APPENDIX – INR OREGON VEGETATION CHANGE REPORT

Oregon's State Wildlife Action Plan

Oregon Vegetation Change 1851 – 2023

With a focus on Oregon Key Habitats

Institute for Natural Resources

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Introduction

This effort compares the total area and spatial overlap between vegetation classes in existing vegetation maps of different eras to provide insight into possible changes in vegetation cover between 1851 and 2023 (Table 1). There are significant differences between the classifications and methods used to make each map, so we focus here on research questions that:

a) relate to at least one specific Key Habitat, and
b) where there is existing research suggesting that the specific pattern investigated is true, and
c) where the differences between the vegetation classifications compared are expected to be smaller than the differences over time.

We used three statewide vegetation maps as the baseline for these analyses: presettlement (1851 – 1937), turn of the millennium (1998), and contemporary (2016 is the most recent available), as well as several other maps that provide additional information to inform specific research questions.

Table 1. Vegetation maps used to compare vegetation changes between 1851 and 2023. Baseline maps are statewide vegetation maps that are used as the default baseline for presettlement (1851 – 1937), turn of the millennium (1998), and contemporary (2016 is the most recent available) timepoints in the following analyses. Other maps are used to inform the analysis if they provide information beyond what is available in the baseline maps. The Map Name is how each product is referred in the following analyses.

Baseline	Map Name	Publication Year	Vegetation Year(s)	Map Type	Mapping Methods	Reference
X	1851 - 1937 Composite Map	2002	1851 - 1937	Classified Vegetation	Composite of polygon map based on General Land Office and Timber surveys.	Tobalske 2002
	Coast GLO Map	2018	1855 - 1937	Classified Vegetation	Polygon Map based on General Land Office surveys.	Hawes et al. 2018
X	1999 GAP Map	1999	1998	Classified Vegetation	Pixel-based map modeled from early satellite imagery.	Kagan et al. 1999, Kiilsgaard 1999
X	2016 Habitat Map	2018	2016	Classified Vegetation	Composite of multiple pixel maps modeled from satellite imagery.	Kagan et al. 2018
	NLCD Maps	2023	1986, 2001, 2016, 2021	Classified Land Cover	Pixel based land cover map modeled from from satellite imagery.	U.S. Geological Survey 2023
	RAP Maps	2022	1986, 2001, 2016, 2023	Continuous Vegetation Cover	Pixel based vegetation cover modeled from from satellite imagery.	Allred et al. 2021

Coastal Dunes

Methods

Using the best available sources for distribution of historic and modern coastal dunes in Oregon, we compared the total coastal dune area in each map, calculating the percent change between 1855 – 1910 and 2016. We also looked at where changes occurred and calculated the spatial overlap between the maps (i.e. what proportion of the historic dunes were also mapped as dunes in 2016).

1855 – 1910 Coast GLO Map (Hawes et al. 2018)

The General Land Office (GLO) survey notes and witness tree records for the coastal strip were translated into a classified vegetation map in 2018 and they represent better information about historic coastal dune distribution than the 1851 – 1937 composite historic vegetation map that is used elsewhere in this analysis. Based on map class descriptions and location (spatial overlap with contemporary dunes), we considered two map classes as coastal dunes:

> Sand bars, defined as "sandy barrens," sand dunes (witness trees > 400 links distant), tidal mudflats (estuarine or riverine), and "quicksand." May have scattered vegetation in unmappable patches.
>
> Sand dune prairie or grassland, defined as "sandy prairie", "sandy plains", "sand hills covered with grass", and "sand glades".

1998 GAP Map (Kagan et al. 1999, Kiilsgaard 1999)

The best available map is the 1998 update to the Oregon GAP Vegetation map. We used one map class from the 1998 GAP Map for this analysis. The mapping methods used in this map are less accurate than those used in the 1855 – 1910 or 2016 maps. Despite that, we include it in this analysis for reference. Coastal Dunes are defined as:

> The coastal dunes of Oregon attain their greatest development between Florence and Coos Bay where they form a continuous surface that extends several miles inland. Dunes can form through a variety of processes that are influenced by local topography, prevailing wind direction, and source supply of sand. While dunes can be found throughout the length of the Oregon coast they mostly are small, discrete features that do not show up in the vegetation map. Coastal dunes, as they relate to this vegetation description, are sparsely vegetated. Dunes are regions of actively moving sand and only a few types of plants do well in this environment, and typically are grasses or grass-like plants. The most commonly encountered plants encountered on these dunes are European beach grass, seashore bluegrass, American dune grass and large-headed sedge. Other forbs are beach morning glory, beach knotweed, yellow abronia, and silver beach weed. Coastal dunes can appear as a mosaic with coastal forest, estuarine and palustrine wetlands and coastal strand vegetation.

