HISTORIC DOUGLAS-FIR COLONIZATION AND LAND USE PRACTICES AT PRESERVATION SITES NEAR EUGENE, OR

by

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Prior to Euro-American settlement in the Willamette Valley, the Kalapuya indigenous group conducted prairie burning to incite annual subsistence rounds of native prairie resources. However, the frequency of fire declined after replacement of indigenous culture with Euro-American settlements and the subsequent introduction of livestock grazing. This research aims to use Douglas-fir core data and vegetative extent comparisons from 1853-54, 1936, and 2011 at three preservation sites near Eugene, OR, to determine whether conifer colonization in historic oak savanna habitat occurred consistently, or was concentrated in one or more specific time periods as a result of external forces related to this shift in land use. References to General Land Office Survey data from 1853-54 and aerial photos from 1936 recreate historic vegetation cover and relate site histories to extracted Douglas-fir core ages and accounts of historic land use. The absence of core data prior to 1903 and the rapidity of forest advance from 1853-1936 are suggestive of a surge in colonization after the turn of the 20th century. However, the lack of site specific land use history is not conclusive in determining which management technique was the most influential in propagating forest advance.

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Table of Contents

List of Figures

List of Tables

Introduction

Through the course of human history, social development has progressed hand-in-hand with land management and environmental ethics. Human-environmental interactions have been shaped by constructs of cultural ideology, and the spatial distributions of vegetation classes are often directly affected by resulting variations in land use. Such vegetative patterns differ from what would typically be assumed to result from natural progression, but rather may be the consequence of centuries or more of human influence. An increase in complexity of social structure that comes with technologic improvement can consequently result in shifts in this land cover at an unnatural rate. Economy supersedes sustainability, and the consumption of natural resource reflects commodity and production. In turn, this set of environmental ethics associated with industry instills a sense of control, rather than existence upon the land (Wildcat, 2009).

This research, specific to the Willamette Valley of western Oregon, is concerned with anthropogenic impact on vegetation cover during the transition period from indigenous habitation to resettlement by Euro-American culture. The project takes a multi-faceted approach in determining the response of vegetation cover to the respective land use methods employed by these fundamentally differing societies. I will focus on primary evidence rooted in historic biogeography depicting stages of vegetation cover which will then be correlated with secondary research and primary accounts of land management and environmental activity representative of both Kalapuya culture and Euro-American colonization. This study will explore the land use methods of these respective societies and evaluate their magnitude of importance in altering the vegetation cover throughout history in the Eugene area conservation sites. Ultimately, the conducted research is intended to challenge the dominant narrative that loss of indigenous controlled burning practices alone accounted for forest encroachment in oak savanna habitat.

Historic Willamette Valley Vegetation Cover

A major goal of conservation efforts in the Willamette Valley involves the restoration of natural open space, in the form of prairie and savanna habitats, to their historic conditions (Alverson, 2005; Charnley et al. 2007; Lane Council of Governments, 2003). Current Eugene area conservation goals imply that vegetation patterns are not desirable for species native to prairie and savanna habitats targeted for conservation. Such preservation goals also emphasize the importance of these microhabitats and their associated native species to the vitality of the Willamette Valley ecosystem. This study focuses on the historically observed gradient from conifer dominant forests to prairies for its ecologic importance in various interspecific relationships.

Essential to the success of many species in this forest-prairie gradient is the existence of the oak savanna ecotone. Denoted as the boundary between two characteristically separate vegetation classes (Boag, 1992), this “ecotone” biome serves as a bridge between prairies and mixed conifer/oak forests and represented over 18% of Willamette Valley land based on estimates derived from observations in General Land Office (GLO) survey data conducted from 1850-1855 (Christy and Alverson, 2011). The valley floor contains open wetlands, dry prairies, and bears a substantial loss in ground water during the relatively dry summer months. As elevation increases, the presence of montane forests and drainage systems become increasingly abundant as wintertime waterlogging decreases; easily supporting closed-canopy upland and riparian forests dominated by Douglas-fir (Christy and Alverson, 2011; White, 1974). The eco-region at the foot of these montane forests enclosing dry prairies and brush is comprised primarily of low-density white oak, and historically has also seen presence of black oak, which both grow slowly and do not reach the dominant heights of their conifer counterparts. When germinated in the same vicinity, Douglas-fir is able to grow comparatively denser and higher, and can rapidly block the incoming sunlight vital to the growth of nearby white oak trees. For this reason, the Douglas-fir is able to readily disperse into savanna and prairie habitat and, upon successful germination and establishment, out-compete the niche-specific oak and brush species that tend to grow closer to the ground (Alverson, 2005; Charnley et al. 2007; Christy and Alverson, 2011; Johannessen et al. 1971).

The colonization of Douglas-fir outside of the closed forest habitat has caused a significant loss of oak savanna habitat in the Willamette Valley over the past few decades, and in turn posed a threat to the existence of valley prairie and savanna openings. Evidence for changes in vegetation patterns can be found in comparisons of GLO survey data to modern forest extent as well as in the visual presence of dense Douglas-fir stands bordering modern prairie edges. Such habitat is vital for its ability to both provide a specific ecological niche distinguishable from surrounding forest and prairie habitats, and host various native species that have been historically important to societies native to the Willamette Valley (Boag, 1992). An example of this relationship can be directly witnessed in conservation efforts to increase population of Kincaid's

Lupine among Eugene-area prairie preserves, which are used by the endangered Fender's Blue Butterfly as larval food plants (Lane Council of Governments, 2003). Both species are native to the Willamette Valley, and both are immediately threatened by the rapid loss of savanna and prairie habitat in this bioregion. Respect for the historic state of South Willamette Valley vegetation cover is vital in promoting a more robust picture for biogeographic relations between native species.

Indigenous Land and Resource Management

Conservation efforts in the southern Willamette Valley aim to restore species native to historic prairie and savanna habitats, but do little to emphasize their cultural importance to the indigenous population that depended so heavily on their existence. Prior to colonial settlement, the Willamette Valley was occupied by the Kalapuya indigenous group, one geographically isolated and subsequently cut off from marine species which were staples of diet and economy for many other indigenous groups of the Pacific Northwest. Rather, the Kalapuya sought out plants, insects, small game, and large game accustomed to the unique ecological niche presented by dry prairies, shrub lands, and the oak savanna ecotone (Boag, 1992; Boyd, 1999a and b). Though it is apparent that vegetation cover has been drastically altered in the time period following the appearance of Euro-American settlement, it has been a common misconception propagated by secondary research on settlement accounts during the mid-19th century that these travels through North America took place on pristine and untouched land. This fallacy is rooted in a desire to promote themes of wilderness preservation and maintain the mystery of its associated wildness (Whitlock and Knox, 2010).

This preconception has recently been put under scrutiny in the Willamette Valley as well as with many other global indigenous groups as exemplified in the Intergovernmental Panel on Climate Change's most recent climate assessment report, which identifies indigenous lifestyle as readily capable of adaptation and mitigation to climate stress (IPCC, 2014). Indigenous interactions with the environment, including the Kalapuya within the Willamette Valley, have been historically influential in promoting fitness and culture. Specific to the Willamette Valley, evidence of indigenous environmental activity exists primarily in dendrology and pollen study revealing high local levels of biomass burning associated with these prairie and savanna openings. Prairie fire has long been a natural process, and while charcoal and pollen records show a shift in spatial concentration of fire associated with locations of indigenous populations, its general frequency remained relatively constant through Kalapuya occupation (Walsh et al. 2010).

The available evidence of past burning suggests that the Kalapuya were involved in the shaping of their environment, but did not cause exceptional disturbances in the natural occurrence of prairie fires. Therefore, Euro-American settlers did not arrive on untouched land, but land subject to indigenous movement and control of a natural force already present in the vegetation cycle of the area.

