Historical Vegetation of the Willamette Valley, Oregon, circa 1850

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Abstract

Land survey data recorded by the General Land Office between 1851 and 1910 were used to map historical vegetation in the Willamette Valley, Oregon. Of the 202 townships included in our study area, 148 (73%) were surveyed between 1851 and 1855. Widespread but dispersed and small-scale Euro-American settlement preceded the surveys by 5 years or more, but census records indicate that farming and logging at the time of survey had affected less than 4 and 0.5 percent of the valley, respectively. Native habitats presumably were grazed to an unknown extent by free-ranging livestock, but not otherwise disturbed by drainage or plowing. Ten vegetation classes were mapped, comprised of 66 subclasses. Prairie covered the largest area, followed in diminishing order by upland forest, savanna, woodland, riparian and wetland forest, water, shrubland, emergent wetlands, unvegetated, and herbaceous upland. Distribution of vegetation classes reflected gradients in precipitation, hydrology, soil moisture, topography, and fire frequency. In general, prairie occupied a central position in the valley surrounded by more or less concentric bands of savanna, woodland, and closed forest. Prairie and savanna dominated the southern and central valley, while forest and woodland were more abundant in the northern portion of the valley. To some extent, woodland may have been savanna under an earlier Native American fire regime. All subclasses except coniferous forest have declined in area since 1850.

Introduction

Since 1994, we have used public land survey data of the General Land Office (GLO) to map historical vegetation for the Willamette Valley. Mapping of the area has been incremental, funded by a variety of agencies, and portions of our work have appeared in a number of publications (e.g., Christy et al. 1997, Ashkenas et al. 1998, Boyd 1999a, Christy 2002, Gregory et al. 2002, Hulse et al. 2002, Taft and Haig 2003, Baker et al. 2004, Hulse et al. 2004, Oetter et al. 2004, Robbins 2004, Schumaker et al. 2004, and Van Sickle et al. 2004), but the entire body of work has never been published. In this special issue of Northwest Science we present the first comprehensive summary of historical vegetation in the valley, based the most recent version of the dataset (Christy et al. 2010).

GLO surveys of the Willamette Valley were initiated in 1851, establishing the rectangular grid of townships and ranges that is the foundation for all legal land descriptions to this day (Atwood 2008). Of the 202 townships included in our study area, 148 (73%) were surveyed between 1851 and 1855, covering the valley floor and lower foothills. Most higher-elevation forest land within the study area was surveyed between 1856 and 1895. The surveys document a landscape in the midst of conversion from an estimated 10,000 years of occupation by Native Americans, to proliferating Euro-American farms, transportation networks, and towns. Prior to their catastrophic decimation from several regional pandemics of European diseases thought to have occurred between about 1770 (or earlier) and 1833 (Robbins 1997, Boyd 1999b, Walsh et al. 2010a), Native Americans managed habitats with fire to enhance production of a multitude of plant species used for food and fiber. Archaeologists have documented camas (*Camassia* spp.) ovens in the Willamette Valley that are more than 7000 years old (Aikens 1993). The frequency and extent of aboriginal burning, though believed to be extensive, is subject to ongoing debate (Boyd 1986, 1999a; Boag 1992; Storm and Shebitz 2006; Whitlock and Knox 2002; Lepofsky and Lertzman 2008; Walsh 2008; Walsh et al. 2010a, 2010b). Research indicates that fire varied over time in response to fluctuations in both climate and the population density of Native Americans.

When the Willamette Valley was surveyed between 1851 and 1855, impacts from farming, logging, and fire exclusion caused by widespread but dispersed and small-scale Euro-American settlement already would

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have altered vegetation to a limited extent. The first trading post in the valley was established in 1812 by the Pacific Fur Company at Wallace House, near what is now Salem (Manion 2006). By 1838, retirees from the Hudson Bay Company's Fort Vancouver had fenced or cultivated about 500 ha on French Prairie (Boag 1992). Opening of the Oregon Trail in the mid-1840s dramatically increased the influx of people, and the 1850 census enumerated over 11,000 settlers residing in the valley (Bowen 1978). Despite the number of settlers present at the time of survey, they were often not able to clear or cultivate all of the 65 ha or 130 ha claims granted to them under the federal Donation Land Claim Act. In 1850, the average area of improved (fenced or cultivated) agricultural land on each of the 1,700 farms recorded for counties in the Willamette valley was less than 30 hectares (U.S. Bureau of the Census 1880). GLO township plat maps delineated plowed fields at the time the survey, but most of them were relatively small and located in prairies (e.g., Boag 1992, Map 5; Atwood 2008, plats among Figures 13-41). The 1850 census documented 24 sawmills in the valley, with capacity for approximately 60,000 logs per year (Bowen 1978). Assuming an average stand density of about 50 trees/ha, logging concentrated near mills and along streams could have impacted about 1,200 ha per year. Based on these figures, we estimate that farming and logging at the time of survey had affected only about 4 and 0.5 percent of the valley, respectively. Native habitats presumably were grazed to an unknown extent by free-ranging livestock, but not otherwise disturbed by drainage or plowing. Although the Native American population had been reduced greatly by 1851, prairie fires were documented by early settlers as late as the 1840s (Bowen 1978). Successional changes that may have occurred over the 10-15 years since burning had ceased would not have been long enough to obscure the presettlement structure of prairie and savanna. Because woodland usually had a better-developed shrub layer than savanna, it presumably had been released from fire for a longer period of time. These changes, though widespread, do not appear to be great enough to affect our overall interpretation of presettlement vegetation.