2016 Habitat Map (Kagan et. al. 2018)

We used one map class from the contemporary habitat map for this analysis. Coastal Dunes and Beaches are defined as:

> Coastal beaches, open sand dunes, dune wetlands (including deflation plain wetlands and estuaries in dunes), shrublands and forests occur all along the coast. The largest areas are along the central Oregon coast between Coos Bay and Florence, most in the Oregon Dunes

National Recreation Area. Extensive dunes also occur below the Columbia River, at Sand Lake, at Pistol River, and just north of the California border.

Results

This analysis suggests that there was minimal change in the amount of dune habitat between 1855 – 1910 and 1998, and a 24% loss in coastal dunes by 2016. 54% of the area mapped as Coastal Dunes in 2016 was also mapped as Coastal Dune in 1998, and 38% of the 1855 – 1910 dune area was also mapped as coastal dunes in 2016.

Table 2. Total Area – Coastal Dunes. The left three columns show the total acres of coastal dune acres in 1855 – 1910, 1998, and 2016 and right two columns show the percent change between the mapping efforts.

Acres			Percent Change		
			1855 to	1998 to	1855 to
1855 – 1910	1998	2016	1998	2016	2016
42,131	43,348	32,009	3%	-26%	-24%

Discussion

The minimal gain (3%) by 1998 reported here differs in magnitude from the 18% increase reported in Kagan 1999, likely due to increased accuracy in the mapping of historic dunes. We believe that the 24% loss by 2016 is more likely to reflect true changes over time and the uncertain accuracy of the 1998 dune mapping means that it is not possible to tell when in the 1855 – 2016 time period the majority of the changes happened.

The Coast GLO map coastal dune polygons are reasonably large, so they likely include small patches of vegetation, but these are likely balanced by non-dune historic map classes that likely have inclusions of open sand. This analysis suggests a loss of 24% of the historic coastal dunes between 1910 and 2016. Only 38% of the areas that were mapped as coastal dunes in the 1855 – 1910 composite vegetation map were also mapped as open dunes in 2016. While some of this is due to offsets in locating the narrow coastal beaches, there do appear to have been significant shifts in where open dunes are located, with some dunes now stabilized and open sand dunes established where vegetation was previously stabilized.

Grasslands, Sagebrush Habitats – Juniper Encroachment

In order to investigate Juniper encroachment into Grassland and Sagebrush habitats, we compared the total area and spatial overlap for Juniper Woodlands in the three baseline maps. Juniper woodlands were defined relatively similarly (greater than 10% Western Juniper cover with no other trees present) between three baseline vegetation maps, so this analysis considers all three maps.

Methods

We compared the total area of Juniper Woodlands in each map, calculating the percent change in acres. We also use spatial overlap between the maps to report on the major patterns of conversion.

1851 - 1937 Composite Map (Tobalske 2002)

The Juniper woodland class was defined as 'Juniper' without additional description in the Andrews maps that cover most of the range of Juniper woodlands. The Juniper woodland class from the GLO coverages that are also included in this map is defined as:

> 'Juniper woodland often with bunchgrass. Sometimes on rocky scabland.'

1998 GAP Map (Kagan et al. 1999, Kiilsgaard 1999)

We used one map class for this analysis. The Juniper Woodland Class is defined as:

> Western juniper is a common foothills vegetation type for many of the mountain ranges of eastern Oregon. Juniper reaches its greatest extent in the High Lava Plains Ecoregion centered on Bend, Oregon. This woodland type is typified by its open canopy (less than 30% crown closure), single story, short stature (6-20 feet tall) trees. Understory vegetation in these stands tends to be dominated by sagebrush species, although introduced annual grasses and native bunchgrasses can be important depending on site history and disturbance. As site productivity conditions improve, or as soil moisture availability increases, the pure stands of juniper give way to mixed stands of juniper and ponderosa pine. In most stands western juniper dominates the tree layer. The most frequently encountered shrubs in this cover type are sagebrush species. Big sagebrush is the most common with rigid sagebrush and low sagebrush also commonly found. Other shrubs associated with this type are mountain mahogany, bitterbrush, and rabbitbrush. Grasses characterize the herbaceous layer. Cheatgrass and bottlebrush squirreltail are typical and dominant on overgrazed or disturbed sites. Native bunchgrasses can usually be found. Idaho fescue, bluebunch wheatgrass, Thurber's needlegrass, and Sandberg's bluegrass are the most commonly encountered. Western juniper occupies the transition zone between conifer dominant uplands and the shrub-steppe basins of eastern Oregon. In the driest mountain ranges of southeastern Oregon, i.e. the Trout Creek and Pueblo Mountains, juniper is found at all elevational ranges.