The role of fire in the subsistence of various Kalapuya subgroups around the Willamette Valley was perhaps the most important land management practice in facilitating the fitness of species targeted as primary sources of food. Even though the Willamette River provided ample opportunity for fishing, ethnographic and archeological research implies that this society was largely dependent on species of grasses, roots, berries, and various insects and game comprising the Willamette Valley ecosystem. These observations are primarily based on the presence of prairie fire, contact and settlement journal analysis, and studies of Kalapuya nouns explicitly referring to the types of resources that were frequently gathered in their culture (Boag, 1992; Boyd, 1999a; Johannessen et al. 1971, Zenk, 1976). The Kalapuya were a hunter-gatherer society, residing in montane villages during the colder months, and departing to the Willamette Valley floodplain in the drier months to provoke seasonal succession of provisions such as camas root, tarweed, and hazel. Burning also worked to stave off the dispersal of Douglas-fir in oak savanna and prairie habitats, which does not re-sprout after being razed like White Oak (Boag, 1992; Boyd, 1999a; Halpern et al. 2010; Johannessen et al. 1971). Widespread indigenous use of fire reflects a sense of cultural and animistic reverence for its effectiveness in providing a steady source of sustenance. A similar dependence on fire is standard for the Kalapuya; as the absence of ground water and precipitation in the Willamette Valley during these late summer months did not allow them to exert efforts in traditional irrigation to sustain native species (Boag, 1992; White, 1974). With the exception of tobacco cultivation on a relatively large scale, the use of fire in creating healthy soil and reducing overgrowth and competition for prairie plants mirrors the absence of conventional forms of agriculture seen in many other indigenous groups. From the fire forestry of the Paiute, to the Seminole in Florida, fire is globally prominent for its vitality in nutritional and economic interdependence (Boyd, 1999a; Pyne, 1982). The Kalapuya placed great value in resources within these prairie and oak savanna habitats, and the practice of prairie burning left an observable mark in Willamette Valley vegetative history.

Kalapuya Prairie Burning in a Cultural Context

Synonymous with indigenous land use and resource management, both in the Willamette Valley and globally, is a referral to the frequency of controlled burning. Due to the scale in which domesticated fire was able to sustain indigenous civilization, accounts exist of reverence for it as a higher power of nature. Many tribes of the eastern United States honored fire as a dominant force for this reason, and humanized the act of controlled burning by collectively referring to it as “Our Grandfather Fire” (Pyne 1982, 71). The Kalapuya used knowledge of the Willamette Valley setting to implement prairie burning as a land management system that maximized the fitness of native species vital to their subsistence. This land use method both stabilized an entire society for roughly two centuries (Boag, 1992; Boyd, 1999a), and maintained a habitat gradient that has since been overrun with the dominant growth of Douglas-fir as evident in comparisons of contemporary forest cover with cadastral survey observations.

The use of fire for culturally complex and elaborative actions has similarly provided indigenous culture with a more symbolic link to a dominant force of nature. In regards to the Willamette Valley, there are two well documented forms of fire hunting conducted by the Kalapuya: burning grass allowed mass collection of grasshopper and rings of circular fire were set in order to corner black and white tailed deer, inducing easy shooting (Boyd, 1999a). The latter is of importance because this “circle deer hunt” was not only a method of gaining food prior to retreat into the mountains before winter, but also a profound accomplishment. It required the manpower of many members of society, including Kalapuya boys able to wield a bow. The process also called for meticulous planning and foresight in order to accurately drive enclose deer for hunting

(Boag, 1992; Boyd 1999a, 110). Upon successful completion, the provision of food to carry the civilization into the harsh Cascade Mountain winters was seen as a vital achievement. During these winter months, fire similarly provided warmth and a setting for passing of oral histories from generation to generation during a time when hunting and gathering was not feasible (Juntunen, 2005). Evidence present in Willamette Valley archaeologic research also suggests that the Kalapuya used fire for crafting of ceramics and weapons to assist in complex resource extraction techniques (Boag, 1992; Zenk, 1976).

Kalapuya dependence on fire is also reflected in journals kept by the initial arrival of Euro-American settlers, who note razed prairies and distant smoke plumes while documenting their travels within the Willamette Valley. Evidence found in direct references to expedition journals, like those written by Alexander McLeod and David Douglas upon entrance to the Yamhill Valley in September of 1826, point to the lingering presence of prairie fire conducted by the Kalapuya (Boyd, 1999a). The duo noted the following observations of the landscape they encountered:

> 9/27 Country undulating; soil rich, light and beautiful with solitary oaks and pines interspersed through it and must have a fine effect, but being all burned and not a single blade of grass except on the margins of the rivulets to be seen.
>
> 9/30 (heading south) … Most parts of the country burned; only on little patches in the valley and on the flats near the low hills that verdure is to be seen. Some of the natives tell me it done for the purpose of urging deer to frequent certain parts to feed, which they leave unburned and of

> course are easily killed. Others say that it is done in order that they may better find honey and grasshoppers, which both serve as articles of winter food. (Boyd, 101)

These observations make note of both the timing and the possible uses of fire communicated directly from native populations. Again the frequency and timing of indigenous burning is documented in September of 1841 by Henry Eld and George F. Emmons while exploring the Hudson Bay Trail. Eld stated that:

> Atmosphere filled with smoke consequently unable to see much of the surrounding country. Country much burnt … Our route has been through what might be called a hilly prairie country, the grass mostly burnt off by recent fires, and the whole country sprinkled with oaks, so regularly as to have the appearance of a continued orchard of oak trees (Boyd, 104).

These expedition accounts indicate that the Kalapuya were still using prairie fire into the 19th century, after their population began to decline, and that fire was a determinate force in preserving the appearance of the oak savanna ecotone.

Colonial Land and Resource Management

The latter half of the 19th century saw an influx of colonial movement west into the Pacific Northwest and the Willamette Valley. This cultural migration effectively replaced the Kalapuya as Euro-American settlers transmitted lethal disease to the indigenous group, and rampantly divided up valley land for private ownership.

Contraction of disease may have occurred as early as the late 1700's and continued into the 19th century, thus halting the annual prairie burning schedule set in place by the indigenous culture. This land ownership transition is first observed in contact journals in roughly the 1820's, continued to expand throughout the Eugene-area into the twentieth century (Boag, 1992; Boyd, 1999b; U.S. Department of the Interior, 1853-54). The strict delineation of land introduced by the Willamette Valley settlers altered the face of land use through new resource management methods and introduction of non-native plant and animal species, re-defining the interspecific relationships that had flourished during indigenous occupation. Sheep and cattle were brought to Willamette Valley prairies and, in turn, widespread livestock grazing took the place of biomass burning (Galbraith and Williamson, 1991). The ensuing reduction in the volume of native grass present in South Willamette Valley Prairies opened the land and exposed pristine soils for future establishment of Douglas-fir. Therefore, this use of rangeland was not tailored to prevent the establishment of Douglas-fir, jeopardizing the presence of both the oak savanna ecotone and valley prairies.

Euro-American Livestock Regimes

The first Euro-American expeditions into the Willamette Valley brought in contact two cultures with drastically different agendas for the use of an abundance of open prairie land. Accounts from contact journals of this settlement culture have been shown to reflect the occurrence of prairie burning at high volumes as early as the first quarter of the nineteenth century (Boyd, 1999a). Twenty five years later, the population of the Kalapuya had exponentially declined as a compounding result of both diseases contracted from the new settlers and introduced livestock, as well as reduced access to resource as land became scarce (Boyd, 1999b). By the 1850's, the Kalapuya population in the southern Willamette Valley was dwindling, and the frequency of burning subsequently reduced shortly after, until relatively few fires were recorded in charcoal and pollen records after the year 1930 (Andrews and Kutara, 2005). Direct examples of measures taken by the U.S. Secretary of State to lessen the occurrence of fires caused by humans are evident in the Oregon Fire Law of 1983, and again in 1897 with the Federal Forest Fire Law (U.S. Department of Agriculture, 1898).

Specific to this case study, the majority of divisions of land and settlement by Euro-American population within the Township and Range subdivisions that contain the preservation sites followed this time period, exemplified within the next decade near the Coburg Ridge Preserve where nearly all of the available land between the Middle Fork of the Willamette and the McKenzie Rivers fell into grid-like ownership. The rapidity of settlement and division of land plats introduced a grid-like ownership system that had never been present in indigenous culture prior to this transition period.

Though the introduction of the plat system introduced political alterations to the land, the influx of grazing in the Pacific Northwest, which occurred in conjunction with this transition, provided a physically dynamic system of resource allotment. In Oregon East of the Cascade Mountains and North at the mouth of the Willamette River, livestock in the form of cattle arrived and multiplied as early as the 1820's, and the Willamette Valley was regarded by president Andrew Jackson in 1835 as one of the finest rangelands in the country (Galbraith and Anderson, 1991). The existence of sheep in Oregon census data had been climbing exponentially in the 1870's and 80's, rising from one million to nearly ten million pounds of wool being produced statewide by

1890 (U.S. Department of Agriculture, 1898). However, it was not until a significant economic drought in 1892 that the livestock industry shifted primarily to sheep, due to ease of upkeep in a period of significant economic hardship, and this industry boomed significantly in central Oregon. The late nineteenth century and early twentieth century were some of the most lucrative grazing times for cattle despite the unpredictable climate, and the population of sheep in Oregon began to grow exponentially after the drought (Galbraith and Anderson, 1991).

