Central and Eastern Washington | WA - DNR." Available [here](#).

³⁷ Ibid.

³⁸ USDA, "National Insect and Disease Risk Maps - 2012." Available [here](#).

directions, both having the potential to influence the economic value and financial return associated with keeping a parcel as a working forest.

In one case, the line of causality suggests that increasing difficulties sourcing inputs (seedlings, cones, etc.) to support forest management and replanting after harvesting may influence a landowner's decision to convert a parcel after harvesting. It is just too hard, and too expensive to replant--particularly when selling after harvest offers an immediate financial return.

Similarly, at a landscape scale, as land is converted out of working forest entirely, or moved into management structures that have longer harvest rotations the supply of logs to mills declines to the point where these mills are no longer financially viable. As mills close, and distance to mills increases this has the potential to increase costs and management burdens, particularly for small working forest landowners, which could accelerate or initiate decisions to convert land out of working forest to other uses.

In 2024 DNR engaged Evergreen Economics and ESSA to provide an updated understanding of wood supply in Washington state and the impacts of various forest management scenarios on wood supply and the viability of the commercial logging industry. However, this analysis did not specifically address any correlation between sawmill availability, proximity to sawmills and private landowner decisions to convert land uses. Further, our review of the literature did not identify any studies that specifically established a direct relationship between supply chain dynamics and small forest landowner decisions to convert working forests to other uses.

2.2. Programs, Policies, and Incentives

Concurrently with the literature review, the team identified and evaluated a number of existing and past programs that have been designed to address factors of conversion risk. Key programs are summarized in the sections below. A complete review of programs is included in Appendix A.

Growth Management Act

The Growth Management Act (GMA) was enacted by the Washington State Legislature in 1990 in response to rapid urbanization and population growth in the state during the late 20th century. The GMA aimed to address the consequences of unplanned growth, including environmental degradation, loss of agricultural and forest land, and increased traffic congestion. The GMA mandates that counties and cities engage in comprehensive planning processes focusing on land use and the provision of public services. Specifically, the Act requires jurisdictions to adopt comprehensive plans that address housing, transportation, parks, and public services to ensure that development aligns with community needs and complies with environmental requirements.

Over the years, the GMA has undergone a number of amendments reflecting changing priorities and the nature of urban development. Key provisions of the GMA include the designation of urban growth areas (UGAs), which delineate where growth should occur,

thereby protecting rural and resource lands from urban sprawl. The GMA also emphasizes the importance of public participation in the planning process, encouraging community members to have a voice in shaping the neighborhoods in which they live and work.³⁹

The GMA creates a structured legal framework addressing forest conversion risks through specific land use provisions. It defines "forestland" as land dedicated to long-term commercial timber production, with established criteria to assess whether the land is suitable for such use. These criteria include proximity to urban areas, compatibility with surrounding land uses, local economic factors, and the availability of public infrastructure. This has the effect of establishing clear legal standards for determining whether forestland should be maintained for timber production or can be rezoned for other uses. The rural land use element under the Act allows for rural development alongside forestry but requires counties to adopt measures that protect rural character and prevent conflicts with designated forestlands under RCW 36.70A.170. This mandate limits the conversion of forestland to other uses, safeguarding the protection of land designated for commercial timber production.

The Act also imposes legal requirements on counties to establish defined boundaries for rural development, with the intent of preventing rural expansion into forested areas. Importantly, forestland with long-term commercial significance is excluded from urban growth areas, legally restricting the expansion of urban development into designated forestlands, which serves as a measure to protect forestland from conversion to urban use.

There are several aspects of the GMA that can have a negative impact on keeping land as working forests. By restricting growth and development to designated areas, land values in those areas can become artificially inflated- creating incentives for landowners to subdivide their land into smaller parcels that can be sold for development.

There are also loopholes in the statute that allow permits to be issued and conversion to occur even if that use is being challenged. Often even if the matter is resolved in favor of keeping the land zoned for forest use, by the time the decision is handed down conversion has already occurred. The ability to vest permits for developments that ultimately flout GMA provisions thus poses serious risks to community integrity, agricultural land, and importantly, forest conversion.⁴⁰

Recent GMA Updates

In 2023, the Washington State Legislature enacted House Bill 1181, which updates the GMA to address housing supply and affordability issues. Specifically, the new legislation requires local governments to plan for a sufficient supply of housing and promote policies that facilitate housing development by way of mandating that jurisdictions assess their housing needs and

³⁹ Washington State Legislature. (1990). *Growth Management Act*. [Available here](#).

⁴⁰ The Urbanist. "How the GMA's Illegal Growth Loophole Works in Practice" (2021). [Available here](#).

implement strategies to meet those needs.⁴¹ This may put high value forest lands in urban areas at risk of conversion to meet those needs.

Specifically related to managing wildfire risks, HB 1181 mandates the use of land use planning tools to safeguard forest health and reduce the risks posed by development in wildfire-prone areas. These tools include separating residential development from wildfire-prone landscapes and ensuring that human activity does not encroach on vulnerable forested regions, with the goal of protecting forestland from being converted into residential or commercial spaces, especially in high-risk areas.⁴² Also related to wildfire risk management, in jurisdictions that have adopted the Wildland Urban Interface (WUI) Codes defensible space requirements may result in tree removal.⁴³

Transfer of Development Rights Programs

One of the primary impacts of population growth and urbanization on conversion pressure is the appreciation of land values and the incentive to convert in order to realize financial gain. Programs that allow landowners to realize the “development potential” value of their lands, while not actually converting the land to other uses, are a way to ensure that landowners can realize financial returns while still protecting valuable forest lands. Transfer of Development Rights (TDR) programs are one example of this mechanism.

TDR programs are a market-based approach to preserve land in designated areas by allowing property owners to transfer the right to develop their land to other areas where such development is more appropriate. Under these programs, local governments designate sending areas, typically consisting of agricultural or ecologically sensitive lands, where development rights can be sold or transferred. Conversely, receiving areas are identified as zones suitable for higher-density development, where rights can be applied to increase development potential, such as adding a unit, a story height, or other bonuses to a development. The TDR approach purports a myriad of benefits. It facilitates the preservation of open space and agricultural lands while accommodating growth in urban areas, thus helping to alleviate pressures associated with sprawl. Property owners in sending areas can benefit financially by selling their development rights, which can incentivize them to maintain their land in its current use. Meanwhile, developers in receiving areas gain the opportunity to enhance project viability through increased density, potentially improving economic returns.

King County was one of the first counties to pilot the use of TDRs to protect land from development. Between 1998 and 2022 King County protected over 145,600 acres of rural land through its TDR program.⁴⁴ According to Forterra, there are TDR programs in four counties

⁴¹ Washington State Legislature. (2023). Engrossed Second Substitute House Bill 1181: An act relating to housing supply and affordability. [Available here](#).

⁴² Ibid.

⁴³ Wildland Urban Interface Code. 2023. Washington State Building Code Council. Available [here](#).

⁴⁴ King County. Transfer of Development Rights. [here](#) and [here](#).

(King, Pierce, Snohomish and Kitsap) and 15 cities.⁴⁵ However, in assessing the impact of TDR programs on mitigating forest conversion risk, it is important to note that most programs are not limited to protecting forest lands and may also include the sale of development rights on agricultural lands or lands with other habitat and biodiversity characteristics.

The Landscape Conservation and Local Infrastructure Program (LCLIP), authorized under RCW 39.108, is another program that allows cities to access tax increment financing in exchange for the creation of a TDR program and the acceptance of a specified amount of regional development rights. The program is available only to select cities in King, Pierce, and Snohomish counties within the central Puget Sound region. This program is being expanded with funding from the Puget Sound Partnership through the Habitat Strategic Initiative. Under the LCLIP, a county agrees to contribute a portion of its regular property tax revenue to the participating city for a period of up to 25 years. This funding is then directed towards infrastructure investments that support growth in the city's TDR receiving areas. The program is designed to facilitate the transfer of development rights from agricultural and forestland of long-term commercial significance to urban areas, thereby conserving those rural lands while promoting urban development. LCLIP is the first program in the United States to combine TDR with tax increment financing, offering cities a financial incentive to participate in regional conservation and growth management efforts.⁴⁶ In addition to LCLIP activities in King County, the County's Forestry Program also aims to address the threat of forestland conversion by providing education, technical assistance, and economic incentives to private forest landowners throughout the County. Through this program, forest stewardship classes and workshops are provided to landowners in partnership with the Washington State University Extension. Staff foresters visit private properties to provide technical advice and support, conducting approximately 400 landowner consultations annually.⁴⁷

Conservation Easements and Acquisitions

A conservation easement is a voluntary legal agreement between a landowner and a land trust or government agency that limits certain uses of the land for an established period of time, sometimes permanently, in order to protect its conservation values. For instance, a conservation easement could require a landowner to relinquish the right to develop the land in return for payment. The purpose of a conservation easement is to protect natural resources, wildlife habitat, open space, agricultural land, etc. in the long term.⁴⁸

There are numerous land trusts and other organizations in Washington state that work with landowners to establish conservation easements that conserve natural lands. Examples include

⁴⁵ Forterra, "Investing in T.O.D. with Market-Based Tools," April 29, 2022. Available [here](#).

⁴⁶ Landscape Conservation and Local Infrastructure Program, RCW 39.108, Washington State Legislature, Available [here](#) (accessed September 24, 2024).

⁴⁷ "King County Forestry Program - King County, Washington." Available [here](#).

⁴⁸ Washington Association of Land Trusts. Conservation Easements. Available [here](#).

county-based organizations like Whatcom Land Trust, Jefferson Land Trust, Whidbey Camano Land Trust, and Skagit Land Trust as well as state, regional, and national organizations like the Washington Association of Land Trusts and Trust for Public Land to name a few. Many of these land trusts and conservation groups work with forest landowners to develop agreements that prevent the land from being subdivided or commercially developed but still allow timber harvesting and other forest management activities. In return the land trust compensates the landowner often through a mix of government and grant funding. In 2020, over 133,000 acres of land in Washington state was protected via a conservation easement managed or held by a land trust.⁴⁹

Many state agencies also use conservation easements as a mechanism to protect specific natural resources and institute them via the programs described below. Conservation easements are a common practice among several programs because they can provide small forest landowners with a financial incentive to preserve their forested land for an extended period of time if not indefinitely. This mechanism is a powerful tool that can preserve private forest land both present day and in the future.

Recreation and Conservation Office Programs

The Washington State Recreation and Conservation Office (RCO) administers several grant and technical assistance programs that either directly or indirectly address the threat of forestland conversion. While most of the programs target state agencies and jurisdictions, some allow private landowner participation as well. RCO administers two grant programs that allow agencies, local jurisdictions, tribes, and nonprofits to acquire forested land or other habitats for the purpose of conservation and to prevent conversion to other land uses – the Community Forest Program and Washington Wildlife and Recreation Program.

The **Community Forest Program** was established in 2020. This program offers grants to help communities purchase and protect nearby forests, while also supporting the development of collaborative, community-based forest management models. Local governments, nonprofits, special purpose districts, state agencies, and tribes may apply for this program, which is funded from the sale of general obligation bonds.⁵⁰ This program funds activities such as buying forestland, restoring forest health or habitats, or developing recreational facilities. The Community Forest Program was designed to limit the fragmentation and development of forested areas that provide numerous community benefits by providing a mechanism through which the community can purchase and manage said forested land long term.

The **Habitat Conservation Projects – Washington Wildlife and Recreation Program (WWRP-Habitat)** was established in 1990. This program provides funding for the conservation of natural areas. The goal of the program is to acquire recreational and habitat land before they are lost to other uses and to develop recreation areas for a growing population. State agencies, local

⁴⁹ Land Trust Alliance. Washington. Available [here](#).

⁵⁰ Washington State Recreation and Conservation Office. Community Forests Program. Available [here](#).

jurisdictions, tribes, nonprofit organizations, and special purpose districts can buy land to conserve wildlife habitat or restore state lands using this grant program. Projects that acquire land must be managed perpetually for the purpose of conservation and recreation. Restoration projects have a ten-year compliance requirement. This program specifically protects lands at risk for conversion for other land uses in an effort to preserve Washington's diverse ecosystems and unique flora and fauna for a minimum of ten years.

In addition to these two programs, RCO administers several grant programs aimed at improving aquatic, nearshore, and riparian habitat to support salmon recovery efforts and public recreation. While the ultimate purpose of these programs is not forestland conservation, the long-term management requirements tied to these grants effectively protects these project areas from forestland conversion for a minimum of ten years. Private landowners may apply to several of these grants and receive funding for salmon habitat enhancement such as barrier removal or riparian habitat restoration. By participating in these programs, recipients receive payment to both improve their forested land as habitat and maintain it as such into the future. These four programs are briefly described below.

In 2014, the **Brian Abbott Fish Barrier Removal Board (BAFBRB) grant program** was established in an effort to identify and remove impediments to salmon and steelhead migration. The program is jointly administered by Washington Department of Fish and Wildlife (WDFW). Private landowners with a fish-bearing stream are amongst those who are permitted to apply for this grant. Projects typically involve the planning for or actual removal of a culvert, bridge, or some other stream barrier. The RCO grant agreement requires the project sponsor to operate and maintain the project area for its intended purpose, which is to provide habitat conservation, through a ten-year compliance period. Though the main purpose of this grant is to improve salmon habitat, during the ten-year compliance period the landowner could not convert the area to another use, effectively keeping that parcel safe from conversion for ten years. It is important to note that this program could only be used to combat forest conversion by private landowners with a fish bearing stream with a barrier.⁵¹

The **Estuary and Salmon Restoration Program (ESRP)** is also jointly managed with WDFW. This program provides grants and technical assistance for projects that restore and conserve nearshore areas in Puget Sound to improve the health and resiliency of Washington's shorelines. This program supports projects that protect near-shore and wetland habitat, restore salmon habitat, remove or breach dikes or bulkheads, and the decommissioning of roads and removing fill. Agencies, tribes, nonprofit organizations, private institutions, and educational institutions may apply for a grant under this program. Like the BAFBRB, projects developed using these grants have a long-term commitment. Any land acquired using this grant funding must be managed forever for the purposes stated in the grant agreement and all restoration projects have a ten-year compliance period. Again, the long-term management of these projects effectively prevents conversion on these lands for ten years or indefinitely depending

⁵¹ Washington State Recreation and Conservation Office. Brian Abbott Fish Barrier Removal Board. Available [here](#).

on project type. While this grant is not available for private landowners, it allows organizations like state agencies and Land Trusts to acquire land for conservation and restoration purposes that could have otherwise been converted for development.⁵²

The **Aquatic Lands Enhancement Account (ALEA)** has been providing grant funding for the acquisition, improvement, and protection of aquatic lands for public purposes since 1984. All tidelands, shore lands, harbor areas, and beds of navigable waters are considered aquatic lands. This program permits state and local agencies and tribes to submit estuary restoration projects, bulkhead removals, waterfront boardwalk replacement projects, shoreline restoration projects, and waterfront park development for grant funding. Property acquired, developed, or renovated with ALEA grants must be kept for public outdoor recreation use forever. Though specific to shorelines, any property bought or improved using ALEA grant monies must be managed for public recreation permanently. Any forested shoreline involved in one of these projects would then effectively be protected from the risk of conversion.⁵³

The Salmon Recovery Funding Board was established in 1999 and awards grants under two programs – **general salmon recovery grants** and **Puget Sound Acquisition and Restoration (PSAR)** grants.⁵⁴ These grants aim to protect and restore salmon habitat, as well as support related activities. Most projects focus on restoring degraded habitats, removing barriers to fish migration, and conserving high-quality, intact ecosystems. As of 2023, restoration projects made up the largest percentage of funded projects (47 percent), followed by planning efforts (21 percent), combined salmon recovery actions (12 percent), and land acquisitions (12 percent).⁵⁵ Private landowners, state and local agencies, special purpose districts, tribes, nonprofit organizations, and regional fisheries enhancement groups can apply for PSAR funding. Like other RCO programs, PSAR funded acquisition projects must be managed and protected as salmon habitat forever and restoration projects must be managed and maintained as improved salmon habitat for at least ten years after construction is completed.

Department of Natural Resources Programs

Similar to RCO, the Department of Natural Resources (DNR) implements several grant and technical assistance programs that help prevent the conversion of forestland to other uses. DNR has many programs that specifically aim to help small forest landowners meet regulatory obligations and rules including the Washington Forest Practices Rules (FPRs). FPRs are designed to protect natural resources while allowing for sustainable timber harvesting and forest management and stipulate that all landowners conducting any regulated forest activity submit a Forest Practices Application prior to conducting that activity. FPRs that limit timber harvesting

⁵² Washington State Recreation and Conservation Office. Estuary and Salmon Restoration Program. Available [here](#).

⁵³ Washington State Recreation and Conservation Office. Aquatic Lands Enhancement Account. Available [here](#).

⁵⁴ Washington State Recreation and Conservation Office. Salmon Recovery Funding Board. Available [here](#).

⁵⁵ Ibid.

are typically adjacent to riparian zones of ecological sensitivity and/or importance wherein timber production activities may be harmful or disruptive to wildlife and their habitats.

The **Service Forestry Program**, is the primary program DNR manages which is designed to help landowners navigate Washington's Forest Practices Rules (FPRs) and comply with the requirements for submitting Forest Practices Applications or Notifications. The Service Forestry Program focuses on delivering both technical and financial assistance to support small forest landowners in harvesting timber responsibly and in compliance with state regulations.⁵⁶ For many small landowners, a timber harvest is a once-in-a-lifetime event. The program is committed to providing the guidance and resources needed to manage their forestland sustainably and legally. By making the regulatory process more accessible and manageable, the program plays a vital role in keeping small-scale forestry a viable option across Washington State.

DNR manages the Service Forestry Program (formerly two distinct but complementary programs serving small forest landowners: Forest Stewardship Program and Landowner Assistance) with support from the U.S. Forest Service (USFS). This program offers technical assistance to help forest landowners "assess resource conditions and forest health, identify potential problems and opportunities, and recommend management practices."⁵⁷ The program also determines financial assistance eligibility and assists with treatment implementation to help achieve objectives. Funding from the Service Forestry Program partially supports WSU Extension Forestry to provide courses and educational resources tailored to family forest owners. Its flagship course includes coached planning services that guide landowners in developing a comprehensive Forest Stewardship Plan—a key tool for ensuring compliance with FPRs and promoting the "continuity of management [to] help ensure that one's vision for their property continues well into the future."⁵⁸ This combination of education, technical support, and financial assistance helps make forestland management more accessible, especially for those navigating the often complex regulations and responsibilities involved.

Under FPR regulations, the increased considerations for timber harvest within the riparian management zones in combination with the need for significant additional technical expertise not readily available to small landowners has minimized small forestland owners' potential timber revenues and their willingness to keep lands in forestry.⁵⁹ To accommodate these cases, the state legislature has established **alternate timber harvest plan** options for small forest landowners whose impact on aquatic resources is relatively low. These alternate plans provide comparable protection for natural and public resources to FPR practices while lowering the

⁵⁶ Washington State Department of Natural Resources. 2025. Small Forest Landowner Regulations Assistance Program. Available [here](#).

⁵⁷ Washington State Department of Natural Resources. 2025. Forest Stewardship Planning. Available [here](#).

⁵⁸ Ibid.

⁵⁹ Washington State Department of Natural Resources. 2023. Forest Practices Board Manual: Section 21 Guidelines for Alternate Plans. Available [here](#).

overall costs to small forest landowners, increasing their willingness to keep their lands in forestry.

DNR also enables small forest landowners to apply for **Long-Term Practices Permits** and **Forest Practices Permits**. Any small forest landowner can apply for a Long-Term Practices Permit. The duration of the permit can range from 4-15 years and applications may contain alternate plans for all or portions of a given forestland. These permits provide regulatory flexibility and cost savings since they are specifically tailored to meet the needs of landowners who plan to manage their forests over a 4-to-15-year period. If accepted, land managed under these long-term permits must follow the long-term practices permit stipulations, thus eliminating the potential for conversion to other land uses during this time frame.

DNR also implements the **Forest Riparian Easement Program (FREP)**, a voluntary initiative that compensates small forest landowners for preserving protected areas by granting the state a 40-year conservation easement. The easement reimbursement covers up to 90 percent of the commercial value of timber required to be left unharvested due to applicable FPRs. This easement does not relinquish ownership of the property, but owners are “prohibited from cutting, removing or damaging the timber within the easement.” For the first ten years of the Forest Riparian Easement, the landowners may only sell the land within the boundaries of the easement to other small forest landowners. After the first 10 years have elapsed, there are no restrictions on who the property can be sold to; however, the easement is still in effect for the full 40 years and the restrictions on timber harvest remain. Small forestland owners are able to profit from the land conserved in the easement without having to actually go through the harvesting process. The easement also ensures that the land protected within avoids conversion for at least 40 years.

Financial Assistance for Wildfire Resilience and Forest Health (formerly known as the cost-share program) is another part of the Service Forestry program. The program provides technical and financial assistance to forestland owners in an effort to build forest resilience against insect infestation, disease, and wildfire. The program offers “free consultations to best determine wildfire and forest health risks, prioritize potential actions to take to reduce those risks, and then share in paying for the cost of treatment with qualified landowners.”⁶⁰ In this scenario the program aims to reduce conversion from environmental forces rather than anthropogenic ones by instructing small forest landowners on how to reduce environmental risk factors.

The **Family Forest Fish Passage Program (FFFPP)** provides financial and technical assistance to private and small forestland owners whose property contains a culvert associated with a road located on a fish-bearing stream.⁶¹ Program participants are provided with a project manager with technical expertise to manage all aspects of the project including engineering, permitting,

⁶⁰ Washington State Department of Natural Resources. 2025. Financial Assistance for Wildfire Resilience and Forest Health. Available [here](#).

⁶¹ Washington State Department of Natural Resources. 2025. Family Forest Fish Passage Program. Available [here](#).

contracting, and accounts. Since its inception in 2003, over 376 landowners have utilized the program to remove 433 barriers and open more than 1,149 miles of stream habitat. The landowners who participate in this program are required to maintain the fish passage in perpetuity.⁶² Under RCW 77.57.030, all dams or stream obstructions should have a durable and efficient fishway.⁶³ The FFFPP provides funding to small forest landowners to help them comply with Washington state regulations. Without support, the financial and logistical challenges, such as maintaining or replacing culverts, can place significant strain on landowners, sometimes prompting them to sell their property for development. By offering both financial assistance and technical support, the program helps make forestland management more feasible for those who may lack the resources to meet these demands on their own.

In addition to offering assistance and mechanisms to meet regulatory obligations associated with small forestland management, DNR has other programs that minimize conversion risk through permanent conservation easements and consultation to reduce environmental conversion factors.

The **Rivers and Habitat Open Space Program (RHOSP)** funds the state purchase of permanent conservation easements from forestland owners whose property contains habitat for state-listed threatened or endangered species (“critical habitat”) or channel migration zones (CMZs). Since 2002, when funding first became available, the program has protected 1,332 acres of important habitat through 26 conservation easements.⁶⁴ This program provides forestland owners with a way to ensure their land remains forested in perpetuity, which is enticing to those with strong stewardship and ecological values. Lands that enter into a permanent easement under RHOSP have zero risk of conversion to another land use.

Natural Resources Conservation Service Programs

The Natural Resource Conservation Service administers three programs that help reduce the risk of forestland conversion indirectly. While these programs do not offer long-term protection through easements or extended contracts, they provide critical technical and financial assistance to forest landowners who may lack the resources to manage their land sustainably. This support can empower landowners to continue forest stewardship rather than selling their land for development.

The **Environmental Quality Incentives Program (EQIP)** is widely regarded as the flagship conservation program of the NRCS, serving farmers, ranchers, and forest landowners. EQIP provides both technical and financial assistance to eligible participants for the development and implementation of conservation plans that address natural resource challenges and wildlife habitat concerns. EQIP conservation practices target a range of goals, including but not limited to improving water and air quality, conserving ground and surface water, enhancing soil health,

⁶² Washington State Recreation and Conservation Office. 2023. Family Forest Fish Passage Program. Available [here](#).

⁶³ Revised Code of Washington 77.57.030. Available [here](#).

⁶⁴ Washington State Department of Natural Resources. Rivers and Habitat Open Space Program. Available [here](#).

reducing erosion and sedimentation, creating or improving wildlife habitat, and building resilience to drought and increasing weather volatility.⁶⁵ The program offers technical assistance via Technical Service Providers (TSP) or Qualified Individuals (QI) for conservation activities. Financial assistance opportunities for EQIP can be provided through enrollment in specific conservation initiatives or incentive contracts. Incentive contracts have an initial length of five years and provide producers with financial assistance to adopt conservation management practices on working landscapes.⁶⁶ Although contracts may be terminated with financial penalties, the program plays a critical role in reducing land conversion risk by providing forest landowners with funding to offset the costs of sustainable land management. This financial support can be the key factor that enables landowners to continue managing their forests rather than being forced to sell or abandon forestry operations.

The **Conservation Stewardship Program (CSP)** is a national initiative with over 70 million acres of working agricultural and forest land enrolled. This voluntary program targets working lands for the enhancement of natural resources and critical habitats within their boundaries. CSP provides technical assistance and planning for “conservation activity used to treat natural resources and improve conservation performance. . . designed to maintain or exceed the quality criteria, or stewardship level, for the resource concern.”⁶⁷ Private forest landowners are eligible for this program so long as they comply with adjusted gross income (AGI) provisions and the land meets “highly erodible land and wetland conservation requirements.”⁶⁸

The **Conservation Technical Assistance Program (CTA)** “provides land users with one-on-one advice, proven conservation technologies and the delivery system needed to achieve the benefits of a healthy and productive landscape.”⁶⁹ Forest landowners are a primary demographic of CTA, given the inherent proximity to and interaction with key natural resources on forestland. The CTA provides individuals, communities, organizations, and governments with the necessary support to conserve, maintain and improve natural resources and assist decision makers in complying with environmental regulations at all levels. The CTA technical assistance typically leads to the development of conservation plans for resource management ranging from site-specific contexts to community or area-wide plans. Like EQIP and CSP, the technical and financial assistance offered through this program helps reduce conversion risk by offsetting management costs—often making the difference between continuing in forestry or selling the land.

⁶⁵ USDA Natural Resources Conservation Service. 2025. Washington – Environmental Quality Incentives Program. Available [here](#).

⁶⁶ USDA Natural Resources conservation Service. 2022. Environmental Quality Incentive Program: Conservation Incentive Contracts. Available [here](#).

⁶⁷ USDA Natural Resources Conservation Service. 2025. Washington – Conservation Stewardship Program. Available [here](#).

⁶⁸ Ibid.

⁶⁹ USDA Natural Resources Conservation Service. 2025. Conservation Technical Assistance Program: How it Works. Available [here](#).

US Forest Service and US Fish and Wildlife Service Programs

The US Forest Service and Fish and Wildlife Service (FWS) administer several programs that help reduce the risk of forestland conversion, either directly through long-term conservation easements or indirectly by providing technical and financial assistance to support sustainable land management. Each program is described below, along with an explanation of how it helps reduce the risk of forestland conversion.

The **USDA Community Forest and Open Space Conservation Program** provides a unique opportunity for communities to acquire and manage forest lands. Local governments, tribal governments, and qualified nonprofits can participate in the program. The program pays up to 50 percent of the project costs and requires a 50 percent match. Projects are chosen on a national level through a competitive application process and must provide public access.⁷⁰ In 2024 one project in Washington received funding to protect 70 acres on Whidbey Island adding to an existing 556-acre community forest managed by the Whidbey Camano Land Trust.⁷¹ With the exception of 2017, at least one project in Washington has received funds every year since 2016.

The **Forest Legacy Program (FLP)** is a federal grant program administered by the Forest Service and carried out by the Washington DNR through an interagency partnership. The program utilizes federal grants to pay for conservation easements and/or fee-simple acquisitions of forestland owners that function to remove development rights and “allows the landowner to continue long-term forestry on a property that might otherwise be sold for development.” This program takes direct action, in the form of easements, to restrict development on forestlands that would impede traditional forest uses (mainly timber industry) and negatively impact natural habitats. A Forest Legacy area map identifies areas of key interest for conservation. Applications must be within either Priority A or Priority B areas on this map to be considered for funding. Primary applicants are land trusts, conservation organizations, and large landowners.⁷²

Safe Harbor Agreements (SHAs) are voluntary agreements between private/non-federal landowners and FWS (or NOAA fisheries). Under these agreements landowners engage in actions that contribute to the recovery of listed endangered and threatened species under the Endangered Species Act (ESA). As of May 13, 2024, SHAs have been combined with Candidate Conservation Agreements with Assurances to create a single type of agreement called a Conservation Benefit Agreement (CBA).⁷³ All the stipulations for SHAs still apply in the context of CBAs. These agreements provide landowners with formal assurances from FWS that if they fulfill the conditions of the CBA, FWS will not require any additional or different management activities. This is significant because it protects participants from additional ESA restrictions if

⁷⁰ USDA Forest Service Community Forest and Open Space Program. Available [here](#).

⁷¹ USDA Forest Service Community Forest Program 2024 Funded Projects. Available

⁷² College of Forest Resources, University of Washington, “Retention of High-Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State,” March 25, 2009. Available [here](#).

⁷³ U.S. Fish and Wildlife Service. 2025. Safe Harbor Agreements. Available [here](#).

listed species later occupy their land as a result of their conservation efforts. Many agreements also come with technical guidance and cost sharing or grants. Like NRCS programs, this initiative helps ease regulatory, technical, and financial burdens that might otherwise discourage forest landowners from continuing to manage their land.

Partners for Fish and Wildlife is a voluntary federal program under FWS in partnership with other federal, state, and local agencies, soil and water conservation districts, and private conservation organizations that serve private owners of forestland, cropland, grasslands, or wetlands. This program offers free technical assistance on the restoration of endangered habitat types and their associated species, emphasizing the restoration of “degraded wetlands, native grasslands, streams, riparian areas, longleaf and bottomland hardwood forests, and other habitats to their original condition.”⁷⁴ Landowners enter into an agreement of at least 10 years with the program, committing to management activities that restore identified habitat(s) for the duration of the agreement and typically involves a dollar-for-dollar cost-share between landowners and applicable agencies associated with Partners for Fish and Wildlife. Though participating landowners can break their contract, the technical and financial assistance supplied through this program can reduce financial pressures that could lead forest landowners to abandon land management efforts.

Section 6 Land Acquisition Grants provide funds that can be used to secure, restore, and protect crucial habitat for species listed under the Endangered Species Act. The grants are awarded through a competitive process and administered by the Washington Department of Fish and Wildlife, the Department of Natural Resources and the US Fish and Wildlife Service. State and local governments, housing authorities, non-profits and tribes are eligible. A 20-30 percent non-federal match is required. Section 6 also funds the Habitat Conservation Plan (HCP) and Recovery Land Acquisition (RLA) programs.⁷⁵

Tax Credits and Reductions

In addition to the programs mentioned above, Washington State offers several tax credits and policies that help reduce the financial burden of forest land management and timber harvesting. These incentives can encourage landowners to retain their property and continue sustainable land management practices. These tax policies are detailed below.

Small harvesters (forestland owners/operators harvesting less than 2 million board feet of timber annually)⁷⁶ with forestland under FPRs can enroll in the **Forest and Fish Leave Tree Tax Credit**. To receive this tax credit, landowners must calculate taxes for forestland timber operations under RCW 84.33.074 – wherein a state excise tax is levied on the value of timber harvested. This tax credit covers revenue lost to timber that is subject to “enhanced aquatic

⁷⁴ Conservation Finance Center. 2025. Partners for Fish and Wildlife. Available [here](#).

⁷⁵ Land and Water Conservation Fund. Cooperative Endangered Species Conservation Fund- Section 6. Available [here](#).

⁷⁶ Washington State Legislature. 2004. RCW 84.33.035 Definitions. Available [here](#).

resources requirements” and therefore unable to be harvested. This tax credit helps offset the financial loss of having to leave valuable timber standing. For small landowners who harvest infrequently, this loss can be significant. The financial support makes it more likely that small forest landowners will retain ownership and continue managing their land, rather than selling it for development.

The **Designated Forest Land (DFL) Tax** is an excise tax on harvesters of timber based on the stumpage value of timber harvested or the value of the timber sold after harvest. The excise tax applies to any forestland (public or private) on which timber is harvested for sale or for commercial/industrial use.⁷⁷ The excise tax replaces the traditional sales tax in Washington, which is a higher percentage than the 5 percent DFL excise Tax. The excise tax system seeks to make the continuation of forestland ownership more desirable and support the timber and wood product industries in Washington, as well as support the recreational and ecological benefits of standing timber and forestlands.

Washington State also supports the larger **DFL program**. To qualify for this program, landowners must be growing and harvesting timber on 5+ acres of land, with no more than 10 percent of land used for incidental purposes, and they must comply with forest practice laws and regulations. Lands designated DFL pay lower property taxes. Rather than pay taxes based on the lands’ highest and best use, which is often development, they pay taxes based on its current forestry use which is typically dramatically lower. If DFL is sold and the new owner wants to use the land for another purpose, they have to pay a compensating tax to recover the deferred value. Reduced property and sales taxes provide financial support to forest landowners, increasing the likelihood that they will continue managing their land for forestry. The compensation tax can also lessen the chances of forestland conversion. However, there are several exemptions that allow for land that was previously designated as forest land to be removed from the program. While there are potential penalties for removal, those penalties are often either not enforced or are minimal compared to potential gain that may be realized from removal and subsequent conversion.

The original **Business and Occupation (B&O) tax credit** was created in 1935, establishing business excise taxes as a core revenue source. In 2007, the Washington State Legislature instituted a reduction to a range of manufacturing industries, including timber. The tax on businesses processing and/or manufacturing timber into timber products was reduced to 0.2904 percent of either the gross income of the business or the gross proceeds of sales. These tax reductions were instituted to reduce to the economic hardships that make maintaining profitable businesses in industries where this is becoming increasingly difficult, like the timber industry. Decreasing the tax on the timber industry helps make the entire supply chain viable in an industry with fluctuating prices that can result in small margins. In turn, this makes the

⁷⁷ Washington State Legislature. 2010. RCW 84.33 Timber and Forestlands. Available [here](#).

entire industry more stable, which can encourage forest landowners to continue managing their land for timber over selling to a developer for a one-time payout.

2.3. Programs and Incentives to Support Private Landowners

Our literature review identified a clear correlation between access to information and technical assistance and landowner decision making.^{78 79} More recent studies here in Washington confirm and reinforce this relationship, as did our interviews with program managers and stakeholders. Many of the programs reviewed above are specifically designed to provide support to small forest landowners. These programs are recapped below, particularly ones that are managed by DNR.

DNR provides technical and financial assistance to small forest landowners through their **Small Forest Landowners Office**.⁸⁰ Technical and financial assistance are also offered through the **Service Forestry Program**, Regulation Assistance, and related programs.⁸¹ Financial assistance programs include the **Family Forest Fish Passage Program (FFFPP)**, the **Forestry Riparian Easement Program (FREP)**, and the **Rivers and Habitat Open Space Program (RHOSP)**. The FFFPP “helps landowners replace culverts and other stream crossing structures that prevent trout, salmon, and other fish from reaching their upstream habitat”.⁸² The FREP “compensates eligible landowners in exchange for a 40-year easement agreement on qualifying timber on their property”.⁸³ The RHOSP “acquires permanent forestland conservation easements for unconfined channel migration zones and habitat that is critical for state threatened or endangered species”.⁸⁴

The **Service Forestry Program** as described in the DNR 2023 Forest Action Plan⁸⁵ offers technical and financial assistance for forest health, wildfire resilience, disease and pest management, invasive species management and removal, wildlife habitat improvement, and forest management plan creation. Initially this program served Eastern Washington but has now expanded to serve Western Washington as well. The expansion was funded by the Wildfire Response, Forest Restoration, and Community Resilience account described above. The Service

⁷⁸ M. Kilgore, S. Snyder, D. Eryilmaz et al. 2015. Assessing the Relationship Between Different Forms of Landowner Assistance and Family Forest Owner Behaviors and Intentions. *Journal of Forestry*. Available [here](#).

⁷⁹ K. Andrejczyk, B. Butler, B. Dickinson et al. 2015. Family Forest Owners’ Perceptions of Landowner Assistance Programs in the USA: a Qualitative Exploration of Program Impacts on Behavior. *Journal of Small-Scale Forestry*. Available [here](#).

⁸⁰ “DNR’s Watershed Resilience Action Plan by Washington State Department of Natural Resources - Issue,” February 6, 2022.

⁸¹ Ibid.

⁸² “Small Forest Landowner Office | WA - DNR.”

⁸³ Ibid.

⁸⁴ Ibid

⁸⁵ Lawson et al., “Forest Action Plan Annual Report.”

Forestry Program includes a financial assistance program to help offset the cost of certain management activities. These management activities help improve forest health and reduce the risk of damage from wildfire and insect infestation. The program covers two separate project categories that are eligible for financial assistance: forest health improvement and wildfire hazard reduction practices, and forest stewardship plans. Landowners can receive funding for up to 50 percent of the cost of practices including brush control, thinning, pruning, and tree planting. In 2022, the first year the program was available in Western Washington, the financial assistance program assisted 98 projects covering 964 acres of completed treatments.⁸⁶ The increased funding also supported increased staffing and introduced a financial assistance program in Western Washington. There are several programs offered within this larger program, some of which are regional. For example, the Southeast Region's Forest Resilience Program has recently instituted a wildfire mitigation project. The newly instituted service foresters and service forestry specialists provided technical assistance to landowners and conducted over 400 site visits in the first year of expansion, 2022.⁸⁷

The DNR Small Forest Landowner office provides funding incentives via the Family Forest Fish Passage Program (FFFPP) and the Forestry Riparian Easement Program (FREP).⁸⁸ FFFPP and FREP were created in the early 2000s to partly compensate for lost timber value as a result of the passage of the Forest and Fish agreement in 1999.⁸⁹ These programs provide incentives for landowners to participate in practices that benefit threatened and endangered species and improve forest health.⁹⁰ The FFFPP assists small forest landowners in removing stream barriers that keep fish from reaching upstream habitat. Since 2003, over 375 landowners have utilized the program to remove 433 barriers and open more than 1,149 miles of stream habitat.⁹¹ FREP is another voluntary program that reimburses small forest landowners 90 percent of the value of trees they are required to leave along streambanks to protect fish habitat in a 40-year conservation easement.⁹² Both programs support forest health by protecting streams, which provide habitat to critical species and soil moisture necessary to support forest systems.

⁸⁶ Lawson et al., "Forest Action Plan Annual Report."

⁸⁷ Ibid.

⁸⁸ Washington State Department of Natural Resources, "DNR's Watershed Resilience Action Plan by Washington State Department of Natural Resources - Issue," February 6, 2022.

⁸⁹ "Preventing Forest Conversion," July 26, 2024.

⁹⁰ College of Forest Resources, University of Washington, "Retention of High-Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State," March 25, 2009.

⁹¹ "Family Forest Fish Passage Program | WA - DNR."

⁹² "Forestry Riparian Easement Program | WA - DNR."

3. Stakeholder Interviews, Listening Sessions, and Workshops

Interviews were conducted and listening sessions were held with DNR staff, representatives from partner organizations and agencies, and other stakeholders in order to refine the understanding of drivers of conversion risk and to provide detail and local context to the literature and program reviews. In addition to stakeholder interviews at the outset of the project, two workshops were held so that stakeholders could provide input to the development of the model and the analysis tools.

In partnership with DNR, the team identified seventeen agencies and organizations (or categories of organizations) to be engaged as listed in Table 2 below. Selected Representatives from these same groups were also invited to participate in the workshops.

Table 2. Organizations, Programs, and Partners

State Agencies, Departments, and Programs	
Department of Natural Resources	
	Forest Legacy Program
	Small Forest Landowner Office
	Forest Health and Resilience Team
	Natural Heritage Program
	Watershed Resilience Action Plan- Snohomish
Puget Sound Partnership	Indicators Development Team
Department of Commerce	
	Zoning Atlas
	Forest Products Roundtable
Department of Fish and Wildlife	Riparian Data Engine Team
Recreation and Conservation Office	Community Forest and Forest Land Easement Program Teams
Land Trusts and Community Partners	
	Northwest Community Forest Coalition
	Land Trust Alliance
	Washington Association of Land Trusts
	Washington Farm Forest Association
	Cascades to Coast Landscape Cooperative
	Trust for Public Lands

State Agencies, Departments, and Programs	
	Jefferson Land Trust
	Inland Northwest Land Conservancy
	Forterra
	Columbia Land Trust
Other Entities	
	Puget Sound Regional Council
	King County Conservation Program
	University of Washington Natural Resource Climate Impacts Group

Ten interview sessions were held, some with multiple participants. Participants were asked to identify the top three drivers of conversion risk as well as the top three tools, resources, or programs available to mitigate those drivers. The discussions also explored whether there were differences between Eastern and Western Washington. Participants were also asked to reflect on programs that they directly managed, with particular emphasis on what contributed to program effectiveness and what could be done to increase success. Finally, participants were asked whether there were programs or interventions that they were aware of, that might be effective in Washington but might not be currently available. Results of these engagements were collated in spreadsheet format and used by the project team to inform the development of the input variables for the model and the development of the analysis tools. Key findings from these conversations are summarized in the section below.

3.1. Stakeholder and Program Staff Interview Findings

The findings from the interviews conducted are grouped below into first identifying the drivers of conversion risk and then identifying and assessing the programs and tools designed to mitigate conversion.

Drivers of Conversion Risk

As noted in the literature review, there are multiple studies that identify potential drivers of conversion risk. The initial framing of the research identified population growth, climate, and supply chain dynamics as key drivers of risk. Our goal as a research team was to confirm these as key drivers and to determine, from the perspective of the interviewees, whether there were other drivers that were as, or more important, based on their experience.

Population Growth, Housing Demand, and Land Values

Population growth is frequently cited in the literature as a key driver and was identified as a driver in the framing of the original research. Our interviewees did not identify population

growth itself as a distinct driver, but rather focused on the impacts of population growth- on land values in general, and in particular the relationship between population growth and housing demand in areas where land is scarce and housing stock is limited. Interviewees focused on escalation of land values, particularly in peri-urban urban areas as a key driver or incentive. This was perceived to be more of a problem on the western side of the state. One interviewee identified proximity to previously rural areas adjacent to urban centers that were experiencing population influx (the area around the city of Duvall in King County specifically) as an example of where real estate values and suburbanization development were impacting land values and landowner decisions.

A sub-set of interviewees specifically focused on larger tracts owned by investment consortia, rather than individual private landowners, as being more vulnerable to development induced conversion pressures. This is likely due to the fact that landowners made up of shareholders and investors would be more likely to weigh profit higher than stewardship or other non-monetary returns.

Climate Change

Climate change was framed as a potential driver in the original research question. Many of the stakeholders interviewed for this project also mentioned climate change as an important driver of forest conversion in Washington state. However, in our interviews climate change was framed not as a direct driver but rather interviewees noted the impacts of climate change as a contributing factor. Again, mainly through the impacts of climate change on management requirements and increased vulnerability of loss due to pest, disease, or wildfire.

Supply Chain Dynamics

A third aspect of conversion risk that was identified in the initial research framing related to supply chain dynamics. None of the interviewees proactively identified supply chain dynamics as a driver. However, when promoted, only two stakeholders specifically discussed supply chain dynamics as part of the conversion risk equation, although they did not directly identify them as drivers of conversion risk per se. In one conversation it was noted that the management and harvest activities associated with a forest parcel that is being managed for conservation or preservation are not the same as those associated with the industrial forest model. The volume of wood coming from these parcels will never provide the volume of board feet needed to sustain a commercial mill.

Landowner Demographics

In addition to the three drivers originally framed in the research question, our interviewees identified a fourth factor for consideration. Several of the agency stakeholders interviewed as well as representatives from land trusts identified changes in the demographics of land ownership as a driver of conversion risk based on their interactions with landowners.

While there is significant data in the literature documenting this relationship in other geographic regions,^{93 94} most of the data available for Washington is anecdotal. A 2021 study found that between 25,000 and 50,000 small forest landowners indicated an intention to sell or give away some or all of their forest land in the next ten years but did not specifically identify whether demographics factored into those decisions.⁹⁵ Similarly, the 2020 report “Washington’s Small Forest Landowners in 2020” identified family circumstances and financial need as drivers of conversion risk, but did not establish direct correlation between age or other demographic factors and conversion risk.⁹⁶

From the experience of interviewees, family circumstances and financial need have played a role in sale decisions that could lead to conversion. One interviewee shared the experience of a landowner needing ready cash to address unanticipated medical expenses choosing to sell rather than use the land as collateral to assume debt to finance the expense. This decision was also tied to landowner age and the low probability that they would be able to continue to manage the land as forest going forward.

A second aspect of changing owner dynamics that was mentioned in the interviews was related to landowner awareness and understanding. New owners (whether through purchase or inheritance) who may be younger and who may not have direct experience managing working forest lands may be overwhelmed by the management challenges. These new or younger owners may also be unaware of and ultimately overwhelmed by regulations and management requirements.