Travelers' accounts describing vegetation in the Willamette Valley prior to 1850 usually lacked sufficient detail for accurate mapping (e.g., Smith 1949). In contrast, the GLO survey notes offer a comprehensive, more or less consistent dataset describing the composition and extent of vegetation and environmental conditions at the time of survey. Despite the fact that about 4 percent of the Willamette Valley had been farmed by Euro-Americans at the time of survey, the notes remain one of the most important sources of historical information about vegetation, providing valuable benchmarks for habitat restoration and planning (Manies et al. 2001, Whitney and DeCant 2001).

Study Area

Our study area is the Willamette Valley ecoregion (Thorson et al. 2003), encompassing 1,353,795 ha, but excluding the 26,628 ha portion that occurs in the Umpqua River basin because it is not part of the Willamette Valley (Figure 1). The study area is about 201 km long and 32-81 km wide. Hulse et al. (2002) described the physical and climatic setting for the entire Willamette River Basin, which is slightly more than twice as large as the study area.

Previous Work

Data from the GLO surveys have been used by ecologists in many areas of the United States since the 1920s to reconstruct vegetation patterns that existed prior to Euro-American settlement (e.g., Bourdo 1956, Hutchison 1988, Galatowitsch 1990, Whitney 1994, Whitney and DeCant 2001, Fritschle 2008, Kilburn et al. 2009). In the Willamette Valley, Habeck (1961, 1962) was the first to use GLO notes to map historic vegetation for seven townships in the central valley, with a focus on one particular township. Johannessen et al. (1971), Towle (1974, 1982), and Bowen (1978) used GLO data to map historical vegetation in 35 townships in the southern valley, and Johannessen et al. (1971) and Bowen (1978) used GLO plat maps to delineate the extent of major prairies throughout the valley. Boag (1992) described the relationship of the GLO survey to Donation Land Claims (DLCs) and mapped four townships partially overlapping those mapped earlier by Towle. Sedell and Froggatt (1984), Alverson (1993), Shively (1993), and Benner and Sedell (1997) used GLO data to map or describe vegetation and river channel configurations in the southern Willamette Valley and portions of the Tualatin Valley. Day (2005) used GLO survey data to document changes in a former savanna in the foothills of the western Cascades.

Methods

Transcription of Survey Notes

We transcribed GLO survey notes for 202 townships covering the study area, including portions of townships extending into the adjacent Coast Range, Western Cascades, and Klamath Mountain ecoregions. Transcriptions were entered into an Access database,