Such widespread grazing caused prairie land to open up, as livestock feed on species of grass native to the Willamette Valley and Oregon that normally would compete with Douglas-fir seedlings. This eases the process of conifer colonization in nutrient-rich soil and propagates the out-competition of other fauna species in the prairie and savanna habitats once maintained by frequent use of controlled fire.

Willamette Valley Land Use Timeline and Implications

The generally accepted timeline of this land use and vegetation dynamism involves the immediate encroachment of Douglas-fir into the bordering oak savanna ecotone with the loss of indigenous fire. However, this timeline does not account for which human-environmental force (early loss of fire or later intensive grazing) was the most responsible for such a significant and widespread change in vegetation cover. In this study, I will address the following research question: Does the dispersal and successful colonization of Douglas-fir in oak savanna and prairie habitat proceed at a constant rate after the decline of Kalapuya population in the 1850's, or rather occur more disconnectedly as a result of distinct human-environmental disturbances?

This project is concerned with the facts supporting this timeline, and attempts to use primary evidence to identify the most physically influential change in land use tendency occurring with the loss of Kalapuya society and replacement by Euro-American settlement culture between the years of 1850-1930. Similar to a study conducted by David H. Peter and Timothy B. Harrington at Joint Base Lewis-McChord, Washington, this project compares data from Douglas-fir cores to extents present in GLO survey observations in defining the time period immediately after the decline of indigenous population (2014). The narrative constructed by this Eugene area case study intends to inform future management principles when dealing with conservation of prairie and oak savanna habitat throughout the Willamette Valley.

Materials and Methods

This research was conducted as a case study of three Eugene area conservation sites of various locations, sizes, and vegetation cover. These three sites include the Willow Creek, Coburg Ridge, and the Willamette Confluence Preserves, which can be referenced in **fig 1** for geographic relationship to Eugene, Oregon.

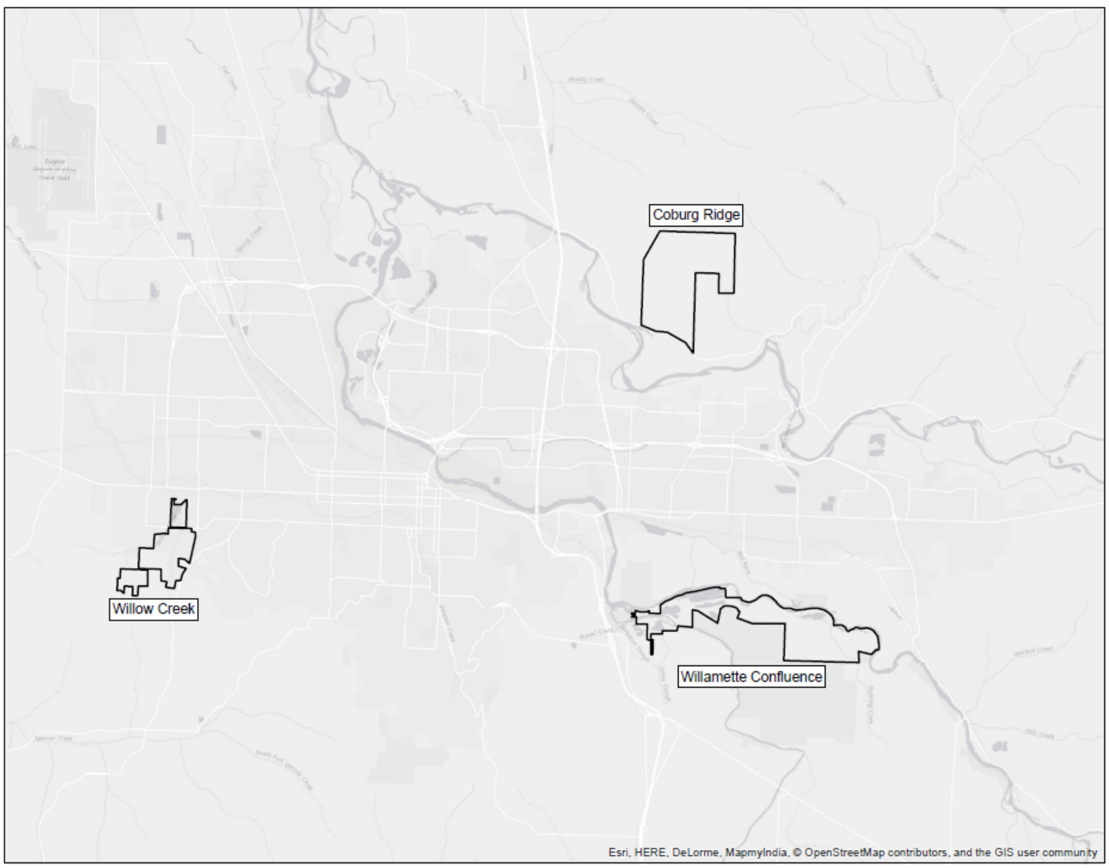


Figure 1 – Reference map of studied preservation sites at the scale of the Eugene Urban Growth Boundary.

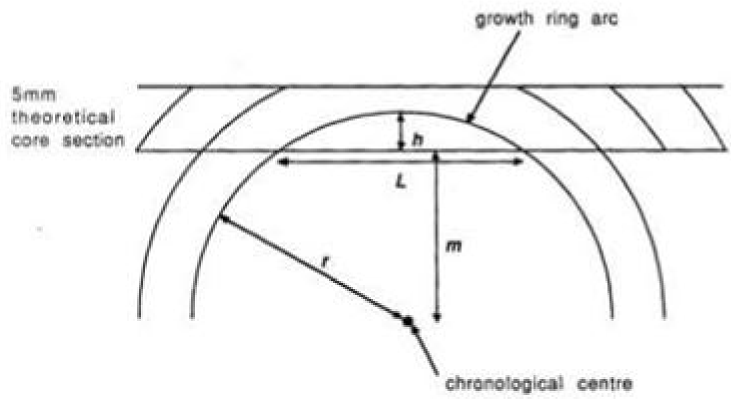
All sites are owned by The Nature Conservancy Willamette Valley Field Office, and with the help of a research agreement spanning the end of the 2014 calendar year, permission was granted to extract primary data in the form of increment cores of Douglas-fir within the historic white oak savanna habitat, most of which are now overrun by conifer forest. Cores were obtained to determine stand history, and were then compared to analysis of historic vegetative extent dated to the 1850's and 1936, in order to gauge the rate of conifer dispersal within these specific sites. The materials used and research methodology will be presented in this order, beginning with the coring process, and concluding with the geographic analysis and relations to the nature of corroborated secondary material.

Douglas-fir Coring

In order to determine any temporal patterns present in the distribution of mixed forests, Douglas-fir cores were collected to be aged and compared across the different preserve sites within similar vegetative scenarios. The objective for this process was to uncover stand histories of groups of Douglas-fir appearing old enough to be placed in this land management transition period between 1850 and 1936, when the ownership of rangeland was placed in the hands of the Bureau of Land Management (BLM). The targeted locations for core extraction exist within oak savanna restoration projects that were conducted simultaneously with this study on all sites. The conifer removal process, headed by The Nature Conservancy, significantly thinned Douglas-fir surrounding established white oak trees that were at risk of out-competition. Due to the nature of this goal, the ability to determine the borders of historic oak savanna habitat while onsite was greatly expedited through examination of site maps. Wedges from the logged Douglas-fir were left near the stumps, which were collected for further examination if they reached the pith, or the center of visible growth rings, and appeared to be older than eighty years on rough estimation. The forest thinning project also allowed access to exposed stumps of logged conifers to gain a rough age estimate and narrow the pool of potential trees based on comparisons between diameter sizes before the increment bore was necessary.

Once a stand was identified to contain trees older than roughly eighty years or with a basal diameter of greater than sixty centimeters, cores were extracted locally to determine ages of dispersal specific to each stand. The GPS coordinates of each tree were logged, along with the diameter and breast height (DBH), and any important notes about the tree or core upon extraction to ease future identification and analysis. The achievable percentage of total trees sampled per stand was limited by constraints of time and logistics inherent with entering TNC land and coordinating with volunteer schedules, but stands are represented by more than five trees in all cases. In total, sixty-one specimens were collected for analysis from thirty-nine different Douglas-fir trees, including five cookie samples (cross sections obtained from previously logged trees).

If the aim of the increment bore within the tree was initially poor, more cores were then successively taken until the distance from and growth rate near the pith, or the section representing the center of growth within the tree's cross section, could be accurately measured. Once mounted and sanded to increase visibility of tree rings, the cores were aged under a stereoscope. Years present beyond the curvature of rings on the core have been estimated using a pith indicator or a measurement of curvature distance once this accuracy is established (Speer, 2010). The following equation was first introduced in R.P. Duncan's analysis of error in estimating ages of trees from increment cores that did not reach the pith. Variables used in this equation are exemplified in the following figure and equation.



$$r = \frac{L^2}{8h} + \frac{h}{2}$$

Figure 2 – Distance to Pith equation with variable figure. This figure depicts the location of different variables in reference to tree rings present on a theoretical increment core (Speer, 2010).