Programs and Policies to Mitigate Risk

In addition to identifying and prioritizing drivers of conversion risk, interviewees were asked about the effectiveness of their own programs and whether they had any ideas about programs and approaches that could be developed. Interviewees identified programs that educate and support landowners as critical, like the Forest Riparian Easement and Family Forest Fish Passage programs. Interviewees also cited the importance of the work of the Small Forest Landowner Office.

When asked about innovative solutions that are not yet active, two were identified. In addition to the influence of land values and real estate market gains on a landowner’s decision to convert holdings out of working forest, increasing land values were also seen as having a significant impact on the ability of land trusts and other partners to acquire lands that are at risk in order to prevent conversion. Several stakeholders cited the inability of land trusts and community groups to quickly access or amass the necessary cash to offer competitive bids for

⁹³ Markowski-Lindsay. P. Catanzaro. A. Milman, D. Kittredge. 2016. Understanding Family Forest Land Future Ownership and Use: Exploring Conservation Bequest Motivations. *Journal of Small-Scale Forestry*. Available [here](#).

⁹⁴ Nana Tian, M. Pelkki. 2021. Nonindustrial private forest landowner perspectives on forest certification: A look at awareness and Barriers. *Forest Policy and Economics*. Available [here](#).

⁹⁵ Analyzing State Regulatory Impact on Small Forestland Owners. 2021. NRSIG. Available [here](#).

⁹⁶ Sergey Rabotyagov, et. al. 2020. Pg 27.

lands at risk of being sold as a limiting factor. Furthermore, many acquisition programs utilize the “Uniform Appraisal Standards for Federal Land Acquisitions” or “yellow book” value to assess land value and are not allowed to pay more than that for a parcel. Whereas a developer sees, and will pay for, the unrealized potential value of the land, making it difficult, if not impossible for conservationists to compete. These interviewees identified the need to create some type of “quick access” fund or revolving loan fund that would allow land trusts and community groups to be more proactive in making competitive offers for parcels at risk.

Thinking about landowners’ need for ready cash as a driver of conversion, one stakeholder suggested the idea of “forward contracts” and advance payments as a way to guarantee income for landowners and land managers and also help mills anticipate processing volume. As explained, community forests or other lands managed with a conservation or preservation objective face a double bind in that they are perpetually short of cash and because of longer harvest rotations are unable to sell timber to generate revenue. Mills faced with uncertainty as they often cannot predict when, or at what volume, harvesting will occur. They are additionally vulnerable because larger commercial operations are able to time the market and can delay harvests until market prices are favorable. A forward contract mechanism between a community forest (for example) and a mill, guaranteeing timing and supply of timber, with a portion of the proceeds paid up front, would simultaneously generate immediate revenue for the community forest and smooth out the unpredictability for a mill. This concept requires further exploration, and there are many details that would need to be developed, but this is one example of a creative solution that could generate multiple benefits.

3.2. Prioritization Workshops

Two workshops were held to give stakeholders an opportunity to provide input into the development of the modeling approach and the assessment tools.

The first workshop focused on presenting the findings from the literature review and interviews and linking those to development of the model. Participants were introduced to two different modeling approaches and invited to explore a number of different potential input variables to the models. The concept of using overlay layers to depict assets (salmon habitat, water quality etc.) that would be at risk if conversion occurred was also introduced. The results and recommendations from the workshop are integrated into the discussion Chapter 4.

The second workshop focused on the analysis tool themselves and how the overlay layers can be used to identify areas at risk for conversion as well as the associated factors at risk should conversion take place. A final aspect of the tool allows the user to identify potential policy or program interventions that could be used to mitigate conversion risk. These tools and their use are discussed in detail in Chapters 5 and 6.

Participant lists and presentation slides for both workshops are included in Appendix B.

4. Modeling Conversion Risk

This chapter covers the entire process of developing a model of forest conversion risk. Each step is addressed in a subsection starting with an overview of the modeling approach, then describing the GIS database, then defining the dependent variable (the variable which we are trying to predict, in this case conversion from forest land), and independent variables (those which are used to predict the dependent variable), then moving through two separate models and the results from each and comparing them. Some general observations conclude this chapter.

4.1. General approach to Modeling

This project seeks to assess two sources of change to private forest lands: 1) urbanization and 2) climate-induced ecosystem change of forests to non-forest types (e.g., sage-steppe), either by direct forest die-off or climate-induced extreme fire. Agricultural expansion is recognized as a potentially important driver of forest change but is not modeled here due to data limitations.

Our analysis of climate-driven risk of forest conversion consisted simply of overlaying private parcels with WA DNR's "trailing edge" data set, which depicts the risk of forest type conversion due to changing climate on a scale of 1-3 and is described in detail in Meigs et al. (2022). The procedure involved taking zonal averages of trailing edge pixels by parcels and converting them to a score of 1-3. A map of this score is shown in Figure 3.

The remainder of our modeling analysis described in this section relates to urbanization. Here we define urbanization as conversion due to the construction of new buildings and infrastructure. Conversion of forests leads to numerous potential impacts which are described fully in section 5 of this report.

The remainder of this section details work on modeling conversion risk due to urbanization. This modeling works by quantifying factors that either drive or constrain urban development (legally, economically, or physically) and statistically relating these factors to actual observed land development. Examples of these factors are listed in the green area of Figure 2, but the specific variables tested are discussed in section 4.4. By looking at statistical relationships between past urbanization and various predictor variables, we could use those same variables to estimate which parcels are most at risk from future urbanization. The results of this modeling are then used to predict the probability of development for each parcel given the specific input values for each parcel.

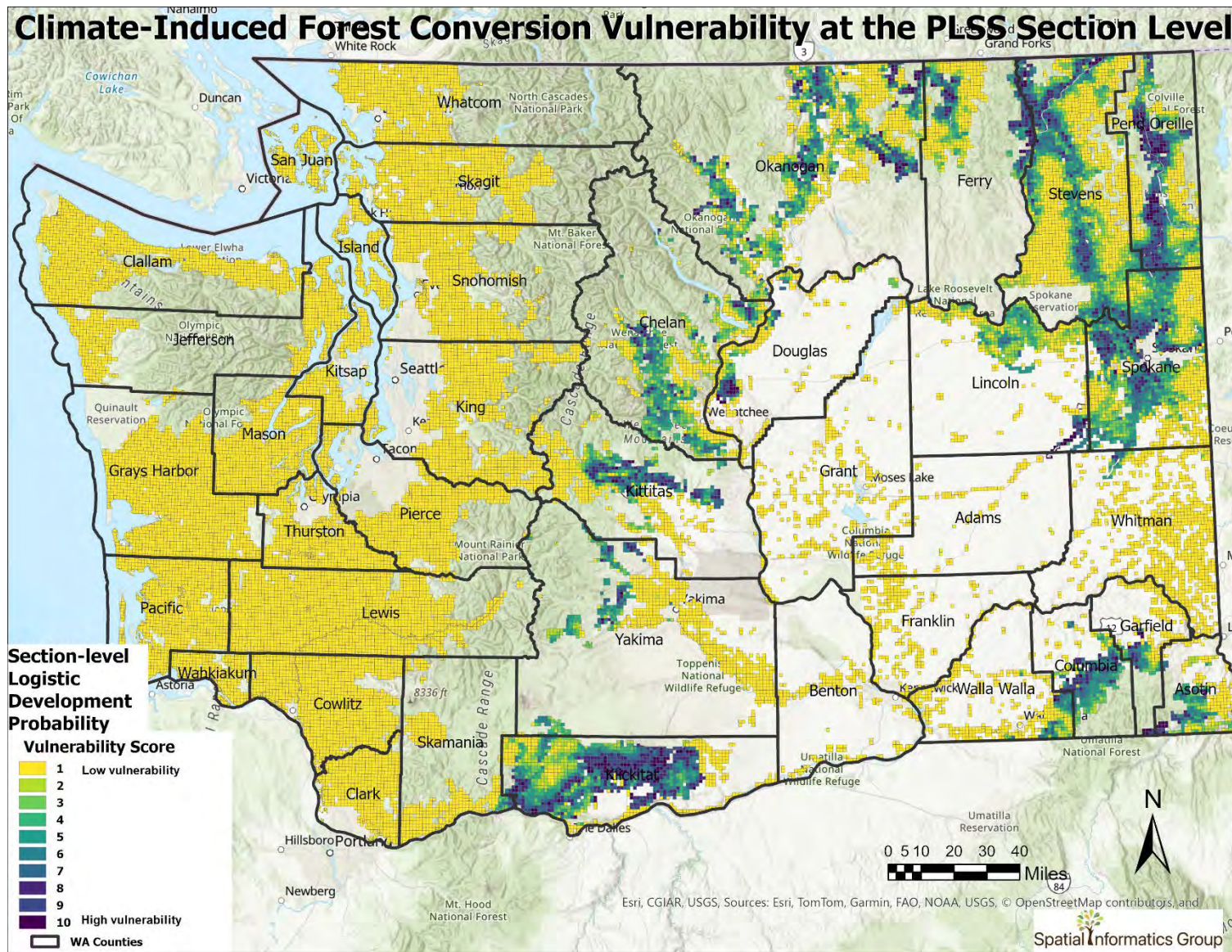


Figure 3. Climate Induced Forest Conversion Vulnerability at the PLSS Section Level

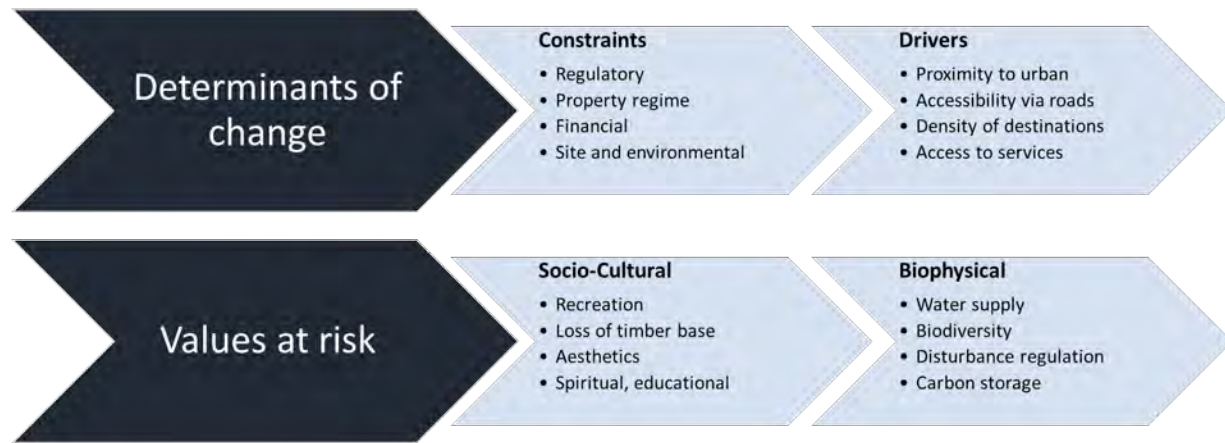


Figure 4. Conceptual Framework for Understanding Urban Change Drivers of Conversion Risk

Spatial Informatics Group initially ran two types of statistical models to predict the probability of urbanization: logistic regression and Decision Tree modeling. In both cases, the dependent variable takes a value of 1 or 0 to represent change due to urbanization and no change, respectively. This means that we do not account for the extent of development in a parcel, which would be statistically infeasible given the limited number of observable development events in the data set. Logistic regression is a method used to predict the probability of an outcome that can only have two possible values, such as yes/no or success/failure. It works by finding a relationship between any number of predictor variables and the likelihood of a particular outcome. Instead of giving a straight line like regular regression, it produces an "S"-shaped curve to estimate probabilities. Decision Tree analysis is a different approach that was used for comparative purposes. Decision Tree models are a supervised machine learning method used for both classification and regression tasks. They operate by recursively partitioning the data into subsets based on feature values (defined by break values in the predictor variables), forming a tree-like structure where each internal node represents a decision based on a feature, and each leaf node represents a predicted outcome. The model selects splits using statistical measures such as Gini impurity, entropy, or variance reduction, optimizing the separation of classes or the reduction of prediction error.

The second part of the decision context then hinges on whether, and to what extent, a particular intervention is effective in mitigating a conversion driver or increasing a constraint (Figure 2). Drivers are things that are likely to contribute to conversion risk and include: Land Use/Land Cover, Proximity to Infrastructure, Accessibility to Services, and Ownership. Constraints are variables that are likely to inhibit conversion and include: Physical Constraints (soil suitability, slope etc.), Flood Zone Proximity and Regulatory Zoning. The interventions then become the other criteria that will be matched with the drivers.

Once both models were run and statistical coefficients estimated, we then extrapolated which parcels were most likely to be subject to urbanization based on model coefficients and parcel characteristics. We also compared outputs between the two methods. Even though it was not as strong on the eastern side of the state, the Decision Tree had a better validated accuracy than the logistic model (86% accuracy, which is high for this kind of statewide model) which meant that it was considerably more accurate in the west. After assessing the accuracy of the two approaches and visually reviewing their spatial prediction patterns in different regions of the state, we chose to average the probabilities of the two models. Averaging the two gives results that capture the best of both and gives results that look more realistic.

Parcel development probabilities were later upscaled to the Public Land Survey System Section (PLSS) level and converted to a 1-10 score, using the natural breaks classification method. The PLSS map was then uploaded to ArcGIS online and an online app was created allowing users to query for the parcels with development probabilities higher than a user-specified threshold as well as other “overlay” scores” (as described in section 5 below), representing values of concern, such as biodiversity/habitat, importance for water supply or contribution to the local forest industry. This query tool therefore enables stakeholders to identify candidate parcels for conservation based on both risk of conversion and ecological or socio-economic importance.

4.2. Creating A Filtered Parcel Layer

This dataset was created by combining the NRSIG 2019 Washington State Forestland Database (provided to us by University of Washington NRSIG lab) with the state parcel database available from the WA State Geospatial Open Data Portal. They needed to be combined for several Reasons. The NRSIG layer only included parcels that had a previous Forest Practices application and there were many forested parcels that had not submitted such an application but are still reasonable candidates for forest conversion. However, the NRSIG layer did have numerous important variables that were not in the state-supplied parcel layer. Furthermore, Ferry County was included in the NRSIG layer but not the state layer.

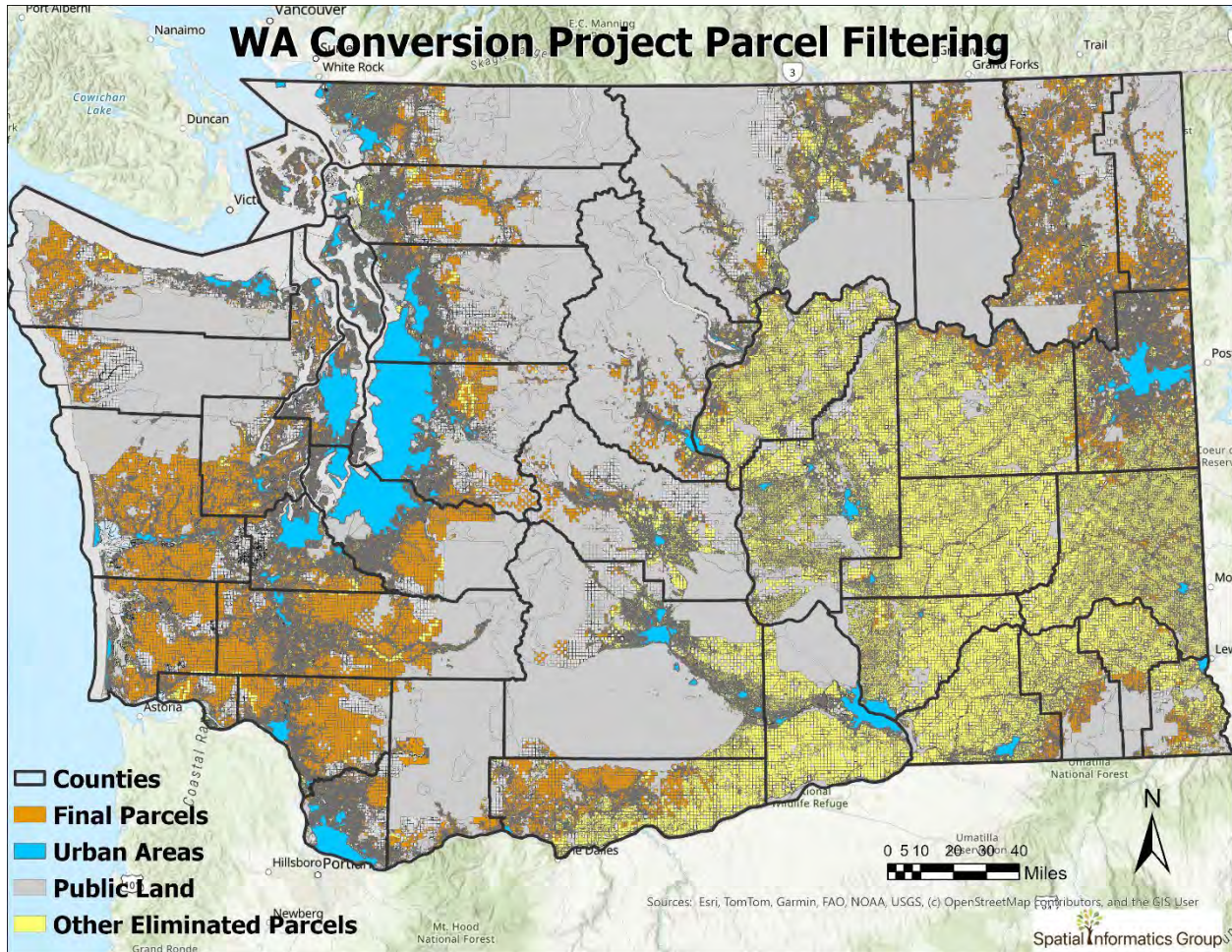


Figure 5. Parcel Filtering

Our intent was to include only parcels that are in private ownership, larger than an acre, and part of a tract (group of parcels of common ownership) that is larger than five acres (if it is part of a tract). Public lands were not included as we assume the vast majority of public forestlands are not at risk of development and conversion to non-forest uses. The filtering resulted in about 700,000 parcels remaining of the original 3+ million.

Upon looking at the remaining parcels, we found that it included many with no forest, or next to no forest, with both agricultural and residential sites still in the dataset. Therefore, we added another filter based on forest cover. We initially used the USGS National Land Cover Dataset Tree Canopy layer for filtering, but after close review it was determined that it incorrectly characterized many row crop lands as forests. Therefore, we switched to a different forest cover product, Landfire, created by a consortium composed of the US Department of Agriculture and US Department of Interior. We queried for all pixels with any of their designated forest types and converted that query to a 1/0 layer from which forest area by parcel could be calculated. Our next step was to query for parcels with less than one acre of

forest and drop those. At the end of this process, we had approximately 273,000 parcels remaining.

A final filter was based on urban areas. This analysis focuses on conversion risk to forestlands outside of urban cores. Urban parcels are typically smaller in size and surrounded by existing development, making it difficult to manage these parcels as working forests. By identifying and eliminating parcels in Census-designated urban areas, the final total number of parcels included in this analysis was reduced to 240,740 parcels, representing 10,099,740 acres. Figure 5 shows a color-coded map of parcel selection with the final parcels (orange) juxtaposed with areas that were dropped due to being public land (grey), urban areas (blue) or for other reasons, like lack of forest cover or parcel size (yellow).

4.3. Generating the Dependent Variable

The dependent variable was characterized using the Washington Department of Fish and Wildlife High Resolution Change Detection (HRCDD) database, which used remote sensing imagery to characterize land change between 2011 and 2017 (and up to 2021 for some locations). This layer includes many types of change, so we have selected only the polygons representing change due to urbanization. Those polygons were converted to raster pixels, and the area of land use change was then summarized by parcel using the “zonal statistics” function, along with the percent area that was changed.

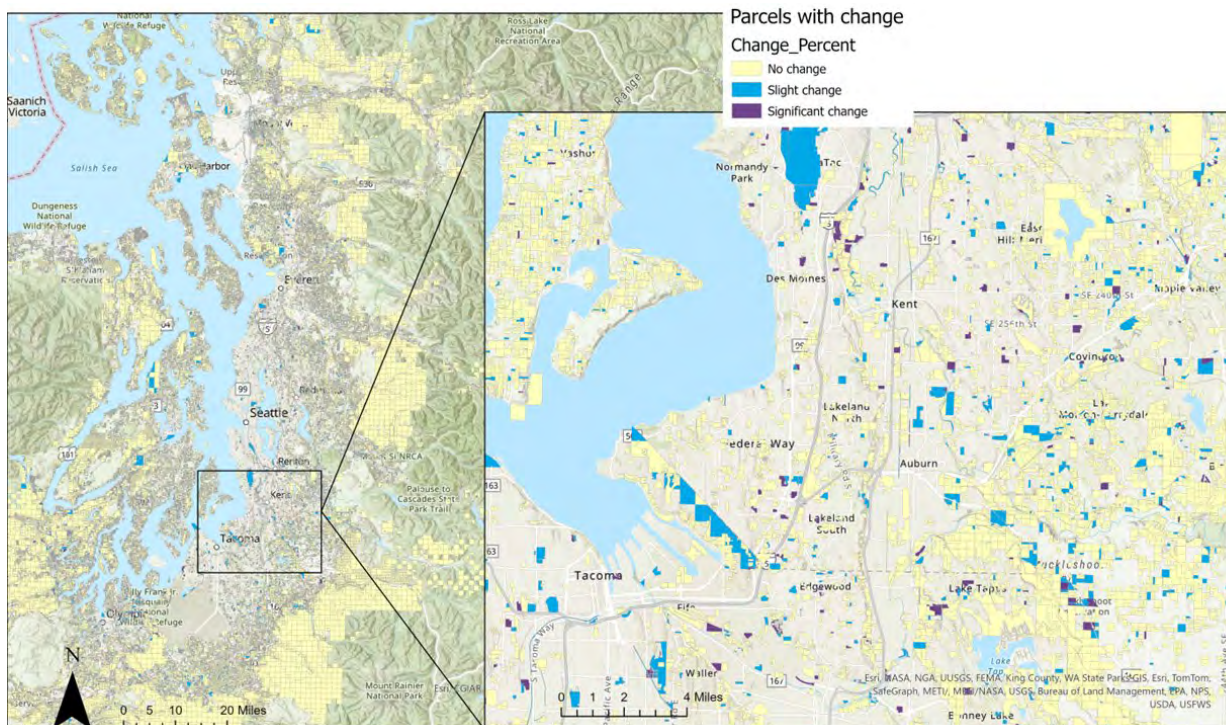


Figure 6. Historic Change Due to Urbanization by Parcel

The following table gives the breakdown of parcels with observed change in our filtered dataset.

Table 3. Breakdown of Parcels by Land Use Change Category

Category	Percent	Count
No Change	93.5	224,978
Change	6.5	15,762
Total		240,740

4.4. Generating Independent Variables

Our team conducted an extensive assessment of drivers of land use conversion, based on conversation/interviews with personnel from DNR and University of Washington and on a review of the literature and of past models of regional significance. A key reference for us was the University of Washington School of Environmental and Forest Science report, *Washington's Small Forest Landowners in 2020*, which included the statistical results from a forest landowner conversion model. This model used logistic regression to determine which independent variables were associated with conversion from private forestland to development. While we found this to be an impressive model, our literature review indicated that it could be improved upon. First, it lacked several important site-level constraint variables that have been found to be highly predictive in land use change modeling, such as soil type, flood plains, and steep slopes, among others. Second, we felt that the NRSIG variables used for representing development proximity and pressure could be operationalized in a way that would be more predictive. Third, the authors themselves admitted in the report that their land use change model performed relatively poorly. Hence, while we used some of the predictor variables from their model, we also used many new ones. Many of these variables required extensive spatial analysis to build, in some cases requiring automation routines. Detailed methods for each variable can be provided upon request. One example of a variable that was added based on the recommendation of interviews with DNR personnel was a “dummy variable” representing parcels located in municipalities that had been transferred regulatory authority for forest practices from the state. Put differently, this means that a municipality has entered into an agreement with the state to take responsibility for enforcement and monitoring of forest practice regulations on private land, including those related to construction. It is considered possible that many of these municipal jurisdictions might enforce building restrictions in sensitive areas, such as riparian buffers, less rigorously than the state. This variable, “TransferCity,” initially had 4,124 of the total observations (1.6%) coded as having this trait. However, when the Census urbanized areas were eliminated from the dataset, that number declined to only 143, since the vast majority of transfer jurisdictions are in urban areas. However, we still kept the variable. A complete list of the 31 variables tested and the 11 chosen for analysis (15 in the case of decision tree) is given in Table 4, along with a description of each.

Variables that were ultimately included have the letter “Y” in the “Included” column. Variables that were in the decision tree, but not the logistic regression are marked “LR: N, DT: Y”

Table 4 Variables Tested in Logistic Regression

Name	Included	Description
NearUGB	Y	Proximity to urban growth boundary (unit= km)
ForestAreaPer	Y	Percent of forested land in parcel
BuffPctWet	Y	% area forest practice regulatory buffers: wetland
RoadLength	Y	Parcel road extent (unit= km)
MedHomeVal	Y	Block group median house value (unit= \$10,000)
SoilDrain	Y	Soils: maximum drainage class per parcel
SlopeMin	Y	Minimum percent slope on parcel
D2Clusters	Y	Distance to nearest business cluster (km)
BldgAreaSum	Y	Area of buildings within 20km buffer (unit= sq km)
TransferCity	Y	In forest practices “regulatory transfer” municipality
FloodPct	Y	% of parcel in 100-year flood plain
BusinessCount10k	LR: N DT: Y	Count of businesses within 10km radius
BusinessCount20k	LR: N DT: Y	Count of businesses within 20km radius
X	LR: N DT: Y	Longitude (degrees)
Y	LR: N DT: Y	Latitude (degrees)
BuffAreaInner	N	Area forest practice riparian regulatory buffers: inner (per hectare)
ForestHarvSum	N	Area of forest harvest activity (unit= hectare)
BuffAreaCore	N	Area forest practice riparian regulatory buffers: core (per hectare)
SoilSubsid	N	Soils: in subsidence zone (% area)
D2Highway	N	Distance to divided highway (per km)
RoadD	N	Parcel Road density (km per hectare)
MedInc	N	Block group income (per thousand \$)
PopD	N	Block group population density
MedAge	N	Block group median age
PopDCh	N	Block group pop density change
Soilerod	N	Soils: erodibility factor

Name	Included	Description
SoilD2WT	N	Soils: depth to water table
Employ	N	Employers/retail within drive time service area ()
Landslide	N	In landslide zone
WaterServ	N	In water service area
BuffAreaOuter	N	Area forest practice riparian regulatory buffers: outer (unit= hectare)
ParcSize	N	Parcel size (per hectare)

4.5. Sampling the Data

We trained our models on a subset of the total population of parcels, consisting of 89,316 observations, and validated our model results on a second separate subset consisting of 22,329 observations. We oversampled observations in which development occurred such that all parcels in which development occurred were included for either the training or validation data sets. The remainder of the observations (parcels with no change) for each subset were sampled at random. The oversampling of parcels that experience development was done to offset the disproportionately large number of parcels with “0” values for the development indicator, relative to values of “1”, thus achieving more balance in the variable effect sizes for our models. This statistical balance was critical for the performance of the dependent variable. Specifically, 80% of the total parcels with a dependent variable value of 1 were sampled in the training dataset (17,868), with the remaining 20 percent (4,467 observations) allocated to the validation dataset. The number parcels with a dependent variable value of “1” designated for the training dataset (17,868), was then multiplied by four to determine the remaining number of training sample observations with a “0” value for the dependent, yielding 71,472 parcels without development, for a total sum of 89,340. A binary dependent variable with a ratio of four “0” values to every “1” is considered an acceptable distribution of data for logistic regression according to the literature. Similarly, for the validation data set, the 4,466 observations with a dependent variable value of 1 were paired with four times that number of parcels with values of zero (17,868), yielding 22,335 validation observations.

4.6. Choosing Significant Variables: Logistic Regression

Of the predictor variables mentioned above in Table 2, most were dropped for our final model (see column entitled “included?”). This is because some were statistically insignificant and others were highly “multi-collinear,” meaning they were too similar to each other to be included simultaneously within the same model. Exploratory Data Analysis (EDA) techniques were applied to understand the relationships, patterns, and structures in the data, making it easier to select and prioritize variables. Spearman’s rank correlation test was used to generate correlations among predictor variables. This helped in identifying redundant variables that were highly correlated, allowing an opportunity to filter them to prevent multi-collinearity in later

models. Then univariate logistic regression was used to test each independent variable against the binomial dependent variable within its own individual model (on request we also can provide a table of univariate measures of correlation between each independent variable and the dependent variable).

A multiple logistic regression model should first be built using all candidate predictors to evaluate their joint effect. After fitting the full model, the output is reviewed for insignificant predictors (high p-values) or multicollinearity among them, as indicated by high variance inflation factors (VIFs). Next, systematic stepwise selection is done to eliminate unimportant predictors from inclusion in future models and determine the multivariate model with the best fit. Threshold filtering was used to select key independent variables based on p-values < 0.05 . This approach was compared to a meta-model approach where the predicted probability of forest conversion for a given parcel is computed using the model-averaged coefficients. This incorporates model uncertainty into predictions by weighting contributions from all models, ensuring predictions are not overly reliant on any single model. However, this meta-modeling approach was ultimately not used.

Two approaches were tested for the logistic regression: weighted and unweighted. The former weights observations proportional to the rate that they were sampled, which is relevant in our case given that we oversampled observations with change (and to a lesser extent, those in transfer cities). Therefore, observations with change would get less weight. There are statistical pros and cons to taking this approach, and there is no clear guidance as to whether it is the best approach in this particular application, hence the need to compare them.

The primary differences in the assumptions for logistic regression compared to traditional linear regression include: no required normality of residuals; no required homoscedasticity; and nonlinear relationships are allowed between the independent and dependent variables. One advantage of rare events (weighted) logistic regression is that it corrects for imbalanced data, by using the sample proportions. Ultimately, after comparing the outputs of both logistic regression approaches with the decision tree outputs, we chose to use the unweighted model. Although not in this report, weighted results are available and can be seen upon request.

Cross-validation and confusion matrices were used to evaluate model accuracy, using the reserved validation data set. This method simply solves the logistic regression equation for the reserved observations and records how many correct predictions were made.

4.7. Choosing Significant Variables: Decision Tree

Decision tree models can incorporate variables even if they are correlated. But to be able to directly compare two models, we started with the variables that were chosen for the logistic regression and then added a few additional variables that showed considerable importance for the decision tree model (but were not suited to the logistic regression), including latitude, longitude, and count of businesses within 20 km.

4.8. Logistic Regression Results

The final model strikes a good balance between having enough explanatory variables to capture the underlying relationships in the data while avoiding issues like overspecification and multicollinearity. The Residual Deviance (70,464) is lower than the Null Deviance (89,387), showing the model has acceptable fit. Accuracy of 84 percent, as shown in the confusion matrix in Table 5, demonstrates reasonable predictive power for a complex socio-ecological system. Sensitivity of 28 percent is low and suggests the model has a limited ability to distinguish the true positives. Specificity of 98 percent is very high, indicating the model captures the majority of the true negatives. These values are typical for an imbalanced dataset.

Table 6 presents the coefficients for each variable along with the significance (p values), the exponentiated “odds ratios” and then the “ Δ Odds of Conversion” which essentially shows the marginal increase or decrease in the probability of a development event given a one unit increase in that variable. To interpret this, it is critical to consult the units of measurement in the column to the right. All variables listed in Table 6 are statistically significant, with p-values approaching zero, indicating strong evidence that they are statistically significant as predictors of the outcome variable. Table 7 gives a unitless way to compare the strength of marginal effects of each variable (effect sizes) by showing the coefficient of each variable multiplied by the mean value of that variable.

The retained variables have variance inflation factors (VIFs) below 5, suggesting no severe multicollinearity and absence of significant redundancy which could otherwise bias model results and interpretations. The model captures sufficient complexity (diverse predictors such as geography, land use, and socioeconomics) without introducing too much noise or instability.

Table 5. Logistic Regression Confusion (Accuracy) Matrix:

	Reference	
Prediction	0	1
0	17511	3218
1	352	1248
	Accuracy	0.8401
	Sensitivity (recall)	0.2794
	Specificity	0.9803
	Detection Rate	0.0559
	Balanced Accuracy	0.6299

Table 6. Unweighted Logistic Regression Results Summary

Predictor Variable	B	Sig (p)	Exp(B)	Δ Odds of Conversion	Per unit
ForestAreaPer	-0.0034132	0	0.996593	-0.3407%	% area
NEARUGB	-0.0416622	0	0.959194	-4.0806%	KM
RoadLength	0.1883985	0	1.207314	20.7314%	KM
BuffPctWet	-0.0160802	0	0.984048	-1.5952%	% area
SoilDrain	0.2169717	0	1.242309	24.2309%	arbitrary
BldgAreaSum	0.0186691	0	1.018844441	1.88444%	square KM
D2Clusters	-0.0000345	0	0.999965	-0.0035%	M
FloodPct	-0.0059758	0	0.994042	-0.5958%	% area
MedHomeVal	0.0132439	0	1.013332	1.3332%	per \$10000
SlopeMin	-0.0918679	0	0.912226	-8.7774%	degrees
TransferCity	0.8570876	0	2.356288	135.6288%	yes/no

Table 7. Unitless Effect Sizes of Variables

Predictor Variable	Product: coefficient x mean
ForestAreaPer	-0.2261
NEARUGB	-0.2766
RoadLength	0.0921
BuffPctWet	-0.0228
SoilDrain	0.6531
BldgAreaSum	0.2515
D2Clusters	-0.5421
FloodPct	-0.0255
MedHomeVal	0.5565
SlopeMin	-0.1314
TransferCity	0.0137

4.9. Mapping Development Probability Predictions from the Logistic Regression

After the most important independent variables were identified by the previous processes, the resulting regression equation was applied to the original dataset of 240,740 parcels to predict the probability that each parcel would change in a future period roughly equivalent to the

period over which the historic change used to parameterize the dependent variable was observed. This yielded a predicted probability value for each parcel ranging from 0 to 1. After these were mapped, we summarized risk scores by county using the mean score, the median score and sum of scores (Table 8). The mean represents the average development probability across all included parcels in the county, which provides an indication of the general likelihood of conversion risk in the county, independent of the number of parcels in the county. The sum of scores, on the other hand, provides an indication of the extent or amount of parcels subject to development pressure. So, for instance, a high mean and a high sum indicate that not only do parcels in that county, on average, face a high probability of development, but the number of parcels affected is high. By contrast, a high mean and a low sum would indicate a county where development probability is high on average, but there simply are not many parcels included in the county.

Table 8. Summary Of Risk Scores by County

County	Logistic Regression		Decision Tree		Average	
	Mean	Sum	Mean	Sum	Mean	Sum
Adams	0.116	14	0	-	0.058	7
Asotin	0.025	24	0.001	1	0.013	12
Benton	0.123	46	0.005	3	0.064	24
Chelan	0.123	401	0.126	570	0.125	485
Clallam	0.082	699	0.099	937	0.09	818
Clark	0.187	1,480	0.214	1,856	0.2	1,668
Columbia	0.076	68	0.094	83	0.085	75
Cowlitz	0.087	754	0.117	1,293	0.102	1,024
Douglas	0.134	119	0.014	14	0.074	67
Ferry	0.064	443	0.001	1	0.032	222
Franklin	0.112	27	0.01	3	0.061	15
Garfield	0.032	10	0.068	19	0.05	15
Grant	0.09	33	0.007	0	0.049	17
Grays Harbor	0.128	767	0.119	1,002	0.124	885
Island	0.208	778	0.224	915	0.216	846
Jefferson	0.111	411	0.14	600	0.126	506
King	0.229	2,524	0.15	1,761	0.19	2,143
Kitsap	0.242	1,000	0.271	1,117	0.257	1,059
Kittitas	0.124	460	0.151	761	0.138	611
Klickitat	0.05	370	0.001	4	0.025	187
Lewis	0.15	1,700	0.119	2,000	0.135	1,850
Lincoln	0.046	84	0	0	0.023	42

County	Logistic Regression		Decision Tree		Average	
	Mean	Sum	Mean	Sum	Mean	Sum
Mason	0.154	931	0.185	1,467	0.17	1,199
Okanogan	0.063	579	0.004	60	0.033	319
Pacific	0.091	450	0.076	458	0.084	454
Pend Oreille	0.058	434	0.076	680	0.067	557
Pierce	0.191	1,814	0.159	2,133	0.175	1,973
San Juan	0.18	750	0.286	1,361	0.233	1,056
Skagit	0.132	1,647	0.143	1,961	0.138	1,804
Skamania	0.094	216	0.102	370	0.098	293
Snohomish	0.625	6,119	0.552	5,735	0.589	5,927
Spokane	0.152	3,654	0	9	0.076	1,832
Stevens	0.049	1,237	0	1	0.025	619
Thurston	0.231	2,031	0.261	2,662	0.246	2,346
Wahkiakum	0.074	121	0.074	142	0.074	132
Walla Walla	0.08	236	0.002	3	0.041	120
Whatcom	0.16	1,760	0.274	2,209	0.217	1,984
Whitman	0.1	165	0.001	1	0.05	83
Yakima	0.085	694	0.015	28	0.05	361

4.10. Decision Tree Model Results and Performance

The relative importance of the variables in the decision tree is given in Table 9. As can be seen, these importance values differ considerably from the unitless effect sizes given for the logistic regression. A graphical depiction of the decision tree model, including all its nodes and branches, is given in Appendix E. It shows how each variable affects the branching behavior of the outcomes. It gives threshold break values for each variable that predict differences in outcomes within nested sequences. So, for instance, the following conditions are the nodes of one branch for which, if the conditions are met, the parcel will be classified as undeveloped or 0: The Road Length (km) is less than or equal to 3.54 km; X is less than or equal to -121.75; within that range, the Road Length (km) is 0.00 km or less; the NEAR_DIST_UGB (km) is also 0.00 km or less, and the Forested Area Percentage is less than or equal to 99.81%; the Building Area Sum within a 20 km radius (in square kilometers) is less than or equal to 26.27, and the Business Count within the same radius is less than or equal to 68.50; and the Maximum Drainage Class value is 1.50 or lower.

Table 9. Feature Importance by Variable for Decision Tree

Feature	Importance
Road_Length_km	0.472905
X	0.226132
BldgArea_Sum_10k	0.125173
NEAR_DIST_UGB_km	0.055841
ForestedArea_Percent	0.04898
Y	0.033846
BuffPctWet	0.012482
Slope_MEAN	0.006263
Business_count_10k	0.004605
BldgArea_Sum_20k_Sqkm	0.003731
DrainCI_Max	0.002783
All_100y_Pct	0.002382
Business_count_20k	0.002297
Dist_from_Clusters_m	0.001803
Slope_MIN	0.000686
MedHomVal_2022_per_10k	0.000092

The decision tree model overall accuracy is 0.86 (Table 10). This measures the proportion of total correct predictions out of all predictions made. In decision trees, it evaluates how well the model correctly classifies both the developed and non-developed parcels. However, it does not provide insight into performance in individual classes, especially if the classes are imbalanced (there are more undeveloped parcels compared to developed ones in the training and test datasets).

Table 10. Model Performance Metrics

Decision Tree Model Accuracy	0.86
Decision Tree Model Precision	0.85
Decision Tree Model Recall	0.86
Decision Tree Model F1 Score	0.84

The precision value of our model is 0.85. Precision indicates the percentage of positive predictions (e.g., parcels predicted to be developed) that are actually correct. High precision means fewer false positives.

The recall value of our model is **0.86**. Recall, or sensitivity, is the percentage of actual positives (e.g., parcels that are developed) correctly identified by the model. High recall ensures that most of the true positives are captured, minimizing false negatives.

Since both precision and recall values are 0.76, the F1 score also is **0.84**. The F1 score is the harmonic mean of precision and recall, providing a balanced measure when both metrics are equally important. It is especially useful when the dataset has imbalanced classes, as it penalizes extreme values of precision or recall.

4.11. Mapping Decision Tree Results to Parcels

As with the logistic regression, predicted development probability scores were mapped to each parcel, based on the values of each predictor variable. For the Decision Tree approach, individual probabilities were calculated by the predict function of the Decision Tree model using the Scikit Learn Python package. This function provides the confidence of prediction (between 0 and 1). The confidence probability value in this context refers to the likelihood, as estimated by the model, that a given data point belongs to a specific class. This is often expressed as a probability between 0 and 1 for each class. In a classification model, these probabilities help users understand how confident the model is about its predictions. The model produces the confidence value between 0.5 and 1 for each class. There is no confidence value less than 0.5 because it would fall in the other class. Since we care about the class 1 (the parcels that are predicted to be developed), we inverted the value of class 0 to show the confidence of not-being-developed. This process produces a probability of being developed between 0 and 1. Doing this allowed us to look at a continuous probability of development events ranging from 0-1 (0%-100%), as opposed to just from .5-1 (50%-100%).

4.12. Comparison and Averaging of Models

Figures 7 and 8 present maps of the probability of development at the PLSS section level for the logistic and decision tree methods, using identical numeric intervals to allow comparison. These intervals were initially set for the logistic model using the Natural Breaks method, an approach that adjusts numeric class intervals for a graduated color map based on its statistical distribution. The same interval values were then set for the decision tree map, although only slight changes were needed, given their similarity. As can be seen from the maps, the decision tree model yields very few high development predictions in the central or eastern parts of the state but yields a reasonable amount of heterogeneity in the urbanized eastern portion. Based on this, we decided to average the probabilities from the two models which yielded a map that looked probable across the entire state. This average value map was then plotted, again using the Natural Breaks method, given in Figure 9. Figure 10 shows a zoomed in map of average development probability at the Section scale for the King County area, while Figure 11 shows that same zoomed area mapped out at the parcel scale, allowing readers to see the range in size and configuration of parcels that were used as the basis of this analysis. Histograms were

also made to show the differences in the distribution of development probabilities across the two models (Figure 12). The maps and histograms us to see where there was general agreement between the two models, and where significant differences existed.