2016 Habitat Map (Kagan et. al. 2018)

We used one map class for this analysis. Juniper Woodland is defined as:

> Western juniper woodlands and savannas. Over the last 30 years, juniper has also invaded many of the grasslands and shrublands in the western parts of the Columbia Plateau. Oregon represents the center of the distribution for western juniper, which historically formed ancient open woodlands covering much of central Oregon and the Steens Mountains. These old-growth juniper woodlands continue to decline with the rapid

development occurring around Bend. However, for a number of reasons not widely agreed upon, western juniper is invading many of the sagebrush steppe areas in southeastern and central Oregon, creating problems for many sagebrush habitats.

Results

Total Area

The comparison of total area of Juniper Woodland shows a large (153%) increase by 1998, and then a minor decrease in total area by 2016.

Table 3. Total Area – Juniper Woodlands. The first three columns show the total acres of Juniper Woodlands in 1855 – 1937, 1998, and 2016 and the percent change between the mapping efforts.

Acres			Percent Change	
1851	**1998**	**2016**	**1851 to 1998**	**1998 to 2016**
1,528,244	3,858,855	3,291,819	153%	-15%

Vegetation Transitions 1851 – 1937 to 1998

This analysis traces the transition of grassland and sagebrush ecosystems to Juniper Woodland via Juniper encroachment. We show the historic (1851 – 1937) composition of 1998 Juniper Woodlands as well as discuss the 1998 vegetation classes that used to be Juniper Woodland in 1851 – 1937. The 153% increase in Juniper Woodlands by 1998 means that many areas transitioned to Juniper Woodland (presumably via encroachment) and this analysis looks at what vegetation types were likely lost. The 153% increase found here is similar to the 134% loss reported for a similar time period by Kagan et al. 1999.

Table 4. Vegetation Transitions 1851 – 1937 to 1998. 1851 – 1937 Vegetation Classes that became Western Juniper by 1998. The left column has 1851 – 1937 map classes that had greater than 50,000 acres mapped as Juniper Woodland in 1998, all other map classes are included in the 'Other' category. Acres shows the number of acres mapped as Juniper Woodland in 1998, and the Percentage column shows percent of 1998 Juniper Woodland acres.

1851 – 1937 Vegetation Classes that transitioned to Western Juniper in 1998	**Acres**	**Percent of 1998 Acres**
Big Sagebrush / Bunchgrass Steppe	1,466,870	38%
Western Juniper	810,613	21%
Grassland Steppe	442,294	12%
Low Sagebrush	347,341	9%
Ponderosa Pine - Douglas-fir Steppe	261,551	7%
Semi-Desert Shrub Steppe	103,711	3%
Intermountain Basin Cliff and Canyon	84,216	2%
Rigid Sagebrush, Buckwheat or Bluegrass Scabland	80,941	2%
Eastside Foothill - Canyon Dry Grassland	56,375	1%
Mountain Big Sagebrush	37,730	1%
Ash Bed	33,815	1%
Great Basin Dry Mixed Sagebrush	29,563	1%
Other	74,505	2%

The most common classes that transitioned to Western Juniper Woodland by 1998 were Sagebrush and Grassland classes, with Big Sagebrush / Bunchgrass Steppe making up 38% of the 1998 Juniper Woodland acres and a full 66% mapped as various sagebrush vegetation types in 1851 – 1937.

1998 Vegetation Classes that had been Western Juniper in 1851 – 1937

While there was a significant increase in total Juniper Woodlands by 1998, only 51% of areas that were mapped Juniper Woodland in 1851 -1937 were also mapped as Juniper Woodland in 1998. Together 31% of the historic (1851 – 1937) Juniper woodlands were mapped as 'Big Sagebrush Shrubland' or 'Sagebrush Steppe' by 1998. Only 4% of the 1851 – 1937 Juniper Woodlands were mapped as Ponderosa Pine Forest and Woodlands in 1998.

Vegetation Transitions 1998 – 2016

Juniper woodlands decreased by 15% over this time period and this analysis traces the bi-directional compositional shifts in Juniper Woodlands between 1998 and 2016.

Table 5. Vegetation Transitions 1998 – 2016. 1998 Vegetation Classes that transitioned to Western Juniper in 2016. The left column has 1998 GAP Map classes that had greater than 50,000 acres mapped as Juniper Woodland in 2016, all other map classes are included in the 'Other' category. Acres shows the number of acres mapped as Juniper Woodland in 2016, and the Percentage column shows what percent of the 2016 Juniper Woodland was previously mapped as each class in the first column.