In this equation, variable r estimates the distance to the pith measured from the last present ring in the tree core. L represents the length between curvature present in the tree core, and h the distance between the edge of the core and the apex of the growth ring arc (Duncan, 1989). Measurements were recorded using a sliding-scale micrometer with 5 µm precision (Velmex Inc.) under a stereoscope. Once the radius r is calculated, it is divided by the ring width of the innermost complete ring in order to obtain the estimated number of years missed by the increment bore. The growth history from the oldest cookie sample obtained from Willow Creek was qualitatively noted through analysis of distance between growth rings through time. Doing so informs of any periods of suppressed or rapid growth, which can be compared to other ages of trees obtained from Willow Creek and detail a comprehensive stand history. Collected specimens were labelled and the host trees were documented with photographs. Germination data has been logged and presented to both the University of Oregon and The Nature Conservancy and the physical specimen will be archived with the University of Oregon department of Geography.

Historic Vegetation Extent Analysis

To supplement data collected from Douglas-fir aging, this project analyzes the change in historic vegetative extent in the time period following the decline of Kalapuya population and during colonial settlement using multiple sources of primary data. There are three bearing points on the land management timeline that have been isolated to gain an understanding of the rapidity and uniformity of advancement of Douglas-fir from its historic extent specific to the three conservation sites. The first point of analysis is the vegetative extent during the 1850's, followed by 1936 when grazing was a common practice and fire was significantly less frequent in charcoal and pollen records (Galbraith and Anderson, 1991, Walsh et al. 2010), and concluding with a 2011 representation of modern vegetative extents. The inclusion of these specific dates primarily exists due to the temporal availability of primary data to support claims about vegetation extent. These transitions will be presented graphically by a series of maps, and will be related to the age data from the core specimen collected on these sites as well as secondary material and primary contact journals of Euro-American origin.

The first vegetative extent depiction dating from the 1850's is a result of both secondary and primary research concerned with this time period immediately following the first few Euro-American settlements. In order to present the graphic extent of vegetation from such a temporally and technologically different time period, the figures depend heavily on survey data collected and made public by the BLM. Obtained from Portland State University's geographic information systems (GIS) database as a result of a study conducted by John Christy and Edward Alverson, these figures use a shapefile, or a map file readable by geospatial computer software programs, containing the vegetation cover of the entire Willamette Valley circa the 1850's (2011). Since the study is concerned with a much larger geographic area than this research, delineations between the polygons within this map were double checked by accessing the original documents of cadastral surveys conducted during the decade and archived with the BLM for public access. These documents were transcribed and referenced with a key map to correspond with locations of the three TNC preservation sites.

Due to the fact that cadastral surveys were conducted on foot, the process of recording these observations required a significant amount of time and effort compared to more recent survey techniques, causing the data to span different years within the 1850's for the three sites. Cadastral surveys were conducted on land that would eventually become the Willow Creek and Coburg Ridge Preserves during 1853, and a year later in 1854 on the Willamette Confluence Preserve, along lines delineating sub sections of the Township and Range grid in Oregon and Washington. The location of these section lines, along with the area targeted by TNC's Douglas-fir removal conservation project are depicted by site maps in **fig 3**.

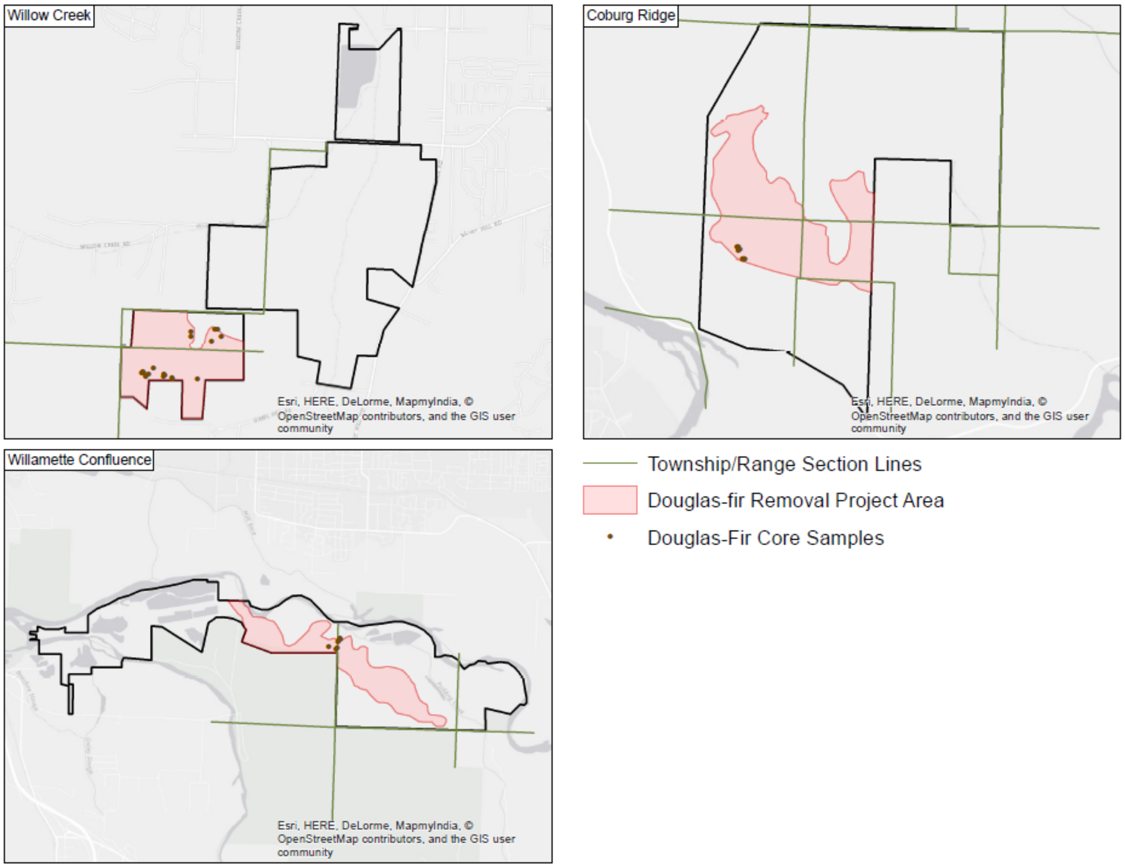


Figure 3 – TNC Preservation Sites and the Location of Douglas-fir removal areas and line transects used for cadastral surveys.

On the Willow Creek Preserve, lines referenced in this study include Line 38, walked north between sections 3 and 4, as well as Line 50, walked east between sections 4 and 9 of Township 18 South and Range 04 West. Coburg Ridge references lines 8, 9, 10, and 22; creating the quadripoint of sections 10, 11, 13, and 14 of Township 17 South, Range 03 West. Finally, the Willamette Confluence Preserve is denoted by lines 55, 56, and 58; creating the quadripoint between sections 7, 8, 17, and 18 of Township 18 South, Range 02 West. These cadastral surveys were referenced to check the accuracy of scale present in the study of the entire Willamette Valley for comparisons to ensuing vegetative states, as the study conducted by Christy and Alverson is a construct of the same survey data. Measuring section lines within the referenced map file allow for validation of the visual accuracy of this map at the scale of the Douglas-fir stands from which the core specimens were collected.

In order to visualize vegetation cover dating to 1936, aerial imagery archived by the University of Oregon Map Library was requested for the geographic extents of the three preservation sites. The grayscale imagery was scanned and used to compare vegetative extents between the specified time periods of human land use history. Since the distortion of the imagery may have suffered from numerous variables, such as the type of camera used to take the image, or the direction and elevation of the aircraft when the image was taken, the 1936 imagery was fitted to the same geographic coordinate system as contemporary aerial photography and the map of 1850's vegetation cover through the process of orthorectification. This procedure uses anchor points marked by hand in aerial imagery of both 1936 and 2011 that have not changed in the time span between the two photos. Both fiducial marks and anchor points match the locations of present objects, which then places the historic imagery in the correct geographic coordinate system and drapes it over a digital elevation model (DEM) to account for variations in terrain. The following figure shows the result of this process on a 1936 aerial photo taken over the core collection sites at the Coburg Ridge Preserve.