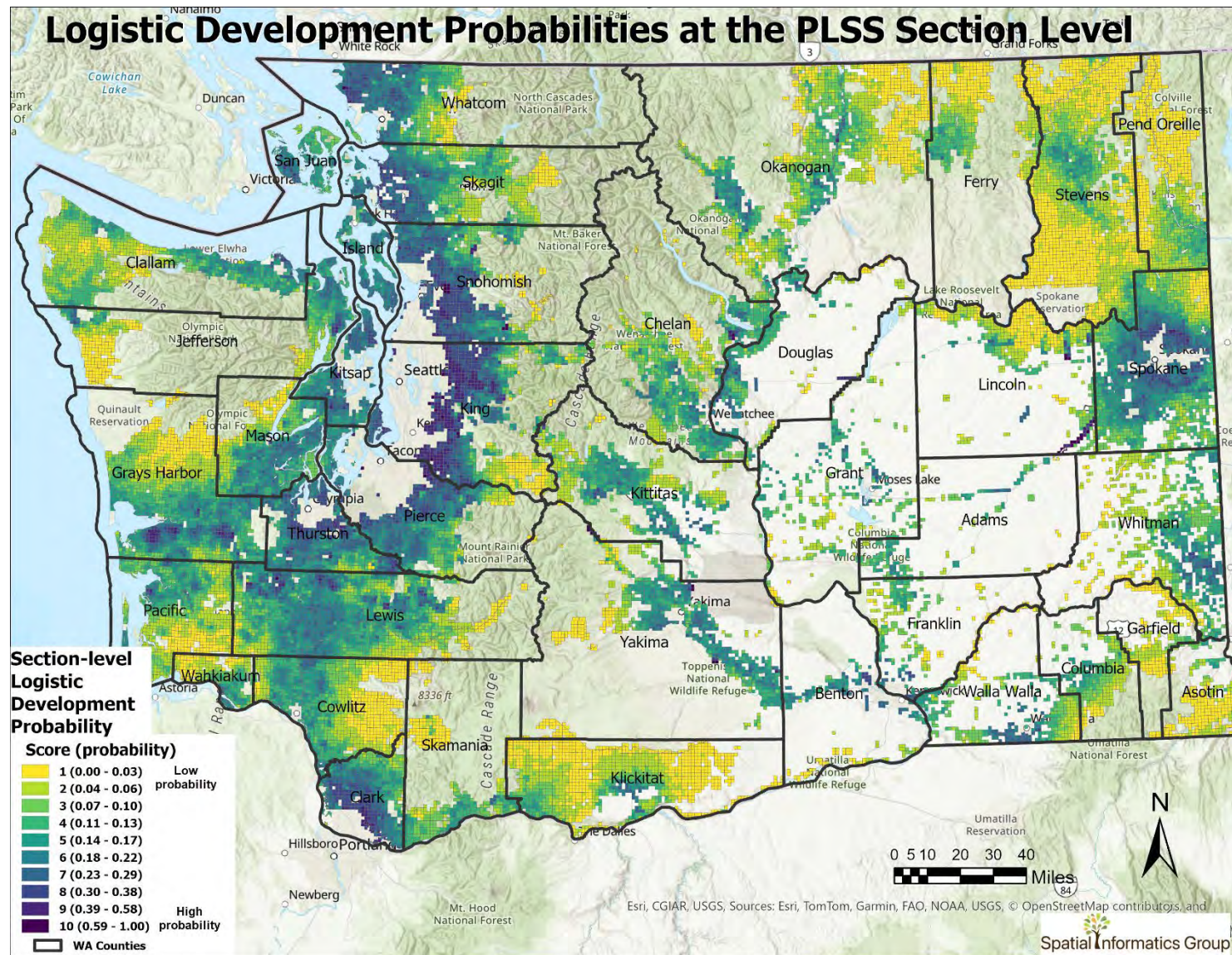


Figure 7. Logistic Development Probabilities at the PLSS Level

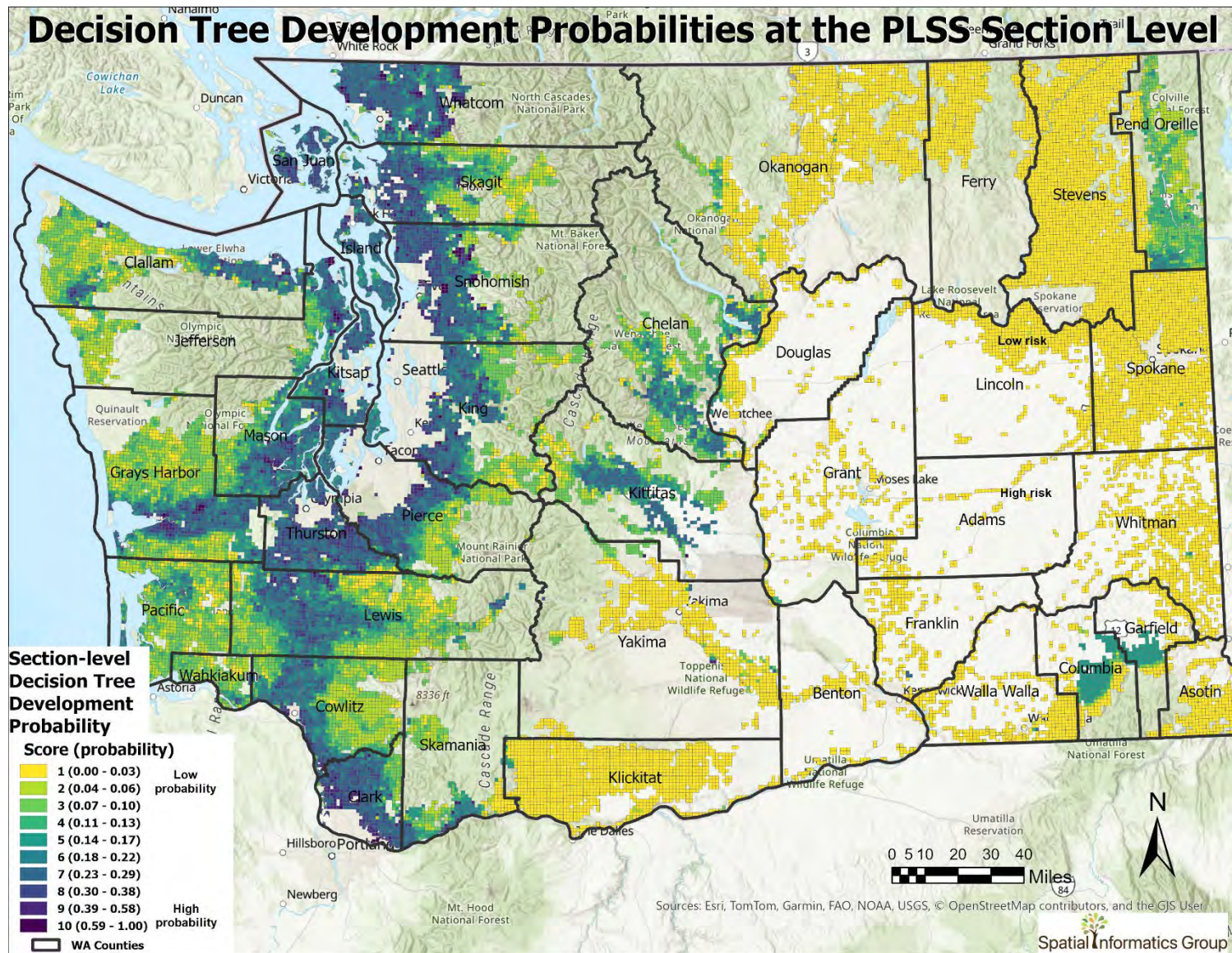


Figure 8. Decision Tree Development Probabilities at the PLSS Section Level

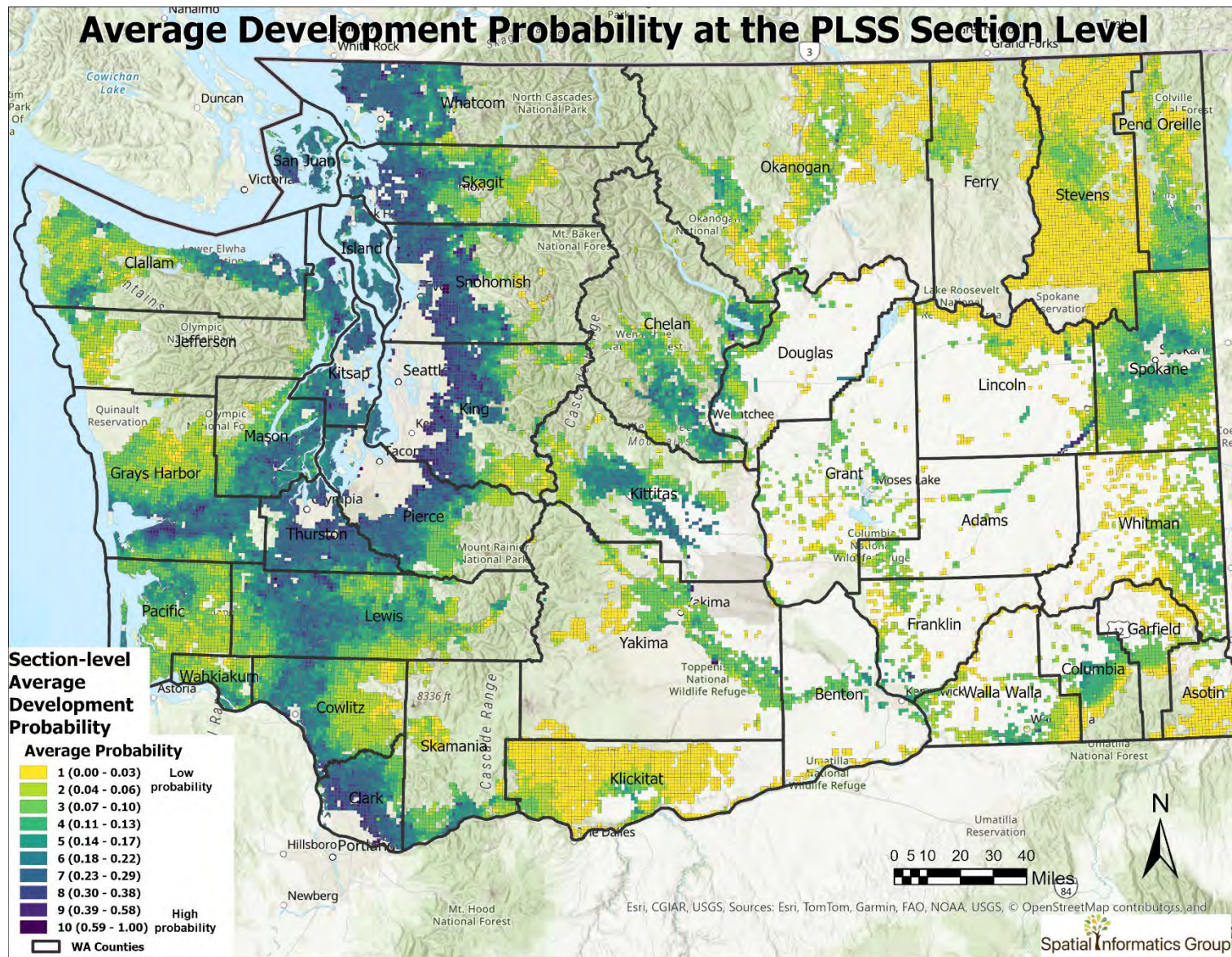


Figure 9. Average Development Probability at the PLSS Section Level

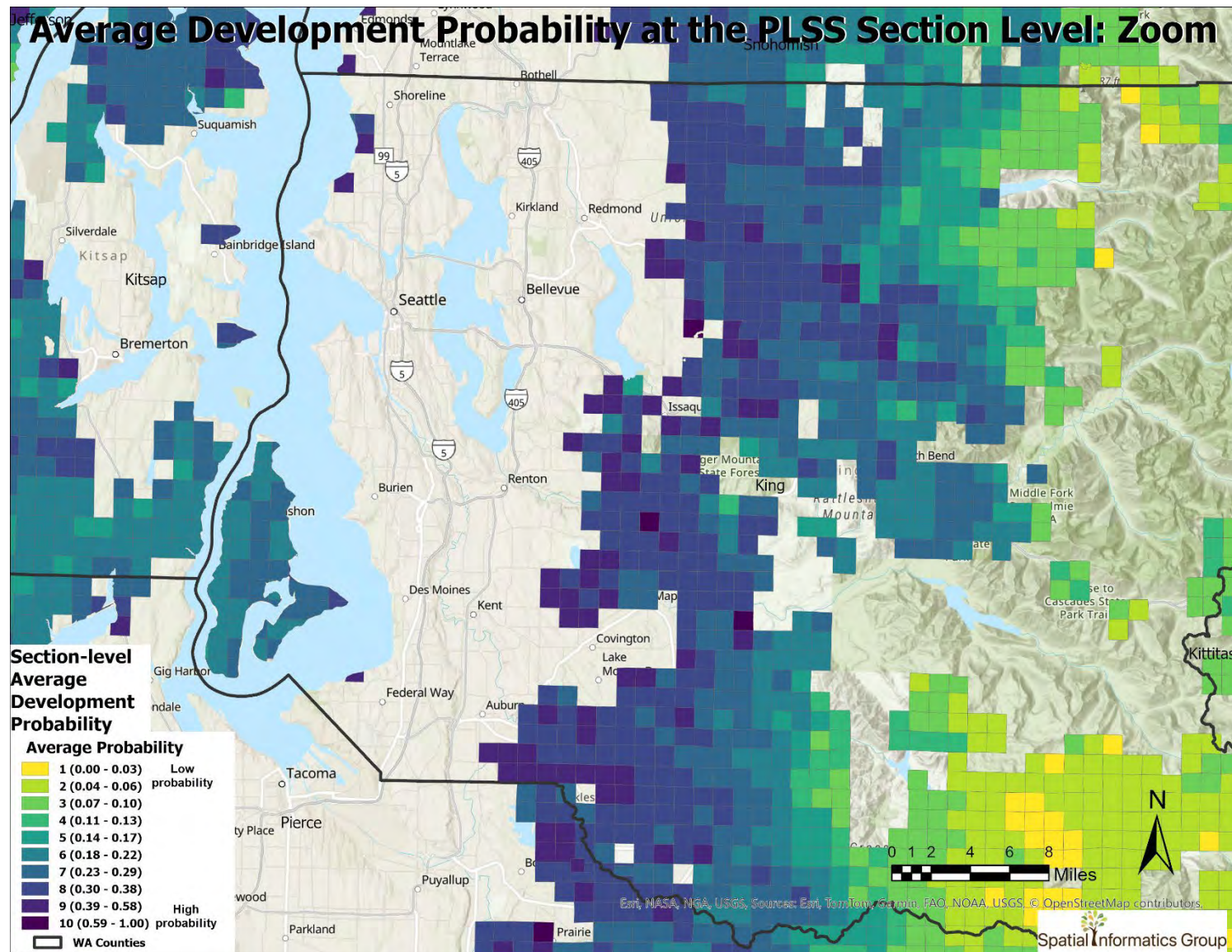


Figure 10. Average Development Probability at the PLSS Section Level

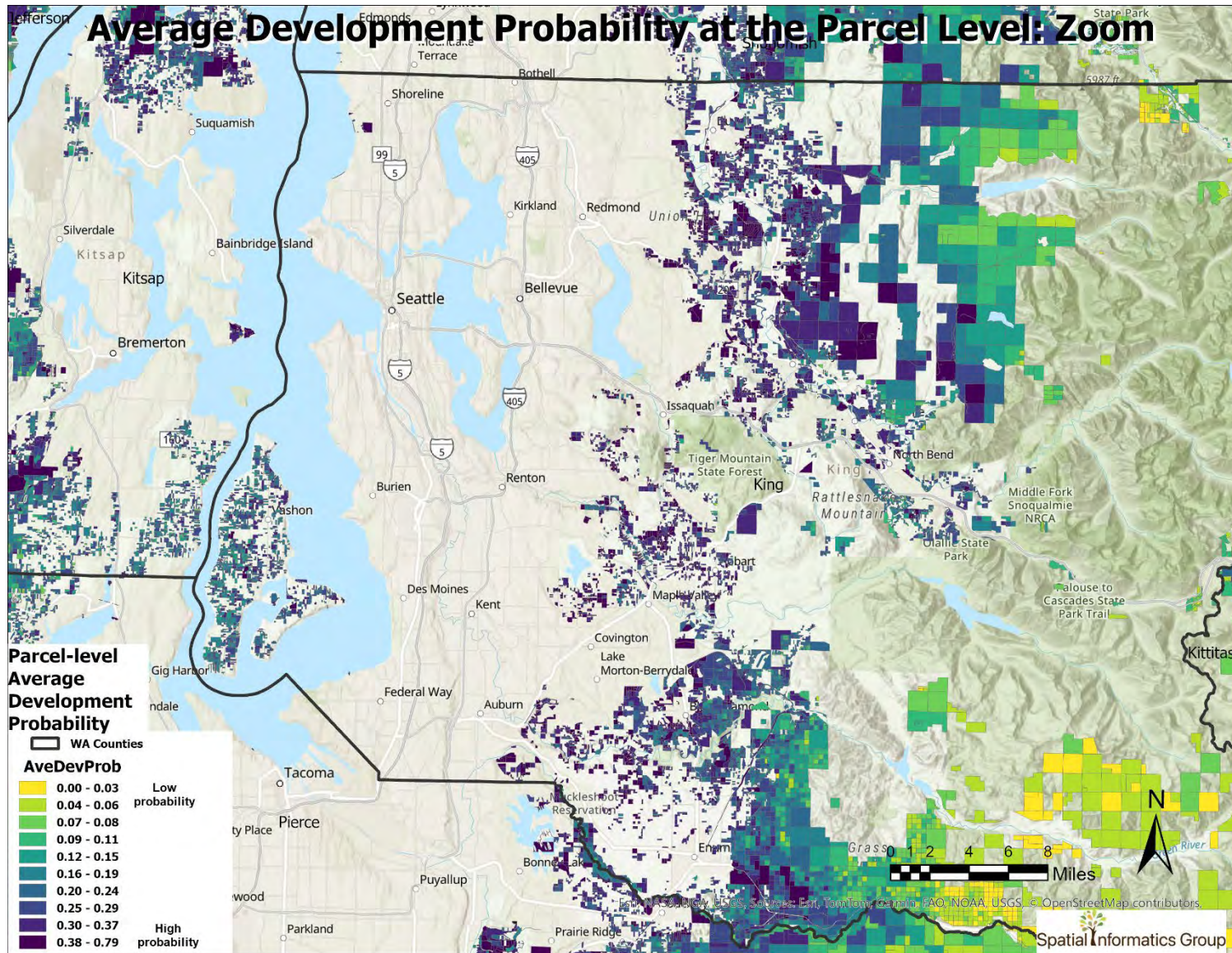


Figure 11. Average Development Probability at the Parcel Level

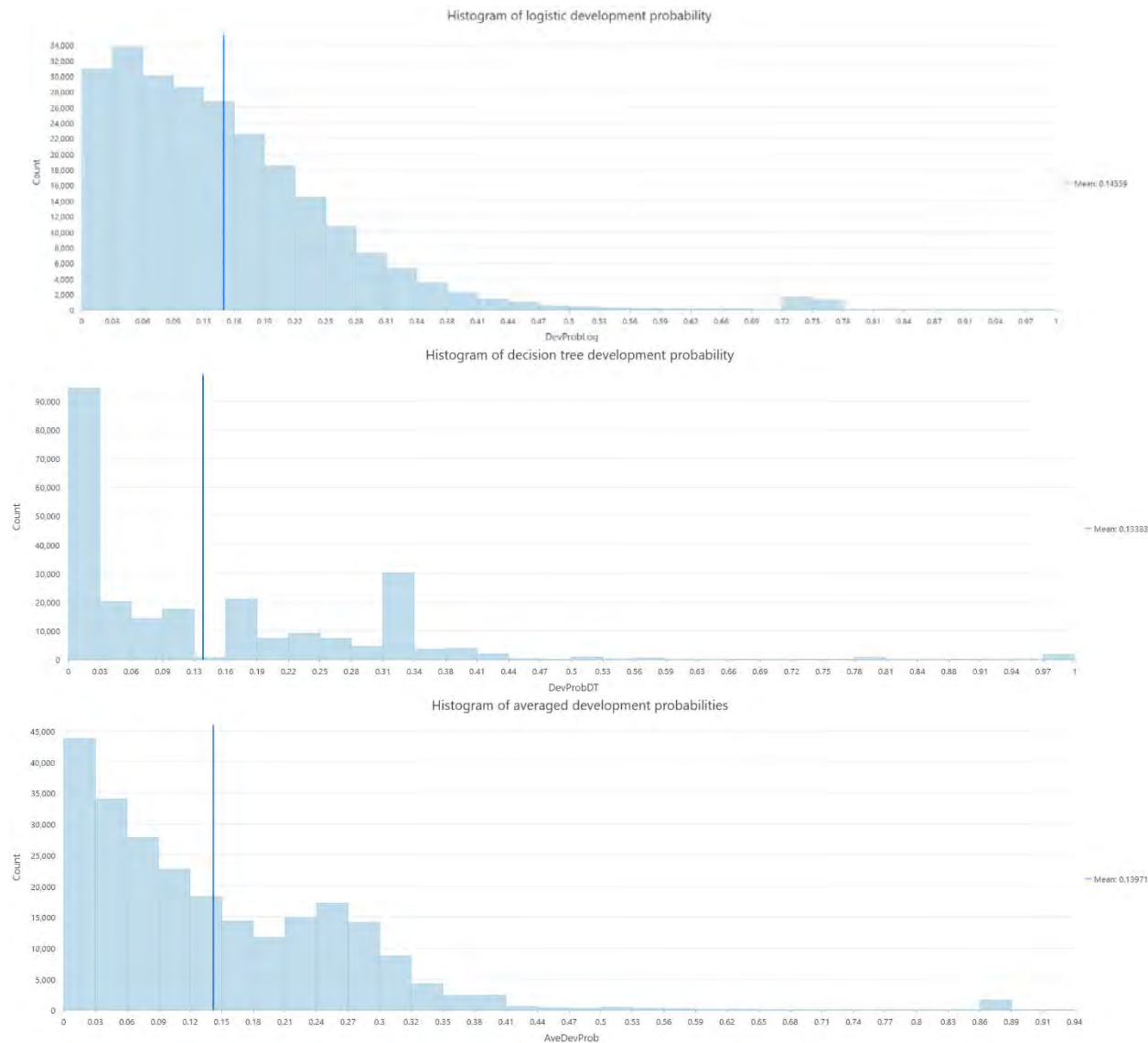


Figure 12. Histograms of Development Probabilities
Logistic Regression (top), Decision Tree (middle) and Average (bottom)

4.13. Overall Observations

Overall, our results paint a picture that is intuitive and unsurprising: development is predicted in and around existing urban centers, but particularly the larger ones in the Puget Sound region and other western parts of the Interstate 5 corridor. While the two models have similar accuracy levels, they disagree somewhat in a number of ways: on the more peripheral parcels surrounding the urban corridor in western Washington; in the areas around smaller cities in the western and southern part of the state; and, as the zoomed-in maps show (Figures 10 and 11) at a finer scale that likely reflects different weightings for site-specific variables (e.g. soils, slope). Regardless, the models overall agree more than they diverge, and together they present a plausible picture of where development is likely to occur.

It is important, though, not to take the development prediction probabilities too literally. For instance, for a parcel with a development probability of 0.6 (60 percent), it would be a stretch to confidently claim that there truly is a 60 percent chance of development (or even a higher than even chance). Rather, the most important signal presented in the prediction data is the order or distribution of those probability values—for instance, a parcel with a 60 percent chance of development is higher than one with only 50 percent.

5. Additional Analytic Overlays

The next aspect of the work focused on creating a suite of layers that can be overlaid with the development probabilities. The initial intent was to create two categories of variables: 1) "importance scores" that pinpoint where conversion would compromise important ecological or socio-economic values and 2) "contextual overlays" that provide information about where those changes are happening.

The "importance scores," which were chosen after extensive testing, included the following eight: 1) water supply; 2) water quality; 3) rare plants and ecosystems; 4) habitat and species; 5) salmon streams; 6) commercial timber Supply; 7) forest carbon storage; and 8) outdoor recreation. Table 11 describes each importance variable and its data sources and more detailed descriptions of each are given below. The only "contextual overlay" detailed in this report, called "policy boundaries," depicts whether parcels are located in urban growth areas and water service areas.

Table 11. Importance Variable Summaries

Name	Data Sources and Description
Water Supply	Importance of land for water supply purposes. Sources: Forests to Faucets Dataset (US Forest Service); water intakes (WA DNR)
Water Quality	Importance of land for maintaining water quality in areas of sensitivity. Sources: National Wetlands Inventory (EPA) and Total Maximum Daily Load area footprints (WA DNR)
Rare Plant/ Ecosystem	Importance of land as actual or potential location of rare plants and ecosystems. Source: Known and Historic Rare Plants/Ecosystem Database (Washington Natural Heritage Program)
Habitat and Species	Importance of land as habitat location for key species. Source: Priority Habitats and Species dataset (Washington Department of Fish and Wildlife)
Salmon Streams	Importance of land as a buffer for nearby salmon bearing streams. Source: The Statewide Washington Integrated Fish Distribution GIS layer (WA Department of Fish and Wildlife in conjunction with the Northwest Indian Fisheries Commission)
Commercial Timber Supply	Importance of land as potential timber supply source for regional commercial timber industry. Source: Forest product mill locations (DNR) and "Forest ownership in the conterminous US circa 2014" (US Forest Service)
Forest Carbon Storage	Importance of land for current total forest carbon storage. Source: Remote Sensing-based Forest Resource Inventory System (RS-FRIS, from WA DNR)
Outdoor Recreation	Importance of land as a buffer to nearby outdoor recreation sites. Source: Shellfish beach lines, trails, campsites, trailheads, and public lands (WA DNR)

The second category of contextual variables was explored to include factors that might influence the design of a policy intervention or the development or application of a program to

mitigate conversion risk. Variables explored for this category included census data, health indices, and policy boundaries, although ultimately only one is included in this description.

A third category of overlay variables was initially considered to capture the impacts on those variables that were not used as independent variables in the land use change models but might still affect urbanization outcomes. These included source water protection areas and wellhead protection areas and the impacts of climate change. These are not included in this report. Most variables were constructed from two or more inputs, often with different units. In cases where inputs were in different units, they were standardized using the widely accepted method of z-scores, in which the mean of a variable is subtracted from its value at an observation and divided by the standard deviation. This gives a unitless measure that can be combined with other z-scores in most cases (depending on distributional characteristics).

Once scores had been calculated at the parcel level, the “summarize within” function in ArcGIS was used to derive average score values at the PLSS Section level. Then, to enhance legibility of the data, we classified the values by converting them from their unitless scores into a more intuitive 1-10 scale using the Natural Breaks numeric classification method. This eliminated negative values and decimals in the final score ranges to aid in legibility and comparison between variables. The only variables that did not take a 1-10 score were the risk due to climate change and the regulatory policy score, both of which were on a 1-3 scale for reasons discussed below.

The development of the water supply; water quality; rare plants and ecosystems; commercial timber, forest carbon storage; outdoor recreation; and salmon streams overlays are explained in detail in the sections below.

5.1. Water Supply

The Water Supply overlay variable integrates data from two sources: the U.S. Forest Service (USFS) Forests2Faucets (F2F) dataset⁹⁷ and the Washington State Department of Ecology’s Water Right Diversions.⁹⁸ The F2F dataset evaluates the relative importance of small watersheds for surface drinking water by considering threats such as development, insect outbreaks, disease, and wildfires. This dataset provides an “IMP_R” attribute, which quantifies the relative importance of areas for surface drinking water at the HUC12 watershed level. For parcels intersecting multiple HUC12s, the research team averaged IMP_R values. The Water Right Diversions dataset, based on the National Hydrography Dataset Model 2.2 (April 2016, updated November 2016), includes statewide records of surface water diversions. For this research, a higher number of diversions suggests increased pressure on local water resources and a greater need for water management.

⁹⁷ Forests2Faucets: https://www.fs.usda.gov/ecosystems-services/FS_Efforts/forests2faucets.shtml

⁹⁸ Water Rights Diversions: https://geo.wa.gov/datasets/03da8f4215f04b5c97cfc8b52fa0bce1_1/explore

To calculate the water supply score, the research team combined the average IMP_R value and the count of water diversions for each watershed, standardized the values by converting them to z-scores, and then calculated a score using a weighted formula: 75 percent weight on watershed importance and 25 percent on water diversion counts. This score was summarized at the HUC12 level and spatially joined to overlapping land parcels. A map of this score at the PLSS level appears in Figure 13.

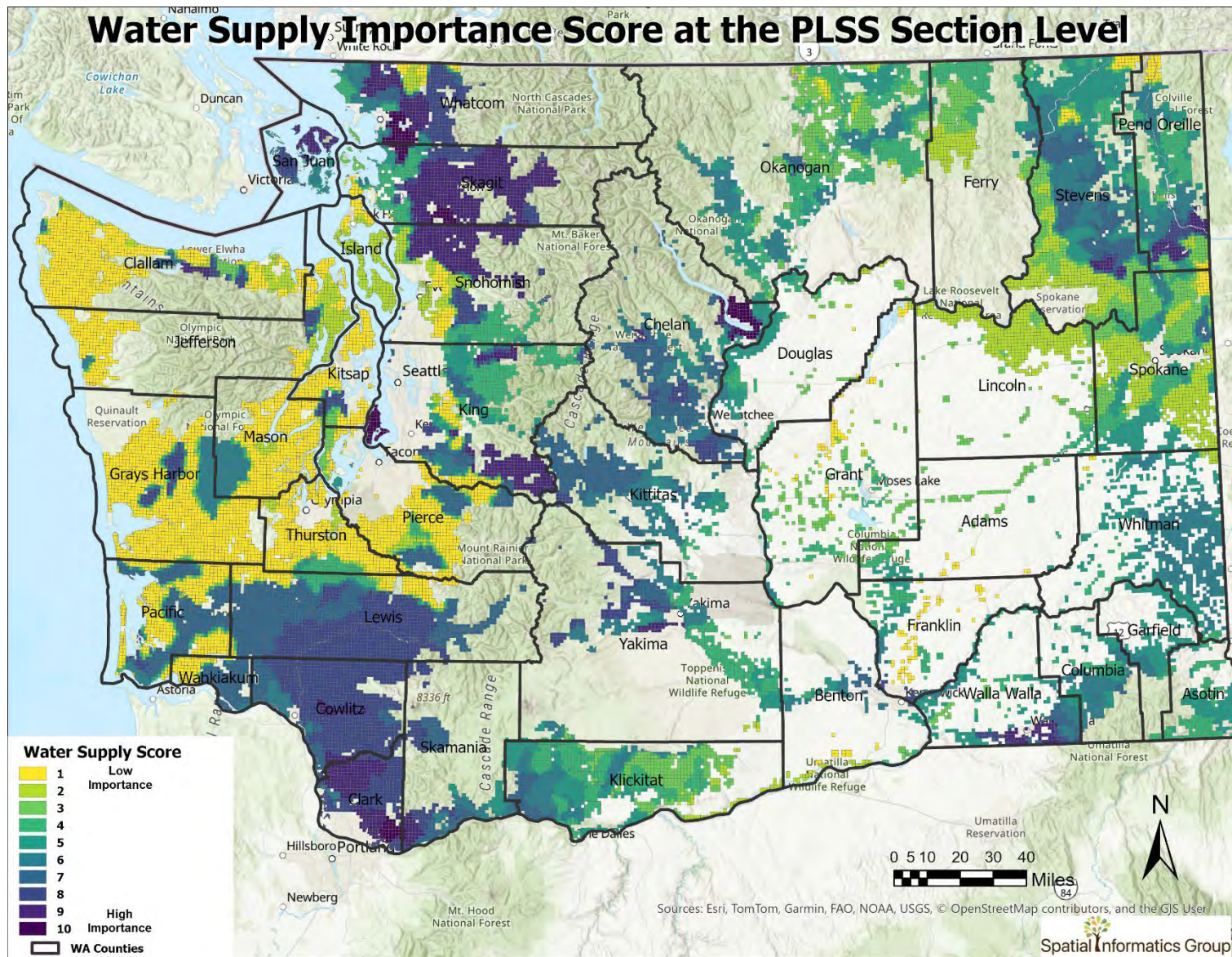


Figure 13. Water Supply Importance Score at the PLSS Section Level

5.2. Water Quality

The research team evaluated potential water quality issues on private land parcels using three complementary datasets: Total Maximum Daily Load (TMDL)⁹⁹ waters, upland wetlands from the National Wetlands Inventory (NWI)¹⁰⁰, and 303(d)¹⁰¹ impaired waters from the EPA. TMDL data, obtained from the Washington State Department of Ecology, identify water bodies involved in water quality improvement projects aimed at restoring polluted waters to meet state standards. For each parcel, the team calculated both the acreage and percentage of private land overlapping TMDL waters. To assess wetland-related impacts, the team filtered the NWI to include relevant wetland types—Estuarine and Marine, Freshwater Emergent, Freshwater Forested/Shrub, and Riverine—serving as a proxy for riparian zones, which are not separately classified in the NWI for Washington. Again, the team calculated both the acreage and percentage of each parcel containing these upland wetland types. Lastly, the team incorporated 303(d) impaired waters from the EPA’s 2022 Water Quality Assessment, which identify water bodies that do not meet quality standards and require remediation. The team calculated the overlap of these impaired waters with private parcels in terms of acreage and percentage. The final water quality score was derived by summing the percentage of each parcel that intersects with TMDL waters, upland wetlands, and 303(d) impaired waters. A map of this score at the PLSS level appears in Figure 14.

⁹⁹ TMDL: <https://ecology.wa.gov/research-data/data-resources/geographic-information-systems-gis/data#>

¹⁰⁰ NWI: <https://www.fws.gov/program/national-wetlands-inventory>

¹⁰¹ 303d impaired waters:
<https://gis.ecology.wa.gov/portal/home/item.html?id=33f8587b53c149c3b391a2f38be8806d>

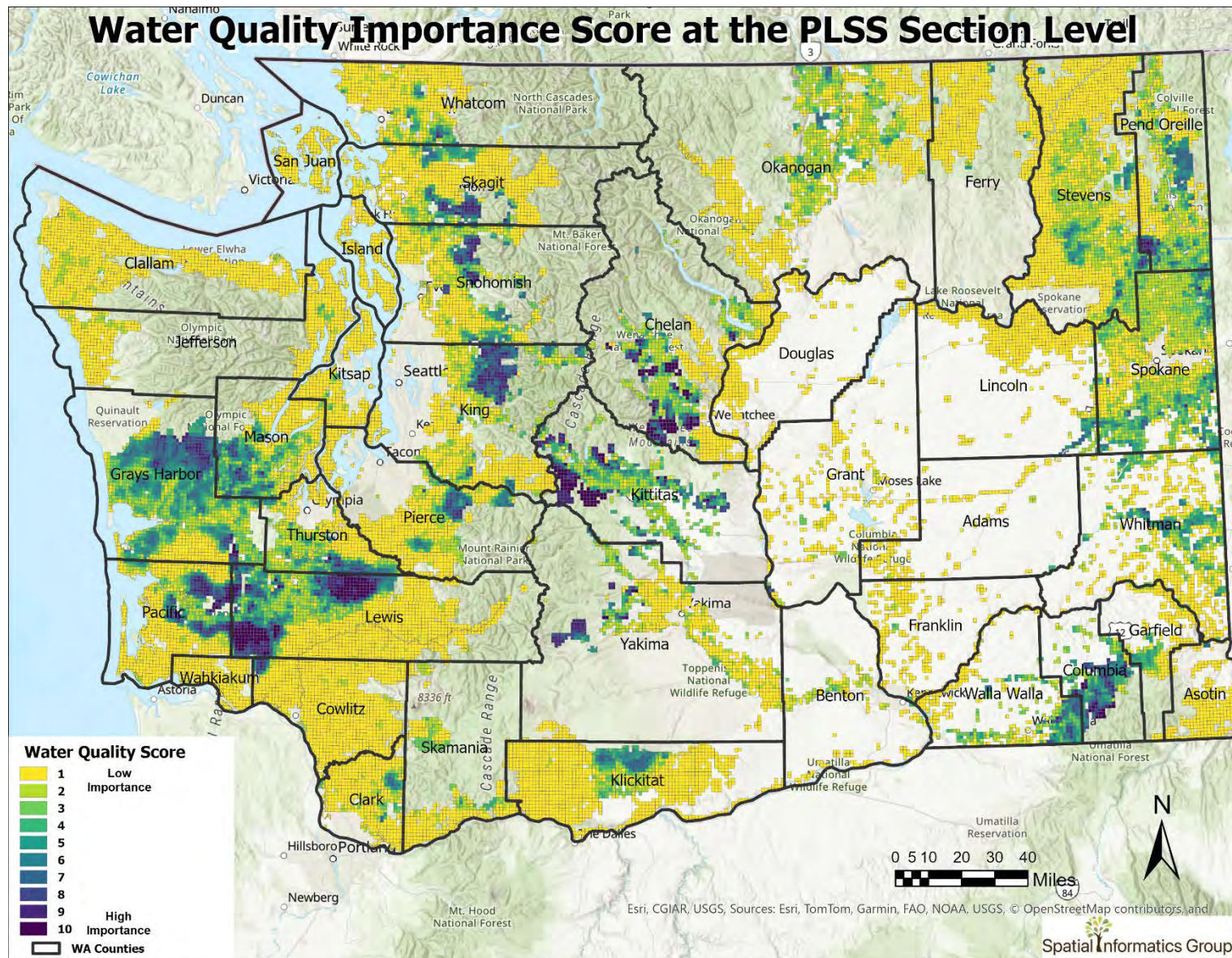


Figure 14. Water Quality Importance Score at the PLSS Section Level

5.3. Rare Plants and Ecosystems

The research team assessed the presence of rare plants and plant communities using data from the Washington Natural Heritage Program (WNHP)¹⁰² as an indicator of ecological value. Rare plants are a red flag for environmental sensitivity and their presence signals that a parcel may face greater scrutiny, tighter regulations, and higher costs during development. For land managers, planners, or investors, knowing where rare species occur helps assess whether a property is a viable candidate for development—or better suited for conservation. The rare plant dataset includes spatial information on both known and historic occurrences of rare plant species and ecological communities. Known occurrences represent verified, current locations, while historic records indicate areas where rare species or communities were previously documented but may no longer be present.

For each private land parcel, the research team counted the number of both known and historic rare plant/community records and calculated the acreage these features covered. To develop a composite score reflecting ecological value, the team applied the following formula: (acres of known plants/communities × count of known plants/communities) + (acres of historic plants/communities × count of known plants/communities). However, due to the presence of extreme outliers in the data, we used the “geometric interval” method to establish the break values for the score classes, unlike in all other score maps, in which we use the “natural breaks” method. Under the natural breaks method, far too many of the polygons fell within the lowest color category, whereas with geometric interval, there was much more heterogeneity in the map. This map, at the section level, appears in Figure 15.

¹⁰² WNHP: <https://www.dnr.wa.gov/NHPdataexplorer>

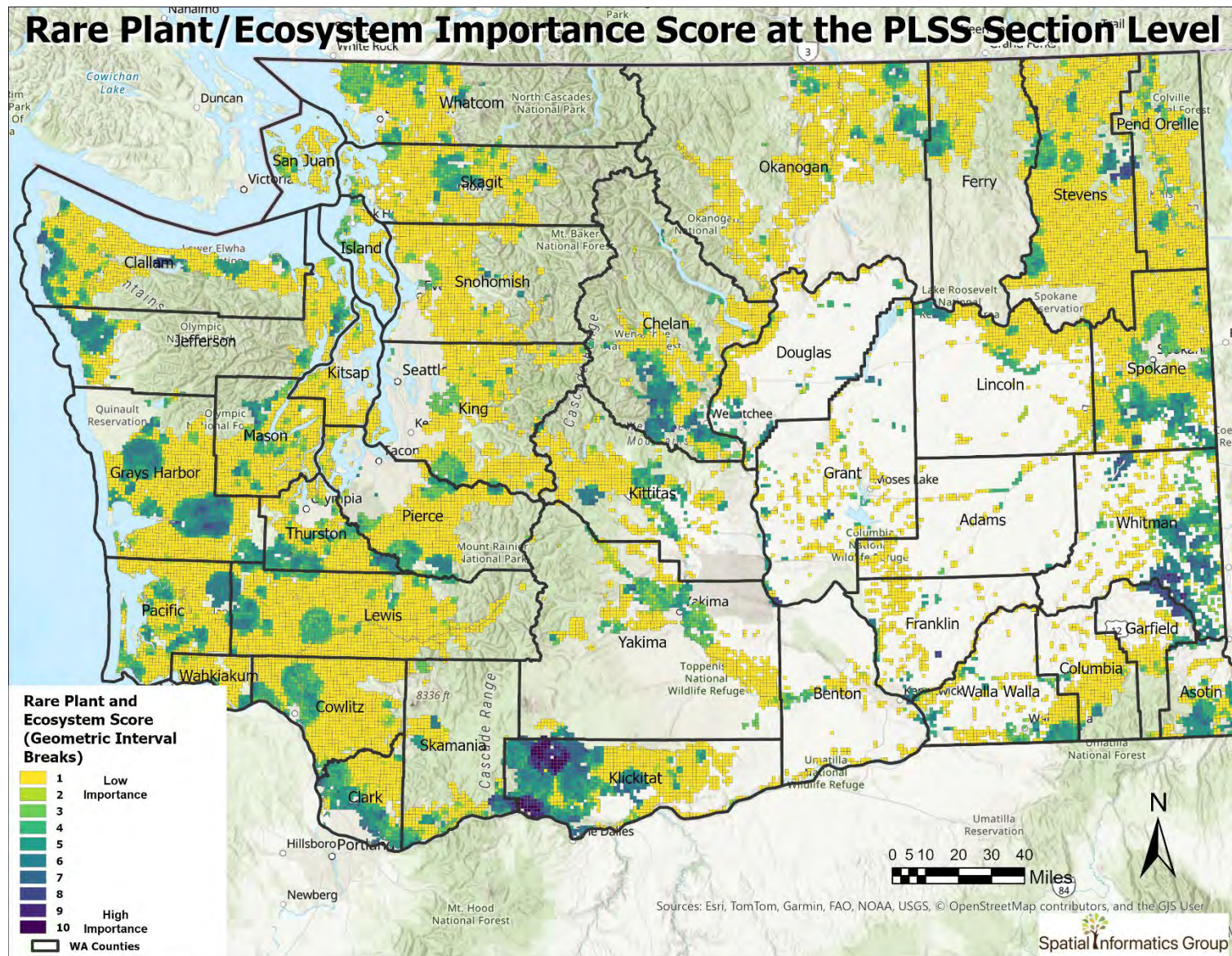


Figure 15. Rare Plant/Ecosystem Importance Score at the PLSS Section Level

5.4. Habitat and Species

This score is designed to represent the importance of lands to key species at two scales: the parcel and the HUC 12 watershed it is contained in. At each scale it represents the quantity of overlapping habitat polygons for different animal species, the quantity of overlapping nesting site buffers for key threatened/endangered species (Northern Spotted Owl and Marbled Murrelet), and the presence of wildlife corridors. The Owl and Murrelet data are from The Washington Department of Fish and Wildlife Endangered Species Act (ESA), and the rest is from the Washington Department of Fish and Wildlife's Priority Habitat and Species (PHS) dataset. Using GIS analysis, separate layers were generated from this dataset including wildlife migration corridors, habitat polygons for animal species, and buffer polygons showing the abstracted (non-sensitive) general locations of siting of Murrelets and Owls. Overlaps for the second two layers were then counted using a GIS function and those average counts were then summarized at both the parcel and watershed level. This resulted in the following equation for the score: $z \text{ score}(\text{Count of maximum overlapping polygons in a parcel [PHS habitats, owl, murrelet, corridors]} + z(\text{count of the same in containing watershed}))$. This was done across two scales because giving the overlap values at only the parcel scale yielded a map where only a tiny fraction of polygons had any score at all, yielding a generally uninformative map but the multiscale map has far more variation and appears to follow general geographic patterns of habitat importance. A map of this score at the PLSS level appears in Figure 16

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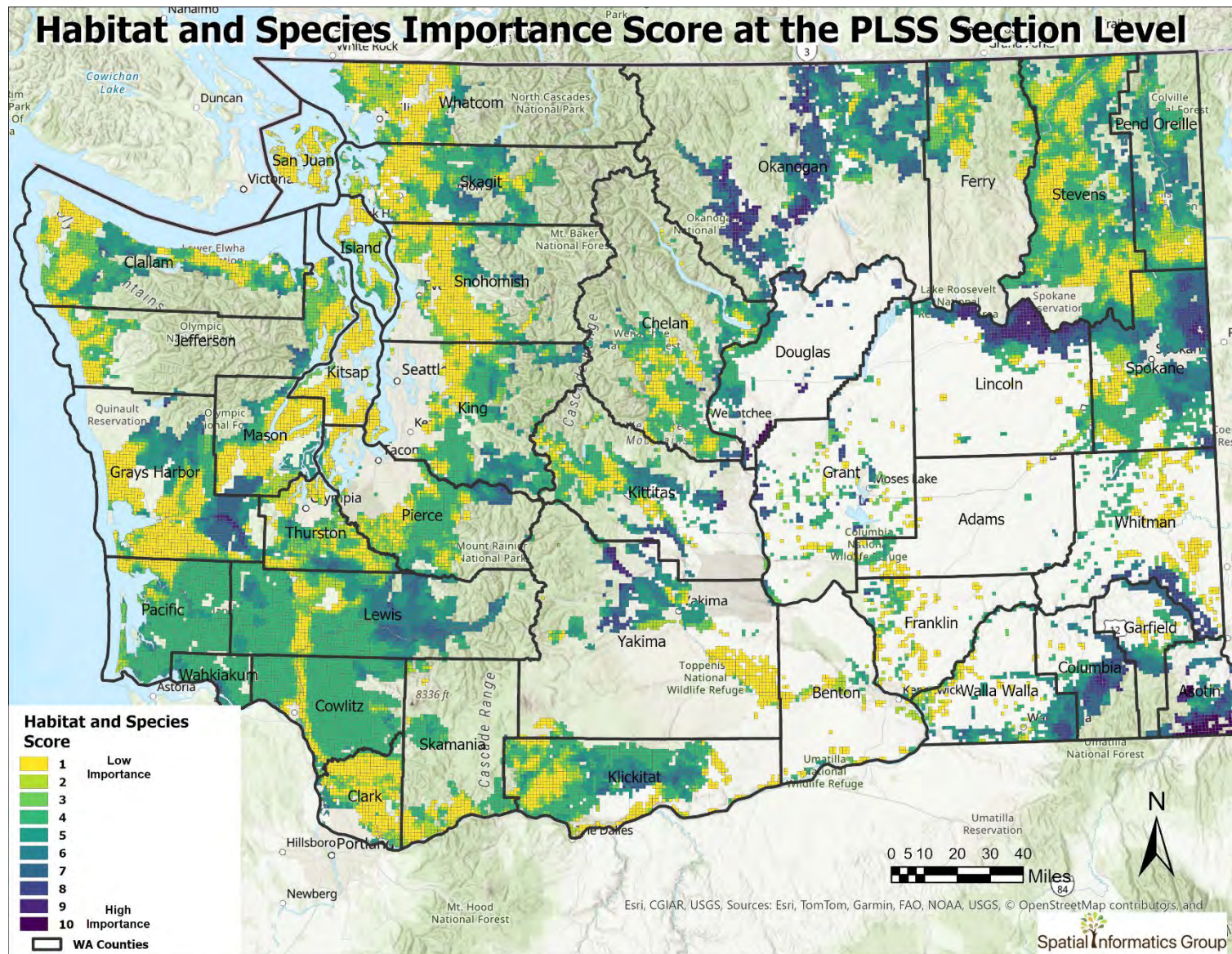


Figure 16. Habitat and Species Importance Score at the PLSS Section Level

5.5. Salmon Streams

This score was designed to characterize parcels where development might compromise nearby stream reaches known to harbor salmon. The intent was to characterize the amount of land close to salmon streams at two scales. The Statewide Washington Integrated Fish Distribution GIS layer, produced by WA Department of Fish and Wildlife in conjunction with the Northwest Indian Fisheries Commission, was obtained from DNR. Those stream reaches designated as salmon bearing were selected and turned into a new layer and buffers were generated around each. Buffers distance was determined by consulting the 2020 Riparian Ecosystem, Volume 2 report from WA Department of Fish and Wildlife. According to it, in forested regions of Western Washington, WA DFW recommends protection of between 100 and 240 feet, the equivalent of one unit of "Site-Potential Tree Height at 200 years. We took the average of those numbers, yielding a 170-foot buffer which was mapped in GIS. The score consisted of the percent of buffer land within each parcel plus the percent of buffer land within the containing watershed in which each buffer was located, with both percents normalized using z-scores. A map of this score at the PLSS level appears in Figure 17.