1998 Vegetation Class that transitioned to Western Juniper in 2016	Acres	Percent of 2016 Acres
Western Juniper Woodland	1,572,981	47%
Big Sagebrush Shrubland	851,998	25%
Ponderosa Pine Forest and Woodland	348,061	10%
Sagebrush Steppe	258,993	8%
Northeast Oregon Mixed Conifer Forest	115,953	3%
Agriculture	62,583	2%
Other	137,124	4%

Table 6. Vegetation Transitions – 2016 Vegetation Classes that used to be Western Juniper in 1998. Juniper woodlands decreased by 15% over this time period and this table shows the 2016 classes that had been mapped as Juniper Woodlands in 1998. The left column has 2016 map classes that had greater than 50,000 acres mapped as Juniper Woodland in 1998, all other map classes are included in the 'Other' category. Acres shows the number of acres mapped as Juniper Woodland in 1998, and the Percentage column shows what percent of the 1998 Juniper Woodland was the 2016 classes in the first column.

2016 Vegetation Classes that were Western Juniper in 1998	Acres	Percent of 1998 Acres
Western Juniper	1,572,981	42%
Big Sagebrush fair - good	466,659	12%

Columbia Basin Grasslands and Prairie	373,862	10%
Low Sagebrush fair - good	225,646	6%
Early Shrub-Tree	167,132	4%
Mountain Big Sagebrush fair - good	157,926	4%
Ponderosa Pine medium	97,571	3%
Ponderosa Pine mature	95,745	3%
Big Sagebrush poor	72,219	2%
Interior Lowland and Foothill Riparian	70,157	2%
Mixed Conifer (White or Douglas Fir/Pine) mature	60,550	2%
Mixed Conifer (White or Douglas Fir/Pine) medium	57,162	2%
Other	357,720	9%

Discussion

The comparison of total area of Juniper Woodland shows a very significant (153%) increase by 1998, and then a smaller decrease (-15%) in Juniper Woodland cover between 1998 and 2016. While not captured in the 2016 Habitat Map, determining how much of the contemporary Juniper Woodlands are old growth is possible using existing products, but it is beyond the scope of this analysis to pull in additional maps.

1851 – 1937 to 1998 Transitions

The 153% increase found here is similar to the 134% loss reported for a similar time period by Kagan et al. 1999. It appears that the majority of the vegetation types that made way for Juniper in 1998 were formerly shrub and grass dominated vegetation where Juniper encroachment has been well documented.

Only 51% of areas that were mapped Juniper Woodland in 1851 -1937 were also mapped as Juniper Woodland in 1998. It is not clear how much of this transition represents modern maps doing a better job of capturing small patches (both small patches of juniper in a sagebrush sea and small patches of sagebrush within Juniper Woodlands), and how much represents true transition of former Juniper Woodlands to Sagebrush via fire or anthropogenic Juniper removal. Only 4% of the 1851 – 1937 Juniper Woodlands were mapped as Ponderosa Pine Forest and Woodlands in 1998, indicating minimal loss of Juniper Woodlands to successional processes.

1998 – 2016 Transitions

The comparison of classes that transitioned to and from Juniper Woodlands between 1998 and 2016 in both directions transitions are largely with geographically adjacent vegetation classes dominated by sagebrush, grasslands, and Ponderosa Pine.

The majority of the vegetation transitions observed may reflect differences in how the maps were made and the difficulties in separating Juniper woodlands from surrounding vegetation, but there have been decreases in Juniper Woodlands resulting from significant efforts by the BLM and Forest Service to remove Juniper. While not hugely significant in terms of percentage, 21,477 acres of 1998 Juniper Woodland transitioned to Suburban (Moderate Intensity Developed) by 2016, mostly in central Oregon.

Grasslands, Sagebrush Habitats – Annual Grass Invasion

There is significant concern regarding annual grass invasion of both Grassland and Sagebrush Habitats. None of the baseline vegetation maps have a consistent vegetation class representing dominance by annual grasses. Instead, this analysis uses the Rangeland Analysis Platform (RAP, Allred et. al. 2021) annual vegetation cover maps to track the total area that is dominated by annual grasses in Oregon in 1986, 2001, 2016, and 2023.