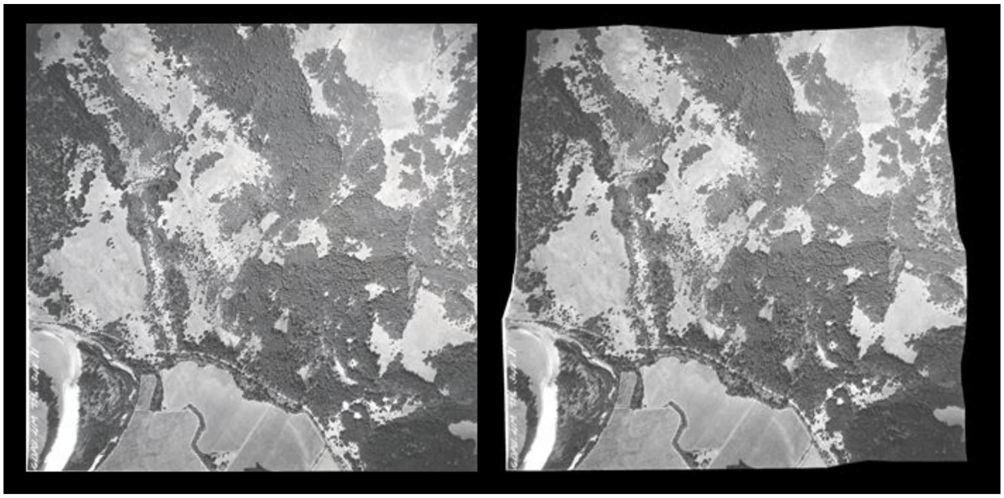


Figure 4 – Left, original scanned aerial photo of Coburg Ridge, obtained from the UO Map Library. Right, Orthorectified image in the correct geographic coordinate system.

The process of orthorectification and compilation of primary material to describe the vegetative extents present on the three TNC preservation sites was conducted to reveal the rate of progress of colonization of conifer dominant forest into the historic prairie and savanna habitat. Maps of vegetative classification were collected and created to show a more discrete visualization of the extent of prairie, savanna, mixed and conifer forest habitats over time. These maps depict the location of all collected core samples, and vegetation classes in the keys have been simplified to match the data classifications presented by the initial cadastral survey study of 1850's vegetation cover for the entire Willamette Valley. This method established criteria based on distance between the surveyor and nearby bearing trees at respective observation points as well as terminology describing stand densities (Christy and Alverson, 2007).

Typically, a region would be considered a "closed forest" if bearing trees were all within roughly 20m of the observer, or the region was denoted as "timber", "heavy", “dense”, or “thick”. The terminology changes with increasing distance from bearing trees, moving to “woodland” if trees are between 20-40m away, “savanna” from 40-80m, and “prairie” if bearing trees are seemingly not present, or greater than 80m in density (Christy and Alverson, 2007. 96). For vegetation of the 1850’s, the map file created by Christy and Alverson was referenced, while 1936 and 2011vector files were drawn by hand near the locations of collected cores for each site. This process examined the frequency of occurrence of oak trees to distinguish between prairie and savanna, and the density and shadow height of both oak and conifer present on these sites to map woodland, mixed, and conifer dominant forests. A distance tool in a geographic analysis software was used to estimate distance between visible trees in stands of different densities to remain consistent with the model presented by Christy and Alverson. The geographic areas of different vegetation classes were recorded at the three time intervals to compare the rate of advance or declination across both sample intervals. This was estimated through incorporation of sample areas around core collection sites to record such areas (in hectares) within spatial analyst software. The sample areas fluctuated based on total area enclosing vegetative class polygons across the different sites, which is dependent on the extent of available aerial photos in 1936 and size of area owned by TNC. Coburg ridge figures were estimated on a 60 Ha sample area, Willamette Confluence a 160 Ha area, and Willow Creek a 40 Ha area.

Results

This section will serve to present the results of the Douglas-fir core data as well as its relation to analysis of progression of Willamette Valley vegetative history.

Results of Douglas-fir Core Analysis

Of the thirty-nine Douglas-fir specimen collected, thirty-four were core samples, and twenty-four of these reached far enough into the tree to obtain the curvature necessary to estimate age, the other ten coming from trees with DBH measurements too large for the longest available increment bore to penetrate. The five non-core specimens consist of four cookies and one field measurement, where all rings are exposed and error is minimized. The following figure shows the distribution of ages of the 29 aged samples collected from TNC sites, as well as the distribution of ages specific to each collection site. The total number of aged specimen was 29, including eleven from both the Coburg Ridge and Willow Creek Preserves, and seven from the Willamette Confluence Preserve.

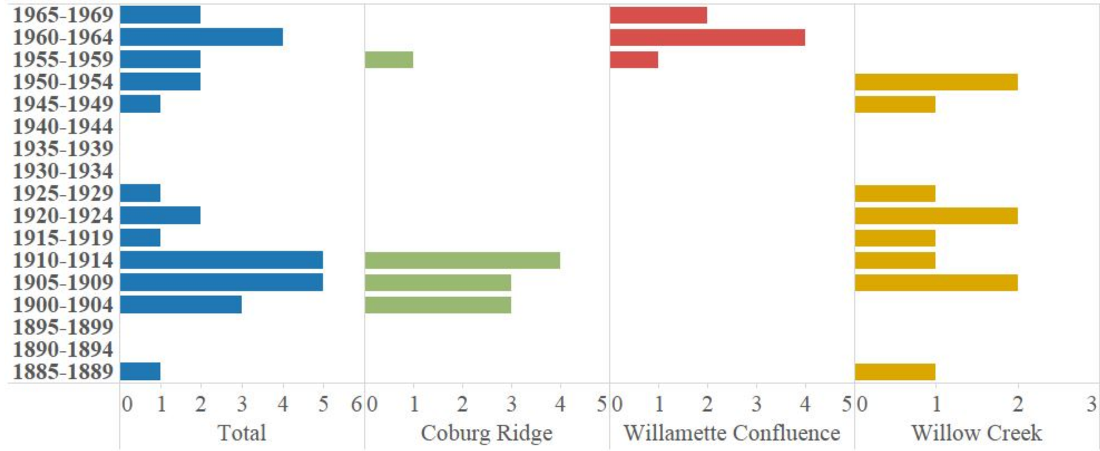


Figure 5 – Douglas-Fir core specimen age result from Eugene area conservation sites owned by The Nature Conservancy. X axis shows number of core samples present in each age increment.

From the sample collected for this study, germination dates range from 1876 to 1954 at the Willow Creek Preserve, while the Willamette Confluence and Coburg Ridge Preserves both show age dates clustered in 10-15 year periods. No specimen analyzed at stands on the Willamette Confluence were accurately dated within the time period in question, but Coburg Ridge recorded two stand histories within the first two to three decades of the twentieth century.

Generally, the total count of germination dates clustered somewhat within the range of 1900-1914, but its range predated this grouping to 1876 and extended to 1969. This generalization includes those samples unable to be properly estimated, but still seemingly old enough to be of interest. From the ten samples without accurate age estimations, eight are shown to possess ages of greater than eighty years, based on the year of the last present growth ring before the core is cut off. Specifically, Willow Creek Preserve constitutes five samples with last present ages of 1903, 1907, 1910, 1929, 1931, and 1933; Coburg Ridge's only samples that did not reach are dated to at least 1913 and 1915; and Willamette Confluence possessed one core dated to at least 1909. These samples from Willow Creek and Coburg Ridge, though incomplete and not reflected in **fig 5**, likely contribute to the stand histories and are relatively the same age as surrounding samples, meaning they can be estimated to have germinated in or near the first fifteen years of the twentieth century. The one older sample obtained from the Willamette Confluence Preserve reached a section of decay and was surrounded by stumps of Douglas-fir from older logging projects, meaning it was likely left behind and does not allow for accurate estimation of the stand history for any remaining trees.

The most intriguing specimen in the context of this research is a cookie sample collected from the Willow Creek Preserve that was dated to have germinated in 1876. This tree would have been dispersed roughly twenty-five years after indigenous controlled burning would have significantly declined. On this sample, notes were made about brief and extended period of suppressed or rapid growth to infer conclusions on the history of its stand and nearby stands. In the growth history of this Douglas-fir, the first major and rapid alteration in growth speed occurs in 1905, when the tree exits a period of significant suppressed growth dating to its germination, and proceeds rapidly until well after the 1930's. There is a period of exceptional growth speed from 1922-1947, where another period of suppression begins. All cores germinated well after the culmination of decline of the Kalapuya population by 1850. Dates of importance to this land use timeline are clustered nearer to the increase of grazing frequency than loss of indigenous presence, spanning the first thirty years of the twentieth century.