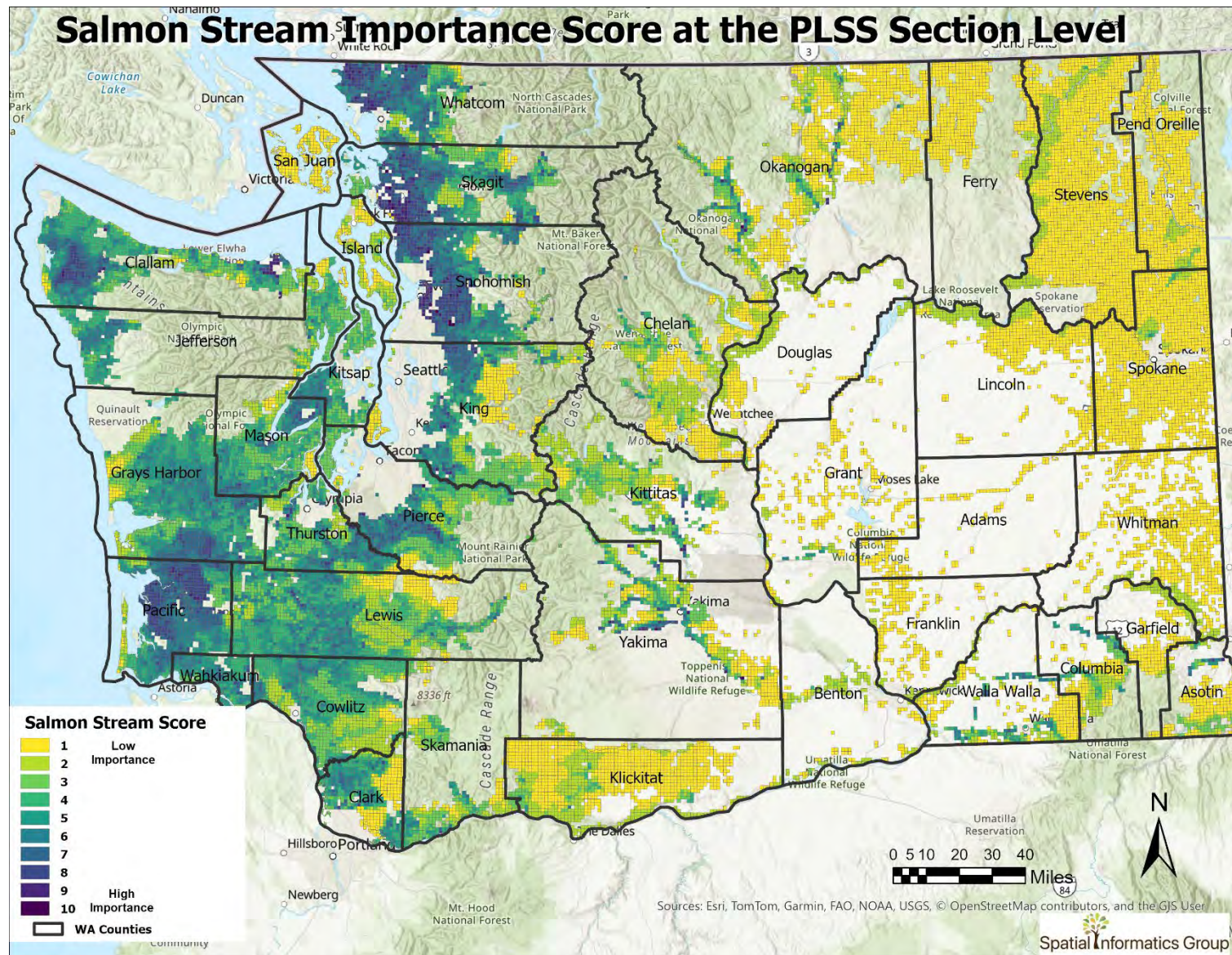


Figure 17. Salmon Stream Importance Score at the PLSS Section Level

5.6. Commercial Timber Supply

To evaluate the potential for commercial timber supply (known as a “timber shed”), the research team combined spatial data on sawmill locations with forest ownership information from the “Forest ownership in the conterminous United States circa 2014” layer from the USDA Forest Service Research Data Archive¹⁰³. The sawmill point location data, provided by the Washington Department of Natural Resources (DNR), included facilities across Washington, Oregon, and Idaho to account for logs from Washington that are processed in neighboring states. To spatially define timber sheds, the team conducted a service network analysis to delineate areas within 50 miles driving distance (as opposed to circular buffers) of a sawmill that are forested and accessible via truck routes. We then counted the number of overlapping timber shed service areas on each private land parcel. In parallel, the team used the USDA Forest Service forest ownership dataset to identify the percentage of commercial timberland by county. To calculate the final score for each parcel, the team applied a weighted formula: 75 percent weight on the standardized (z-score) count of overlapping timber sheds and 25 percent on the standardized percentage of commercial timberland in the parcel’s county. A map of this score at the PLSS level appears in Figure 18.

¹⁰³ Forest Ownership: <https://www.fs.usda.gov/rds/archive/catalog/RDS-2017-0007>

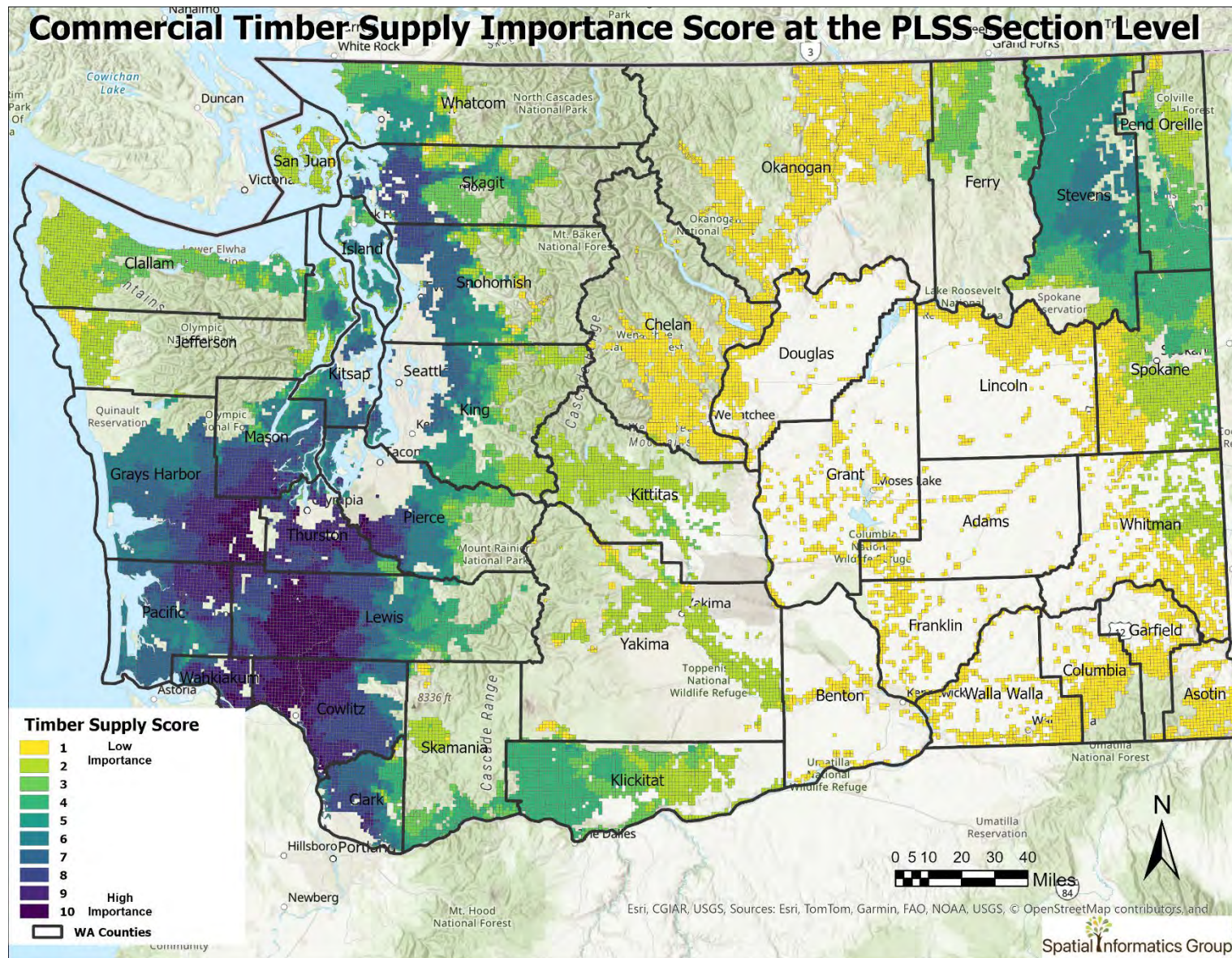


Figure 18. Commercial Timber Supply Importance Score at the PLSS Section Level

5.7. Forest Carbon Storage

The research team assessed forest carbon by using data from the Remote Sensing-based Forest Resource Inventory System (RS-FRIS),¹⁰⁴ a tool developed by the DNR to inventory and evaluate forest conditions across the state. This dataset provides estimates of forest carbon volume measured. To calculate carbon values for each private land parcel, the research team applied zonal statistics to determine the mean carbon volume, measured in metric tons per acre. The final forest carbon score for each parcel was derived by classifying these mean values into ten natural break categories, allowing for consistent comparison across parcels with varying carbon storage potential. A map of this score at the PLSS level appears in Figure 19.

¹⁰⁴ RS-FRIS: <https://gis.dnr.wa.gov/portal/home/item.html?id=bdca280d25874fd2b6c5920a6ddca891>

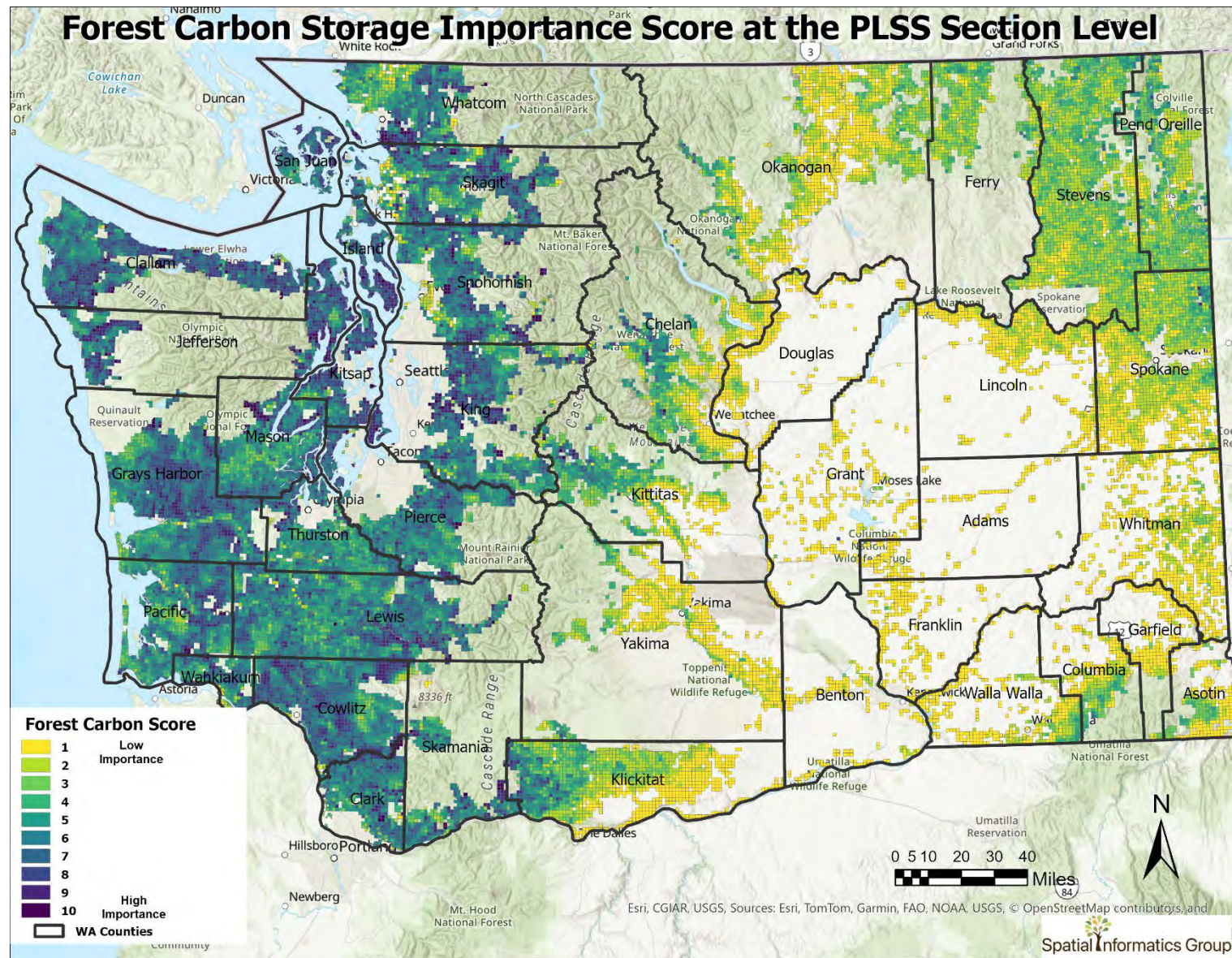


Figure 19. Forest Carbon Storage Importance Score at the PLSS Section Level

5.8. Outdoor Recreation

This variable was designed to highlight parcels that are close enough to areas of outdoor recreation importance, such that if they were developed, they would have the potential to impact or disrupt recreational activities. The score was generated by creating three raster surfaces representing the distance at each pixel to the nearest recreational point, line, or polygon, with points including trailheads and campsites, lines including trails and shellfish beaches, and polygons including public lands with a recreational designation (e.g. National Parks, National Forests, Local/County Parks). All data was provided by Washington DNR. Because we hypothesize a steep drop-off with distance in terms of the impact of development on recreation, the raster surfaces topped out at a distance of 50,000 feet, with all raster cells further than that taking a value of 50,000. At each parcel, the average of each raster surface was taken yielding average distance to points, to lines and to polygons. Each was then multiplied by negative 1, converted to a z-score and summed. A map of this score at the PLSS level appears in Figure 20.

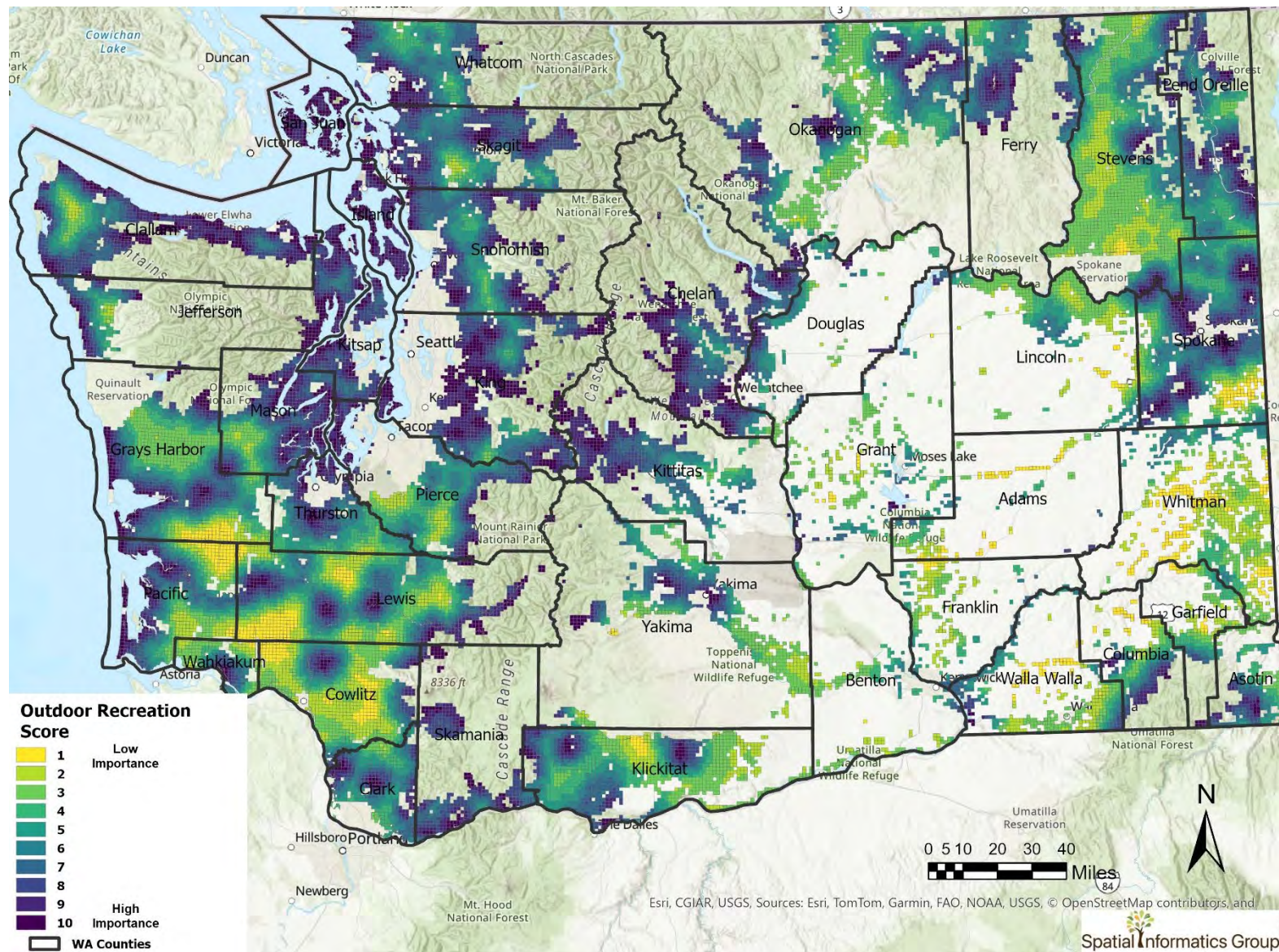


Figure 20. Recreation Importance Score at the PLSS Section Level

5.9. Policy

The research team incorporated a policy variable composed of two datasets—Urban Growth Areas (UGAs)¹⁰⁵ and Drinking Water Service Areas (DWSAs)¹⁰⁶—to assess infrastructure readiness, planning frameworks, and the potential for future development. UGAs, defined by local governments under Washington’s Growth Management Act, represent areas where urban expansion is planned and supported. Land within a UGA is more likely to be approved for development, as it aligns with county or municipal plans and is typically prioritized for infrastructure such as roads, utilities, and schools. Parcels in UGAs are also often zoned for higher-density uses, further supporting development potential. The DWSA dataset includes areas served by Washington State public water systems. Because access to drinking water is a fundamental requirement for both residential and commercial growth, parcels within these service areas are more likely to support development.

To evaluate the influence of these variables, the research team performed a proximity analysis to determine whether each private land parcel fell within a UGA, a DWSA, both, or neither. Scores were assigned accordingly: 0 for parcels in neither area, 1 for those within a UGA only, 2 for those within a DWSA only, and 3 for parcels within both. A map of this scoring at the PLSS level is available in Figure 21.

¹⁰⁵ UGA: <https://geo.wa.gov/datasets/washington-state-city-urban-growth-areas/explore>

¹⁰⁶ DWSA: <https://geo.wa.gov/datasets/WADOH::drinking-water-service-areas/explore>

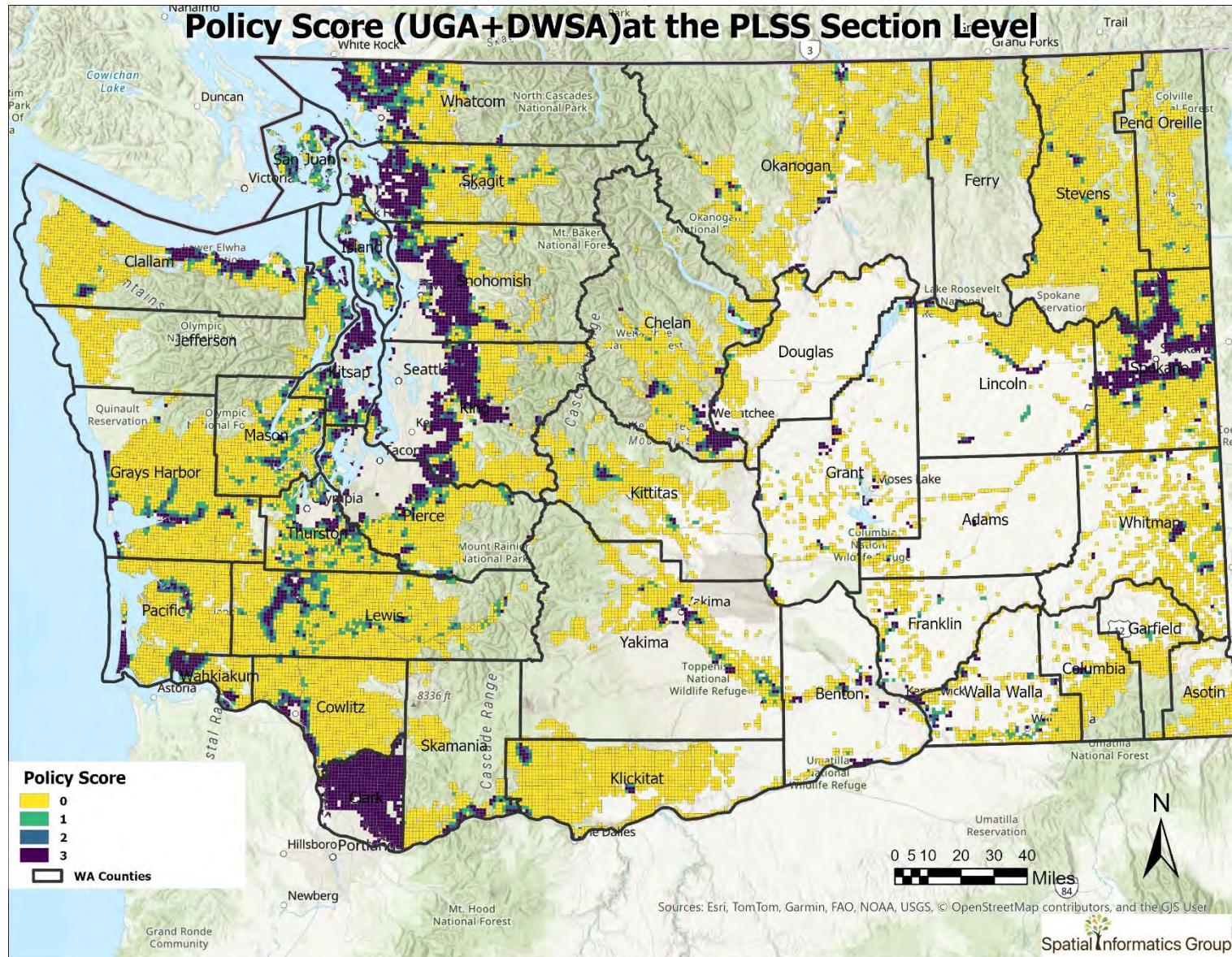


Figure 21. Policy Score at the PLSS Section Level

5.10. Socio Economic Context Variables

The literature is clear that there are causal relationships between demographic factors and conversion risk.^{107 108} However these relationships are complex, and they are not linear. Landowner age alone may not be a determinant, and when it is, it is often not the actual age of the landowner, but conditions or situations that arise as a result of age. For example, not all landowners over sixty are going to experience a catastrophic health event that necessitates immediate sale either to generate revenue or because they are no longer able to manage the property. Similarly, not all landowners fail to develop a succession plan leaving heirs vulnerable to offers of ready cash. The team tested using census data as well as developing overlays based on the Washington Health Disparities to capture these impacts. Using census data at the block group level, which is what would be used for the PLSS maps, the team observed that in rural areas, which constitute the focus of this analysis, the blocks are too big to provide meaningful information. Because of the uncertainties and complexities associated with the interplay between these factors it was determined that an overlay based on this limited data did not add significant illumination to the understanding of the problem.

¹⁰⁷ Forest Land Conversion in Washington State. Available [here](#).

¹⁰⁸ Markowski-Lindsay, Marla, P. Catanzaro. A. Milman and D. Kittredge. 2016. Understanding Family Forst Land Future Ownership and Use/ Exploring Conservation Bequest Motivations. Small Scale Forestry. 15:241-256. Available [here](#).

6. Tools to Assess Program and Policy Eligibility

The final layer of analysis developed for this project allows the user to explore the nexus between the characteristics and requirements associated with a given program and the drivers of conversion risk.

As outlined in Chapter 2 and detailed in Appendix A, a number of programs and policy instruments were initially reviewed in detail in order to understand how they operated and to identify the requirements for eligibility and participation. Because of the known positive relationship between access to information and technical assistance and landowner decision making regarding land management and conversion, the team focused on programs that were focused on small forest landowners. The team then identified data sources that could be aligned with program requirements serving as indicators of whether or not a parcel was eligible for a particular program. Thirteen of these programs were selected for inclusion in the framework, due to their program focus as well as the availability of data that could reliably be used to predict eligibility. These thirteen programs served as “proof of concept” and were selected because they provided a range of key requirements that allowed the research team to test a range of different indicator variables and data sources. As the framework currently functions, the programs included could serve as proxies to explore programs that were not included but have similar eligibility requirements. Recommendations for additional programs that should be included in the framework in the future are discussed in Chapter 9.

The crosswalk for these thirteen programs is presented in Table 12 below.

Table 12. Variables and Data Sets Used to Determine Program Eligibility

Program	Key Requirements	Indicator Variable Data Layer	Program Web Site Link
Brian Abbott Fish Barrier Removal Board	Contains a fish-bearing stream	Fish-Bearing Stream: WA State fish passage inventory	https://rco.wa.gov/grant/brian-abbott-fish-barrier-removal-board/
Estuary & Salmon Restoration Program	Contains 1 or more of the following: - Fish-bearing stream - Riparian area	Fish-Bearing Stream: WA State fish passage inventory Riparian area data layer- NR SIG	https://rco.wa.gov/grant/estuary-and-salmon-restoration-program/
Aquatic Lands Enhancement Account	- Riparian area - Adjacent to a body of water	Riparian area data layer- NR SIG Water body adjacency	Aquatic Lands Enhancement Account - Recreation and Conservation Office
Community Forests Program	- Parcel of 5+ acres OR - Collection of parcels that total 5+ acres	SIG Development Data	Community Forests Program - RCO
Habitat Conservation Projects – Washington Wildlife and Recreation Program	Contains T&E species Contains riparian area	PHS: Priority habitats and species, WDFW Riparian area data layer- NR SIG	https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-habitat/
Salmon Recovery & Puget Sound Acquisition & Restoration	Located in Puget Sound East of Cape Flattery	Puget Sound Y/N	https://rco.wa.gov/grant/salmon-recovery/
Family Forest Fish Passage Program (FFFP)	Fish-Bearing Stream Road	Fish-Bearing Stream: Fish passage inventory, WA Dept. of Fish and Wildlife (WDFW) Road: Statewide roads and routes, WA Dept. of Transportation	www.dnr.wa.gov/fffp

Program	Key Requirements	Indicator Variable Data Layer	Program Web Site Link
Safe Harbor Agreements	Private Forestland PHS	Private Forestland: SIG DD PHS: Priority habitats and species, WDFW	NA
Business and Occupation (B&O) Tax Reduction (RCW 82.04.260)	Commercial Timberland	Private Forestland: SIG DD Commercial Timberland: SIG DD; sawmills	NA
Partners for Fish and Wildlife	<u>1+ of the following:</u> - Riparian Zone(s) - Wetlands - PHS - Rare Plants	Private Forestland: SIG DD Riparian Zones: Data not available Wetlands: National Wetlands Inventory, U.S. Fish and Wildlife Service PHS: Priority habitats and species, WDFW Rare Plants: Washington National Heritage Program rare species and ecosystems data	www.fws.gov/program/partners-fish-and-wildlife
Forest Riparian Easement Program	Private forestland Small forest landowner Riparian zone	Private Forestland: SIG DD Riparian Zones: Data not available	www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/forestry-riparian-easement-program
Service Forestry Program	Private Forestland (5+ acres)	Private Forestland: SIG DD	www.dnr.wa.gov/forest-stewardship-planning

Program	Key Requirements	Indicator Variable Data Layer	Program Web Site Link
Rivers and Habitat Open Space Program	Private forestland <u>1+ of the following:</u> - PHS - Channel Migration Zone (CMZ)	PHS: Priority habitats and species, WDFW ESA: Endangered species	www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/rivers-and-habitat-open-space

This information was used to create an additional filter capacity at the PLSS Level. This filter illustrates potential policy applicability at the PLSS level. In these maps, the numeric value given for every PLSS section represents the percentage of the filtered private parcels contained within that section that are eligible for that policy.

In the AGOL map the user can change the policy category of interest by selecting the Policy Eligibility layer in the left layers list. Then, by clicking the styles icon on the right, the user can choose the policy (attribute) that is of interest. After that, the user can then click "Counts and Amounts (color)" to select a different color scheme or break values. The attribute table can be viewed by clicking on the three dots next to the Policy Eligibility layer and clicking "show table."

An example of a map depicting areas where the Family Fish Passage program could be applied is provided in Chapter 6.

The utilization of these three layers (risk score, context and impact overlays and program policy eligibility) to assess conversion risk and identify and prioritize potential interventions is explored in Chapter 7.

7. Designing A Decision Framework to Address Conversion Risk

The goal of this research was to develop a methodology and a set of tools that program and policy managers could use to identify areas at risk of conversion and better understand both the underlying drivers of conversion risk and the potential policy interventions that could be used.

Planning and policy analysis is complex. There are multiple dimensions, scales, and factors, multiple streams of information, and multiple time frames that need to be considered – often simultaneously. Tools ranging from complex statistical models to simple tradeoff matrices can be used to support and inform this type of analysis. The challenge is selecting a tool that has enough power to capture the nuances and complexities of the problem without delving into so much detail that it overwhelms the analytical benefits of the approach.

The tools developed through this research effort provide a high-level understanding of areas where conversion risk potential is greatest and an initial understanding of the potential drivers of that conversion. These high-level results can be used to identify existing programs and policies that can be utilized to address or mitigate conversion risk. They can also identify areas where policies and programs do not currently exist.

The initial approach anticipated for this analysis focused on developing a static weighted decision matrix that evaluated the effectiveness of up to 18 different program and policy instruments based on a set of established criteria. As the research evolved the objective shifted towards the creation of a dynamic, interactive map-based tool that would allow the user to adjust a number of different variables in order to better understand sources/drivers of risk and the availability of potential policy interventions to address conversion risk.

In this chapter we utilize the tools to identify areas that are at high risk for conversion and explore available policies and programs to address that risk. It is important to caveat that the results from these tools are high level directional indications of areas that warrant further exploration and analysis. The tools are not designed to identify specific parcels that are at risk or to say with certainty what is the underlying source of that risk. Further, there is often additional detail associated with the programs and policies that the tool identifies that will need to be explored before definitive action can be taken.

7.1. Developing a Decision Framework

The underlying development probability risk map serves as the basis for the analysis. The initial model assigns a development probability score to each parcel, with score of one indicating low risk and score of ten indicating a high risk. Development probabilities range from a low of zero (indicating little to no risk for conversion) to a high of 10. The web query app [WA DNR Forest Conversion PLSS Web Query App V2](#) can be used to explore these probabilities. The user can

change the development probability scores in order to identify areas where there is conversion risk. For example, setting the development probability to 6 will display all parcels that have a development probability score of six or higher.

The at-risk overlay layers can be considered criteria. Depending on what criteria is important to the user a particular overlay can be turned “on” or “off.” As with the initial development probability, there is a range of scores associated with the overlay layers – again with one being low and 10 being high. The user can choose which overlay layers to apply and at what level of intensity. These scores give us a rough idea of what is at risk if a parcel is converted as well as the kinds of policies that might apply to a given parcel. For example, a parcel with a high salmon score may be important to local salmon populations, perhaps containing or adjacent to a waterway commonly used for spawning, and therefore programs related to salmon protection, recovery, and restoration are likely to be applicable.

As a reminder- the overlay layers include water supply, water quantity, rare plants and ecosystems, habitats and species, salmon streams, commercial timber, forest carbon, outdoor recreation, policy, and climate change. These layers can be explored using the [Web Map: PLSS sections with all output attributes](#) map.

Similarly, the program and policy attributes filter allows the user to determine whether or not an area matches the requirements for specific programs or policies. The thirteen programs at the PLSS level are: 1) Estuary & Salmon Restoration Program, 2) Aquatic Lands Enhancement Account, 3) Brian Abbot Fish Barrier Removal Board, 4) Salmon Recovery & Puget Sound Acquisition and Restoration, 5) WA Wildlife and Recreation Program, 6) Community Forest Program, 7) Family Forest Fish Passage Program, 8) Business and Occupation Tax, 9) Partners for Fish and Wildlife, 10) Forest Riparian Easement Program, 11) Rivers and Habitat Open Space Program, 12) Safe Harbor Agreements and 13) Service Forestry Program.

Areas that meet the minimum eligibility criteria for these programs can be explored using the [Web Map: PLSS sections with all output attributes](#) map.

The conversion risk scores, overlays of loss potential, and program eligibility findings function as “weights” and can all be adjusted by the user to query and filter parcels in the mapping tool. This way, instead of navigating through the map by clicking individual parcels to assess their potential, the user can filter the map to show areas that specific criteria apply to.

7.2. Identifying Priority Areas

The county level mapping tool [Web Map: County level summaries of all attributes](#) can be used to generate a table showing them mean and sum values for development probability as well as the risk scores for overlays and policy applicability (the table is also provided in Appendix F).

Using the average of the logistic and decision tree results and sorting the counties by the sum of average development probability (which gives an indication of the number of areas at risk) regardless of the risk probability score, the results are presented in Figure 22 below.

Not surprisingly, when looking at the areas that have the largest numbers of parcels at risk our model identified Snohomish, Thurston, King, Whatcom, Pierce, Lewis, Spokane and Skagit counties as the counties with the highest number of parcels at risk of conversion, with Snohomish having the highest number (at 5927).

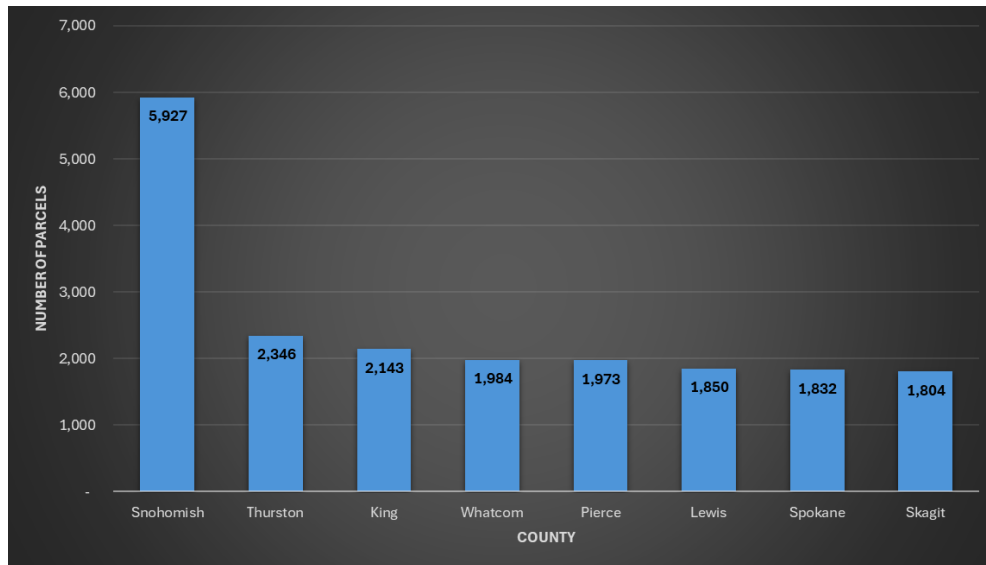


Figure 22. Top Ten Counties by Parcels at Risk

With the exception of Spokane, the remaining counties are all along the I-5 corridor. These findings are not inconsistent with previous studies.

Sorting counties by mean values, which eliminates the effects of county size, yields a similar result, as shown in Figure 23.

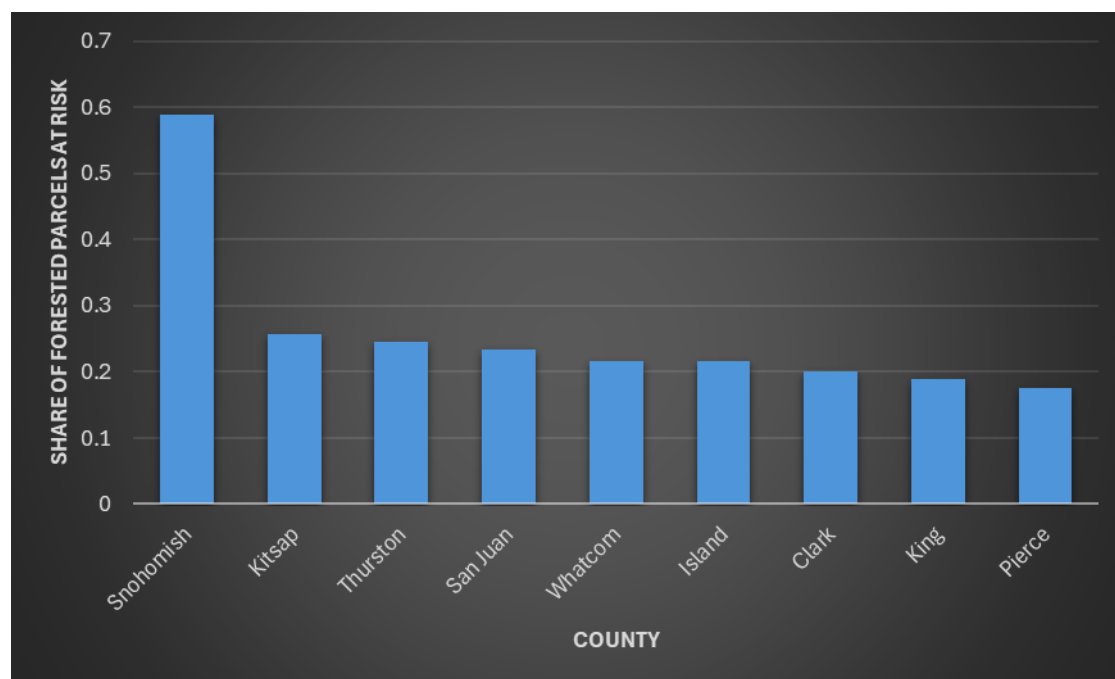


Figure 23. Parcels at Risk as a Share of All Forested Parcels

Snohomish county remains the county with the highest share of parcels at risk, by either measure. Thurston county also has a significant risk. However, when the results are adjusted to account for county size, the risk for King and Pierce counties, while still significant, is lower. Using this metric Kitsap, Thurston, San Juan, Island and Clark counties also have significant areas at risk of conversion. Lewis, Spokane, and Skagit do not.

These findings are not surprising when one looks at the growth rates in these counties since 2014 as shown in Table 13 below.

Table 13. Population Growth from 2014-2023 ¹⁰⁹

County	Population 2014-2018	Population 2019-2023	Percent Change
Snohomish	786.6	834.6	6.1
Thurston	274.7	296.6	8
King	2.2 M	2.3M	4.6
Pierce	859.8	924.1	7.5
Whatcom	216.8	228.4	5.4
Lewis	76.9	83.9	9.1
Spokane	497.9	544.3	9.3
Skagit	123.9	130.4	5.2

¹⁰⁹ Santos, Melissa and F. Fitzpatrick. Jan 8, 2025. Washington Ranks 6th Among States in Population Growth. Axios Seattle. Available [here](#).

County	Population 2014-2018	Population 2019-2023	Percent Change
San Jan	16.5	18.3	10.9
Island	81.6	86.7	6.3
Kitsap	262.5	276.6	5.4
Clark	465.4	510.5	9.7

7.3. Overlay Variables and What is Potentially at Risk

The geographic location of an area at risk provides a starting point for understanding conversion risk. Looking at what could be lost should conversion occur can help decision makers further prioritize where, and how to intervene.

Continuing our example to look at what might be at risk if conversion occurs in the 12 counties that our initial sorting identified, the same map can be used to explore overlay conditions. Using the overlay filter explored using the [Web App: PLSS section level filtering and counting](#) map the scores for the overlay variables in those counties are listed in Table 14 below. These scores are the averages of the Importance Scores for the different overlays.

Table 14. Average Importance Score by Overlay

Conditions at Risk								
County	Water Supply	Water Quality	Rare Plants	Habitat and Species	Salmon	Timber	Forest Carbon	Outdoor Recreation
Snohomish	5.81	2.47	1.19	2.41	6.09	5.25	5.85	7.25
Thurston	1.52	2.57	2.37	2.93	4.22	8.02	5.31	6.02
King	5.62	2.72	1.38	3.60	3.65	4.12	6.08	8.05
Pierce	2.62	1.96	1.82	3.16	4.06	5.70	5.73	5.66
Whatcom	6.99	1.60	2.03	2.24	5.54	3.66	5.33	6.58
Lewis	6.60	3.26	1.64	4.40	3.79	7.55	5.69	4.84
Spokane	3.36	2.49	2.04	4.69	1.05	2.34	2.01	6.05
Skagit	7.77	2.13	1.61	3.31	5.32	4.68	5.84	7.24
San Jan	7.38	1.00	1.35	1.26	1.02	1.81	6.80	9.80
Island	1.84	1.00	1.66	2.06	1.75	5.03	7.12	9.46
Kitsap	2.10	1.13	1.10	1.46	4.21	5.88	6.86	8.31
Clark	8.45	1.44	2.76	1.90	3.50	6.16	5.87	6.14

Viewing the results in table form, it is clear that conditions represented by all of the overlay variables are at risk to some degree across all the counties that met the initial filter criteria.

As discussed in Chapter 5, the overlays are ranked on a scale of 1-10 with one indicating a low risk of loss due to conversion and 10 the highest. Table 14 allows the user to visualize what is at risk in a particular county or by overlay.

In Snohomish County, which has the highest overall probability of conversion risk (see Figures 25 and 26) the impacts to recreation and salmon habitat were strongest. Water supply is also potentially at risk in Snohomish County.

Shading all the overlays with a score greater than six in yellow provides a striking visualization of how at-risk outdoor recreation is, with scores greater than six in all but two of the counties. If the cut-off were lowered to 5, the recreation values would be at risk in all but one of the twelve counties.

Water supply also scored higher than six in five of the counties, and if the bar were lowered to five then it would be at risk in seven of the twelve counties.

These indicators can help determine the approaches one might take and the resources one might draw from to address conversion risk.

Clearly more analysis needs to be done to develop a more granular level of understanding of the situation, but as an example, in the case of Snohomish county, salmon habitat scored above 6, which suggests that policy levers, programs and resources available to protect and restore salmon habitat might be utilized to mitigate conversion risk pressure.

7.4. Program and Policy Solutions

Looking at those same 12 counties, and what is at risk if conversion occurs, another logical line of inquiry would be to understand what, if any, programs, and policies exist to address those risks. Based on the results of filtering the [Web Map: PLSS sections with all output attributes](#) The programs that are currently available to address conversion risk in those counties are listed in the table below.