Methods

RAP Maps (Allred et al 2021)

The RAP annual vegetation cover maps (Allred et al. 2021) are a LANDSAT-derived estimate of percent cover of annual herbs (grasses and forbs), perennial herbs, trees, and shrubs. I calculated the number of acres of annual-dominated vegetation in each of 1986 (the first year of RAP data), 2001, 2016, and 2023 (the most recent year of RAP data). Annual-dominated vegetation class was calculated from these continuous maps, defined as having more than 5% cover of annual herbs and greater cover of annual herbs than perennial herbs.

Results

Table 7. Total Area – Annual Dominated Vegetation. The left four columns show the total acres dominated by annual grasses in 1986, 2001, 2016, and 2023. The right three columns show the percent change in acres between the mapping efforts.

Acres				Percent Change		
1986	**2001**	**2016**	**2023**	**1986 - 2001**	**2001 - 2016**	**2016 - 2023**
2,586,030	5,647,535	9,556,718	8,986,010	118%	69%	-6%

In all years, annual-dominated vegetation is mostly found in the grassland and sagebrush habitats of arid SE Oregon and in the Columbia Basin north of the Blue Mountains.

Discussion

This analysis documents significant increases in annual herb-dominated vegetation since 1986. While the RAP annual herb maps include both annual grasses and annual forbs, we believe the observed pattern to primarily reflect ongoing increases in annual grasses since they tend to dominate the vegetation in Oregon's grassland and sagebrush habitats. Annual plant cover in any one year is variable and some inter-annual variation is expected. For example, wetter spring conditions tend to increase annual vegetation cover. While inter-annual vegetation variability may explain the apparent decrease in between 2016 and 2023, the spring of 2016 was slightly drier than average and the spring of 2023 was slightly wetter than average (PRISM, 2024). To further investigate the apparent decrease in annual grass-dominated vegetation since 2016, it would be best to conduct a trend analysis that considers all intermediate years of data.

Grasslands – Anthropogenic Land Uses

The National Land Cover Database maps (NLCD, US Geologic Survey 2023) are based on the Landsat record and are the best source of anthropogenic land cover information. These maps are newly available annually since 1986. We calculated total acreage of each NLCD class in 1986, 2001, 2016, and 2023. All anthropogenic land use types are absent in the 1851 – 1937 Composite map, which we use to report which natural ecosystems types were converted to anthropogenic land uses by 2023.

Methods

NLCD (US Geologic Survey, 2023)

The following NLCD classes were considered anthropogenic land uses for this analysis: Pasture/Hay, Cultivated Crops, Open Space Developed, Low Intensity Developed, Medium Intensity Developed, and High Intensity Developed. For each year, we combined these 6 classes into a single 'Anthropogenic Land Use' class.

1851 - 1937 Composite Map (Tobalske 2002)

No anthropogenic land uses were captured in the 1851 -1937. We used these classes and the 2023 NLCD data to capture transitions from 1851 – 1937 vegetation to 2023 anthropogenic land uses. The definitions for the vegetation classes that have transitioned to anthropogenic land uses in Table 8 can be found in Tobalske 2002.

2016 Habitat Map (Kagan et. al. 2018)

Anthropogenic land uses in the 2016 Habitat Map were based on NLCD data. We did not use these classes in any of the analyses below, instead using the newer 2023 NLCD data to capture transitions from 1851 – 1937 vegetation to 2023.

Results

This analysis shows relatively consistent area dominated by Anthropogenic Land Uses since 1986. 6,966,109 acres were dominated by Anthropogenic Land Uses acres in 2023.

Table 8. Total Area – Anthropogenic Land Use. The left four columns show the total acres dominated by Anthropogenic Land uses in 1986, 2001, 2016, and 2023. The right three columns show the percent change in acres between the mapping efforts. While not shown in this table, we assume that zero acres were dominated by Anthropogenic Land Uses in 1851 – 1937.

Acres				Percent Change		
1986	**2001**	**2016**	**2023**	**1986 - 2001**	**2001 - 2016**	**2016 - 2023**
7,055,484	6,891,846	6,966,109	6,988,326	-2.3%	1.1%	0.3%

Table 9. Vegetation Transitions 1851 – 1937 to 2023. Anthropogenic Land Uses shifted from an assumed zero acres to ~7,000,000 acres by 1986. The left column has 1851 – 1937 map classes that had greater than 50,000 acres mapped as Anthropogenic Land Uses in 2023, all other map classes are included in the 'Other' category. Acres shows the number of acres mapped as Anthropogenic Land Uses in 2023, and the Percentage column shows percent of the 2023 Anthropogenic Land Uses.