Results of Orthorectification and GIS Analysis

I have created a series of site maps depicting the various aerial photos and vegetation polygons representative of three different eras. The preserve site visualizations are each comprised of five different maps to show progression of time vertically along the figure and have been included as figures at the end of the results section from pages 31-33. The 1850's vegetation cover polygon maps have been compared to original transcripts of cadastral survey observations along lines between subdivisions of the township range grid to find that discrete transitions along these lines are correct to within roughly two chains, or one hundred-thirty two feet, for all three sites. This comparison was conducted in ArcMap, with access to township range subdivision data accessed in the University of Oregon's GIS Data Library. The lines were projected over a map of 1850's Willamette Valley vegetation, and a ruler tool within ArcMap was used to calculate distance along these lines and measure the exact observation points contained in the cadastral surveys.

Coburg Ridge Preserve

The section represented by the extent of the Coburg Ridge map constitutes a portion of the southern and western area of the entire preserve immediately surrounding the core extraction location. Referring back to the age result data, all but one of the eleven samples across two Douglas-fir stands within marginal forest or oak savanna habitat were germinated in between the years 1900 and 1913, and the two samples that did not reach the pith are likely similar in age. When the cadastral survey of this land was conducted by J. Latshaw in 1853, the land to the north the McKenzie River within the township and range subdivisions studied for this figure were not delegated to any form of ownership, nor had any division or development taken place by 1895, the time of the most recent survey plat archived by the BLM. The core samples were taken from the edge of a closed forest extending into prairie habitat as well as from a large patch of oak savanna habitat running north and south. By 1936, this area was located entirely within a young forested area, which grew denser by 2011.

Willamette Confluence Preserve

Vegetative reconstructions of the Willamette Confluence Preserve show colonization rates of Douglas-fir dominant forest prior to 1936 at a faster rate than what was witnessed in the case of the Coburg Ridge Preserve. Samples collected from this site existed on oak savanna habitat near the boundary of a closed upland forest, or what would be regarded as an ecotone. However, by 1936, this savannah had largely been filled in, only breaking the canopy for a few small prairie/savanna-like openings. Furthermore, few of these openings remained by 2011 as a large portion of the confluence site near the banks of the Middle Fork of the Willamette River became thickly forested. It is of interest that the samples taken from this site are all aged to have germination dates more recent than 1947 when an accurate age was able to be estimated. Trees older than this time period are very few and far between, only being estimated by a partial core dated to 1909, when a section of decay and compression from uneven vertical growth caused the increment bore to fail proceeding further into the tree.

Willow Creek Preserve

When the cadastral survey of this portion of the Eugene area was conducted by B. Ives in 1853, the site contained very little presence of Douglas-fir, only in the form of a few patches of mixed forest woodland near hill summits. Samples from this area were also collected entirely from within oak savanna habitat, and have the widest age range of the three sample locations, dating from 1876 to 1955. By 1936, the mixed woodlands had expanded in extend and nearby areas had become dominated by conifer presence, only to thicken by 2011, leaving little mixed woodland and savanna habitat remaining. Areas to the northern section within the Eugene urban growth boundary now constitute a TNC prairie restoration project with aims to restore establishment of Kincaid's Lupine to reduce risk of endangerment of the Fender's Blue Butterfly. However, the areas to the south of these prairies lie outside of the Eugene urban growth boundary, and therefore have not seen extensive development and land division.

In the context of the Willamette Valley land use and management history timeline, the orthorectification process has shown a greater amount of Douglas-fir colonization on all three preserve sites from 1850-1936 than what is seen from 1936-2011. The extent of prairies has remained more consistent in the latter eighty year period. This was estimated through incorporation of sample areas around core collection sites to measure both the increase and decrease of area (in hectares) of these vegetation classes through time. In all cases, the amount of forest increase and prairie and savanna decrease was greater from 1850-1936 than that of 1936-2011. The following table shows the change in area of closed forest, savanna, and prairie vegetation classes across time for the sample areas on each preservation site. The most consistent rate of vegetation change was recorded on the Coburg Ridge sample area, while the Willamette Confluence and Willow Creek Preserve both contain a far greater percentage of change in the earlier time period, sooner after indigenous population decline.

Vegetation Class	**1850 Area (Ha)**	**1936 Area (Ha)**	**2011 Area (Ha)**
	Coburg Ridge Preserve		
Closed Forest	9.7	29	40
Savanna	17.2	14.3	12.3
Prairie	33.8	9.6	7.4
	Willamette Confluence Preserve		
Closed Forest	87.3	136	133
Savanna	48.5	18.4	14.3
Prairie	13.1	3.6	0
	Willow Creek Preserve		
Closed Forest	0	28	33.2
Savanna	31.2	0	2.2
Prairie	<0.1	3.5	2.2

Table 1: Change in area (Ha) of vegetation classes obtained from a sample area containing each core collection site.

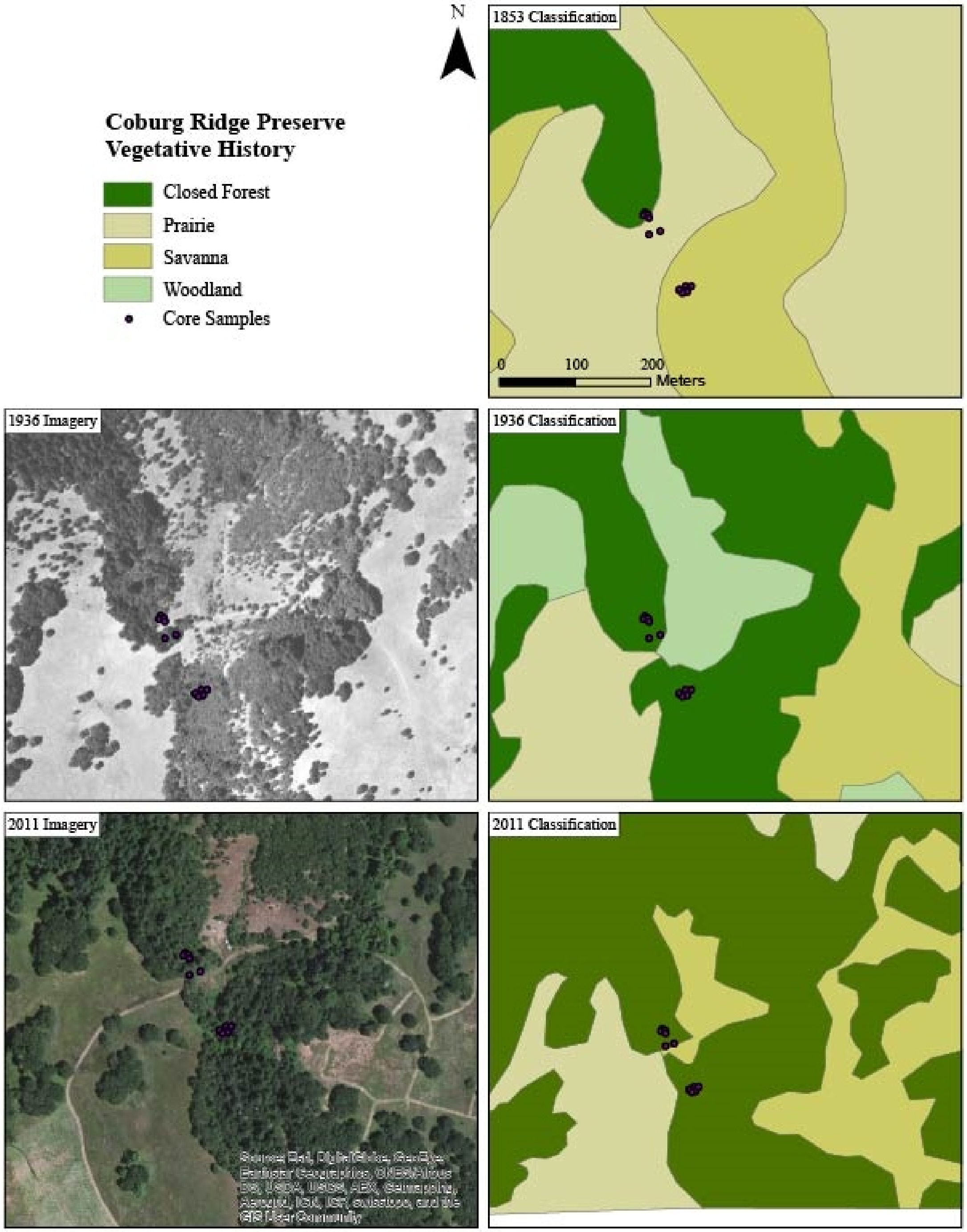


Figure 6 – Aerial imagery and vegetative classification through time at the Coburg Ridge Preservation Site.