Table 15. Percent of Forested Parcels Assessed to be Potentially Eligible for Each Policy

County	Snohomish	Thurston	King	Pierce	Whatcom	Lewis	Spokane	Skagit	San Jan	Island	Kitsap	Clark
Program and Policy Solutions												
Estuary and Salmon Restoration	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Aquatic Lands Enhancement	95%	84%	63%	88%	87%	98%	76%	89%	60%	41%	71%	86%
Brian Abbot Fish Passage	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	3%	10%
Salmon Recovery/PSAR	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	10%
Habitat Conservation Projects (WWRP)	29%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Community Forest Program	2%	22%	8%	2%	4%	3%	1%	4%	70%	6%	2%	0%
Family Forest Fish Passage	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	10%
Business & Occupation Tax	100%	100%	98%	99%	94%	100%	92%	82%	84%	99%	99%	99%
Partners for Fish and Wildlife	57%	53%	55%	72%	51%	78%	67%	46%	39%	34%	10%	72%
Forest Riparian Easement	7%	28%	26%	16%	25%	18%	29%	21%	35%	27%	28%	31%
Rivers and Habitat Open Space	86%	37%	77%	72%	41%	81%	80%	48%	40%	21%	2%	53%

The values in the cells illustrate what percentage of the area in the sample meets the minimum eligibility criteria for the program listed in the first column. For ease of visualization, all programs where more than fifty percent of the area would be eligible in a given county are shaded green. If none of the area in the county is potentially eligible the cells are shaded grey. As noted in the program and policy explanation in Chapter 6, the data layers chosen for this filter are intended to proxy the minimum eligibility criteria for the program. In all cases there are additional factors that will need to be evaluated to fully confirm that a geography is eligible for a given program. Also, this level of analysis does not identify specify which parcels, their relative size, or risk score so it is difficult to prioritize without further analysis.

None the less, this presentation does highlight several interesting results. Firstly, it appears that there are no areas in any of the counties that would be eligible for Estuary and Salmon Restoration funding. This result warrants further exploration. Assuming this result is correct, it would suggest that DNR might want to pursue modifications to the program eligibility or if that is not possible perhaps developing a program that could be used in these areas, particularly in the case of Snohomish County and the relative importance of salmon habitat and the associated threat of loss (as shown in Table 15).

Another interesting result is the number of counties that have high parcel eligibility for the Aquatic Lands Enhancement program, which provides public funds to improve public access and protect and re-establish natural ecological functions of aquatic lands. If program managers are not already working in these counties to develop grant applications for these funds, this would be an area for further exploration.

8. Conclusions, Recommendations, and Next Steps

The landscape of factors that influence a private landowner's decision to convert land out of working forest to other uses is complex. Our review of the literature and engagement with stakeholders narrowed the focus of our analysis from the original three factors down to two drivers of conversion risk: urbanization and climate change. In both cases these drivers were manifested through other factors. For example, general population increases and associated shifts in migration patterns lead to increased urbanization and suburbanization. This puts pressure on land values (particularly in areas where growth is restricted by zoning or land use policies) which increases the incentive for a landowner to sell. Similarly, climate change increased potential risk of loss of timber value from fire, pest or disease may motivate a landowner to harvest and then sell.

We explored the literature regarding the relationship between supply chain dynamics and private landowner decisions to remove land from working forest and did not find evidence of correlation. We also did not find evidence of this relationship in our stakeholder interviews or through our workshops. As a result, we did not include this in our analysis. We also did not attempt to address conversion of forest lands for agricultural uses—both because of lack of data and because, based on our interviews, this does not appear to be a factor in Washington.

Through our interviews landowner demographics were also identified as a potential driver of conversion risk. The literature suggests that landowners between 57 and 67 years old are more likely to consider selling their land.¹¹⁰ Similarly, new landowners are frequently unaware of and unable to manage working forests and are likely to convert.¹¹¹ For both of these examples obtaining data that could accurately be used and building a model at the level of resolution that would be necessary to capture these effects was beyond the scope and budget of this project.

Our analysis of climate-driven risk of forest conversion consisted of overlaying private parcels with WA DNR's "trailing edge" data set, which depicts the risk of forest type conversion due to changing climate on a scale of 1-3.

We modelled conversion risk due to urbanization by quantifying factors that either drive or constrain urban development (legally, economically, or physically) and statistically relating these factors to actual observed land development. By looking at statistical relationships between past urbanization and various predictor variables, we used those same variables to estimate which parcels are most at risk from future urbanization. The results of this modeling were then used to predict the probability of development for each parcel given the specific input values for each parcel. The input variables included in the model are repeated in Table 14 below.

¹¹⁰ Forest Land Conversion In Washington State. Available [here](#). and Small Forest Landowner Demographic Report. Available [here](#). and Retention of High Valued Forest Lands at Risk of Conversion. Available [here](#).

¹¹¹ *ibid*

Table 16. Input Variables for Modelling Urbanization Impacts

Proximity to urban growth boundary (unit= km)
Percent of forested land in parcel
% area forest practice regulatory buffers: wetland
Parcel road extent (unit= km)
Block group median house value (unit= \$10,000)
Soils: maximum drainage class per parcel
Minimum percent slope on parcel
Distance to nearest business cluster (km)
Area of buildings within 20km buffer (unit= sq km)
In forest practices “regulatory transfer” municipality
% of parcel in 100-year flood plain
Count of businesses within 10km radius
Count of businesses within 20km radius
Longitude (degrees)
Latitude (degrees)

Our results were consistent with the literature and with findings from past research. Areas in the Eastern side of the state, particularly along the I-5 interstate corridor, are at highest risk of conversion, with Snohomish County particularly at risk. The tools developed through this research indicate areas that should receive additional focus in order to better understand the nuances of what is driving conversion and ultimately what types of interventions should be developed to address those drivers.

The literature also suggests, and our interviews reinforced, the positive connection between engagement with landowners, and access to information and resources as approaches that successfully mitigate conversion decisions.

As noted in Chapter 2, DNR offers a number of assistance programs directed at small lot landowners, as do Conservation Districts and the Washington State University Cooperative Extension Service. However, there are gaps in some of the landowner assistance programs and some are oversubscribed or underfunded. For example, the Working Woodlands program is free but is only available to landowners with over 2,000 acres of land. Along with the Working Woodlands program, the Designated Forest Land Program has qualifications which may be limiting landowner participation. Landowners may be hesitant to commit to long-term easements offered through the Working Woodlands program and the Small Forest Landowners

Office, which establishes a 40-year easement.¹¹² Financial assistance programs available through the Small Forest Landowners Office—the FFFPP and the FREP—are oversubscribed and underfunded.^{113,114}

8.1. What the Map Reveals

One of the strengths of the single map tool is that it allows the user to identify patterns and see gaps in services. As discussed in Chapter 7, a high-level query sorting and ranking by risk score and then simply exploring the associated overlays and policy and funding filters revealed a number of insights and identified a number of opportunities.

- **Hot-Spot Counties.** Snohomish, Thurston, King, Whatcom, Pierce, Lewis, Spokane, and Skagit contain the largest absolute numbers of high-risk parcels. When adjusted for land area, Island, Kitsap, San Juan, and Clark surge to the top—small counties where even modest raw losses translate into large percentage losses.
- **The I-5 Shadow Effect.** More than **60 percent** of top-decile risk parcels lie within a 30-kilometre band of the I-5 corridor, underscoring the gravitational pull of Puget Sound’s housing market.
- **Climate Cross-Hairs.** Eastern Washington parcels score higher for wildfire exposure; western parcels face emerging drought-induced die-off of western red-cedar. Both phenomena raise management costs and nudge owners toward liquidation.
- **What’s at Stake.** Ten of twelve focus counties register outdoor-recreation scores above 6. Salmon importance peaks in Snohomish, while high drinking-water importance (> 6) clusters in Clark, Lewis, and Skagit.
- **Policy Alignment Gaps.** Not one high-risk inland parcel currently qualifies for ESRP grants. By contrast, **Aquatic Lands Enhancement** eligibility extends to > 60 percent of hot-spot parcels, and the **B&O forest tax credit** theoretically covers about 98 percent, though its small dollar value limits impact.

8.2. Strategic Implications and Opportunities

The analysis tools developed for this research project can be used to help DNR program managers understand the scope and scale of areas where there is potential demand for these programs so that existing resources can be targeted and additional resources can be requested

¹¹² Ibid.

¹¹³ College of Forest Resources, University of Washington, “Retention of High-Valued Forest Lands at Risk of Conversion to Non-Forest Uses in Washington State,” March 25, 2009.

¹¹⁴ “Preventing Forest Conversion.”

to support these programs. Some examples (based on the results of the query explored in chapter 7) include:

- Develop corridor strategies - Stitch together shoreline easements and community-forest acquisitions along lower river valleys (e.g., the Stillaguamish, Chehalis, and Nisqually). Doing so locks in salmon habitat, flood-plain buffering, recreation, and carbon benefits in one package.
- Bundle wildfire prevention and planning and easement programs - Couple Service Forestry fuel-reduction grants (federal cost-share for thinning and pruning) with 40-year riparian easements to prevent post-fire liquidation and lower insurance premiums.
- Develop a quick strike revolving fund - Establish a low-interest loan pool that lets land trusts make rapid offers before speculative buyers close. Fast capital is often the difference between conservation and conversion.
- Expand footprint of salmon funding - Expand ESRP eligibility inland or create a companion “upland buffer” grant program so that headwater streams feeding salmon runs can tap the same dollars as tidal marshes.

8.3. Opportunities for Further Research

The tool is designed to allow the user to select multiple overlay criteria at once in order to explore a range of scenarios and policy options. Examples of additional analysis that the tool can support included exploring the nexus between areas with high conversion risk and high risk of habitat loss; identifying all areas in a geography that are potentially eligible for a particular program or policy; and conversely, identifying areas at high risk where no policy instruments currently apply.

The factors influencing conversion decisions are not linear and no one variable is consistently an accurate predictor of behavior on a household level. These analysis tools are high level directional indicators of areas of concern. They are designed to be used to identify areas for further detailed analysis, in particular through direct engagement with landowners in high-risk areas. It is also difficult to tease out motivation and identify that one key bit of information or assistance that might make a difference in landowner decision making from macro level data. Individual landowner engagement and household level data collection will help DNR refine its understanding of what is needed, and what is missing in terms of landowner support programs.

Another area for further refinement would be to update the data sources that were used to develop the overlay and program eligibility filters. Additional or better data would not only improve the accuracy of the results it would also allow for the inclusion of additional overlay characteristics and programs eligibilities. Thirteen programs were used to build the policy and funding filter. Additional programs (like Family Forest Fish Passage) can be added to the filter tool.

In addition to adding programs to the program and policy filter, the map would benefit from an equity overlay that integrates data indicators from the Washington Environmental Health Disparities Map.¹¹⁵ This would allow users to identify areas that are at high risk from an equity and environmental justice perspective and would potentially therefore be candidates for funding and program interventions associated with the Climate Commitment Act.

8.4. Next Steps

- **Ground truth the data.** Field-check the highest-risk parcels in Snohomish and Thurston by Q3 2025 so that model predictions evolve with real-world observations.
- **Plan for regular data updates.** Update both risk models every two years to absorb new zoning ordinances, census counts, property-sale records, and wildfire scars.
- **Economic Valuation.** Quantify avoided flood-control costs, reduced water-treatment expenses, and potential carbon-offset revenues to strengthen budget requests.
- **Create an Equity Overlay.** Add census-tract vulnerability scores so that conservation dollars also advance **environmental-justice** goals—steering investments toward communities with fewer parks and higher flood risk.
- **Expand the Tool.** Integrate other DNR programs, USDA Farm-Bill programs (e.g., the Healthy Forests Reserve Program) and private “green bond” financing to widen the funding menu beyond the initial thirteen tools.
- **Create a User Community.** Host quarterly **user clinics** and maintain a public **change log** so county planners, tribes, and NGOs can see what has improved and suggest new features.

¹¹⁵ Washington Department of Health. Washington Environmental Health Disparities Map. Available [here](#).

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A

Program Analysis Tables

Table A1. Programs Selected for Inclusion in the Model

Program	Key Requirements	Indicator Variable Data Layer	Program Web Site Link
Brian Abbott Fish Barrier Removal Board	Contains a fish-bearing stream	Fish-Bearing Stream: WA State fish passage inventory	https://rco.wa.gov/grant/brian-abbott-fish-barrier-removal-board/
Estuary & Salmon Restoration Program	Contains 1 or more of the following: - Fish-bearing stream - Riparian area	Fish-Bearing Stream: WA State fish passage inventory Riparian area data layer- NR SIG	https://rco.wa.gov/grant/estuary-and-salmon-restoration-program/
Aquatic Lands Enhancement Account	- Riparian area - Adjacent to a body of water	Riparian area data layer- NR SIG Water body adjacency	Aquatic Lands Enhancement Account - Recreation and Conservation Office
Community Forests Program	- Parcel of 5+ acres - OR - Collection of parcels that total 5+ acres	SIG Development Data	Community Forests Program - RCO
Habitat Conservation Projects – Washington Wildlife and Recreation Program	Contains T&E species Contains riparian area	PHS: Priority habitats and species, WDFW Riparian area data layer- NR SIG	https://rco.wa.gov/grant/washington-wildlife-and-recreation-program-habitat/
Salmon Recovery & Puget Sound Acquisition & Restoration	Located in Puget Sound East of Cape Flattery	Puget Sound Y/N	https://rco.wa.gov/grant/salmon-recovery/

Program	Key Requirements	Indicator Variable Data Layer	Program Web Site Link
Family Forest Fish Passage Program (FFFP)	Fish-Bearing Stream Road	Fish-Bearing Stream: Fish passage inventory, WA Dept. of Fish and Wildlife (WDFW) Road: Statewide roads and routes, WA Dept. Of Transportation (WDOT)	www.dnr.wa.gov/fffp
Safe Harbor Agreements	Private Forestland PHS	Private Forestland: SIG DD PHS: Priority habitats and species, WDFW	NA
Business and Occupation (B&O) Tax Reduction (RCW 82.04.260)	Commercial Timberland	Private Forestland: SIG DD Commercial Timberland: SIG DD; sawmills	https://dor.wa.gov/education/industry-guides/manufacturing-guide/manufacturing-timber-or-wood-products
Partners for Fish and Wildlife	1+ of the following: • Riparian Zone(s) • Wetlands • PHS • Rare Plants	Private Forestland: SIG DD Riparian Zones: Data not available Wetlands: National Wetlands Inventory, U.S. Fish and Wildlife Service PHS: Priority habitats and species, WDFW Rare Plants: Washington National Heritage Program rare species and ecosystems data	www.fws.gov/program/partners-fish-and-wildlife
Service Forestry Program	Private Forestland (5+ acres)	Private Forestland: SIG DD	www.dnr.wa.gov/forest-stewardship-planning
Forest Riparian Easement Program	At least 20+ contiguous acres No more than 80 acres	Acreage: Acres greater than 20, less than 80	www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/forestry-riparian-easement-program

Program	Key Requirements	Indicator Variable Data Layer	Program Web Site Link
Rivers and Habitat Open Space Program	Contains either: Critical habitat of state threatened/endangered species	Private Forestland: SIG DD PHS: Priority habitats and species, WDFW	www.dnr.wa.gov/programs-and-services/forest-practices/small-forest-landowners/rivers-and-habitat-open-space

Table A2. Currently Active Programs Evaluated for Inclusion

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Created	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
Family Forest Fish Passage Program (FFFPP) (RCW 76.13.150)	WA DNR; WDFW; RCO	Cost share; technical assistance	2003	Biannual budget (2023-24); \$5.9 million	Since 2003, over 375 landowners have utilized the program to remove 471 barriers and open more than 1,361 miles of stream habitat; provides 75 to 100 percent of the cost of correcting small forest landowners' fish barriers
Forest Riparian Easement Program (FREP) (RCW 76.13.120)	WA DNR	Direct Payment for 40-year easement to mitigate impacts of Forest and Fish on small landowners	2000	Biannual budget (2023-24; \$5,115,520	FREP reimburses small forest landowners, 90 percent of the value of trees they are required to leave along streambanks to protect fish habitat in a 40-year conservation easement. 508 easements have been purchased to date.
Rivers and Habitat Open Space Program (RCW 76.09.040)	WA DNR	Direct Payment for permanent easements in channel migration zones for timber harvest and critical habitat for state listed threatened or endangered species	2001	Biannual; \$4.7 million for this program for the 2023-2025 biennium	RHOSP started in 2002, and since then has protected 1,441 acres of critical habitat via 28 conservation easements
Forest and Fish Leave Tree Tax Credit (RCW 84.33.0775)	Washington State Department of Revenue (DOR); DNR	16 percent forest excise tax credit for harvests impacted by Forest and Fish riparian requirements	1999	TBD	Credit equals 4-10 percent of value of foregone timber value (2001 DOR Study)

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Created	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
Current Use/Designated Forest Land (DFL) Tax (RCW 83.33)	County Assessors; DOR	Current Use Tax reduction until timber harvest of timber	1972	TBD	6,166,024 acres enrolled (2008). Forest management plan required. Some counties require a 10-year commitment to not develop land.
Forest Practices Act - Alternate Plan Templates	WA DNR	Regulatory relief from Forest and Fish rules with alternate plan providing equal level of resource protection	2000	TBD	Requires professional assistance from Small Forest Landowner Office. Many small landowners forego this option because of expense and complexity. From 2000-2005, 112 alternative plans developed and approved.
Small Forest Landowner Long Term Practices Permit WAC 222-12-030, -035, -0401, -0402, 222-16-010, -050, and chapter 222-20 WAC Forest Practices Permit	WA DNR	Regulatory relief from operation-by-operation Forest Practices permit applications. Available to Small Landowners as defined in WAC 22-21-010(13).	2007	TBD	An approved long-term application will be effective for a term of three to fifteen years at the discretion of the landowner.
Safe Harbor Agreements	United States Fish and Wildlife Service (USFWS)	Voluntary management agreements for listed species with stability for future regulatory restrictions		TBD	TBD
Business and Occupation (B&O) Tax Reduction (RCW 82.04.260)	DOR	Provides tax incentives for the timber products and industries	2006	NA	SSB 6874 (2006) reduces B&O tax rate from 0.484 percent to 0.2904 percent until July 2024 . A 0.052 percent surcharge is imposed for implementation of the state's Forests and Fish Report.
Conservation Stewardship Program	Natural Resource Conservation Service (NRCS)	Direct Stewardship Payment (five-year contract); Technical Assistance	2008	Total obligated: \$350.74M (state or federal)	The minimum annual payment for new and renewed contracts for agricultural producers participating in the Conservation Stewardship Program from \$1,500 to \$4,000 starting in fiscal year 2024. 23,115 contracts for all enrollments (includes ag)

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Created	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
Environmental Quality Incentive Program (EQIP)	NRCS	Cost share (50-70 percent); technical assistance	1996	\$1.75 billion (2024) -state vs federal	10.5 million acres enrolled (2020). Covers road de-commissioning, site prep, and upland wildlife habitat management. Requires forest management plan. Fully subscribed with less than 1/2 of applications funded nationally
Partners for Fish and Wildlife	USFWS	Cost share; technical assistance	1992	\$79.9 million (2024)	Over 6 million acres enrolled (2024).
Wildlife Habitat Incentives Program	NRCS; WDFW, USFWS	Cost share (50-70 percent); technical assistance	1996	\$608,000 (2008-09)	357,700 acres enrolled (2007). Restoration of native habitat and vegetation for threatened and endangered species on forest or agricultural land
Conservation Technical Assistance	NRCS	Conservation planning, design, and implementation assistance	1935	TBD	TBD
Service Forestry Program (previously the Forest Stewardship Program)	WA DNR, USFS	Technical and financial assistance for forest health, wildfire resilience, disease and pest management, invasive species management and removal, wildlife habitat improvement, and forest management plan creation	1990	2023-25 W WA Service Forestry Financial Assistance \$384,974.90	The newly instituted service foresters and service forestry specialists provided technical assistance to landowners and conducted over 400 site visits in the first year of expansion, 2022
Forest Legacy Program	USFS, DNR	Direct payment for fee interest or easement (75 percent federal funds)	1990	\$154 million-	As of September 2023, over 77,000 acres in Washington state have been protected via this program.
King County Transfer of Development Rights	King County	Direct payment from private development interests	2001	NA	145,600 acres protected from 1998-2022.
Conservation Easements	Land Trusts, IRS	Donation or purchase of development rights. Donations may provide federal tax code benefits.	TBD	TBD	Does not require the land remain in commodity production. Depends on mutually agreeable conditions between landowner and easement holder.

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Created	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
Growth Management Act (GMA)	Counties under CTED guidance	Comprehensive Plan designation, zoning codes, Land Use regulations	1991	NA	Lands of long-term commercial significance for forestry (40-80 acre lot size). No evaluation of effectiveness of GMA on facilitating or preventing parcelization of productive forest land.

Table A3. Overview of Proposed or Inactive Programs, Initiatives, Regulations and Legislation

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Proposed or Created	Status	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
Develop Overall State Plan for Retention of Working Forests	WA DNR/Office of Governor/UW Forum	Integrated resource plan across programs, integrating Land Use, Forest Practices, and Forest Tax authorities	2020	Achieved via 2020 Washington Forest Action Plan	NA	The 2020 Washington State Forest Action Plan (Forest Action Plan) provides a comprehensive review of forests across all lands — public, private, rural, and urban — and offers solutions to conserve, protect and enhance the trees and forests that people and wildlife depend on.
Continued Funding for Land Parcel Database	UW Institute of Forest Resources (IFR)	Multi-layered GIS database of properties, based on Assessors' records and resource information	Created in 2007	Active	\$1,056,606	Project sponsors include WA DOH, USFS, WA DOR Four versions of the database have been developed between 2007 and 2012. Work is ongoing to continue development of future versions of the database. To date, 65 agencies / organizations have downloaded the Washington State Parcel database and are using it for 252 documented projects.
Encourage diversified forest products infrastructure	Community Trade and Economic Development (CTED); UW CINTRAFOR	Trade and Market opportunity	TBD	TBD	TBD	TBD

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Proposed or Created	Status	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
		identification and development				
Provide investment incentives for Eastside sawmills and biofuels facilities	Legislature; CTED	Tax relief. Low- interest loans, grants	TBD	TBD	TBD	TBD
Biofuels feasibility study focused on eastside forest health	UW	Analysis and evaluation	TBD	TBD	TBD	TBD
Fully fund DNR Forest Health Initiative	WA DNR	Integrated agency response across disciplines	2021	Active	\$70.8 mil (wildfire response), \$34.5 mil (forest restoration), \$19.6 mil (community resilience) 2021	House Bill 1168, if fully funded provides \$125 million each biennium to fulfill SNR's Forest Health Strategic Plan and Wildland Fire Prevention 10-year Strategic Plan
Joint UW/WSA pilot bioenergy project for forest cellulose conversion	UW/WSU/CTED	Inventory, research and analysis	TBD	TBD	TBD	TBD
Assure stable timber supply from Federal forests	USFS	Implementation of portions of Northwest Forest Plan to allow thinning on federal forests	TBD	TBD	TBD	TBD
Encourage coordination with other public land managers for active thinning programs on Federal lands	USFS/DNR/Tribes/NGOs	Forest health, biofuels reductions	GNA Created in 2017	Active	\$12 million across participating states	DNR, Washington State Fish and Wildlife, and the USFS created a shared stewardship agreement that gives them the ability to raise revenue for forest health treatments and wildfire suppression under the

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Proposed or Created	Status	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
						Good Neighbor Authority (GNA). This tool allows the USFS and Bureau of Land Management to pass-through federal dollars to state agencies like DNR to plan and implement forest health treatments on federal lands and facilitate cross-boundary large landscape projects.
Provide tax incentives for working forest land	Legislature	Review and revise forest tax framework to encourage retention of forest lands	Originally established in 1971	NOT revised	NA	Tax rates in Washington are high in comparison to neighboring states, creating a competitive disadvantage.
Separate rule structure for certified forest lands: Sustainable Forestry Initiative (SFI), Forest Stewardship Council (FSP), American Tree Farm System (ATFS)	Forest Practices Board	Alternative to Forest Practices rules	TBD	TBD	TBD	TBD
Establish a stronger "Right-to-Practice Forestry" in statute	Legislature	RCW (state law)	TBD	TBD	TBD	TBD
Provide regulatory incentives for riparian corridor thinning to produce "desired future conditions of older forest structures"	Forest Practices Board	RCW 76.09.10	TBD	TBD	TBD	TBD
Fully fund existing landowner assistance and mitigation (for Forest and Fish) programs especially	Legislature through DNR	FREP @\$21.4 million FFFPP @\$19.6 million DNR Expert	TBD	Partially complete	See budgets in table above for FFFPP and FREP	These programs are operational - see funding levels under program Budgets have been increased - BUT increased participation means these

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Proposed or Created	Status	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
for small family forest landowners		Forestry Assistance Program @\$797,800 Landowner Incentives @\$414,200				programs need more funding. FFFPP and FREP are oversubscribed and underfunded.
Reduce timber tax in exchange for environmental gains	Legislature; DNR; DOR	RCW amendment similar to tax credit provided in RCW 84.33.0775 for riparian leave trees	TBD	TBD	TBD	TBD
Purchase of Development Rights	NGOs in partnership with DNR	Conservation and/or fee purchase	TBD	TBD	TBD	TBD
TDR Pilot Project	Cascade Land Conservancy (CLC)	Legislatively authorized and funded pilot (\$250,000) in 2006 in Pierce and Snohomish counties	TBD	TBD	TBD	TBD
Regional Transfer of Development Rights (TDR) Market	CLC and regional governments	Private market with government support and framework	TBD	TBD	TBD	TBD
Encourage cities to adopt TDR market	City governments	Local land use codes	TBD	TBD	TBD	TBD
Legislative authority for Rural Village Demonstration projects	CLC and local governments	Pilot project	TBD	TBD	TBD	TBD
Tax incentives for forest land set-asides in exchange for higher density developments			TBD	TBD	TBD	TBD

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Proposed or Created	Status	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
Lease of Development Right (DR) with option to purchase	State or local government	Public lease of DR	TBD	TBD	TBD	TBD
Establish forest of long- term community significance	Local governments		TBD	TBD	TBD	TBD
Private Financing	CLC in conjunction with private business partners	Private “Conservation Timber Fund”	TBD	TBD	TBD	TBD
Public Financing	Non-profit NGOs in partnership with state government and TIMOs	“Triage” financing of large tracts of working forests to prevent subdivision and/or parcelization		Concept exploration	NA	Forest Resilience Bonds (see example in Chelan County) is a similar collaboration between an NGO and public agencies, but it is used to bring together multiple funding sources to support landscape level projects (such as fuel treatment projects)
Community Forest Bonds	Non-profit NGOs	Purchase by non- profit with tax-free bonds issued by local government	TBD	TBD	TBD	TBD
Locally Issued revenue- backed bonds	Local governments	Local government purchase of forest land important for community integrity with General Obligation (GO) Bonds				Not the same, but King County TDR follows a similar concept. The Conservation Fund (TCF) can step in to buy threatened wildlife habitat, working forests, farmland, and other vital conservation properties when public and private conservation partners cannot move quickly enough. They hold the land until partners can secure funding, then resell it to them for permanent protection. That way, TCF recoup their capital and can recycle it over

Program	Implementing Agencies (Suggested or Actual)	Program Type	Year Proposed or Created	Status	Budget	# of acres/stream or habitat miles protected/number of enrollees to date; NOTES
						and over again for maximum impact. They have several forestland projects in WA.
Public development/conservation authorities (PDA/PCA)	Local governments	Revenue Bond proceed purchased timber land, then managed to produce revenue for bond repayment	TBD	TBD	TBD	TBD
State Credit Enhancement for Locally issued revenue- backed bonds	Washington State government	Fill cash flow needs for local government to service debt	TBD	TBD	TBD	TBD
Assess Growth Management Act (GMA) effects on fragmentation and conversion of working forest land	CTED, DNR	Analysis using State Parcel Database	TBD	TBD	TBD	TBD
Zoning policies that support Forestry and infrastructure development	CTED, local governments	Land Use codes	TBD	TBD	TBD	TBD
Regional Forest Program	Puget Sound Conservation Districts (funded through PSP Habitat SIL)	Small forest landowner assistance	2012?	ongoing		

B

Stakeholder Engagement and Workshop Materials



**Washington State Forest Conversion Risk Assessment
and Evaluation: Update Workshop November 6, 2024, 1:00 to 3:00 PM**

Welcome & Introduction



Agenda

Welcome	1:00 to 1:10
Previous Research and Existing Model	1:10 to 1:25
Proposed New Model	1:25 to 1:50
<i>Discussion</i>	<i>1:50 to 2:00</i>
Additional Considerations	2:00 to 2:15
<i>Discussion</i>	<i>2:15 to 2:20</i>
Discussion of Querying, Ranking and Overlays	2:20 to 2:40
Preview of What is to Come	2:40 to 2:50





Previous Research and Existing Models

Conceptual Model of Urban Change Drivers



Determinants of change

Constraints

- Regulatory
- Property regime
- Financial
- Site and environmental

Drivers

- Proximity to urban
- Accessibility via roads
- Density of destinations
- Access to services

Values at risk

Socio-Cultural

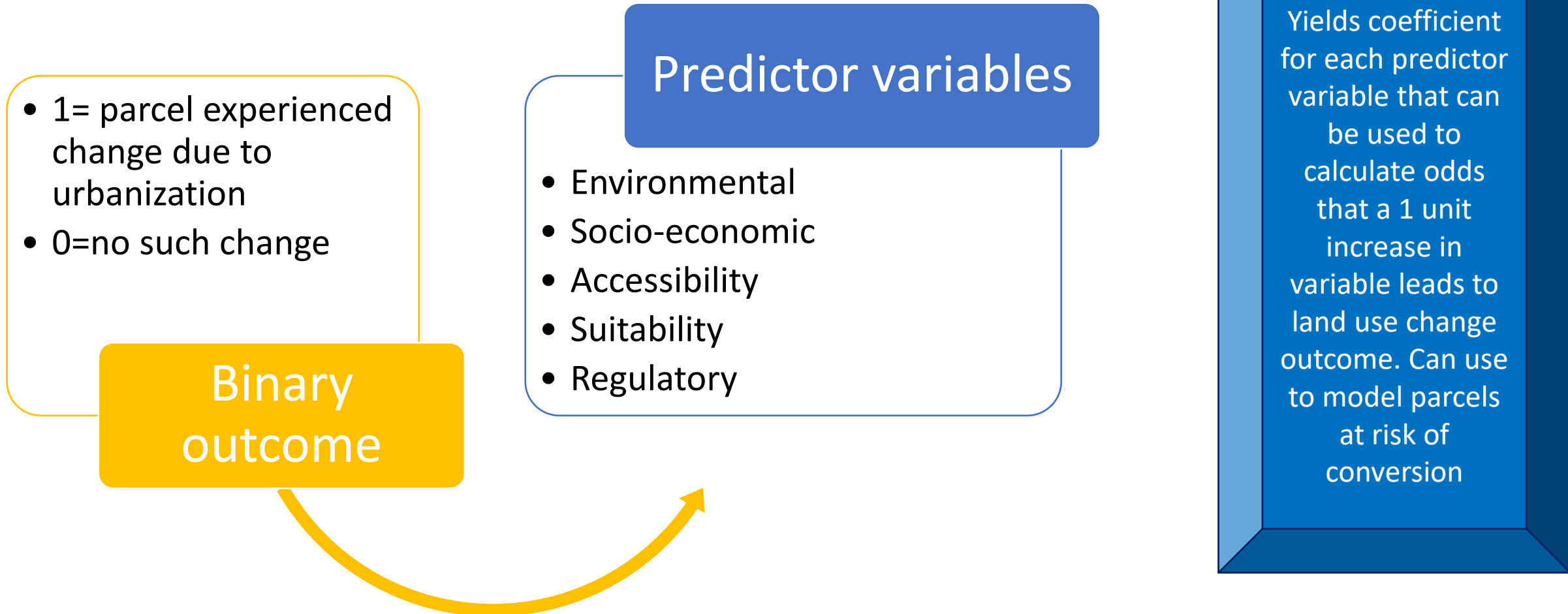
- Recreation
- Loss of timber base
- Aesthetics
- Spiritual, educational

Biophysical

- Water supply
- Biodiversity
- Disturbance regulation
- Carbon storage



Modeling Framework: Logistic Regression



Example – Contribution of Structure/Property Characteristics to Total Loss in Camp Fire

<u>Variable</u>	<u>B</u>	<u>Wald</u>	<u>Sig. (p)</u>	<u>Exp(B)</u>	<u>Δ Odds of destruction</u>
<u>Increase likelihood of destruction</u>					
Mobile home	1.831	105.754	0.000	6.242	524% ↑ in odds
Slope	0.571	28.054	0.000	1.770	77% ↑ in odds
Asphalt Roof	0.557	19.095	0.000	1.745	75% ↑ in odds
Vegetative clearance	0.421	18.539	0.000	1.523	62% ↑ in odds
<u>Decrease likelihood of destruction</u>					
Fire trucks arrived	-4.290	434.258	0.000	0.014	85% ↓ in odds
No vents	-1.347	96.362	0.000	0.260	74% ↓ in odds
Built 1997-2007	-1.001	55.557	0.000	0.367	63% ↓ in odds
Resistant Siding	-0.297	10.352	0.001	0.743	26% ↓ in odds
Fence	-0.276	8.949	0.003	0.759	24% ↓ in odds
Multi Pane Windows	-0.267	6.999	0.008	0.766	23% ↓ in odds

Direction/
magnitude of effect

Is it significant?

What is effect of variable on
odds of outcome?



UW-NRSIG Urbanization Model: Summary Results

Variable	Effect
Proximity to urbanization/Development	↑
Accessibility to roads	↑
Accessibility to "Development"	↑
Development pressure	↑
Proximity to "public roads"	↑
Proximity to urban growth boundary	↑
Median county income	↑
Parcel road extent	↑
Fraction of forested land in parcel	→
Parcel size	→
Riparian regulatory buffers	→
Forest harvest activity	→

“...the land use model’s predictive ability is modest” (p. 179, NRSIG report)

Clearly room for improvement predictors

↑ Positive driver

→ Regionally variable
or indeterminate

Five other variables were insignificant

Source: Rabotyagov et al. Washington's Small Forest Landowners in 2020: Status, trends and recommendations after 20 years of Forests & Fish. January 11, 2021





Proposed New Model

Types of Forest Conversion

Urbanization

Climate change-induced

Agricultural expansion

Overharvest of timber



GIS Team Work to Date on Urban Change Model

- 1) background research/ interviews on land use change predictors and previous NRSIG land use model
- 2) assessing data availability and quality
- 3) choosing variables to include in our model based on the findings of the previous two
- 4) acquiring and processing data, including creating custom statewide map projection
- 5) creating a filtered parcel layer to serve as the analysis baseline
- 6) summarizing observed land use change by parcel for use as the dependent variable in the statistical model
- 7) conducting spatial analysis and modeling needed to generate independent variables

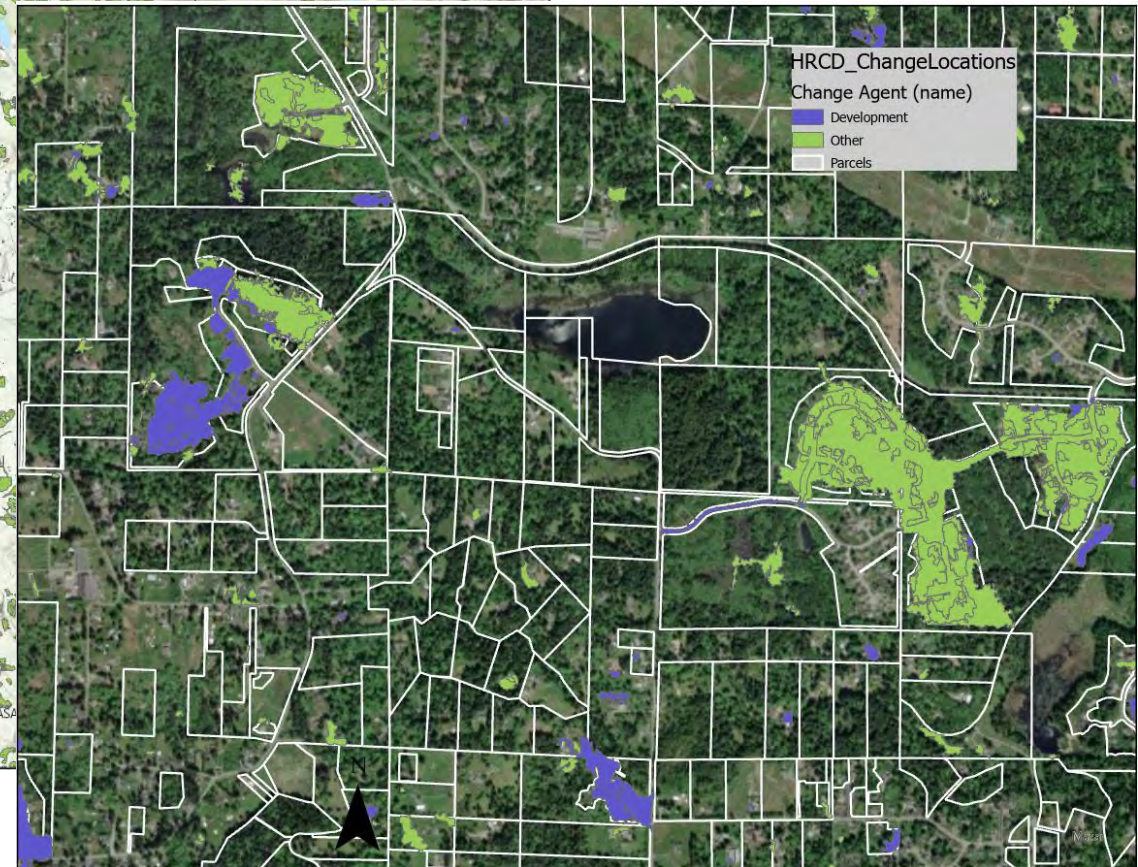
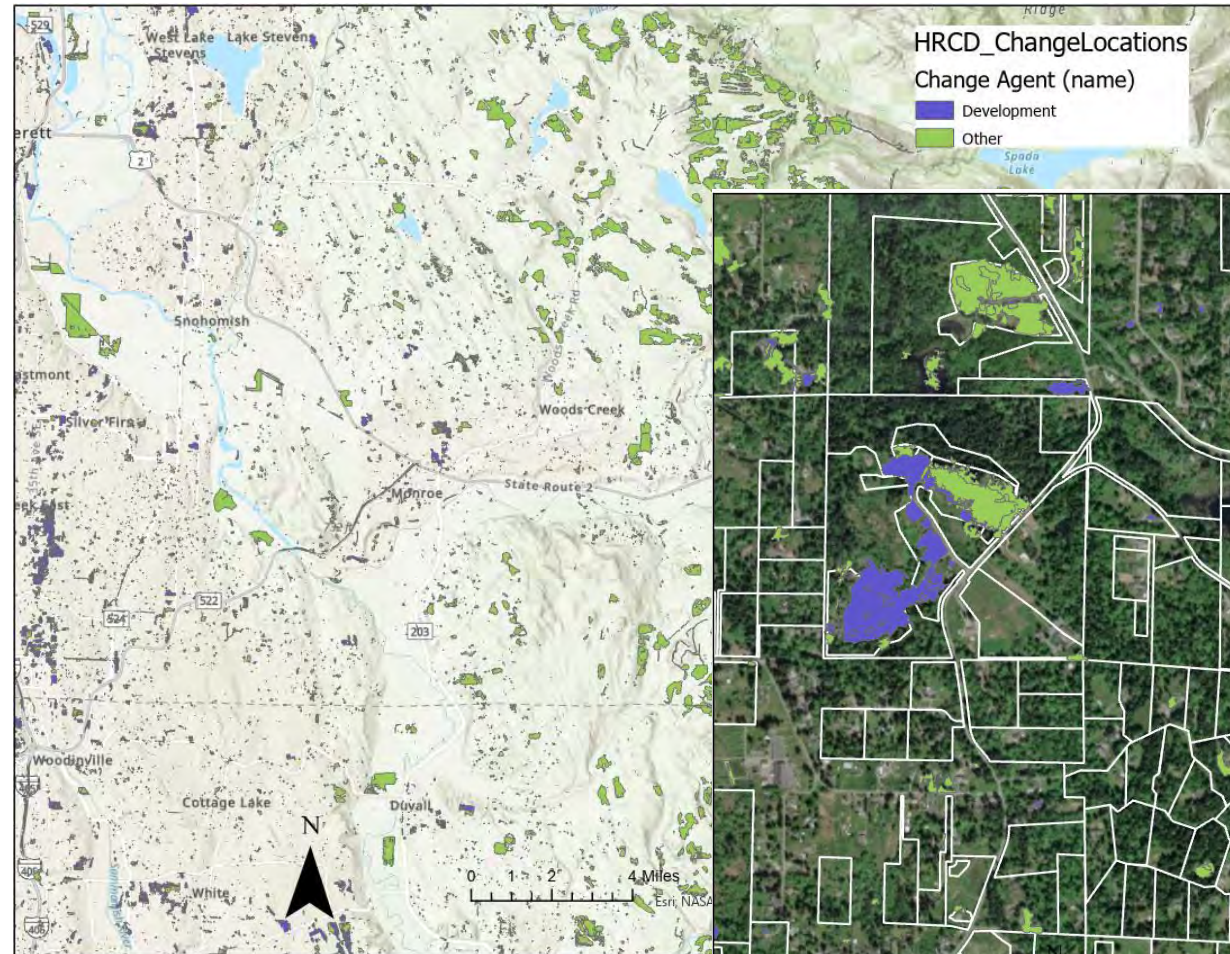


The Dependent Variable: Forest Conversion Due to Urbanization

Uses: High Resolution Change Detection (HRCDD) from Washington Department of Fish and Wildlife.

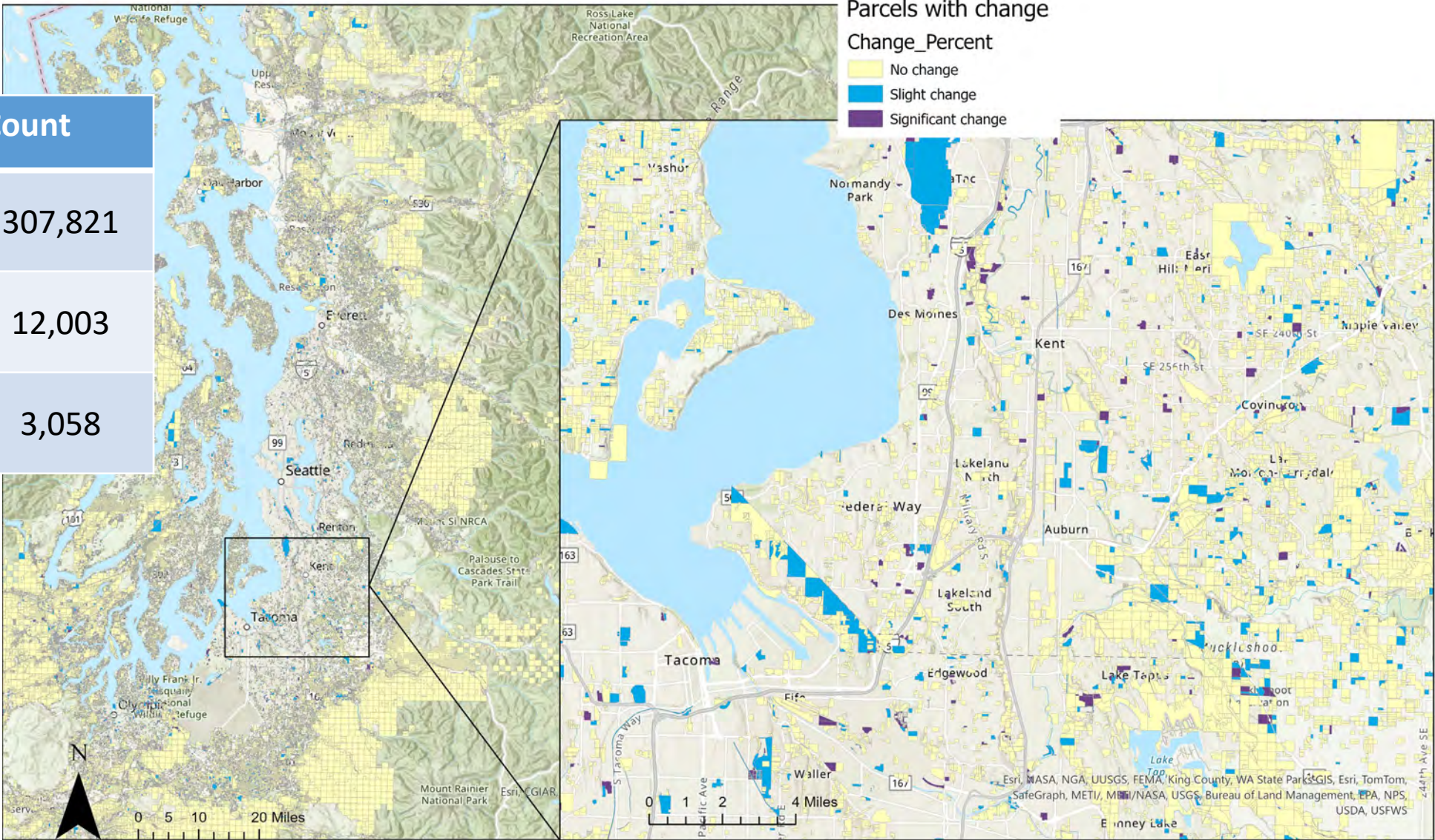
Looks at several types of forest change.