1851 – 1937 Vegetation Classes that were Developed in 2023	**Acres**	**Percent of 1851 Acres**
Big Sagebrush / Bunchgrass Steppe	955,294	14%

Westside Lowland Prairie and Savanna	880,654	13%
Palouse Prairie	628,430	9%
Oregon White Oak	598,372	9%
Westside Douglas-fir or Madrone	420,624	6%
Grassland Steppe	364,537	5%
Ponderosa Pine - Douglas-fir Steppe	275,706	4%
Semi-Desert Grassland	260,555	4%
Columbia Basin Lowland and Foothill Riparian	218,163	3%
Moist-site Western Hemlock - Douglas-fir	212,078	3%
Westside Valley Wet Prairie	193,331	3%
Bigleaf Maple - Douglas-fir	162,824	2%
Alkaline Wetland	56,826	1%
Other	1,564,624	23%

Discussion

Assuming the NLCD-mapped Anthropogenic Land Uses were entirely absent prior to Euroamerican settlement, we see an increase of all 6,988,326 acres by 2023, more than 10% of the state. There have been significant shifts between anthropogenic land uses, trending towards a higher proportion of total anthropogenic land use in the higher intensity use classes, but this analysis finds the total footprint of anthropogenic land uses has been relatively stable between 1986 and 2023. The differences between the years here are probably too small to consider a true pattern.

The vegetation transition analysis indicates that developed lands were formerly largely dominated by perennial graminoids, largely in the 1851 map classes Big Sagebrush / Bunchgrass Steppe, Westside Lowland Prairie and Savanna, Palouse Prairie, and Oregon White Oak.

Late Successional Mixed Conifer Forests

Conifer Forests

Methods

Successional status of forests was only reliably included in the 2016 Habitat Map (Kagan et. al. 2018). For this analysis, we calculated the percent of forests that are classified as 'old-growth' in that map.

2016 Habitat Map (Kagan et. al. 2018)

We considered all forest classes that were separated by seral stage for this analysis. Old-growth forest classes were defined as 'stands with old-growth characteristics', and earlier seral forests were defined as forests in classes 'young', 'medium', or 'mature', defined as forests 0-80 years old and those older than 80 years without old-growth characteristics. All forests with seral stage reported were included in this analysis with the exception of lodgepole pine forests, which do not attain an old-growth structure.

Results and Discussion

In 2016, old-growth forests covered just 3,166,817 acres of the 25,825,195 total acres of forested land mapped with a seral stage, or 12%.

Deciduous Forests

In the absence of active management (e.g. replanting with Douglas-fir) late successional conifer forests often succeed to deciduous or mixed deciduous-conifer forests after disturbance, especially on the west side of the state. These forests are primarily dominated by Red Alder and Bigleaf Maple. Here we report the total area of west-side deciduous and mixed conifer-deciduous forests in 1851, 1998, and 2016 and change in total area between timepoints.

Methods

We looked at west-side deciduous and mixed deciduous-conifer forests cover across 1851 – 1937, 1998, and 2016.

1851 – 1937 Composite Historic Vegetation Map (Tobalske 2002)

We included the following vegetation classes from the 1851 – 1937 Composite Map as deciduous forests: Red Alder or Bigleaf Maple, Bigleaf Maple - Douglas-fir, and Westside Forested Swamp or Wetland. These classes include the "Hardwood, alder-ash-maple" type from in the 1937 timber maps, as well as forests dominated by Bigleaf Maple, Alder or co-dominated by these and Douglas-fir in the GLO mapping efforts.

1998 GAP Map (Kagan et al. 1999, Kiilsgaard 1999)

From the 1998 GAP map we included the following vegetation classes as deciduous forests: Red Alder Forest, Red Alder-Big Leaf Maple Forest, Douglas Fir-Mixed Deciduous Forest, Mixed Conifer/Mixed Deciduous Forest, Siskiyou Mtns Mixed Deciduous Forest, and South Coast Mixed Deciduous Forest. These classes are defined in detail in Kiilsgaard 1999.

2016 Habitat Map (Kagan et. al. 2018)

We used all seral stages of one map class for this analysis, including old-growth stands which would not have been separated out in the earlier maps. Mixed Hardwood-Conifer is defined as:

Bigleaf maple, red alder and mixed low-elevation conifers characterize this mesic habitat which is widespread in western Oregon, and extends into western Washington and northern California. Common conifers include Douglas-fir, western hemlock, and western red cedar, although all westside conifers can occur. They range from sea level up to 5,000 feet, although mostly are found below 3,000 feet. This habitat includes two primary systems. The first is the North Pacific Lowland Hardwood – mixed Conifer Forest ecological system, including the bigleaf maple – Douglas-fir forests, and the second is the North Pacific Broadleaf Landslide Forest and Shrubland, including the red alder communities that dominate areas disturbed by fires and landslides, sometimes in poorly replanted clearcuts. These forests are mapped in four age classes: young (less than 30 years old), medium (31-80 years old), mature (greater than 80 years old without old-growth characteristics), and old-growth (stands with old-growth characteristics).