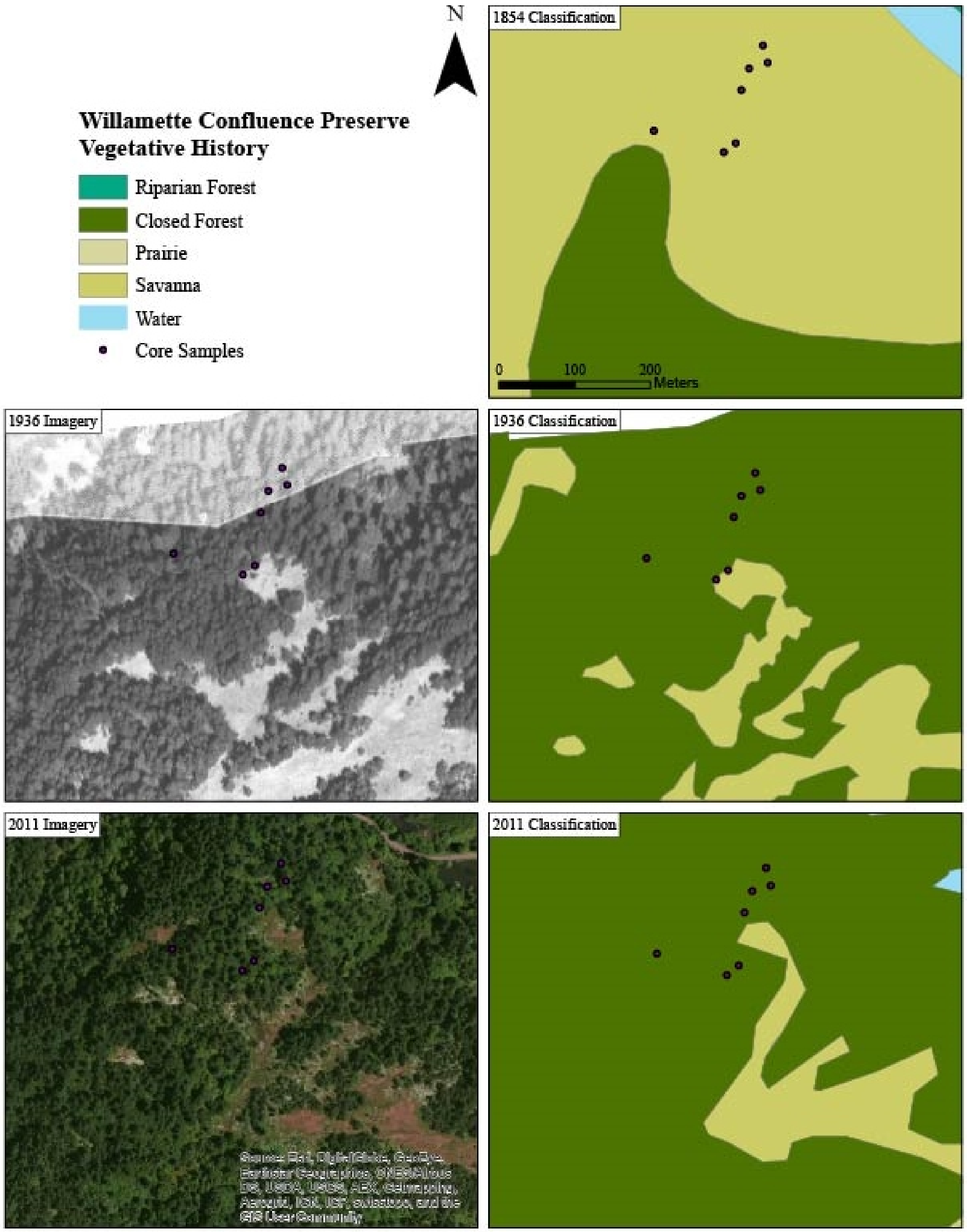


Figure 7 – Aerial imagery and vegetative classification through time at the Willamette Confluence Preservation Site.

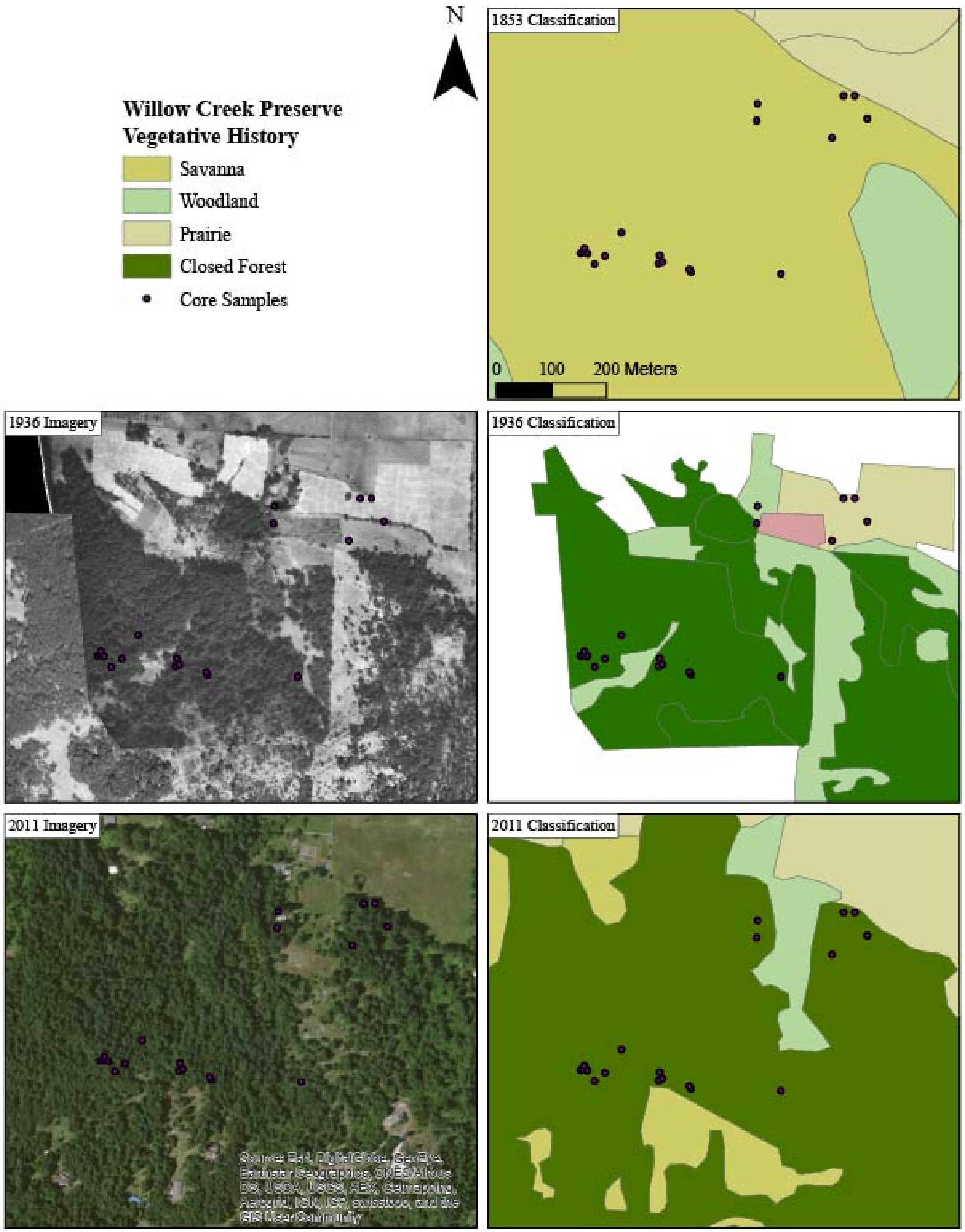


Figure 8 – Aerial imagery and vegetative classification through time at the Willow Creek Preservation Site.

Discussion and Conclusion

Interpretation of Data

Though the perseveration sites composing the case study in this research outline regions that are geographically distant, the control placed on the collection of core samples of historic oak savanna habitat allowed for comparison between their respective age results. That being said, it is evident in the location of samples in the appended vegetative class figures that not all cores were taken directly from oak savanna habitat. Samples from Coburg Ridge specifically spanned historic savanna, prairie, and closed forest habitat. There is a general lack of presence of older trees on these sites that becomes evident after stepping foot in the boundaries of TNC logging projects. Most of the current closed forest consists of primarily younger Douglas-fir of unknown age established well after the 1930's.