For urbanization looks at change between 2011 and 2017 (and up to 2021 for some locations).



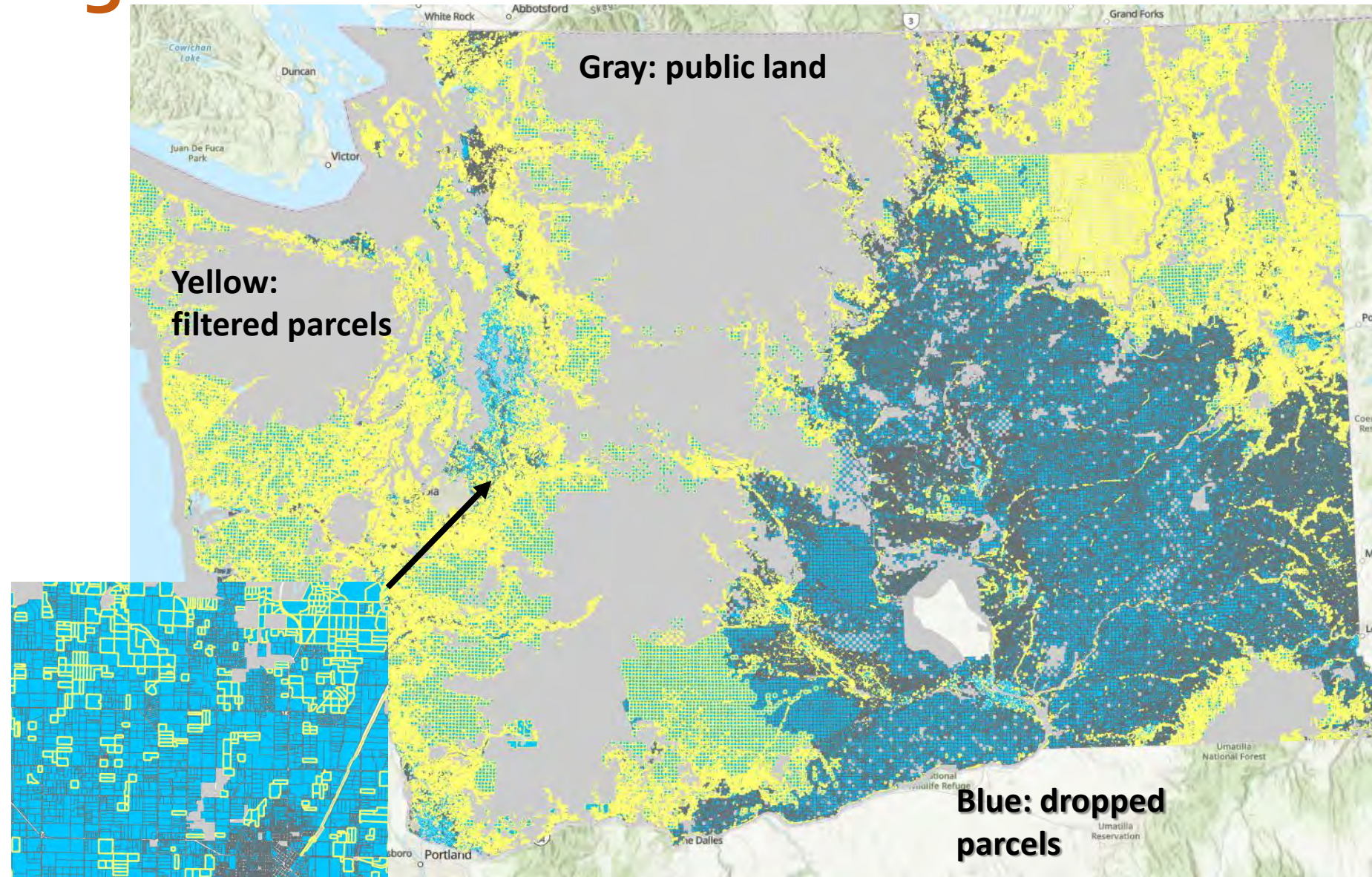
The Dependent Variable by Parcel

Label	% change	Count
No change	0	307,821
Slight change	1-10%	12,003
Significant change	11% and greater	3,058



Parcel Filtering

1. Removed all parcels on public land (federal, state, local)
2. Removed parcels with tract acres less than 5 acres,
3. Removed parcels with forest cover less than 1 acre or 3% coverage of the parcel unless forest clearance occurred there
4. removed all industrial/manufacturing parcels corresponding to the land use codes 21-39.



Variables Chosen For Use from NRSIG Model

Change determinant	Driver/ Constraint	Status/Notes
Proximity to urban growth boundary	Driver	Completed
Parcel size	Depends	Completed
Fraction of forested land in parcel	Constraint - Physical	Completed
Riparian regulatory buffers	Depends/ unclear	Completed but not available for all parcels
Parcel road extent	Driver	Completed
Accessibility to roads/road density	Driver	Completed
Forest harvest activity	Depends/ unclear	Question for DNR: are parcel level private harvest data available?

- Data provided by Luke Rogers from NRSIG along with corresponding parcel layer. Includes all parcels enrolled in a forest program or that have triggered forest regulations
- Problem: there are still tens of thousands of private forest parcels vulnerable to development that are not in their parcel layer, so we added additional parcels from the state parcel database



Additional Predictor Variables Added

Change determinant	Driver/ Constraint	Status/Notes
Flood risk zones	Constraint-legal and physical	Completed
Conservation easements	Constraint-legal	Overlay created, summary by parcel in process
Block group Census variables: median income, pop. density and growth, median age, unemployment rate, median home value	Driver-economic	Mostly completed
Distance to divided highway	Driver-economic	Completed
Soil suitability for development: erodibility (kfactor), drainage class, corrosion of concrete, subsidence, saturated hydraulic conductivity	Constraint-physical	Completed
Slope	Constraint-physical	Slope calculation completed, awaiting summary by parcel
Surrounding level of development: count of buildings within buffer of each parcel	Driver-economic	Will be completed this week
Accessibility to economic activity: Employers/retail density within drive time	Driver-economic	Will be completed this week



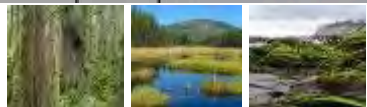
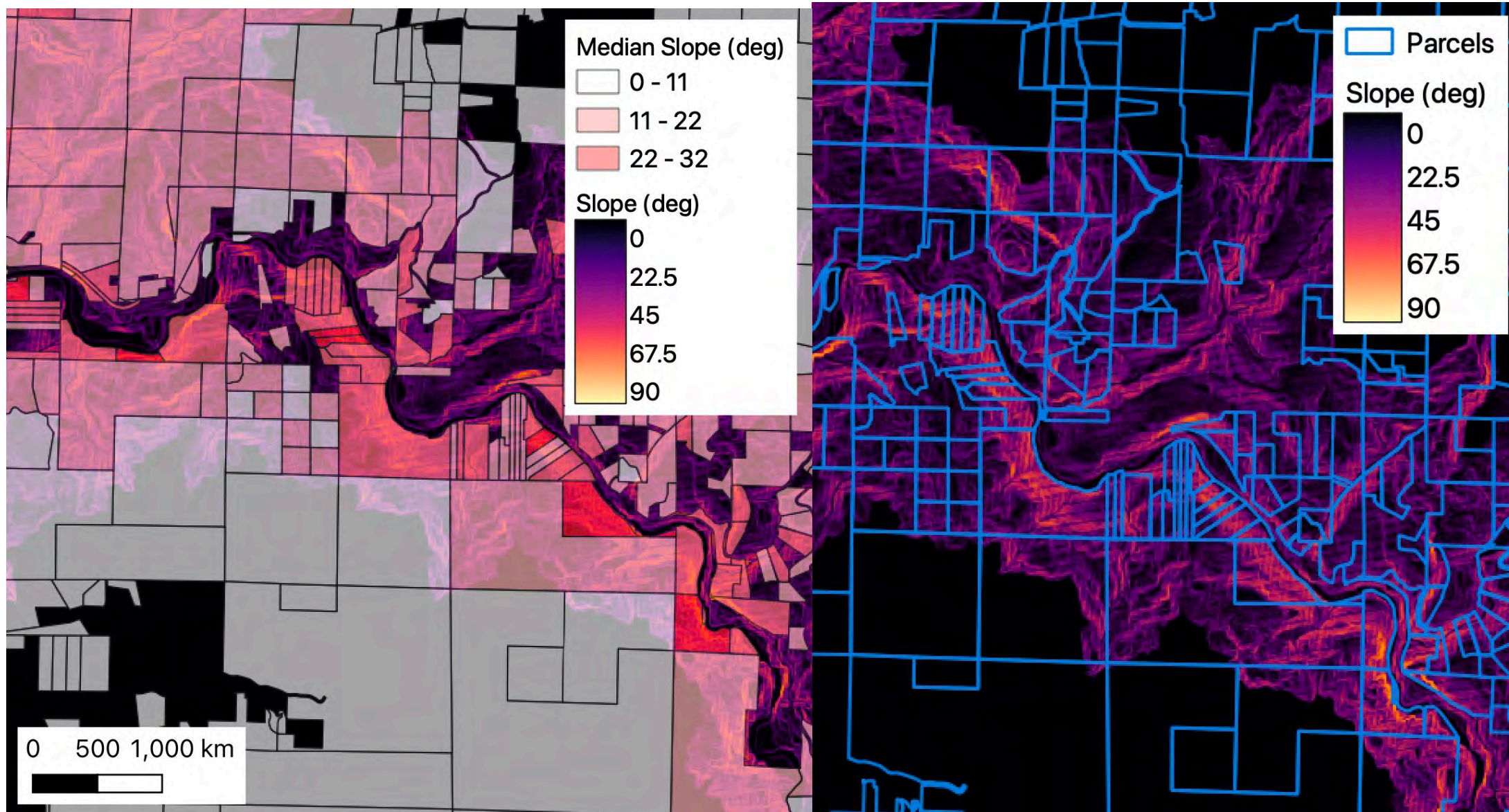
Additional Policy/ Regulatory Predictor Variables for Possible Use

Change determinant	Driver/ Constraint	Status/Notes
Regulatory zoning	Constraint-legal	Available in several counties including King, Pierce, Snohomish, Clark, Thurston, Kitsap, Whatcom, Yakima, Spokane. Determining whether it is too much work to combine these in a meaningful way
Sewer and water service areas	Constraint-legal	Water service area polygons downloaded for entire state. Sewer service areas available for several western counties.
Current use taxation	Constraint-economic	Available from some county assessors
“Transfer of Regulatory Authority”	Constraint-legal	Based on list from DNR

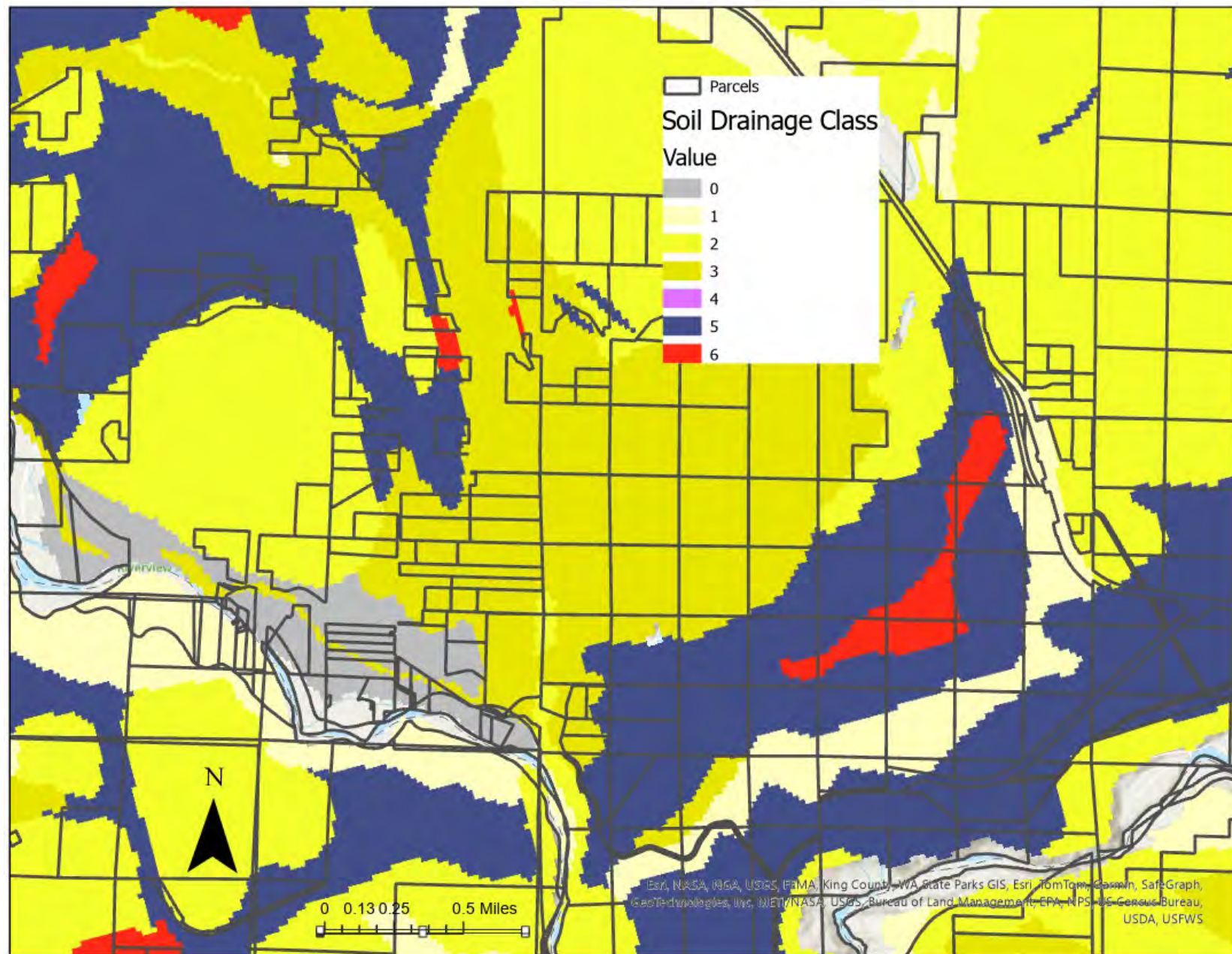


Sample Independent Variable Maps

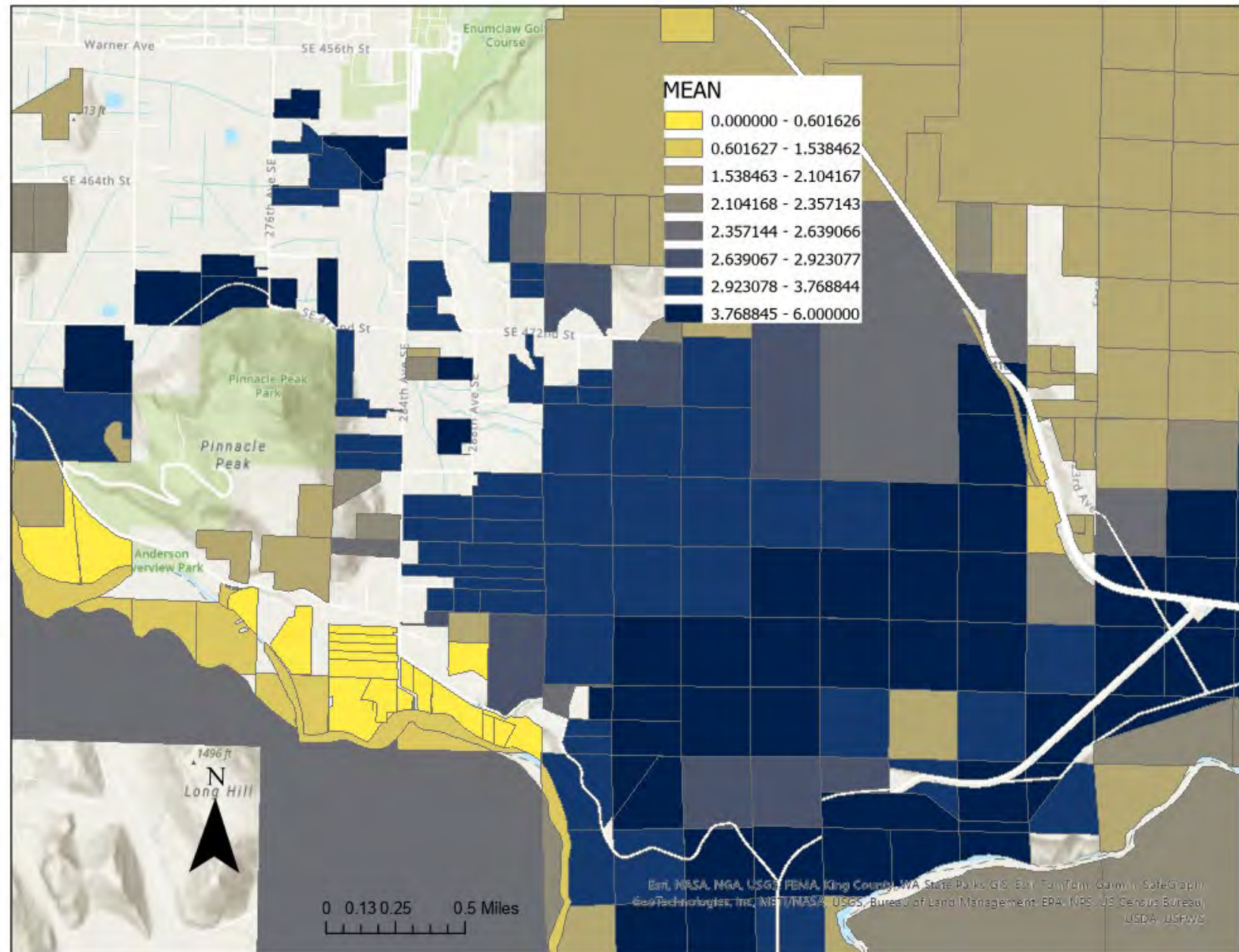
Slope with parcels:
Raw values
and
summary by
median



Soil Drainage Class with Parcels

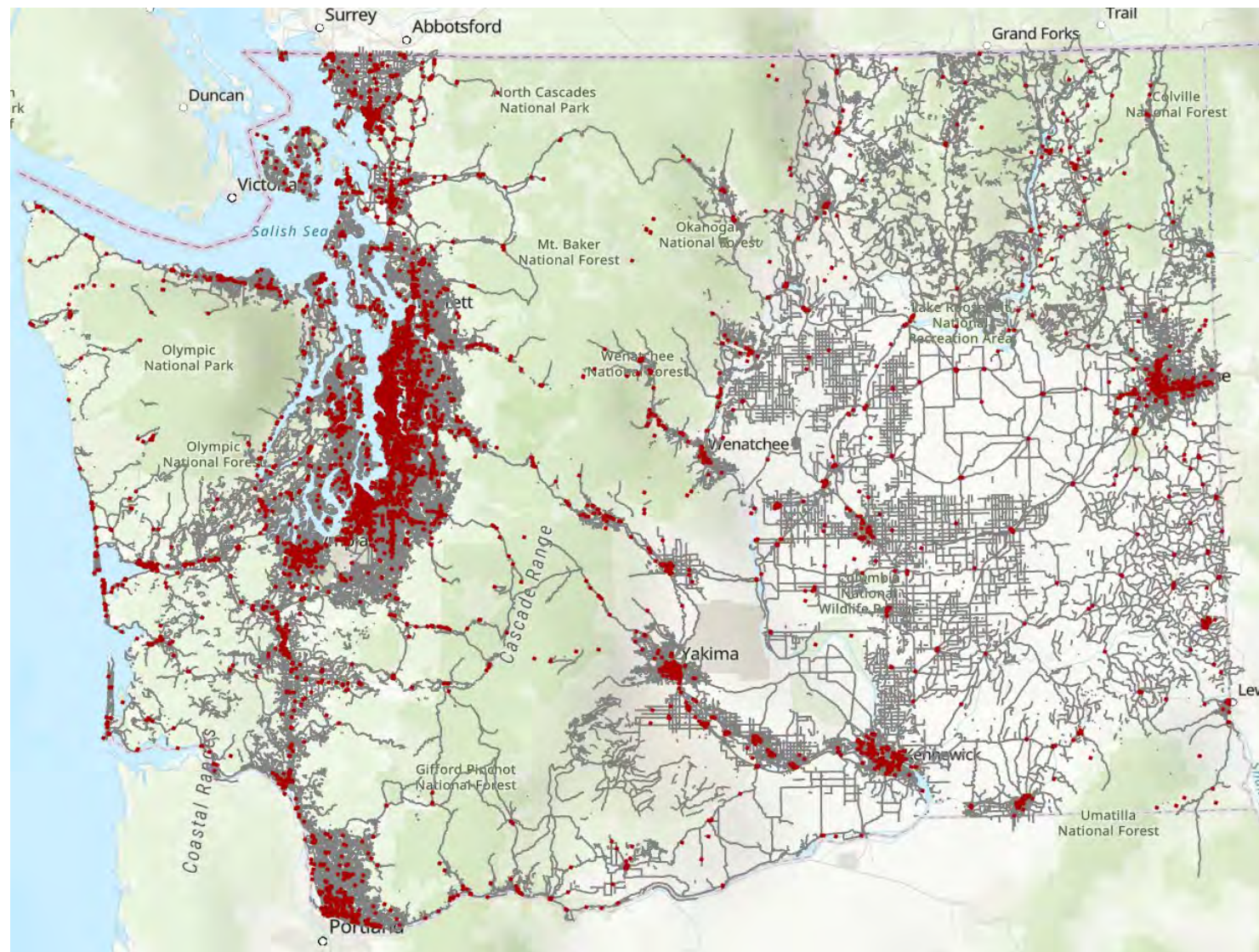


Soil Drainage Class Summarized by Parcel



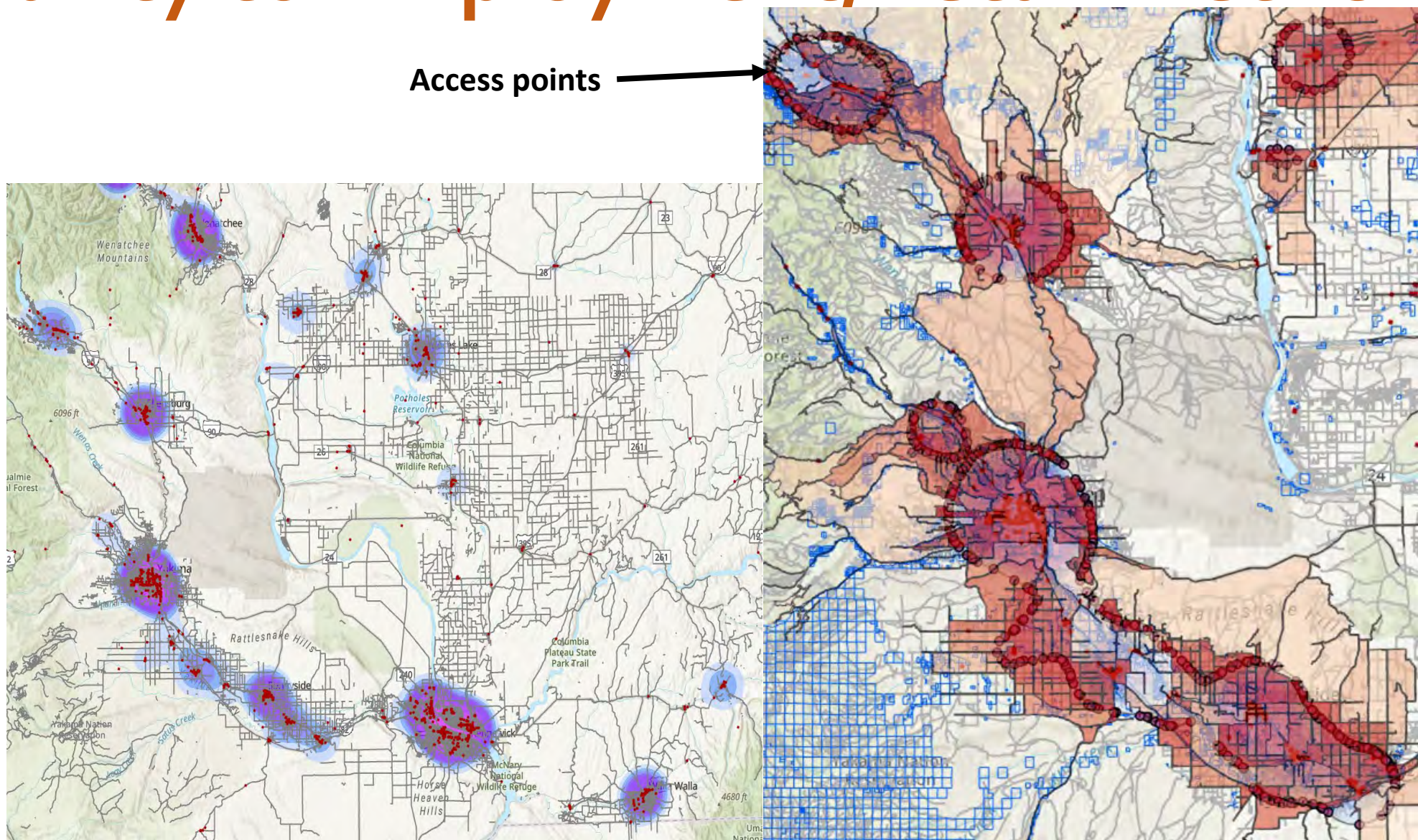
Accessibility to Employment/Retail Metric

Open Street Maps provides more than 60k interest points including businesses, cafes, restaurants, medical facilities, etc.



Accessibility to Employment/Retail Metric

- OSM used to identify business clusters
- Then access points identified for each road leading to each cluster area
- Driving distance calculated from each parcel to nearest commercial access point





Discussion



Additional Considerations

Types of Forest Conversion

Urbanization

Climate change-induced

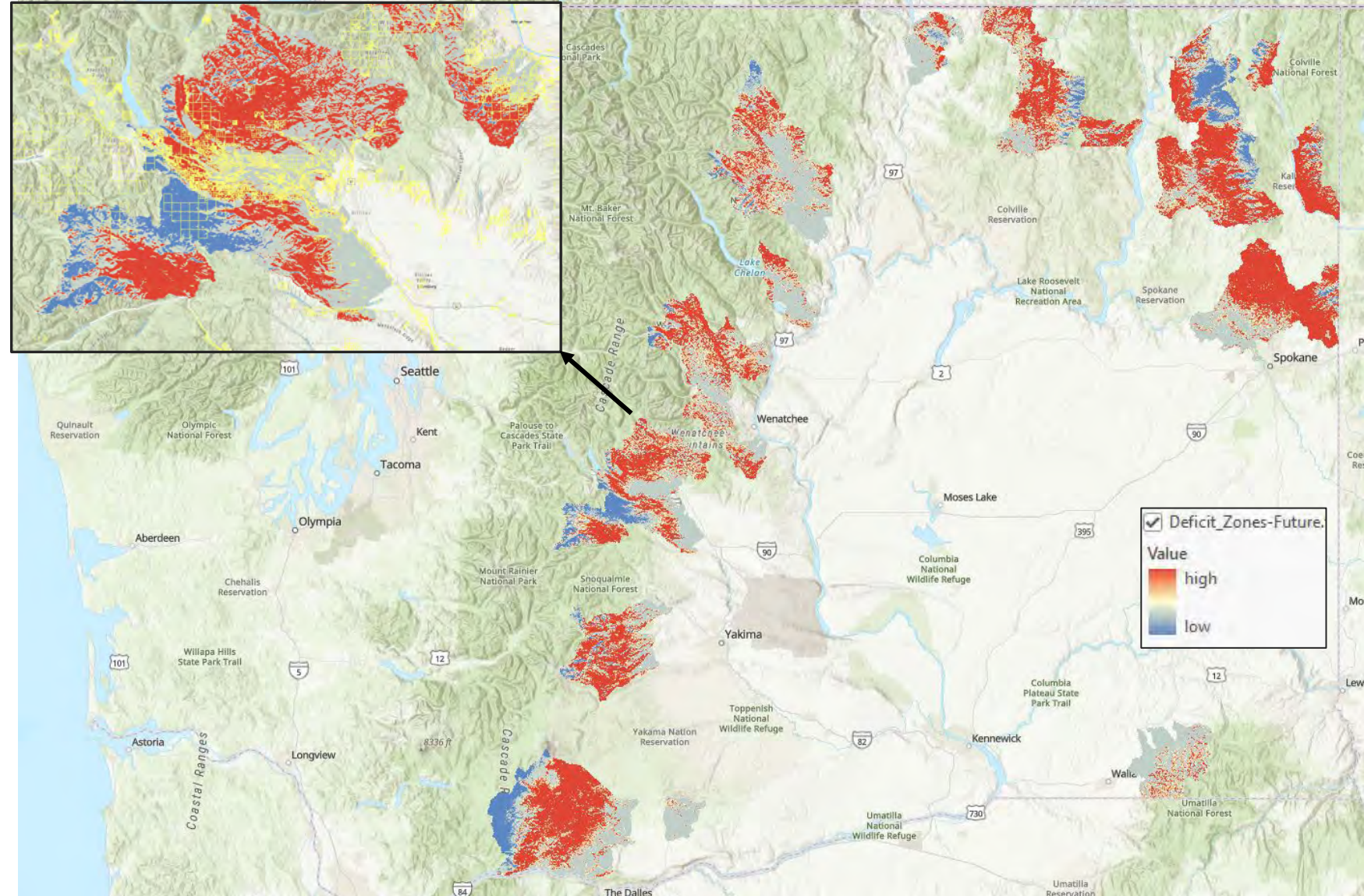
Agricultural expansion

Overharvest of timber



Climate Change-Driven Conversion

Using DNR's “trailing edge” map which combines forested areas and moisture deficit for both current and predicted future conditions (Meigs et al. 2023 and Parks et al. 2019). Requires only simple overlay



Conversion to Agricultural Use

- How important is it to understand conversion from timber into agricultural activity?
- Why?
- Is it more or less important on the east or west side of the state?
- What would be required to model this?
- Could we address this through an overlay?





Discussion

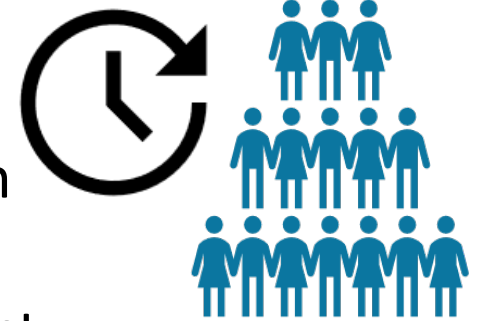


Discussion of Querying, Ranking and Visualization

Ranking and sorting parcels by conversion risk

Possible steps:

- Ranking: order parcels based on probability scores derived from solving model equation.
- Assignment: simulate scenario where certain number of highest-ranking parcels are designated for development
 - Use WA-OFM population forecast
 - Make informed assumption for how much of growth will occur in infill and how much in greenfield
 - Take greenfield fraction of future population and assign to highest ranking parcels, based on feasible housing density per parcel
 - Go down list until population growth is exhausted
 - Can add stochastic component to incorporate random variability
 - Questions: Is this worth it? What forecast year to use? What percentage is assumed to go to infill? What density to assume?



Overlay for High-Risk Parcels: Values at Risk

Possible values to overlay:

- Biodiversity and habitat
- Recreation
- Water supply
- Flood regulation
- Timber supply
- Others?

Once high likelihood parcels identified, we can overlay with key values of interest to identify targets for conservation

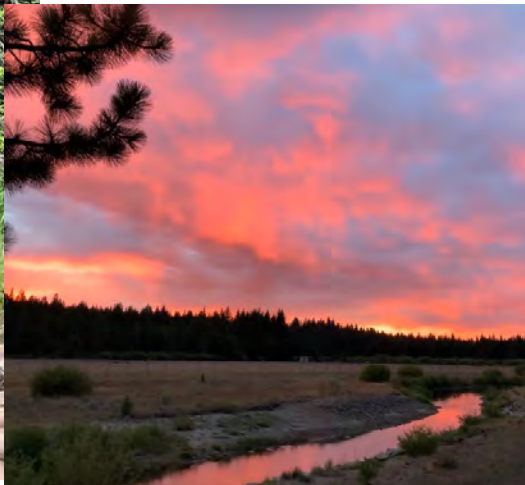


Photo credit: Don Kennedy, Denver Water





Preview of What is to Come

Next steps on Modeling

Urbanization model:

- Complete calculation of predictor variables
- Join all variables to master table
- Sample parcels for inclusion in regression (~30-40%)
- Run logistic regressions with different combinations of variables on sampled parcels
- Optional: use table of coefficients to solve regression equation of “held back” parcels to estimate accuracy
- Solve equation for entire state to assign development probability values (0-1) to each parcel
- Optional: Rank parcels by probability and “convert” the highest scoring parcels based on state demographer projections so as to accommodate that projected addition to population

Climate change analysis:

- Predict forested parcels most likely to convert to non-forest due to climate change (in process)

Values overlays:

- Identify parcels at high risk for conversion that have high levels of ecosystem or socio-cultural value (in process)

Preview of What is to Come

- Have established a conceptual framework for
 - Identifying drivers of forest conversion and
 - Evaluating effectiveness of policy tools
- Model parameters will be developed and reviewed over next few weeks
- Model results will inform role of the 8 drivers
- Opportunity to refine and modify the decision matrix
- Draft results coming soon



Decision Support Tools

- Decision Support Tools: Dimensions, Scales, Factors
- Decision Matrices:
 - Define the decision
 - Identify options
 - Determine criteria
 - Apply a consistent rating scheme

Criteria	Cost	Time	Complexity	SCORE
Option A				
Option B				
Option C				
Option D				





Thank you for coming



Our mission: Manage, sustain, and protect the health and productivity of Washington's lands and waters to meet the needs of present and future generations.

Mapping Drivers and Identifying Program Solutions for Washington State Forest Conversion Risk Assessment and Evaluation

April 24, 2025

PRESENTED TO THE WASHINGTON DEPARTMENT OF NATURAL RESOURCES

BY

GREENE ECONOMICS AND SPATIAL INFORMATICS GROUP



Agenda

- **1:00-1:15- Introductions-** Andrew Spaeth, DNR Project Manager
- **1:15-1:30- Overview of Work to Date-** Bea Covington- Greene Economics
- **1:30-2:00- Conversion Mapping Results-** Austin Troy- SIG
- **2:00-2:30- Program Matrix Overlays** –Gretchen Richter & Karen Grace-Wells
- **2:30-2:40- BREAK**
- **2:40-3:00- Brainstorm Queries** - All
- **3:00-3:45- Queries and Questions** – All
- **3:45-4:00- Conclusions, Recommendations and Next Steps-** Bea Covington- Greene Economics



Introductions

Tell us:

YOUR NAME

YOUR PROGRAM/DIVISION and

WHY YOU ARE INTERESTED IN
COVERSION RISK

GOALS

Share **background and rational** behind the development of the **avoided conversion mapping and matrix decision tools** with agency staff and partners who will be using them for analysis, planning and potential program development.

Introduce staff and partners to the **mechanics and applications for the tools**.

Empower workshop participants to **test the mapping and matrix tools**.

Gather feedback from meeting participants to inform updates to the mapping tool and associated report.

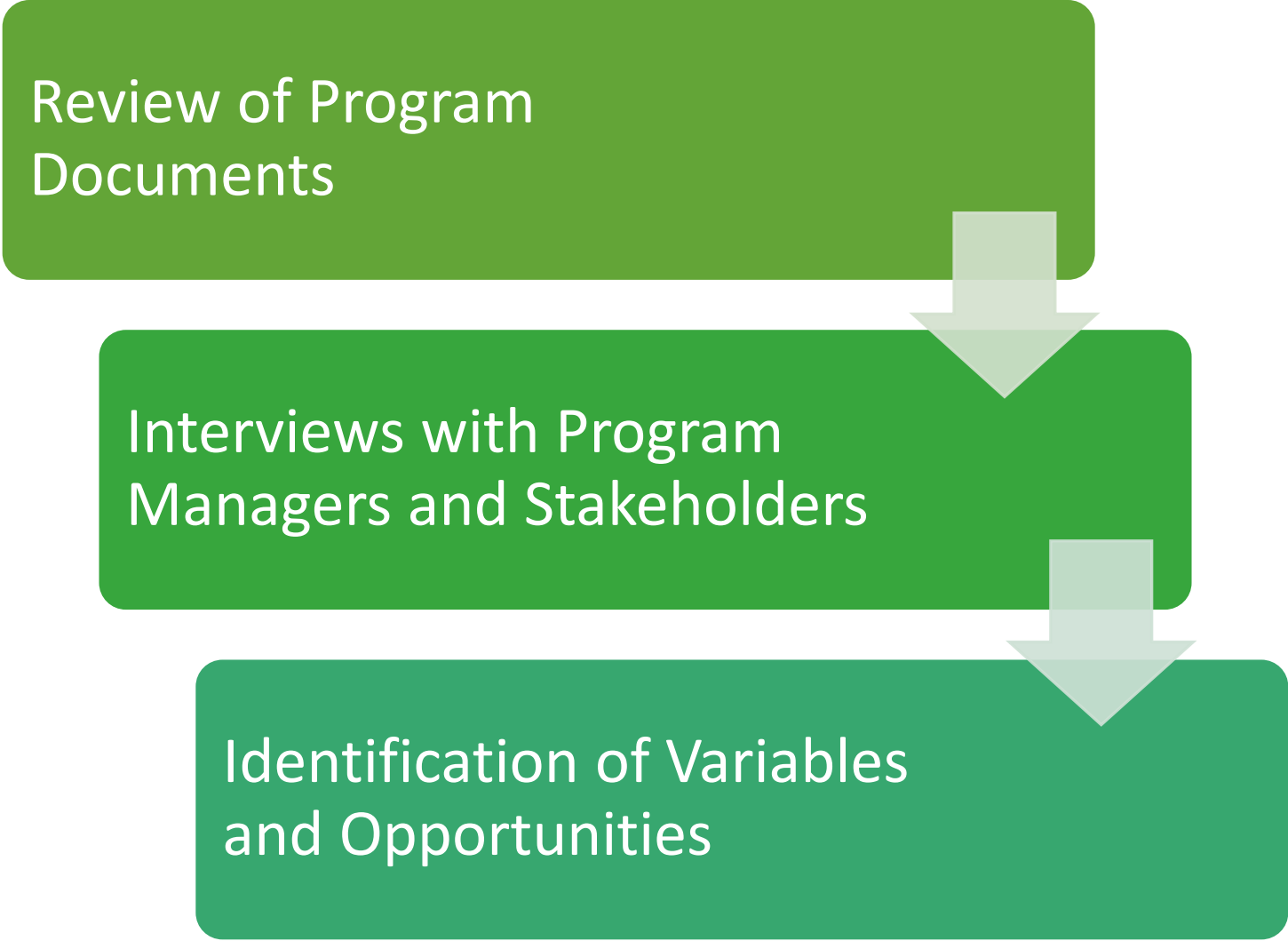
Photo Credit: Pulkkinen, Levi. January 2021. "Tree justice? Lawmakers look to revive forests in Washington cities with eye on racial environmental disparities". InvestigateWest. Available [here](#).

Overview of Work to Date

Conceptualization & Workflow



Review of Program Documents



```
graph TD; A[Review of Program Documents] --> B[Interviews with Program Managers and Stakeholders]; B --> C[Identification of Variables and Opportunities];
```

Interviews with Program Managers and Stakeholders

Identification of Variables and Opportunities

Program Intersection and Availability

Methodology to Characterize and Prioritize Lands

Review of Past
Research

Selection of
Predictor Variables

Logistic Regression-
vs Decision Tree
...OR...
Something Else???