Results

Total Area

Table 10. Total Area – Deciduous Forests. The left three columns show the total acres mapped as West Side Deciduous Forests in 1851 – 1937, 1998, and 2016. The right two columns show the percent change in acres between 1851 – 1937 and each subsequent mapping effort.

Acres			Percent Change	
1851	**1998**	**2016**	**1851 to 2016**	**1998 to 2016**
531,092	1,764,118	1,820,961	232%	3%

Discussion

The massive 232% increase in deciduous forests between 1851 and 1998 likely reflects a shift towards earlier successional forests following logging.

Ponderosa Pine Woodlands

The (Andrews and Cowlin) 1937 timber maps from which most of the historic information from forests are derived include just one large Ponderosa Pine Forest class. That class includes a wide range of forests that have Ponderosa Pine, including open stands of pure Ponderosa Pine and Ponderosa Pine and Juniper woodlands along the eastern flank of the Cascades as well more closed canopy Ponderosa Pine and Mixed Conifer forests in the Blue Mountains. There may have been canopy closure and encroachment of less fire-tolerant conifers like Grand Fir into pure Ponderosa Pine forests since 1851 and 1937, but without separation of open Ponderosa Pine-only woodlands in the historic mapping we aren't able to quantify changes in those forests. For smaller subsets of the state (e.g. Rogue Valley, Blue Mountains) it may be possible to compare GLO mapping with modern vegetation composition but that is beyond the scope of this analysis.

Aspen Woodlands

Kagan 1999 reported a 42% loss in Quaking Aspen forests between 1851 and 1998. Our new analysis indicates a similar 53% loss over the same time period (Quaking Aspen in the 1851 – 1837 Composite Map compared with Aspen Groves in the 1998 GAP map). Quaking Aspen in the 2016 Habitat Map is defined more broadly than in the historic benchmark maps, capturing smaller patches ands well as forests co-dominated by aspen and conifers. A direct comparison would make it seem like Aspen increased 10x in acres, which is not likely. There may have been a significant shift in total area dominated by Aspens since 1998, but the currently published vegetation map products for the state are not sufficient to document the pattern.

Oak Woodlands

Open Oregon White Oak and Black Oak woodlands were common across western Oregon prior to Euroamerican settlement. Their open structure was maintained by fire and the subsequent fire suppression and development pressures of the 20th century led to a loss of Oak Woodlands. In the 1998 map, we use the three baseline maps to investigate changes in oak woodlands since 1851.

Methods

We compared the total area of Oak Woodlands in each map, calculating the percent change in acres. We also use spatial overlap between the maps to report on the major patterns of conversion.

1851 – 1937 Composite Historic Vegetation Map (Tobalske 2002)

We considered the Oak White Oak and California Mixed Oak classes as Oak Woodland, which included the following vegetation types from the 1851-1910 GLO surveys:

> White oak forest, with 'oak brush', or 'oak and hazel brush' notes.
>
> White oak woodland. Brushy understory of hazel, oak sprouts, bracken and other shrubs. No fir, no black oak.
>
> Black oak forest. Southern Lane County and southward.
>
> White oak-black oak forest, often with madrone 'laurel' and ponderosa pine. Understory may include hazel, poison oak, bigleaf maple, willow, oak, fern, briars. Southern Lane County and southward. NO FIR.
>
> Black oak woodland. Southern Lane County and southward.

For areas without GLO data, this class was mapped from the Hardwood, Oak-Madrone class from the 1937 Andrews and Cowlin timber maps.

1998 GAP Map (Kagan et al. 1999, Kiilsgaard 1999)

From the 1998 GAP map, we only include the White Oak Forest class as Oak Woodland. All other oak classes in this map include significant cover of conifers which would overwhelm the Oak-dominated forests in this sort of analysis. White Oak Forest is defined as:

> Common throughout the western Oregon interior valleys of the Rogue, Umpqua and Willamette River valleys and the eastern end of the Columbia River Gorge. Oregon white oak is a low elevation, warm site deciduous tree species. This cover type is rapidly disappearing throughout its range in Oregon due to urban expansion. Oregon white oak dominates the overstory in this deciduous forest that ranges from woodland to forest based on ecological site and site history. Understories in these forests typically contain tall deciduous shrubs and smaller stature deciduous trees. In southwestern Oregon the subcanopy is often California black oak, while in the Willamette Valley it is sweet cherry. The canopy layer is dominated by Oregon white oak. Other canopy trees can be Douglas fir, ponderosa pine, in upland settings. On the valley floor, overstories can be mixed with Oregon ash, cottonwood, and big leaf maple. Shrub layer is prominent and diverse. Commonly encountered shrubs being: poison oak, baldhip rose, California hazelnut, common snowberry, oceanspray, Oso berry, and trailing blackberry. Through most of the interior western valley settings Oregon white oak is the transitional forest from the agriculture dominant valley floor to the conifer forest uplands. Oregon white oak is a

vigorous sprouter after fires and this cover type benefited from frequent fires. Increased fire suppression in this last century has led to invasion of the Oregon white oak stands by upland conifers. Oregon white oak produces an abundance of acorns and is a highly desirable wildlife habitat.

2016 Habitat Map (Kagan et. al. 2018)

We considered the Oak class as Oak Woodland. Defined as:

> Oregon white oak characterizes most oak woodlands and savannas, which are found at low elevations throughout western Oregon, in the Columbia Gorge and in western Klamath County. They have been declining in many areas, becoming mixed oak-conifer woodlands with fire suppression. These woodlands and savannas are important to wildlife and are a priority habitat in most western Oregon ecoregions. From Eugene south, California black oak increases in importance, and in southwestern Oregon a number of other oaks, including Brewer oak, canyon live oak, tanoak, and chinquapin can be important parts of this habitat.

Results

Total Area

The comparison of total area of Oak Woodland shows a large (-72%) decrease in Oak Dominated Forests and Woodlands between 1851 – 1937 and 2016. Oregon White Oak was even lower with 115,689 acres in the 1998 GAP Map (an apparent 94% decrease), but that is likely an underestimate of Oak Woodlands.

Table 11. Total Area – Oak Woodlands. The left three columns show the total acres mapped as Oak Woodlands in 1851 – 1937, 1998, and 2016. The right two columns show the percent change in acres between 1851 – 1937 and each subsequent mapping effort.

Acres			Percent Change	
1851	**1998**	**2016**	**1851 to 1998**	**1851 to 2016**
1,900,066	115,689	526,824	-94%	-72%

Table 12. Vegetation Transitions 1851 – 1937 to 2016. Oak Woodlands decreased by 74% over this time period. The left column has 1851 – 1937 map classes that had greater than 50,000 acres mapped as Oak Woodlands in 1851 – 1937, all other map classes are included in the 'Other' category. Acres shows the number of acres mapped Oak Woodland in 1851 – 1937, and the Percentage column shows percent of total 1851 – 1937 Oak Woodlands.

2016 Vegetation Classes that were Oregon White Oak or California Mixed Oak in 1851	**Acres**	**Percent of 1851 Acres**
Pasture or Hay	239,012	13%
Mixed Hardwood - Conifer medium	205,619	11%
Douglas Fir - Western Hemlock medium	153,599	9%
Oak	**151,487**	**8%**
Cultivated Crops	149,625	8%
Mixed Oak - Conifer young to medium	91,145	5%

Siskiyou Mixed Conifer medium	91,045	5%
Suburban (Moderate Intensity Developed)	84,876	5%
Douglas Fir - Western Hemlock young	81,651	5%
Coastal and Valley Riparian	67,762	4%
Early Shrub-Tree	62,292	3%
Rural Residential (Low Intensity Developed)	60,655	3%
Other	355,260	20%

This analysis finds a significant decrease in oak woodlands/forests in favor of oak and conifer forests and agricultural uses between 1851 and both 1998 and 2016. A mere 8% of the 1851 oak forests were still oak forests in 2016.

Discussion

The 1998 vegetation map didn't separate out the many small patches of Oak Forest within the agricultural matrix of the Willamette Valley the way that the 1981 and 2016 maps were able to, so the apparent collapse of Oak Woodlands by 1998 is likely an overestimate, and the apparent partial rebound in 2016 is likely an artifact rather than a true pattern. Despite that, this analysis likely does capture true conversion of oak woodlands to agriculture, urban development, and oak-conifer and mostly conifer forests by 2016, which reflects the Euro-American settlement of the Willamette Valley and conifer encroachment with less frequent fires.

This analysis finds a significant decrease in oak woodlands/forests in favor of oak and conifer forests and agricultural uses between 1851 and both 1998 and 2016. A mere 8% of the 1851 oak forests were still oak forests in 2016; it appears that many contemporary Oak Forests and Woodlands are historic meadows with Oak encroachment.

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