There is a similar disparity in both the consistency of ages across the three sites and the growth rate of rings from different age classes. For example, the Willamette Confluence samples grew much faster than those of similar DBH collected from other preservation sites, and contain fewer segments and total years of suppressed growth, which indicates a general lack of competition in the germination and successful establishment of local Douglas-fir. It is possible that colonization dates in the 1950's and 60's are results of post-logging forest regeneration. In Lane County alone, from the years of 1938-1947, the output of timber harvest tripled, and required governmental attention by 1962 when private logging was placed under federal control in attempts to reduce risk of deforestation and control the amount of timber being produced in Oregon

(Andrews and Kutara, 2005). Trees on the Willamette Confluence preserve do little to offer to the narrative of vegetative history during the transition period from indigenous to Euro-American habitation, but the level of closed forest advance after the removal of Kalapuya population seen in GIS reconstructions of historic vegetative state at Eugene-area preservation sites remains significant.

Generally, 18 of 29 dates collected from the three sites that are both accurately measurable and old enough to be of interest to this research clustered within the first portion of the twentieth century. Only one tree from the Eugene area taken from the Willow Creek Preserve predates this grouping, and shows a period of significant suppression in its growth history before 1905. No other sample from this site was reliably dated before 1905, indicating an event that could have caused local colonization of Douglas-fir to increase in frequency and allow those already established to grow much faster. The date of this apparent germination period correlates with the temporal trend seen in the Coburg Ridge Preserve results. For both of these preservation sites, the rate of Douglas-fir colonization seems to have sped up during the first five years of the twentieth century and remained high for the next two decades.

The lack of establishment prior to this event does not account for the removal of active burning in the Eugene area conducted by the Kalapuya, but rather is suggestive of land use methods in the early twentieth century that expedited the colonization of Douglas-fir, in contrast to the immediate effect of prairie burning. The vegetative timeline of the sites would place the germination of the core samples roughly twenty to thirty years prior to the date of the 1936 map figure, meaning the mixed forest wooded area that has replaced a majority of the oak savanna could potentially be this old. The mixed forests that have filled in historic savanna habitat in the orthorectified image are also quite young, indicated by differences in shadow height between its canopy and the original portion of closed forest. This implies that a rapid surge in Douglas-fir colonization occurred on Coburg Ridge land in the first few decades of the twentieth century, roughly fifty years after prairie burning would have subsided. However, the lack of uniformity of the Douglas-fir core results do not suggest that the extent of these conifer dominant forests have remained constant in the face of Euro-American land alterations and resource extraction, as few trees of age to support either narrative physically remain on these preservation sites. More time devoted to the collection of Douglas-fir outside of TNC preservation sites would be necessary to gather a more robust primary chronology for the Eugene-area and the Southern Willamette Valley.

If the removal of controlled burning led to the loss of oak savanna and prairie habitat, it would be expected that more trees should date to the last half of the nineteenth century. Their absence suggests that land management events taking place about fifty years after this transition affected the current state of vegetation cover more than solely the loss of fire. GIS analysis of cadastral survey descriptions and historic aerial photos has revealed a shift from primarily oak savanna habitat to more widespread, younger mixed woodlands and closed forests, which eventually become thicker by 2011 across all three sites. It is apparent in both core age data and orthorectification analysis that forest extent increased at a much faster rate before 1936 than it did after to this date, and could have been focused at the turn of the twentieth century. This implies that some force related to the arrival of Euro-American settlement and industry was more influential in propagating the advancement of Douglas-fir.

Determining the nature of land management change specific to the preservation sites of focus to this study presented complications based on the scale of primary data from the time period suggested by the Douglas-fir core and GIS analysis results. Analysis of census data at the state level has informed this timeline of periodic spikes in output of both wool and timber, but at different points in history. The subsequent rapid growth of the sheep industry in Oregon seems to align temporally with a potential rush of Douglas-fir colonization taking place in the early 1900's, less than a decade after accounts of large populations of sheep being introduced to the state. Mechanical logging would not have existed in such frequency during this time, and the level of logging and timber production did not see a similar spike until the mid-twentieth century (Andrews and Kutara, 2005). When sheep stop grazing in a particular area, the low grass cover and exposed mineral soil provide optimal conditions for the establishment of Douglas-fir that, prior to grazing, may have been inhibited by competition with prairie and savanna grasses. Though the correlation in timing between the increase in levels of grazing in the state of Oregon and ages of the oldest Douglas-fir cohort suggests a temporal relationship between the two events, the discrepancy in scale between these two observations do not provide sufficient evidence to support the hypothesis that grazing was the most influential factor affecting the establishment of Douglas-fir. Site specific information on grazing intensity and locality would better inform the land use history timeline at the conservation sites referenced in this study.

Implications of the Study

The objective of this research was to establish a timeline for the changes present in vegetation cover among three preservation sites near Eugene, OR. The results of this study are linked to historic land use practices during an occupational shift in the cultural composition of the Willamette Valley. With a better understanding of the relationship between Douglas-fir colonization and changes in resource dependency occurring as a result of the replacement of indigenous population with Euro-American settlement, commentary can be made on their implication in regards to contemporary land management. The current Eugene-area forest advance narrative states that Douglas-fir colonization in historic oak savanna habitat was a direct result of the loss of indigenous fire. However, there is a significant gap between the decline of Kalapuya population and the appearance of Douglas-fir trees in the oak savanna ecotones present on the Willow Creek, Coburg Ridge, and Willamette Confluence Preserves. Relating forest advance in the Eugene area to a human-environmental force imposed by Euro-American populations would challenge the contemporary conservation narrative and provide important cultural insight relating citizens of the Southern Willamette Valley to the local, natural habitat.

A specialized use of fire allowed the Kalapuya to maintain both a cultural state and a vegetative state conducive to the fitness of native flora and fauna that have since become endangered. Significant reductions in the area represented by both prairie and savanna habitats after the decline of indigenous population increased the ecological stress placed on such native species once vital to their culture. Referenced by Henry Huntington in his multi- case study of scientific integration with Alaskan indigenous groups, the integration of science and traditional ecological knowledge can be a beneficial collaboration in its ability to unite different cultures and reduce the objective bias of scientific inquiry (Huntington et al. 2011). The intersection of Kalapuya voice and conservation development in the Willamette Valley could similarly provide cultural insight about the land being preserved. This draws attention to the absence of indigenous representation in the formulation of current Eugene-area conservation programs. Euro-American settlement culture imposed a stark contrast on the subsistence rounds in place with the introduction of grazing, and the resulting agriculture and livestock regimes have remained a primary use of prairie resource into the modern era. This has challenged the health of prairie species and the existence of the oak savanna ecotone, which represent a large portion of Eugene-area conservation efforts.

In accordance with the importance of Kalapuya culture to historic Willamette Valley resource management is a respect for the magnitude of ecosystem change that occurred after the introduction of contact and settlement culture. This study has shown the impact of Euro-American settlement on the natural frequency of fire, and can pinpoint their arrival as a visible decrease in burning, natural or anthropogenic, in charcoal and pollen records culminating in 1930 (Walsh et al. 2010). Equally significant is the legislation passed to reduce burning (U.S. Department of Agriculture, 1898), denoting a fundamental shift in cultural perception of the role of fire. Rapid introductions of non-native livestock and agriculture developed an ecosystem that could not support the future health of the oak savanna ecotone. In order to return this habitat to its historic state and promote health of native savanna and prairie species, this forest advance and land use timeline must be cleared up to properly comment on the role of Euro-American industry. Doing so could redefine conservation narratives and speak more of the role of fire in oak savanna restoration.

The intended research goal of this study was to determine if Douglas-fir colonization in the post indigenous era was constant, or disturbed by external forces allowing for periods of increased establishment. While core data alone does not explicitly show conclusive evidence that Douglas-fir is either continuous or grouped in specific intervals, its correlation to analysis of historic vegetative states suggests that Douglas-fir dominant closed forests colonized surrounding oak savanna and prairie habitat much more readily from 1850-1936 than from 1936-2011. The absence of core data prior to 1903, and the rapidity of growth on the Willow Creek Preserve after 1905, could imply that environmental forces allowed for such distribution to occur at high levels well after the removal of indigenous presence and controlled fire. It is difficult to identify which environmental force accounts for this trend at preservation sites near Eugene, OR, but this temporally matches with the exponential increase in wool production in state census data, and a similar peak in timber production is not witnessed until 40-50 years later. Research conducted in the grazing and logging history specific to these preservation sites could shed light on the current narrative and better support the level of importance between grazing and logging. The core and GIS results strongly suggest that Euro-American industry and environmental interactions were a greater force in preventing the consistency of historic forest advance Though due to the lack of primary evidence of land use history in the Eugene-area, I do not believe it is possible to conclude that a single land management method, in this case sheep grazing, was more impactful than other human-environment interactions introduced during this occupational transition.

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