Evaluating Options
for Overlays

Spatial overlay analysis

For WA DNR Avoided Conversion Project



Spatial Informatics Group

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Purpose of overlay analysis

- Provide a suite of variables to overlay with development probability. Allows for:
 - Contextual characterization of high development risk (HDR) sites
 - Identifying HDR sites whose conversion would compromise important ecological or socio-economic values
 - Identifying potential policy levers that are relevant at HDR sites
- Level of analysis:
 - Parcel (original)
 - Public Land Survey System “sections” (most parcels nest in these)
 - HUC 12 Watersheds
- Outputs:
 - Static GIS layers, both online and for download. Can be manually queried
 - A beta query app on ArcGIS online
- Format: all scores presented on a scale of 1-10 with intervals calculated using Jenks Natural Breaks method on unitless z-scores

Overlay categories



1. Ecological and Economic “Impact Variables” (Characterize impacts that might occur if a parcel was developed)
 - a. Water supply importance
 - b. Water quality importance
 - c. Biodiversity and habitat
 - d. Rare plant communities
 - e. Carbon
 - f. Adjacency to recreational lands
 - g. Timber-dependent communities/timbersheds



2. Socio-economic “Context Variables” (factors that might influence potential program choices or policy interventions)
 - a. Census data
 - b. Health Indices
 - c. Policy boundaries



3. Variables not in land use change model that limit urbanization probability
 - a. Source Water Surface Water Protection Areas and Wellhead Protection Areas
 - b. ESA critical habitat polygons

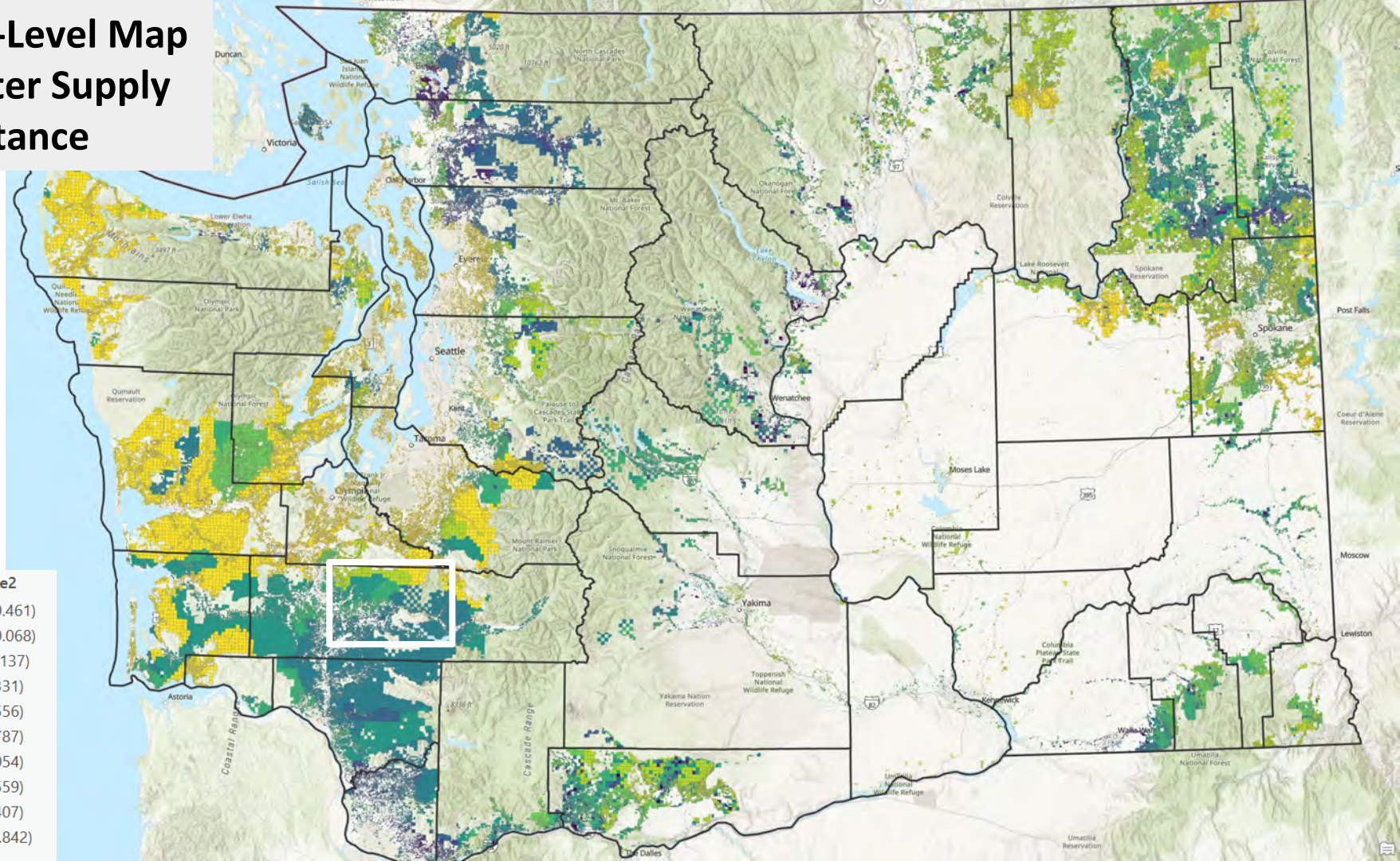
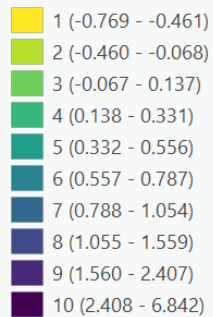
Water Supply Importance



- **Purpose:** show potential impacts of forest conversion on water supply timing/ volume
- **Data sources:**
 - US Forest Service Forests to Faucets (F2F) database
 - WA DOE Water Diversion map
- **Score:** $0.5 * (\text{normalized F2F water supply importance score}) + 0.2 * (\text{normalized \# water diversions in parcel}) + 0.3 * (\text{normalized \# of water diversions in watershed})$; then turned into 1-10 scale using Jenks Natural Breaks method
- **Additional popups (for web map) at the private lands parcel level show**
 - Importance score
 - # water diversions in parcel
 - # diversions in associated HUC 12 watershed
 - whether the parcel is located in a high importance watershed (≥ 50 WDs within the watershed)
 - % of parcel that is within high priority watershed
 - * Normalized using z-score $(x - \text{mean} / \text{STDV})$

Parcel-Level Map of Water Supply Importance

WaterSupplyScore2

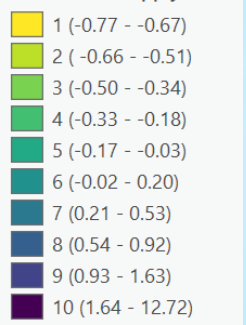


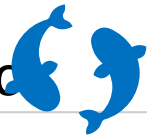
Section-Level Map of Water Supply Importance

This map displays the mean water supply score for various sections in the Pacific Northwest, including Washington, Oregon, and Idaho. The map is color-coded according to the following legend:

Mean WaterSupplyScore2
1 (-0.77 - -0.67)
2 (-0.66 - -0.51)
3 (-0.50 - -0.34)
4 (-0.33 - -0.18)
5 (-0.17 - -0.03)
6 (-0.02 - 0.20)
7 (0.21 - 0.53)
8 (0.54 - 0.92)
9 (0.93 - 1.63)
10 (1.64 - 12.72)

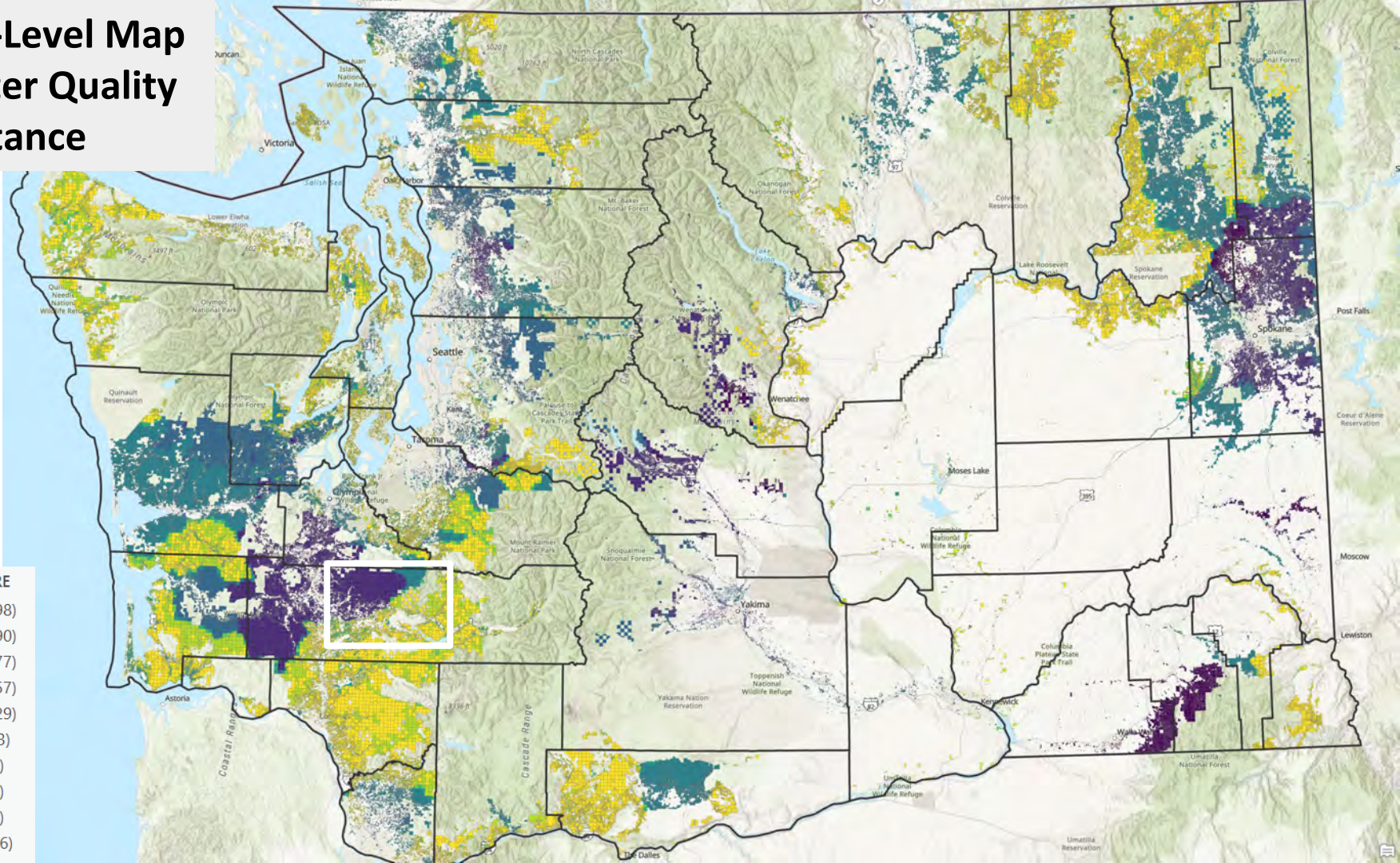
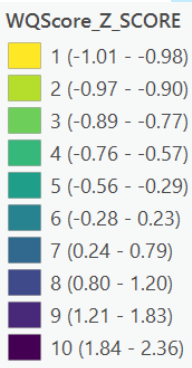
The map shows a high concentration of sections with scores between 7 and 10 (dark green to purple) in the central and eastern parts of the region, particularly around the Cascade Range and the Snake River Plain. Lower scores (yellow and orange) are more prevalent in the western coastal areas and the northern part of the region. Major cities like Seattle, Portland, and Boise are visible, along with significant geographical features like the Cascade Range and the Snake River Plain.



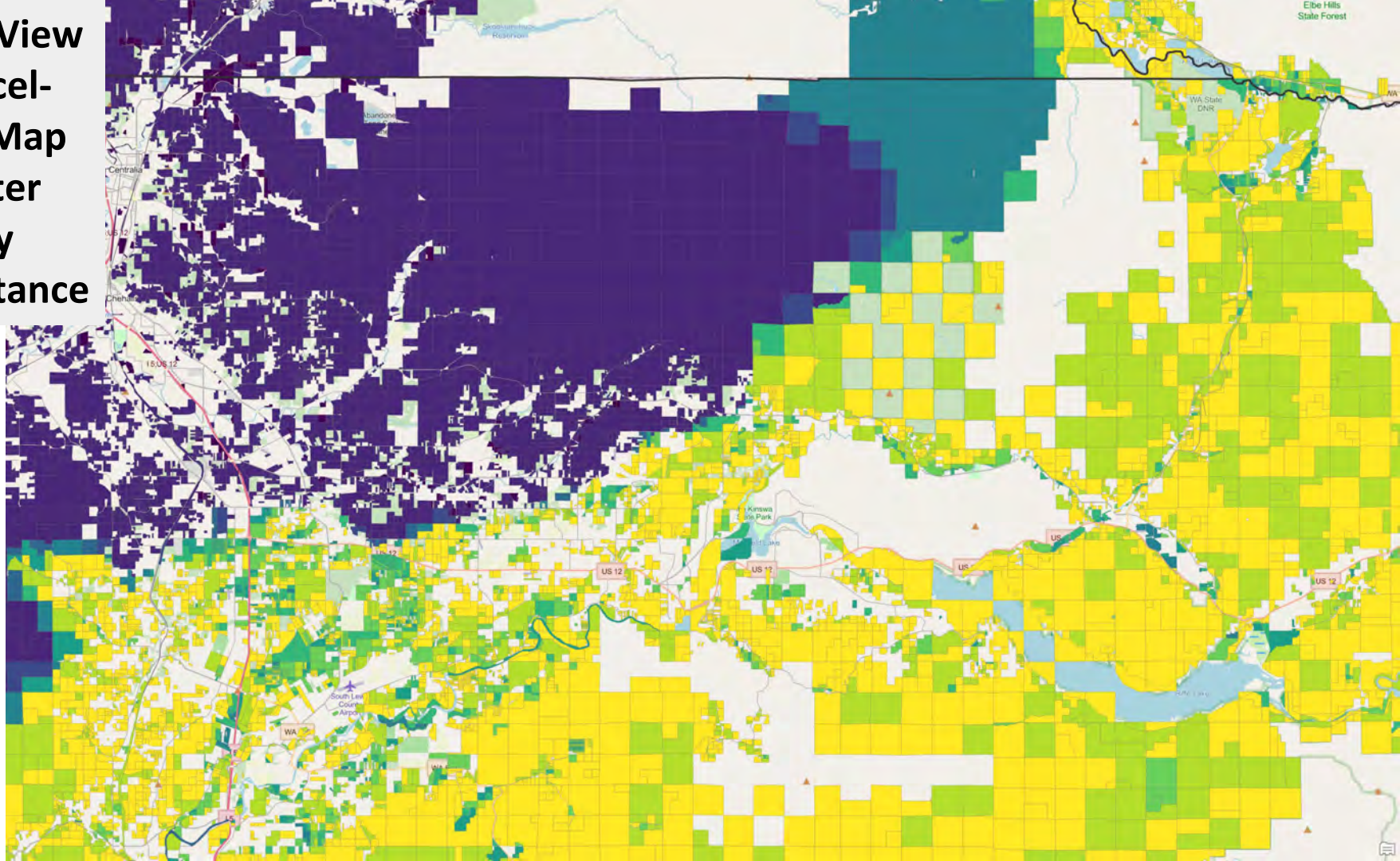


- **Purpose:** show potential impacts of forest conversion on water quality
- **Data sources:**
 - WA DOE TMDL Boundary maps
 - WA DOE Water Quality Assessment 303d maps
 - National Wetlands Inventory Riparian Wetlands
- **Score:** % area wetlands + % area 303d waters + % area TMDL polygons; then converted to a z-score and turned into 1-10 scale using Jenks Natural Breaks method
- **Additional popups at the private lands parcel level show**
 - - if the parcel is located in a TMDL area or nearby (within 1km)
 - - the # of TMDL boundaries within the parcel
 - - the % of private lands within a TMDL boundary
 - - if there are wetlands on the parcel or nearby (within 1km)
 - - the type pf wetland present
 - - the % of private lands that include wetlands
 - - if there are 303d waters on the parcel or nearby (within 1km)

Parcel-Level Map of Water Quality Importance



Zoom View of Parcel- Level Map of Water Quality Importance

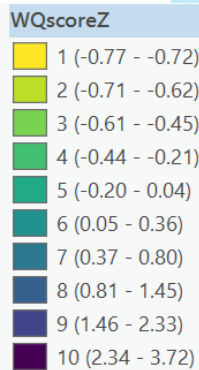


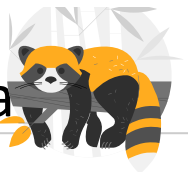
Section-Level Map of Water Quality Importance

This map displays the water quality importance across the Pacific Northwest, from British Columbia, Canada, down to Washington and Oregon, USA. The map is overlaid with a grid where each cell is colored according to its Water Quality Score (WQscoreZ). The legend on the left indicates that scores range from 1 (yellow, lowest importance) to 10 (dark purple, highest importance). High-scoring areas (scores 8-10) are concentrated in the coastal regions of British Columbia and Washington, particularly around the Fraser River and Puget Sound, as well as in the Willamette Valley of Oregon. Other high-scoring areas are scattered throughout the region, including parts of the Okanagan and Kootenai basins. The map also shows major geographical features like the Coast Range, Cascade Range, and various national parks and reserves. Major cities such as Vancouver, Seattle, Portland, and Astoria are marked. The map is titled 'Section-Level Map of Water Quality Importance' in the top left corner.

WQscoreZ

1	(-0.77 - -0.72)
2	(-0.71 - -0.62)
3	(-0.61 - -0.45)
4	(-0.44 - -0.21)
5	(-0.20 - 0.04)
6	(0.05 - 0.36)
7	(0.37 - 0.80)
8	(0.81 - 1.45)
9	(1.46 - 2.33)
10	(2.34 - 3.72)





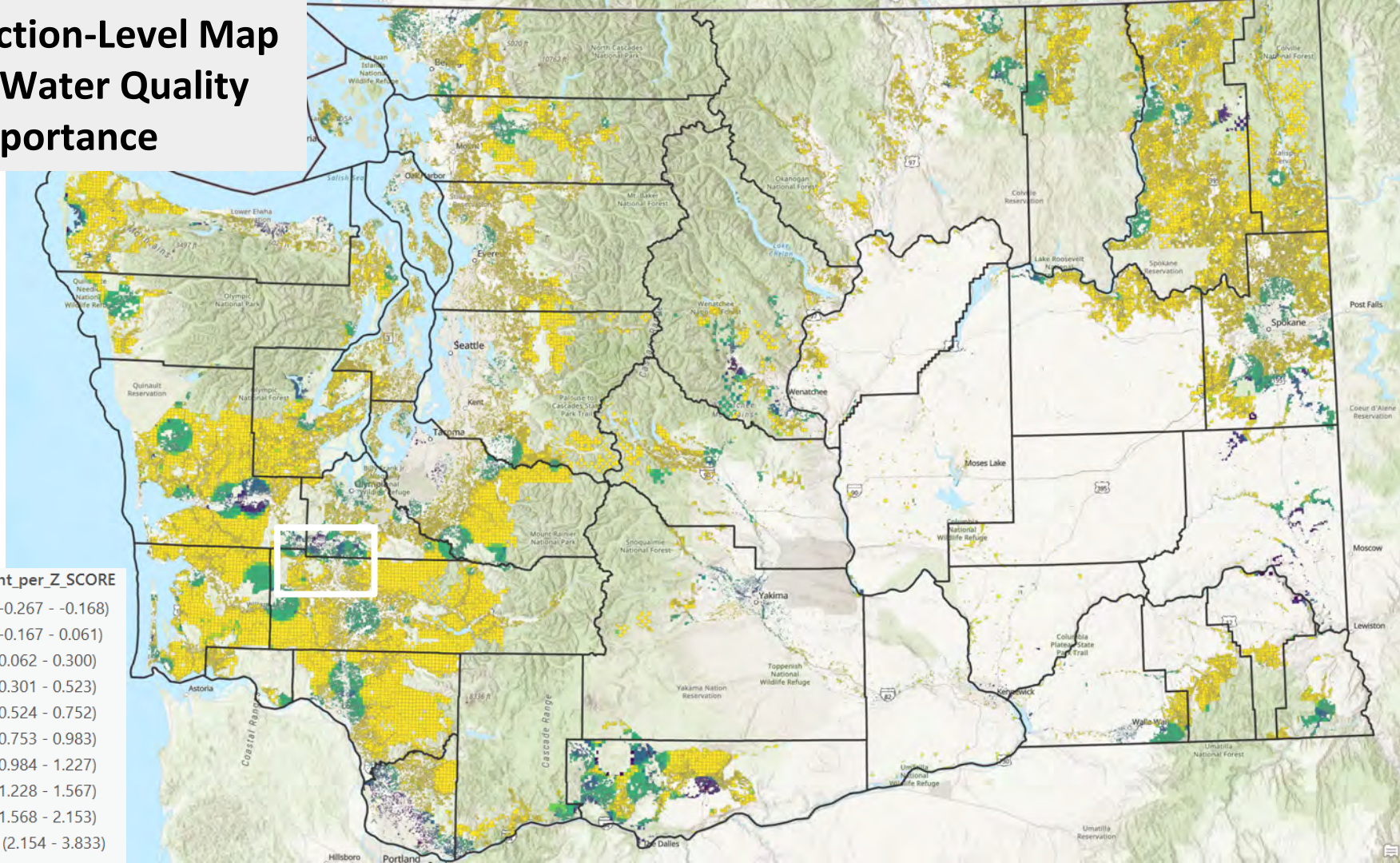
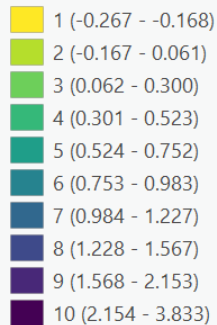
- **Purpose:** show potential impacts of forest conversion on wildlife and their habitat
- **Data sources:**
 - WA DPFW Priority Habitats and Species dataset
 - Additional priority indicator species distributions calculated as part of WA DNR ESIAP project based on PHS
- **Score:** % area with indicator species habitat (elk, deer, mountain goat, Taylor's checkerspot) + % area with PHS biodiversity corridor + % area with 2 or more overlapping habitats; then converted to a z-score and turned into 1-10 scale using Jenks Natural Breaks method
- **Additional popups at the private lands parcel level show**
 - - parcel acres- the count of overlapping PHS habitats on private lands
 - - total acres of habitats on parcel
 - - % of parcel that contains at least 1 priority habitat (total could be greater than 100 if multiple habitats are present and overlap)
 - - the count of overlapping indicator species
 - - total acres of indicator species on parcel
 - - % of parcel that contains at least 1 indicator species (total could be greater than 100 if multiple species are present and overlap)



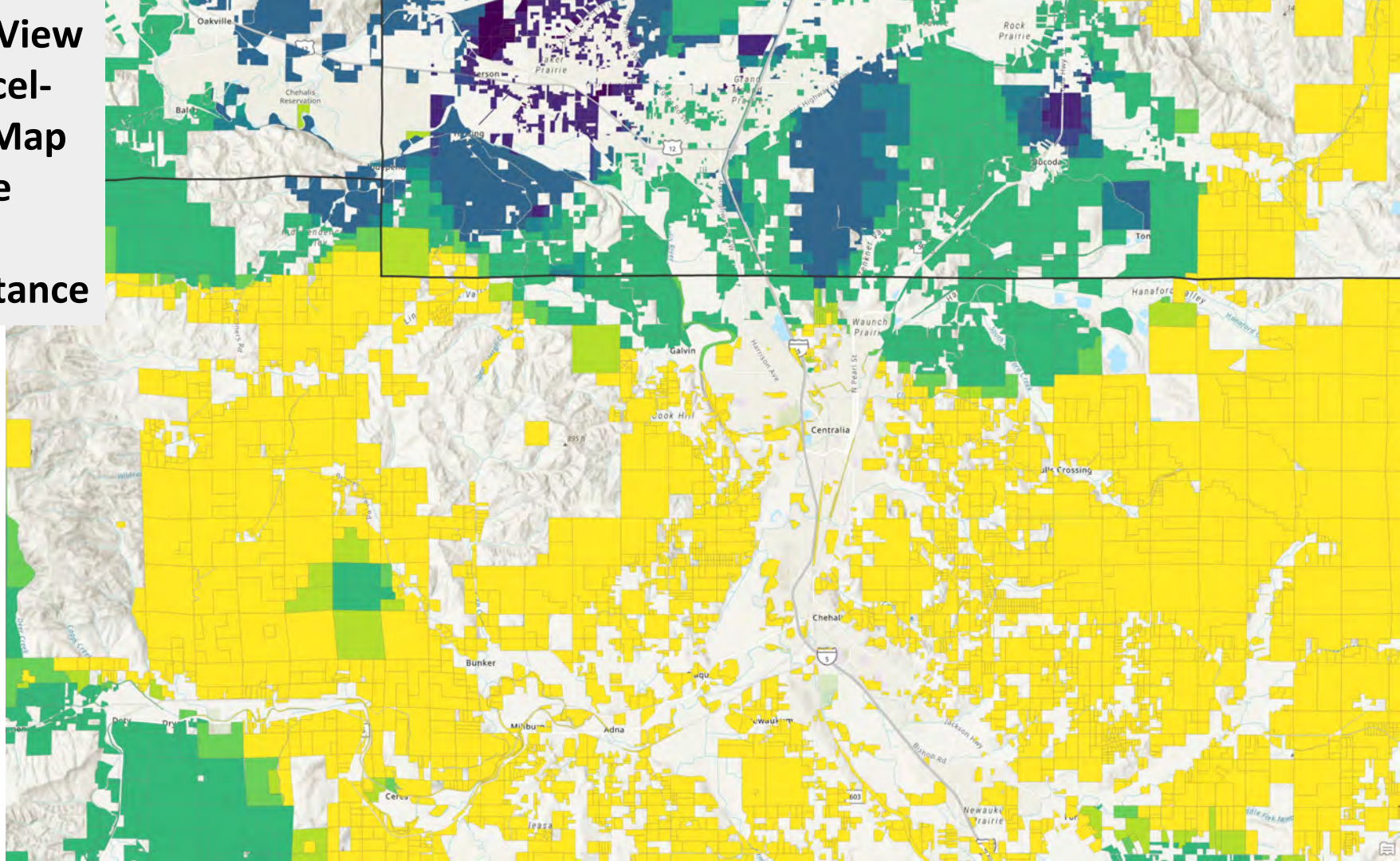
- **Purpose:** show potential impacts of forest conversion on rare plants and their habitat
- **Data sources:**
 - Natural Heritage Program Rare Plant Communities
- **Score:** $\text{sum}(\% \text{ area known rare plant distribution for each plant type}) + \text{sum}(\% \text{ area historic rare plant distribution}) / 2$; then converted to a z-score and turned into 1-10 scale using Jenks Natural Breaks method
- **Additional popups at the private lands parcel level show**
 - - if known or historic rare plants are present, within 1km, or further than 1km
 - - count of known or historic plants on private land parcels
 - - acres of known or historic rare plant areas on private land parcels
 - - % of known and historic rare plants on private areas (known acres / parcel acres OR historic acres / parcel acres)
 - - total count of all known and historic rare plants on parcel
 - - total acres of all known and historic rare plants on parcel
 - - total % of all known and historic rare plants on parcel

Section-Level Map of Water Quality Importance

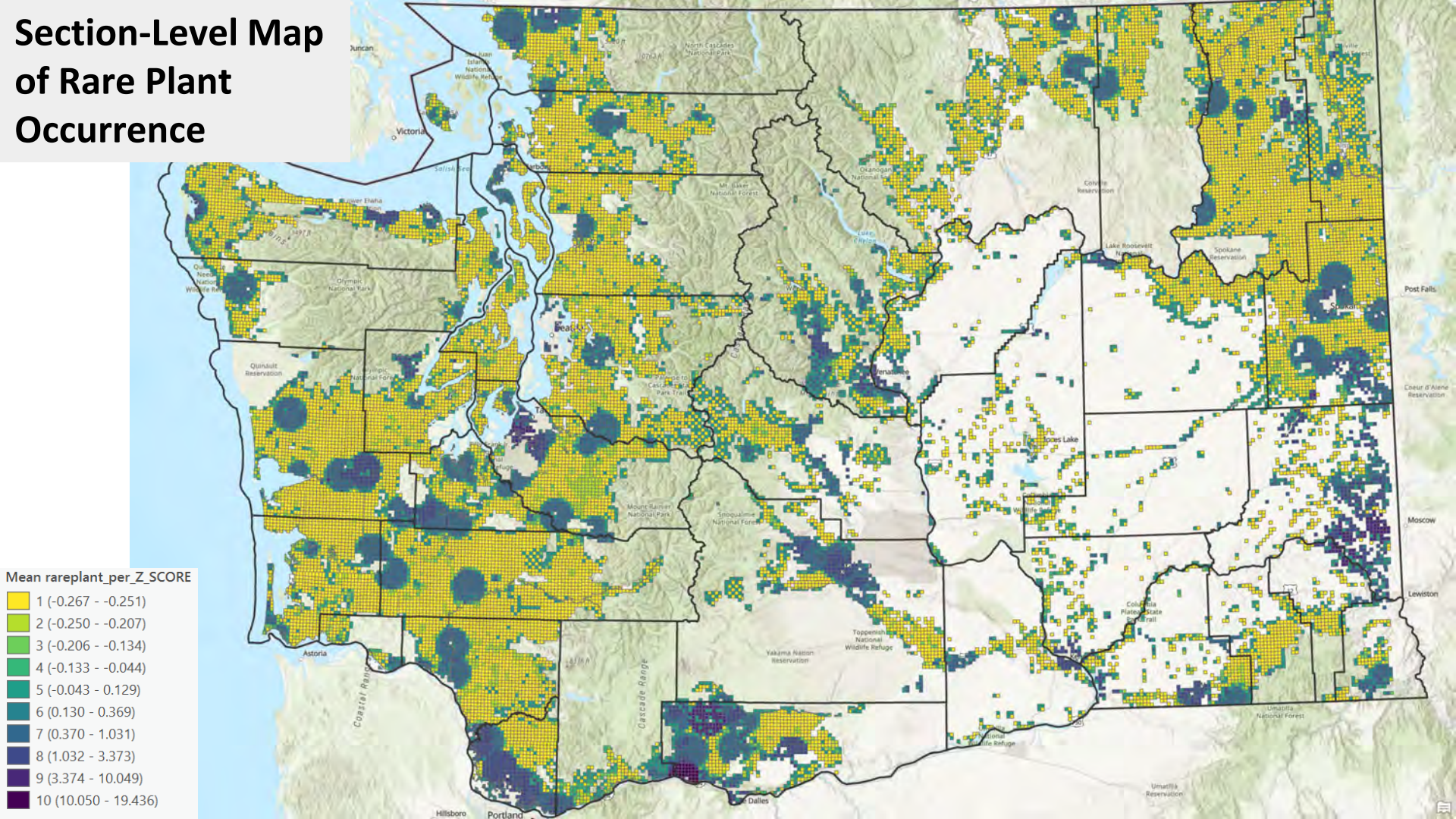
rareplant_per_Z_SCORE



Zoom View of Parcel- Level Map of Rare Plant Importance



Section-Level Map of Rare Plant Occurrence





- **Purpose:** show potential impacts of forest conversion on key recreation areas
- **Data sources:**
 - Variety of recreation resource data from WA DNR and assembled for ESIAP
- **Score:** z score(point density of trailheads, recreation "activities", recreation "accommodations")+ z score (mean inverse distance to trails and beach lines) + z score (mean inverse of distance to nearest public land with a "recreation" primary designation).
- **Additional popups at the private lands parcel level show**
 - if recreation amenities are present, within 1km or further than 1km
 - # of points in each parcel
 - # trails/beaches and total miles in each parcel
 - # state parks/private lands and acreages per private land parcels

Awaiting new map

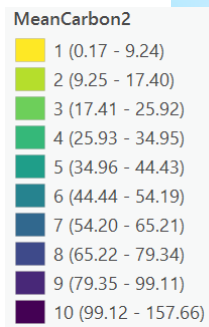


- **Purpose:** show potential impacts of forest conversion on forest carbon storage
- **Data sources:**
 - WA DNR RS-FRIS (remote sensing-based forest inventory) data
- **Score:** Average metric tons of total forest carbon per acre per parcel, created by taking mean of FRIS pixel values by parcel
- **Additional popups at the private lands parcel level show**
 - metric tons of carbon per acre

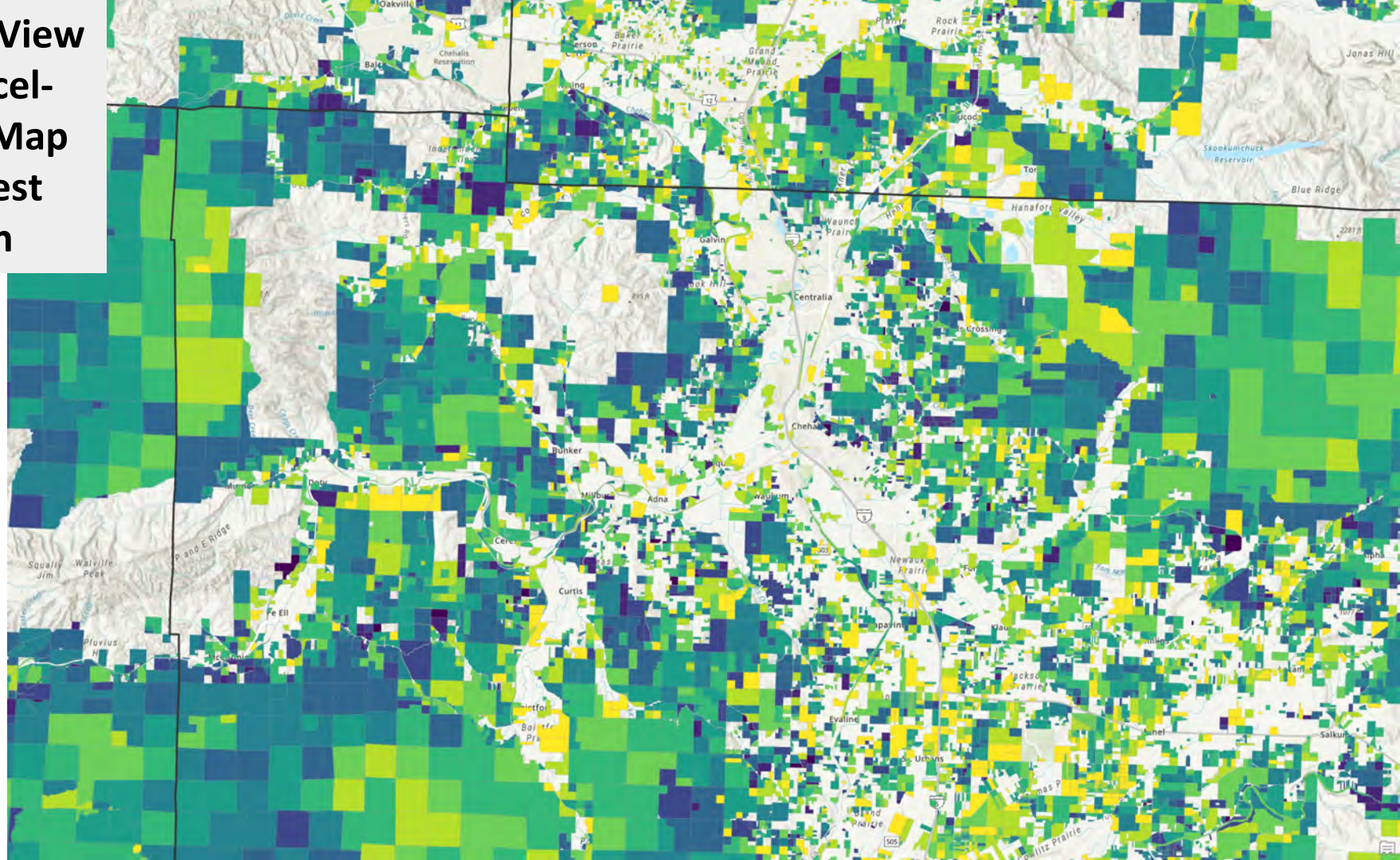
Parcel-Level Map of Forest Carbon Importance

MeanCarbon2

Color	Range
Yellow	1 (0.17 - 9.24)
Light Green	2 (9.25 - 17.40)
Green	3 (17.41 - 25.92)
Dark Green	4 (25.93 - 34.95)
Teal	5 (34.96 - 44.43)
Dark Teal	6 (44.44 - 54.19)
Dark Blue	7 (54.20 - 65.21)
Blue	8 (65.22 - 79.34)
Dark Blue	9 (79.35 - 99.11)
Purple	10 (99.12 - 157.66)



Zoom View of Parcel- Level Map of Forest Carbon



Section-Level Map of Forest Carbon Importance

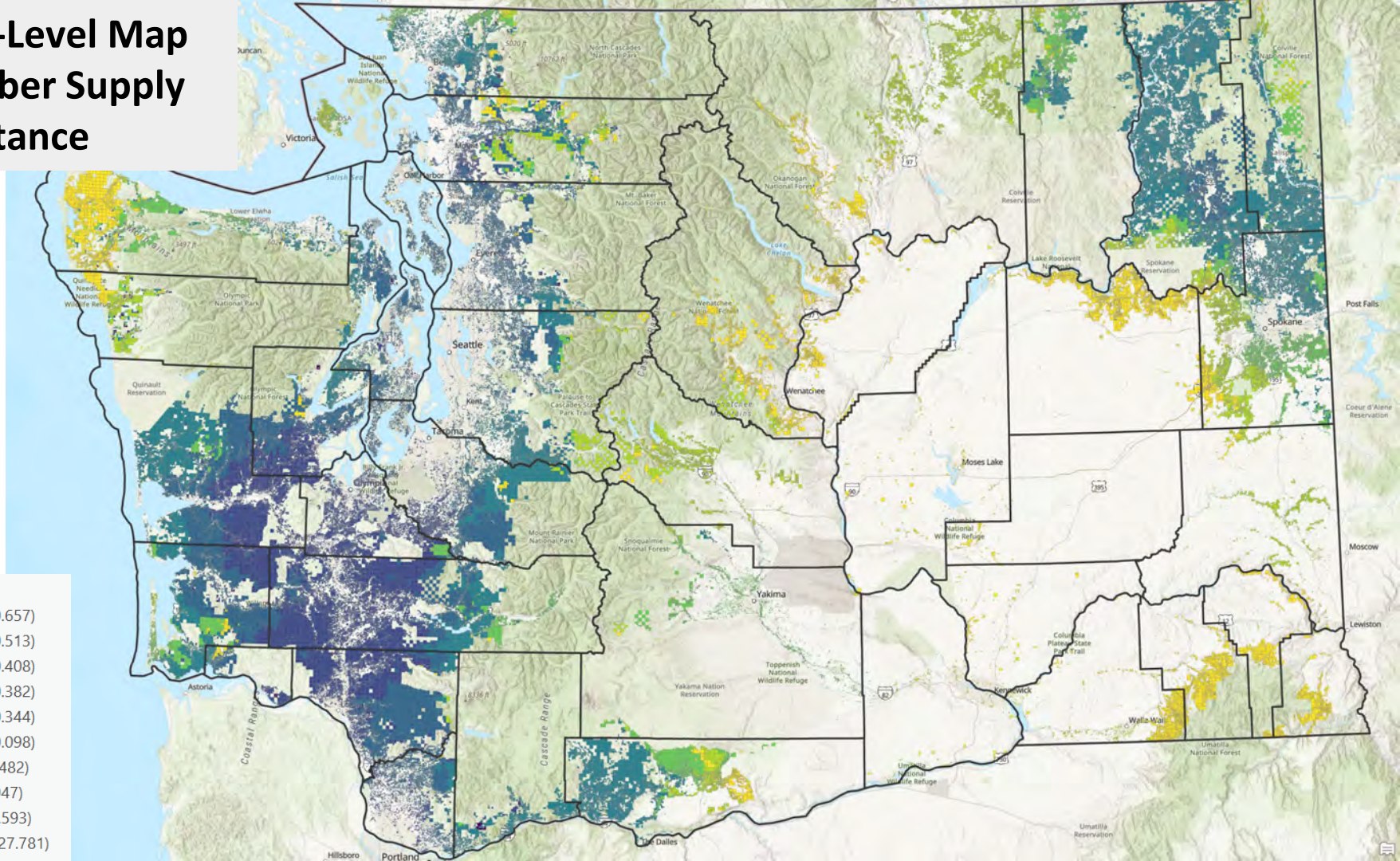
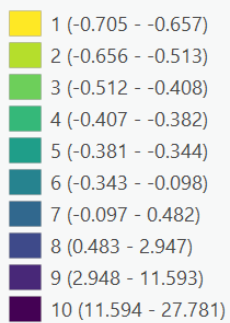




- **Purpose:** show potential impacts of forest conversion on economically important timber supply
- **Data sources:**
 - Forest Product Mill Locations (provided by DNR)
 - Timber Harvest Volume by parcel (from WA DNR Forest Estate Data, only for western half of the state)
- **Score:** z-score (# of 50 mile drive sheds each parcel is in) + z-score (harvest volume, where available)/2; turned into 1-10 scale using Jenks Natural Breaks
- **Additional popups at the private lands parcel level show**
 - - # service areas overlapping on private land parcel
 - - acres of service areas overlapping on private land parcel
 - - % of private land parcel included in service areas (service are acres / private parcel acres)
 - - harvest volume mean
 - - harvest volume sum
 - - harvest volume acres
 - - % of private land parcel used for timber harvest (harvest volume acres / private parcel acres)

Parcel-Level Map of Timber Supply Importance

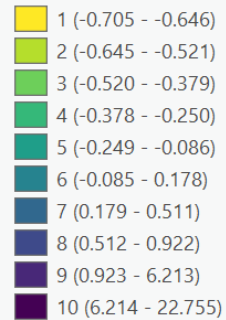
Timber_Mean2



PLSS-Level Map of Timber Supply Importance

Mean Timber_Mean2

Color	Range
Yellow	1 (-0.705 - -0.646)
Light Green	2 (-0.645 - -0.521)
Green	3 (-0.520 - -0.379)
Dark Green	4 (-0.378 - -0.250)
Teal	5 (-0.249 - -0.086)
Blue-Gray	6 (-0.085 - 0.178)
Dark Blue	7 (0.179 - 0.511)
Navy Blue	8 (0.512 - 0.922)
Purple	9 (0.923 - 6.213)
Dark Purple	10 (6.214 - 22.755)





- **Purpose:** show health status of communities in potential forest conversion zones
- **Data sources:**
 - WA DOH Primary Care and Health Professional Shortage Areas (HPSA)
 - WA DOH Environmental Health Disparities (EHD) map
 - WA DOH Sensitive Populations (death from cardiovascular disease; low birth weight)
- **Scores:** Mean score of all the above by parcel
- **Additional popups at the private lands parcel level show**
 - - count of HPSA areas on private lands
 - - acres of HPSA areas on private lands
 - - % of HPSA areas on private lands
 - - mean PC score of all HPSA areas on private lands
 - - count of EHD areas on private lands
 - - acres of EHD areas on private lands
 - - % of EHD areas on private lands

Additional layers for contextual purposes

- Overlays not in land use change model that might indicate reduced urbanization probability
 - WA DOH Drinking Water Surface Water and Wellhead Protection Areas
 - ESA critical habitat polygons
- Policy boundaries: to be used to address possible policy levers in areas of predicted development
 - Urban growth boundaries (already in development model)
 - Drinking water service areas

Putting the Data to Use

CONNECTING THE DOTS BETWEEN
ARCGIS LAYERS AND PROGRAM
REQUIREMENTS.



Program Requirements

Program Name	Agency	Program Type	Requirements
Family Forest Fish Passage Program (FFFPP) (RCW 76.13.150)	WA DNR; WDFW; RCO	Cost share; technical assistance	Since 2003, over 375 landowners have utilized the program to remove 471 barriers and open more than 1,361 miles of stream habitat; provides 75 to 100 percent of the cost of correcting small forest landowners' fish barriers
Forest Riparian Easement Program (FREP) (RCW 76.13.120)	WA DNR	Direct Payment for 40-year easement to mitigate impacts of Forest and Fish on small landowners	FREP reimburses small forest landowners, 90 percent of the value of trees they are required to leave along streambanks to protect fish habitat in a 40-year conservation easement. 508 easements have been purchased to date.
Rivers and Habitat Open Space Program (RCW 76.09.040)	WA DNR	Direct Payment for permanent easements in channel migration zones for timber harvest and critical habitat for state listed threatened or endangered species	RHOSP started in 2002, and since then has protected 1,441 acres of critical habitat via 28 conservation easements

Program	Key Requirements	Data/Source(s)
Family Forest Fish Passage Program (FFFPP)	- Private Forestland - Fish-Bearing Stream - Road	Private Forestland: SIG Development Data (DD) Fish-Bearing Stream: Fish passage inventory, WA Dept. of Fish and Wildlife (WDFW) Road: Statewide roads and routes, WA Dept. Of Transportation (WDOT)
Safe Harbor Agreements	- Private Forestland - PHS	Private Forestland: SIG DD PHS: Priority habitats and species, WDFW
Business and Occupation (B&O) Tax Reduction (RCW 82.04.260)	- Private Forestland - Commercial Timberland	Private Forestland: SIG DD Commercial Timberland: SIG DD; sawmills
Partners for Fish and Wildlife	- Private Forestland <u>1+ of the following:</u> - Riparian Zone(s) - Wetlands - PHS - Rare Plants	Private Forestland: SIG DD Riparian Zones: Data not available Wetlands: National Wetlands Inventory, U.S. Fish and Wildlife Service PHS: Priority habitats and species, WDFW Rare Plants: Washington National Heritage Program rare species and ecosystems data, WA DNR
Service Forestry Program	- Private Forestland (5+ acres)	Private Forestland: SIG DD

Other Programs to be Included

Family Forest Fish Passage Program (FFFPP)
(RCW 76.13.150)

Forest Riparian Easement Program (FREP)
(RCW 76.13.120)

Rivers and Habitat Open Space Program
(RCW 76.09.040)

Forest and Fish Leave Tree Tax Credit (RCW
84.33.0775)

Current Use/Designated Forest Land (DFL)
Tax (RCW 83.33)

Forest Practices Act - Alternate Plan
Templates

Small Forest Landowner Long Term
Practices Permit WAC 222-12-030, -035, -
0401, -0402, 222-16-010, -050, and chapter
222-20 WAC Forest Practices Permit

Safe Harbor Agreements

Business and Occupation (B&O) Tax
Reduction (RCW 82.04.260)

Conservation Stewardship Program

Environmental Quality Incentive Program
(EQIP)

Conservation Technical Assistance

Service Forestry Program (previously the
Forest Stewardship Program)

Forest Legacy Program

King County Transfer of Development
Rights

Conservation Easements

Growth Management Act (GMA)

Wildlife Habitat Incentives Program

Partners for Fish and Wildlife

Program	Key Requirements	Data/Source(s)
Family Forest Fish Passage Program (FFFPP)	- Private Forestland - Fish-Bearing Stream - Road	Private Forestland: SIG Development Data (DD) Fish-Bearing Stream: Fish passage inventory, WA Dept. of Fish and Wildlife (WDFW) Road: Statewide roads and routes, WA Dept. Of Transportation (WDOT)
Safe Harbor Agreements	- Private Forestland - PHS	Private Forestland: SIG DD PHS: Priority habitats and species, WDFW
Business and Occupation (B&O) Tax Reduction (RCW 82.04.260)	- Private Forestland - Commercial Timberland	Private Forestland: SIG DD Commercial Timberland: SIG DD; sawmills
Partners for Fish and Wildlife	- Private Forestland <u>1+ of the following:</u> - Riparian Zone(s) - Wetlands - PHS - Rare Plants	Private Forestland: SIG DD Riparian Zones: Data not available Wetlands: National Wetlands Inventory, U.S. Fish and Wildlife Service PHS: Priority habitats and species, WDFW Rare Plants: Washington National Heritage Program rare species and ecosystems data, WA DNR
Service Forestry Program	- Private Forestland (5+ acres)	Private Forestland: SIG DD

Program	Key Requirements	Data/Source(s)
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Service Forestry Program	- Private Forestland (5+ acres)	Private Forestland: SIG DD

Key Program Requirements (E.g.)

Family Forest Fish Passage Program

- Private and/or Small Forest Land
- Must contain a culvert
 - The culvert must be associated with a road
 - The culvert must be on a fish-bearing stream
 - The stream must have a gradient of 20% or less
 - The stream must be wider the 2' if in Western Washington, and 3' if in Eastern Washington

Key Program Requirements in Layers

Family Forest Fish Passage Program

- Private and/or Small Forest Land
- Must contain a culvert
 - The culvert must be associated with a road
 - The culvert must be on a fish-bearing stream
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Key Program Requirements in Layers

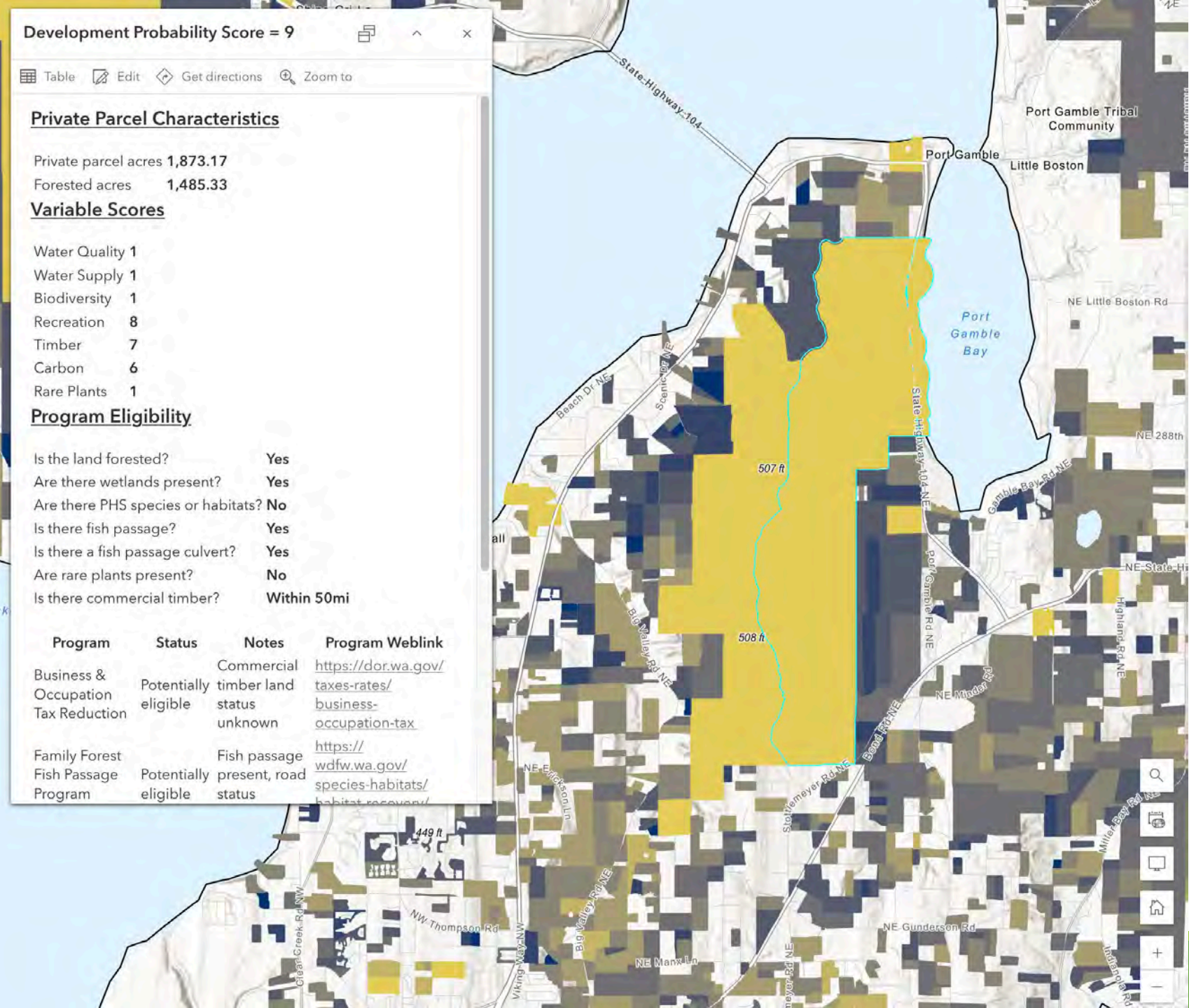
Family Forest Fish Passage Program

- Private and/or Small Forest Land
- Must contain a culvert
 - The culvert must be associated with a road
 - The culvert must be on a fish-bearing stream
 - The stream must have a gradient of 20% or less
 - The stream must be wider the 2' if in Western Washington, and 3' if in Eastern Washington

Using the data layers we have, we can determine if a parcel is *potentially* eligible for the FFFP Program, but we lack the road association data to say for certain if it is.

FFFPP In Action

- Large plot of forest land just west of Port Gamble Bay
- It has a high conversion risk score of 9, indicated by the yellow color
- It is forested, and may include commercial timber land, but we do not know if it includes a culvert associated with a road
- Based on the layers we have, it's "Potentially Eligible" for the FFFP Program, depending on if it's culvert and road status can be determined



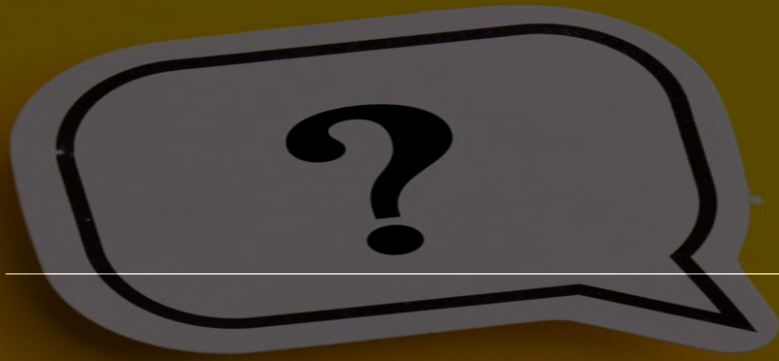


Lets try it live!

<https://gsal.sig-gis.com/portal/apps/mapviewer/index.html?webmap=beabf53193cd4dfa8eeb7581af7e842d>



BREAK



Brainstorm Questions and Queries

Observations, Insights and Recommendations

Thanks!



Using the Policy Eligibility Map

Background

This tool was developed to fulfill two primary roles: to serve as a quick-glance way of seeing what forested areas were at a real risk of conversion, and to allow a user to hone in on individual parcels to see what programs those private lands may be eligible for. This allows users to scope out areas that might be at risk of conversion and then check what kinds of programs are available for landowners in those areas, to scope out areas that are at a low conversion risk and see what programs may be supporting that, and, potentially, to allow a user to make individual, personalized recommendations for programs a landowner may be eligible for without realizing.

Using the Map

On launching the policy eligibility map, you will see the map shown in fig.1. As shown in the legend, this map is color coded by a stat referred to as DevProbDT, which is a score for how likely it is that a plot of private forest land will be cleared and developed on. This serves as our quick-glance method of seeing how at-risk a given area is, or highlighting parcels that are at a particularly high risk and warrant further investigation as to why, and what existing programs for limiting conversion are or are not available to them. Darker areas are at a higher risk.

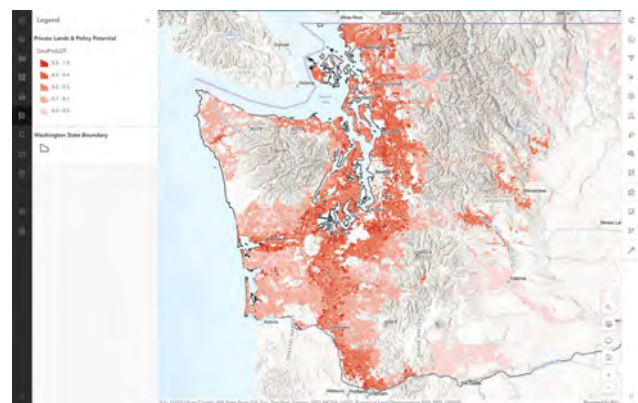


Fig. 1 - Policy Eligibility Map

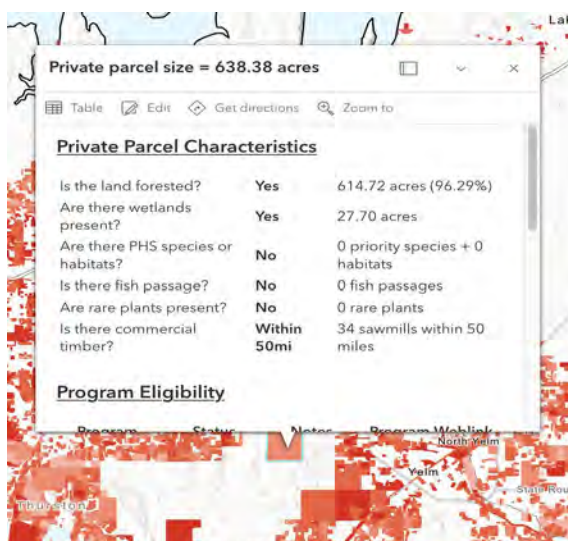
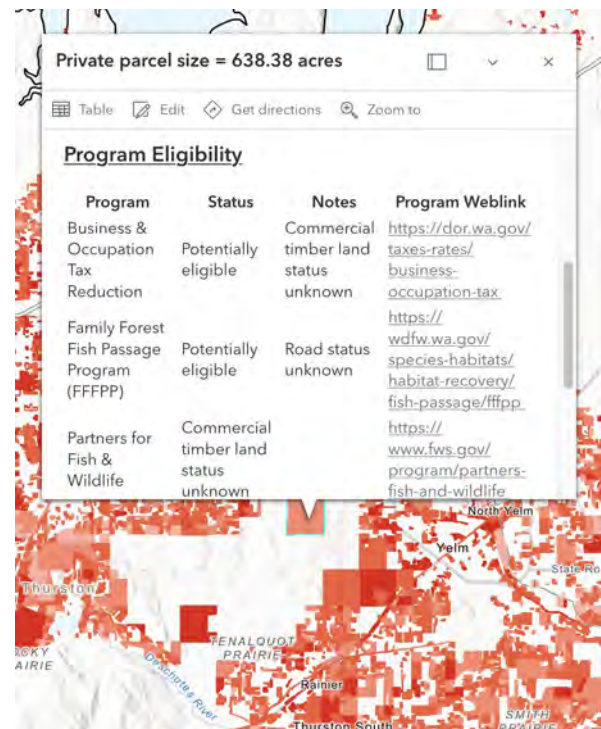


Fig. 2 - Parcel Pop-Up with Characteristics Table

Once you have identified a parcel of interest, you can look deeper into it's specific situation by simply zooming in with the +/- buttons in the bottom right-hand corner and clicking on the parcel. Clicking on the parcel should bring up an informational pop-up that looks similar to what's shown in fig.2. Here, we can see that I've chosen a large plot of land just outside Olympia. We can see it's total size, just under 640 acres, as well as a selection of important geographical and environmental information about the plot. This information is the criteria being used to determine the parcel's eligibility for an array of government programs that could

be used to incentivize maintaining it's forest land instead of converting it for development. These criteria include it's total forest coverage, how much of it is taken up by wetlands, water features, or specific habitats, if there are any specific species of plants or animals, and how much commercial timber infrastructure is in it's local area.

Hovering over this text box and scrolling down will bring up the second main use of this map: Identifying what forest conversion programs apply to that specific plot. As seen in fig.3, this table includes the program name (Program), the parcels eligibility status (Status), notes on said eligibility status where applicable (Notes), and a web link to the programs online homepage (Program Weblink). The eligibility for each site is determined by comparing existing GIS map data to the listed requirements of each program. For example, if a programs only eligibility requirements were that a parcel be over 10 acres and be at least 50% forested, eligibility is determined by seeing if the parcels size on the map is over 10 acres, and if the forestation percentage is over half. For programs whose requirements can be determined by this kind of available data, every parcel will be either "eligible" or "not eligible" in that second column. If, however, a program has eligibility requirements that are not available through this kind of GIS data, like the parcels status as commercial or non-commercial timber land, then depending on the results of that programs other requirements, the program may show as "potentially eligible", which simply means that the user or landowner would need to confirm some additional details to determine if the program would apply to that parcel.



Program	Status	Notes	Program Weblink
Business & Occupation Tax Reduction	Potentially eligible	Commercial timber land status unknown	https://dor.wa.gov/taxes-rates/business-occupation-tax
Family Forest Fish Passage Program (FFPPP)	Potentially eligible	Road status unknown	https://wdfw.wa.gov/species-habitats/habitat-recovery/fish-passage/ffppp
Partners for Fish & Wildlife	Commercial timber land status unknown		https://www.fws.gov/program/partners-fish-and-wildlife

fig. 3 - Parcel Pop-Up with Program Eligibility Table

Review

These instructions should walk you through using the map for any given parcel of land, but if you're not sure you understood all of it, you can check your understanding By trying to answer each of the following questions, and checking your results with the key on the next page.

1. How many sawmills are within 50 miles of the southern most tip of Camano?
2. Is the largest plot of high-risk land on Mercer Island eligible for the Service Forestry Program?
3. Why can't we be certain if the northern-most at-risk parcel on the Olympic peninsula is eligible for the Family Forest Fish Passage Program?

C

User Guide

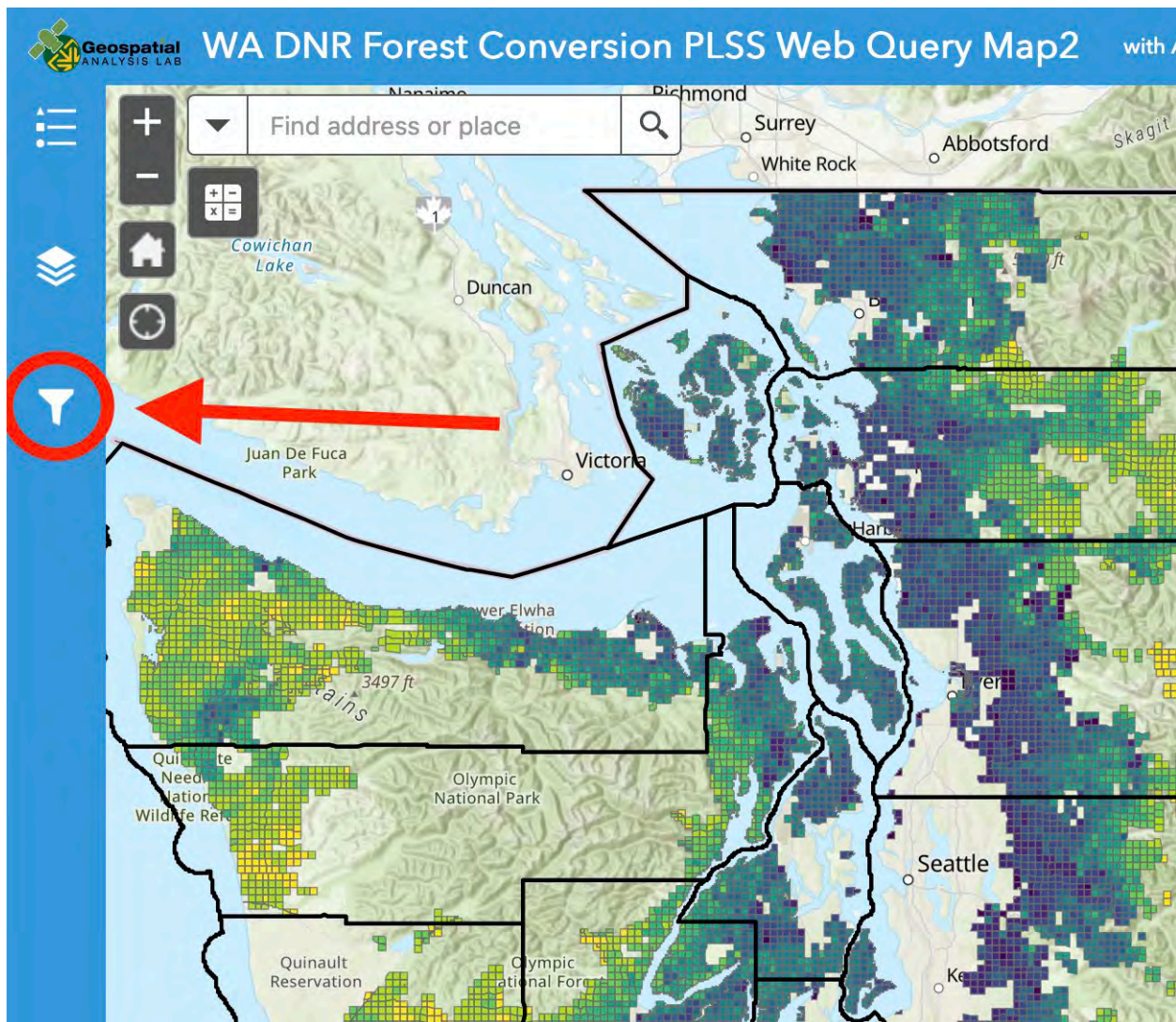
Using the PLSS Maps

There are two forms of PLSS maps you'll encounter when using the online GIS PLSS maps.

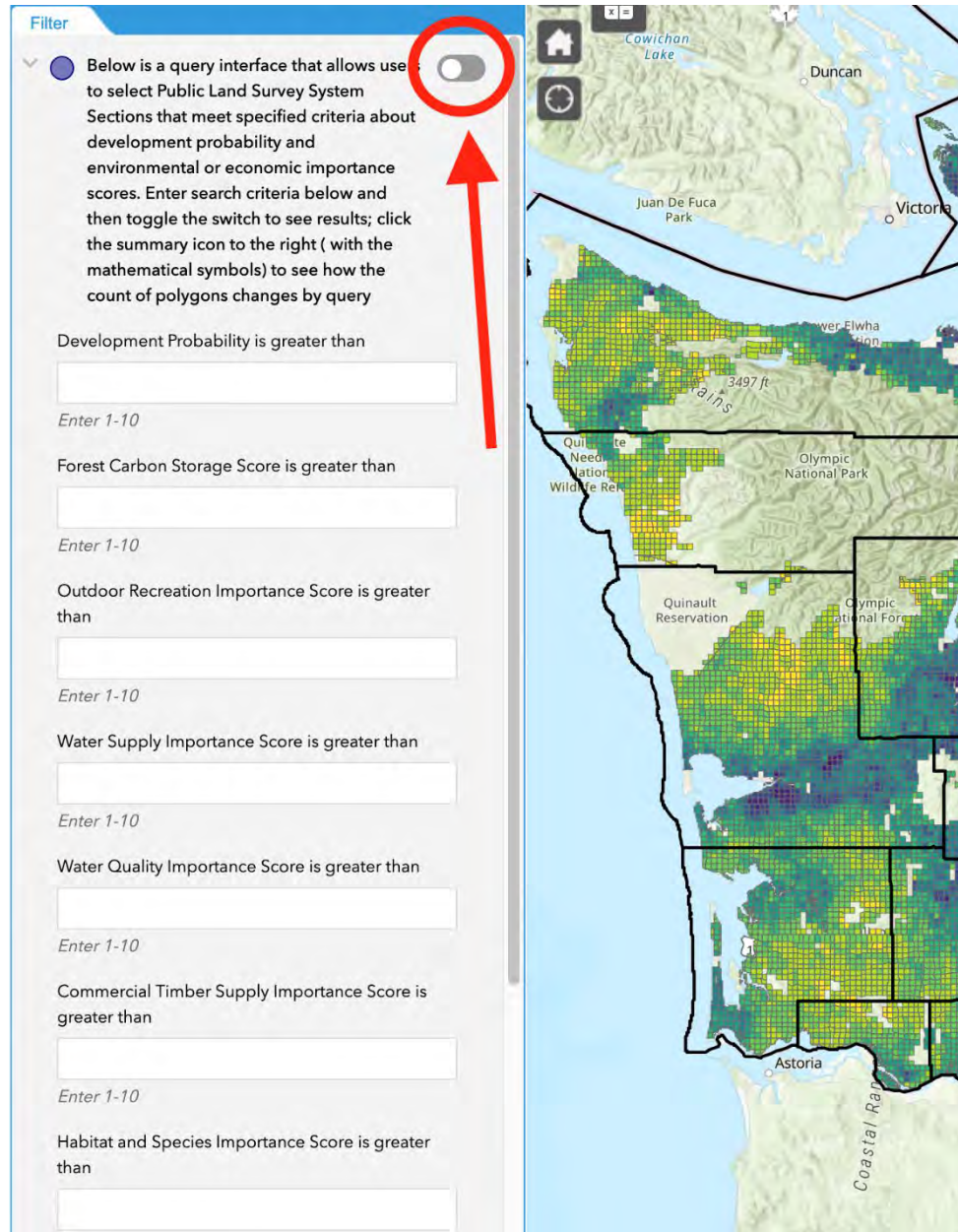
Style 1

This style applies to the following maps:

- <https://gsal.sig-gis.com/portal/apps/webappviewer/index.html?id=9efba22763884f698d070b3909f87e2f>



To effectively query this style of map, click on the filter icon on the left hand side, circled in the image. This will bring up the pane shown in the image below. Simply fill out the fields you wish to query, and toggle the filters on, circled in the second image.



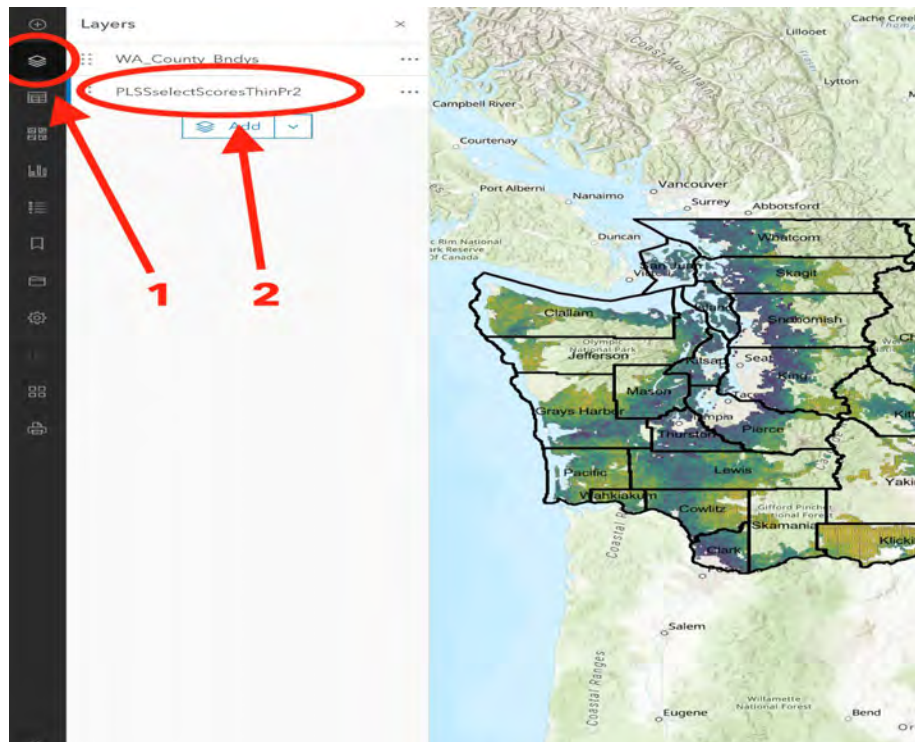
Note that the description of the query interface fields is located to the left of the toggle button. Setting a numerical value will display all areas that scored at or above the selected value. For a detailed description of the layers and the development of the 1-10 scales for each see Chapter 5.

Style 2

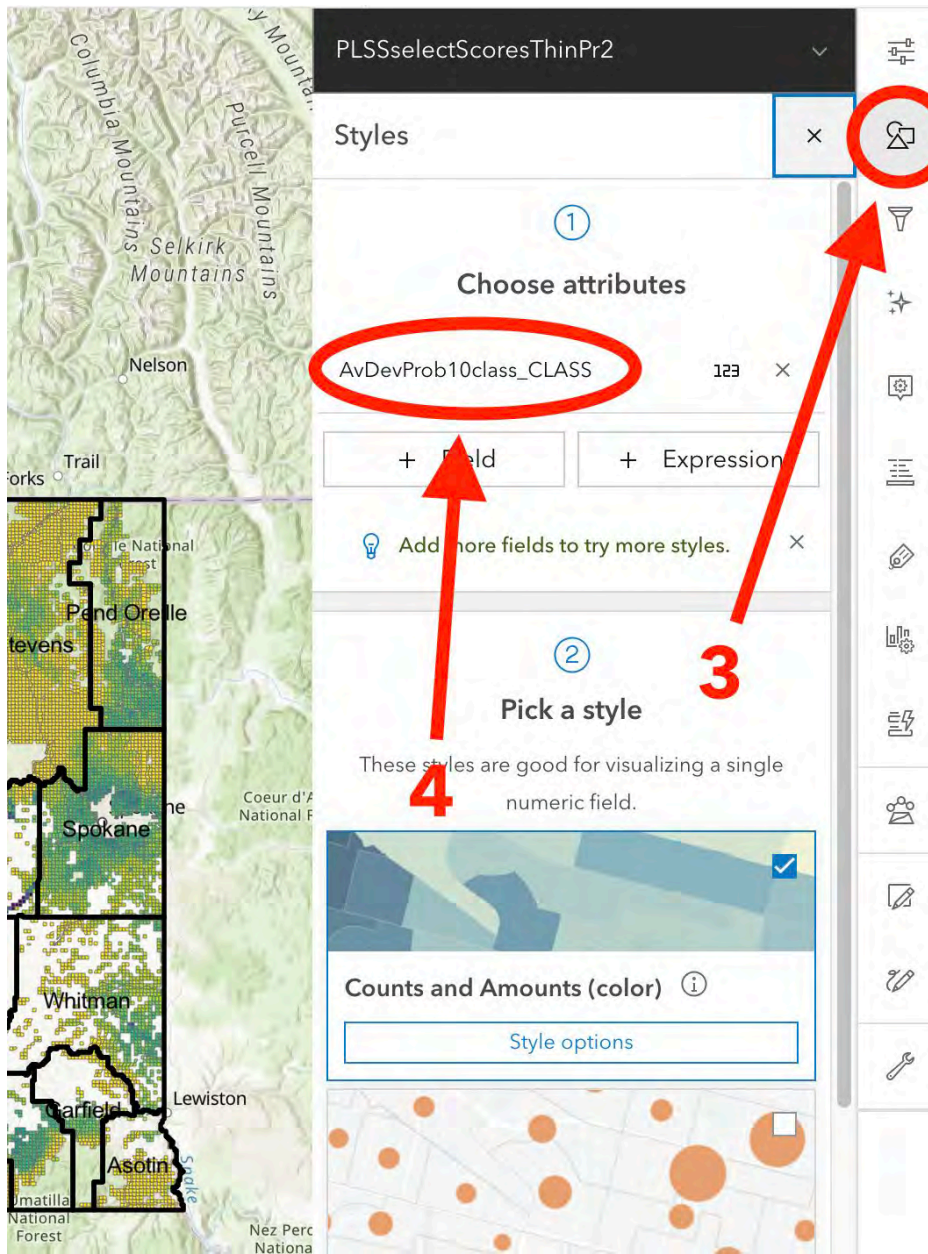
This style applies to the following maps:

- <https://gsal.sig-gis.com/portal/apps/mapviewer/index.html?webmap=1f06fa0b0430410dab7d5ba351263adf>
- <https://gsal.sig-gis.com/portal/apps/mapviewer/index.html?webmap=a892309902f4439597102dc b012b1739>
- <https://gsal.sig-gis.com/portal/apps/mapviewer/index.html?webmap=ebf93278a5a5498591fc543315fd8515>

This style of map will look roughly like the following image. To view specific overlays on these maps, click on the “Layers” button on the right-hand side (1), then select the variable layer (2).



Next, go over to the left hand side and click the Styles button (3), then click on the layer field (4). This will open a menu that will allow you to select your desired layer to display on the map.



D

Literature Review

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E

Priority Areas

COUNTY_C	COUNTY_L	Carbon	Recreation	WaterSupply	Timber	Salmon	WaterQual	Habitat	RarePlants	mean_DevProbLog	sum_DevProbLog	mean_DevProbDecTree	sum_DevProbDecTree	mean_AveDevProb	sum_AveDevProb	ESRP	ALEA	BAFBRB	SalmonPSAR	WWRP	CFP	FFFP	BORCW	PFW	FREP	RHOSP
1	Adams	1.04	2.87	3.50	1.00	1.00	1.11	2.65	1.34	0.116	14.04	0.00	0.00	0.06	7.02	0.0%	90.5%	4.0%	4.0%	0.0%	4.5%	4.0%	0.0%	17.0%	32.5%	14.3%
2	Asotin	1.69	5.39	4.47	1.00	1.78	1.06	7.48	3.18	0.025	23.71	0.00	0.75	0.01	12.23	0.0%	90.1%	1.2%	1.2%	0.0%	31.1%	1.2%	0.0%	96.1%	23.6%	99.0%
3	Benton	1.14	3.53	4.62	1.04	1.63	1.43	2.06	1.63	0.123	45.77	0.00	2.78	0.06	24.28	0.0%	83.8%	0.0%	0.0%	0.0%	5.9%	0.0%	14.5%	39.7%	38.6%	27.4%
4	Chelan	2.86	8.18	6.90	1.00	1.80	3.37	3.35	2.77	0.123	400.57	0.13	569.64	0.12	485.11	0.0%	92.2%	0.0%	0.0%	3.1%	5.2%	0.0%	13.6%	78.9%	30.3%	78.7%
5	Clallam	6.80	7.46	1.78	2.55	4.73	1.07	3.10	2.06	0.082	699.49	0.10	937.25	0.09	818.37	0.0%	92.8%	1.3%	1.3%	1.7%	3.1%	1.3%	37.5%	25.6%	18.6%	19.3%
6	Clark	5.87	6.14	8.45	6.16	3.50	1.44	1.90	2.76	0.187	1480.42	0.21	1855.60	0.20	1668.01	0.0%	86.2%	0.1%	0.1%	0.0%	0.0%	0.1%	99.2%	72.1%	31.3%	52.7%
7	Columbia	2.04	5.11	5.43	1.00	2.29	5.28	6.29	1.32	0.076	67.57	0.09	82.88	0.08	75.22	0.0%	96.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	95.1%	22.5%	99.5%
8	Cowlitz	6.22	3.60	7.78	8.55	3.68	1.16	3.77	1.66	0.087	754.22	0.12	1293.30	0.10	1023.76	0.0%	97.3%	0.1%	0.1%	0.0%	2.4%	0.1%	99.7%	92.3%	10.5%	94.9%
9	Douglas	1.17	5.71	4.30	0.98	1.56	1.01	5.75	2.00	0.134	118.92	0.01	14.24	0.07	66.58	0.0%	73.6%	0.1%	0.1%	0.0%	7.3%	0.1%	0.0%	73.6%	27.9%	98.4%
10	Ferry	2.66	6.93	3.44	2.86	1.06	1.10	3.56	1.58	0.064	443.34	0.00	0.63	0.03	221.99	0.0%	89.9%	0.5%	0.5%	0.0%	1.9%	0.5%	98.6%	85.7%	34.6%	86.2%
11	Franklin	1.02	3.22	3.75	0.98	1.11	1.07	2.40	1.61	0.112	27.03	0.01	2.82	0.06	14.93	0.0%	85.9%	0.0%	0.0%	0.0%	40.0%	0.0%	0.0%	63.7%	21.0%	68.5%
12	Garfield	1.16	3.65	4.98	0.98	1.25	1.75	5.16	2.87	0.032	10.38	0.07	18.80	0.05	14.59	0.0%	97.7%	0.3%	0.3%	0.0%	0.0%	0.3%	0.0%	89.1%	10.3%	90.9%
13	Grant	1.10	4.09	2.99	1.00	1.26	1.22	3.98	1.77	0.090	32.94	0.01	0.35	0.05	16.65	0.0%	78.6%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	56.4%	30.6%	67.9%
14	Grays Harb	6.16	5.31	1.96	7.45	4.67	3.93	3.44	2.47	0.128	766.88	0.12	1002.14	0.12	884.51	0.0%	98.0%	0.2%	0.2%	0.1%	0.3%	0.2%	99.9%	37.4%	11.5%	17.7%
15	Island	7.12	9.46	1.84	5.03	1.75	1.00	2.06	1.66	0.208	778.25	0.22	914.54	0.22	846.39	0.0%	40.9%	0.0%	0.0%	0.0%	6.1%	0.0%	98.6%	33.8%	27.4%	21.0%
16	Jefferson	6.96	7.71	1.79	2.89	3.93	1.12	2.68	2.52	0.111	411.06	0.14	600.01	0.13	505.54	0.0%	90.8%	0.3%	0.3%	0.2%	4.6%	0.3%	85.5%	44.7%	17.6%	24.9%
17	King	6.08	8.05	5.62	4.12	3.65	2.72	3.60	1.38	0.229	2523.81	0.15	1761.24	0.19	2142.53	0.0%	63.4%	0.1%	0.0%	0.0%	8.0%	0.1%	97.5%	55.2%	25.9%	76.9%
18	Kitsap	6.86	8.31	2.10	5.88	4.21	1.13	1.46	1.10	0.242	1000.30	0.27	1116.94	0.26	1058.62	0.0%	72.1%	2.5%	2.5%	0.0%	1.5%	2.5%	99.0%	9.5%	27.7%	2.3%
19	Kittitas	3.27	7.19	6.34	2.05	2.63	4.60	3.95	1.99	0.124	460.14	0.15	761.39	0.14	610.77	0.0%	89.1%	0.7%	0.6%	4.7%	7.1%	0.6%	89.1%	64.9%	29.3%	76.7%
20	Klickitat	2.74	4.86	4.37	3.23	1.40	1.55	3.56	3.79	0.050	369.54	0.00	4.44	0.03	186.99	0.0%	92.4%	0.4%	0.4%	0.0%	18.6%	0.4%	83.3%	90.5%	17.2%	74.3%
21	Lewis	5.69	4.84	6.60	7.55	3.79	3.26	4.40	1.64	0.150	1700.08	0.12	1999.69	0.13	1849.88	0.0%	97.6%	0.0%	0.0%	0.0%	3.2%	0.0%	99.9%	77.7%	17.5%	80.7%
22	Lincoln	1.35	3.54	2.37	1.00	1.22	1.36	6.29	1.57	0.046	84.17	0.00	0.21	0.02	42.19	0.0%	91.3%	0.4%	0.4%	0.0%	0.0%	0.4%	0.0%	86.7%	18.1%	96.3%
23	Mason	5.72	7.08	2.23	7.10	4.25	2.86	2.75	1.75	0.154	931.34	0.19	1466.55	0.17	1198.94	0.0%	87.8%	0.3%	0.3%	0.0%	11.5%	0.3%	97.8%	17.5%	23.4%	7.0%
24	Okanogan	1.92	5.55	4.24	1.01	1.64	1.65	6.13	1.44	0.063	578.71	0.00	60.22	0.03	319.46	0.0%	83.4%	0.6%	0.6%	0.0%	17.2%	0.6%	79.2%	76.7%	48.6%	84.9%
25	Pacific	5.55	5.27	4.03	7.42	5.93	2.79	3.72	2.06	0.091	449.60	0.08	458.36	0.08	453.98	0.0%	98.7%	0.4%	0.4%	0.0%	0.5%	0.4%	98.0%	84.4%	10.4%	86.1%
26	Pend Oreill	2.93	6.58	5.16	3.37	1.09	2.72	4.21	1.48	0.058	433.80	0.08	680.11	0.07	556.96	0.0%	87.4%	0.2%	0.2%	0.0%	0.0%	0.1%	98.5%	59.4%	25.0%	64.6%
27	Pierce	5.73	5.66	2.62	5.70	4.06	1.96	3.16	1.82	0.191	1813.64	0.16	2132.69	0.18	1973.16	0.1%	88.1%	0.1%	0.1%	0.0%	1.5%	0.1%	98.6%	72.4%	16.4%	71.8%
28	San Juan	6.80	9.80	7.38	1.81	1.02	1.00	1.26	1.35	0.180	750.07	0.29	1361.16	0.23	1055.61	0.0%	59.9%	0.0%	0.0%	0.0%	70.4%	0.0%	83.5%	39.3%	34.6%	39.8%
29	Skagit	5.84	7.24	7.77	4.68	5.32	2.13	3.31	1.61	0.132	1646.62	0.14	1960.82	0.14	1803.72	0.0%	88.5%	0.5%	0.4%	0.0%	3.7%	0.4%	81.7%	46.1%	21.2%	48.0%
30	Skamania	5.60	8.25	7.11	3.06	2.80	1.49	2.83	2.46	0.094	216.37	0.10	370.42	0.10	293.39	0.0%	93.2%	0.1%	0.1%	5.2%	38.5%	0.1%	96.7%	74.6%	17.3%	66.9%
31	Snohomist	5.85	7.25	5.81	5.25	6.09	2.47	2.41	1.19	0.625	6119.09	0.55	5735.33	0.59	5927.21	0.0%	95.1%	0.0%	0.0%	28.5%	2.0%	0.0%	99.5%	57.1%	7.0%	85.8%
32	Spokane	2.01	6.05	3.36	2.34	1.05	2.49	4.69	2.04	0.152	3654.31	0.00	8.90	0.08	1831.60	0.0%	76.0%	0.0%	0.0%	0.0%	0.8%	0.0%	91.6%	67.4%	29.4%	79.7%
33	Stevens	2.67	4.20	4.73	4.66	1.13	1.68	3.07	1.44	0.049	1237.23	0.00	0.81	0.02	619.02	0.0%	84.2%	0.2%	0.2%	0.0%	0.4%	0.2%	98.4%	55.7%	32.7%	63.7%
34	Thurston	5.31	6.02	1.52	8.02	4.22	2.57	2.93	2.37	0.231	2031.27	0.26	2661.51	0.25	2346.39	0.0%	84.4%	0.1%	0.1%	0.4%	21.7%	0.1%	99.9%	52.7%	28.1%	36.6%
35	Wahkiakun	5.64	4.55	5.00	8.42	5.11	1.01	4.26	1.36	0.074	121.38	0.07	141.82	0.07	131.60	0.0%	94.9%	0.2%	0.1%	0.0%	57.3%	0.2%	95.8%	90.8%	19.1%	99.9%
36	Walla Wall	1.54	3.79	5.90	0.99	2.22	2.81	4.33	2.15	0.080	236.32	0.00	2.79	0.04	119.56	0.0%	91.8%	0.8%	0.8%	0.0%	0.1%	0.8%	6.8%	92.2%	26.9%	93.4%
37	Whatcom	5.33	6.58	6.99	3.66	5.54	1.60	2.24	2.03	0.160	1759.73	0.27	2209.03	0.22	1984.38	0.0%	86.7%	0.2%	0.2%	0.0%	4.4%	0.1%	93.6%	50.9%	24.9%	40.9%
38	Whitman	1.34	2.67	5.37	1.40	1.08	2.10	3.65	3.48	0.100	164.81	0.00	0.70	0.05	82.76	0.0%	92.3%	1.2%	1.2%	0.0%	6.3%	0.9%	86.4%	82.2%	25.9%	40.8%
39	Yakima	1.74	5.01	5.76	1.88	2.53	2.23	3.98	2.05	0.085	693.57	0.01	28.40	0.05	360.98	0.0%	83.5%	0.9%	0.9%	0.0%	0.4%	0.8%	96.3%	67.8%	29.3%	56.9%

COUNTY_	COUNTY_L	WaterSupply	WaterQual	RarePlants	Habitat	Salmon	Timber	Carbon	Recreation	mean_DevProbLog	sum_DevProbLog	mean_DevProbDecTree	sum_DevProbDecTree	mean_AveDevProb	sum_AveDevProb
1	Adams	3.50	1.11	1.34	2.65	1.00	1.00	1.04	2.87	0.116	14.04	0.00	0.00	0.06	7.02
2	Asotin	4.47	1.06	3.18	7.48	1.78	1.00	1.69	5.39	0.025	23.71	0.00	0.75	0.01	12.23
3	Benton	4.62	1.43	1.63	2.06	1.63	1.04	1.14	3.53	0.123	45.77	0.00	2.78	0.06	24.28
4	Chelan	6.90	3.37	2.77	3.35	1.80	1.00	2.86	8.18	0.123	400.57	0.13	569.64	0.12	485.11
5	Clallam	1.78	1.07	2.06	3.10	4.73	2.55	6.80	7.46	0.082	699.49	0.10	937.25	0.09	818.37
6	Clark	8.45	1.44	2.76	1.90	3.50	6.16	5.87	6.14	0.187	1480.42	0.21	1855.60	0.20	1668.01
7	Columbia	5.43	5.28	1.32	6.29	2.29	1.00	2.04	5.11	0.076	67.57	0.09	82.88	0.08	75.22
8	Cowlitz	7.78	1.16	1.66	3.77	3.68	8.55	6.22	3.60	0.087	754.22	0.12	1293.30	0.10	1023.76
9	Douglas	4.30	1.01	2.00	5.75	1.56	0.98	1.17	5.71	0.134	118.92	0.01	14.24	0.07	66.58
10	Ferry	3.44	1.10	1.58	3.56	1.06	2.86	2.66	6.93	0.064	443.34	0.00	0.63	0.03	221.99
11	Franklin	3.75	1.07	1.61	2.40	1.11	0.98	1.02	3.22	0.112	27.03	0.01	2.82	0.06	14.93
12	Garfield	4.98	1.75	2.87	5.16	1.25	0.98	1.16	3.65	0.032	10.38	0.07	18.80	0.05	14.59
13	Grant	2.99	1.22	1.77	3.98	1.26	1.00	1.10	4.09	0.090	32.94	0.01	0.35	0.05	16.65
14	Grays Harbc	1.96	3.93	2.47	3.44	4.67	7.45	6.16	5.31	0.128	766.88	0.12	1002.14	0.12	884.51
15	Island	1.84	1.00	1.66	2.06	1.75	5.03	7.12	9.46	0.208	778.25	0.22	914.54	0.22	846.39
16	Jefferson	1.79	1.12	2.52	2.68	3.93	2.89	6.96	7.71	0.111	411.06	0.14	600.01	0.13	505.54
17	King	5.62	2.72	1.38	3.60	3.65	4.12	6.08	8.05	0.229	2523.81	0.15	1761.24	0.19	2142.53
18	Kitsap	2.10	1.13	1.10	1.46	4.21	5.88	6.86	8.31	0.242	1000.30	0.27	1116.94	0.26	1058.62
19	Kittitas	6.34	4.60	1.99	3.95	2.63	2.05	3.27	7.19	0.124	460.14	0.15	761.39	0.14	610.77
20	Klickitat	4.37	1.55	3.79	3.56	1.40	3.23	2.74	4.86	0.050	369.54	0.00	4.44	0.03	186.99
21	Lewis	6.60	3.26	1.64	4.40	3.79	7.55	5.69	4.84	0.150	1700.08	0.12	1999.69	0.13	1849.88
22	Lincoln	2.37	1.36	1.57	6.29	1.22	1.00	1.35	3.54	0.046	84.17	0.00	0.21	0.02	42.19
23	Mason	2.23	2.86	1.75	2.75	4.25	7.10	5.72	7.08	0.154	931.34	0.19	1466.55	0.17	1198.94
24	Okanogan	4.24	1.65	1.44	6.13	1.64	1.01	1.92	5.55	0.063	578.71	0.00	60.22	0.03	319.46
25	Pacific	4.03	2.79	2.06	3.72	5.93	7.42	5.55	5.27	0.091	449.60	0.08	458.36	0.08	453.98
26	Pend Oreille	5.16	2.72	1.48	4.21	1.09	3.37	2.93	6.58	0.058	433.80	0.08	680.11	0.07	556.96
27	Pierce	2.62	1.96	1.82	3.16	4.06	5.70	5.73	5.66	0.191	1813.64	0.16	2132.69	0.18	1973.16
28	San Juan	7.38	1.00	1.35	1.26	1.02	1.81	6.80	9.80	0.180	750.07	0.29	1361.16	0.23	1055.61
29	Skagit	7.77	2.13	1.61	3.31	5.32	4.68	5.84	7.24	0.132	1646.62	0.14	1960.82	0.14	1803.72
30	Skamania	7.11	1.49	2.46	2.83	2.80	3.06	5.60	8.25	0.094	216.37	0.10	370.42	0.10	293.39
31	Snohomish	5.81	2.47	1.19	2.41	6.09	5.25	5.85	7.25	0.625	6119.09	0.55	5735.33	0.59	5927.21
32	Spokane	3.36	2.49	2.04	4.69	1.05	2.34	2.01	6.05	0.152	3654.31	0.00	8.90	0.08	1831.60
33	Stevens	4.73	1.68	1.44	3.07	1.13	4.66	2.67	4.20	0.049	1237.23	0.00	0.81	0.02	619.02
34	Thurston	1.52	2.57	2.37	2.93	4.22	8.02	5.31	6.02	0.231	2031.27	0.26	2661.51	0.25	2346.39
35	Wahkiakum	5.00	1.01	1.36	4.26	5.11	8.42	5.64	4.55	0.074	121.38	0.07	141.82	0.07	131.60
36	Walla Walla	5.90	2.81	2.15	4.33	2.22	0.99	1.54	3.79	0.080	236.32	0.00	2.79	0.04	119.56
37	Whatcom	6.99	1.60	2.03	2.24	5.54	3.66	5.33	6.58	0.160	1759.73	0.27	2209.03	0.22	1984.38
38	Whitman	5.37	2.10	3.48	3.65	1.08	1.40	1.34	2.67	0.100	164.81	0.00	0.70	0.05	82.76
39	Yakima	5.76	2.23	2.05	3.98	2.53	1.88	1.74	5.01	0.085	693.57	0.01	28.40	0.05	360.98