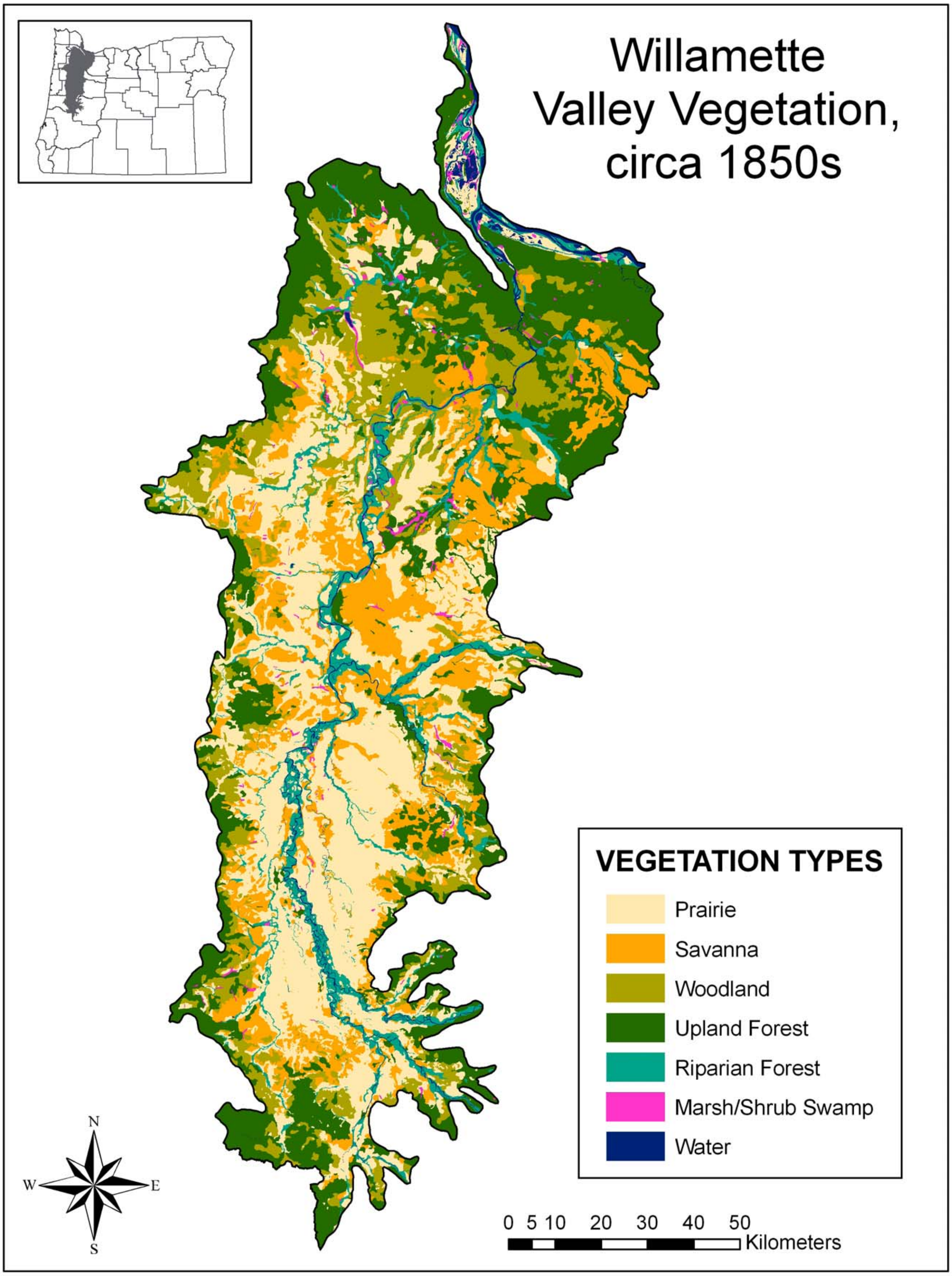

Figure 1. Historical vegetation classes in the Willamette Valley, Oregon, based on General Land Office survey data, 1851-1910.

following in part methods used by previous GLO projects in Minnesota and Michigan (e.g., Comer et al. 1995, Albert and Comer 2008). Data tables for each township usually contained between 600 and 1200 records, providing copious details about topography, vegetation, and cultural features. Transcription included notes for all section, township, and meander lines, but time and funding did not permit transcription of DLC surveys. Mountainous portions of townships that were not amenable to settlement and farming usually were surveyed at a later time, often years or several decades after the initial survey. Where more than one survey existed for an area, such as a resurvey of an earlier line, we transcribed data from the oldest survey.

Classification of Vegetation

We classified vegetation units based on surveyors' descriptions of vegetation, species composition, and the distances they recorded between survey section or quarter corners and "witness" or bearing trees (Table 1), independent of modern vegetation classification (e.g., Grossman et al. 1998, Anderson et al. 1999). GLO surveyors were usually consistent when differentiating stands with dissimilar structure or composition, and they routinely segregated closed forest ("timber"), savanna ("openings"), and woodland ("scattering timber") from prairie. Today, these structural classes are often segregated by percent canopy cover or stand density, but such data were not recorded in GLO notes and must be extrapolated from distances between survey corners and witness trees. In contrast to Habeck (1961) and researchers in the American Midwest who used 75 links (15 m) between survey corners and witness trees to demarcate forest from savanna, we used a maximum distance of 100 links (20 m) to provide a slightly more conservative estimate for the area of savanna and woodland, particularly in the absence of canopy cover data. This was done to accommodate the often large tree diameters in the Pacific Northwest, particularly in coniferous forest, resulting in fewer trees needed for classification as woodland or forest community (e.g., giant forest alliances of Grossman et al. 1998). Few survey corners in the valley actually had distances to bearing trees between 75 and 100 links, and surveyors almost always segregated "openings," "scattering timber," or "prairie" from forest only when average distances to bearing trees exceeded 100 links. Exceptions to the general pattern of vegetation description were often encountered in the survey notes, and subjective ecological judgment had to be used to limit cover types to a manageable number.

Delineation of Map Units

Map units were delineated as polygons on mylar sheets overlying 1:24,000 U.S. Geological Survey (USGS) quad maps, and the polygons were then digitized to create a GIS layer. GLO survey notes provide distances that accurately locate vegetation breaks and other features along section lines, but they do not provide data for features in the interiors of sections. We mapped features located wholly within sections only if there was reference to them in the survey notes, or if their existence was firmly supported by secondary sources. This approach no doubt excluded some prairies, wetlands, and waterbodies that may have been present at the time of survey, but for which no supporting evidence could be found in the historical data. Whether maps are created manually or by automated GIS processing, under-representation of small patch vegetation types that may have been intersected only infrequently by section lines is a common result in GLO work (e.g., Brown 1998, Manies and Mladenoff 2000, Whitney and DeCant 2001). Given these limitations, resulting vegetation maps are therefore a simplification of what really occurred on the landscape. We estimate our mapping accuracy to be within 10 m along section lines, and 100-300 m in the interiors of sections.

TABLE 1. Classification of vegetation stand structure in Willamette Valley, ca. 1850, based on General Land Office survey data.

Vegetation	Distance to bearing trees	GLO descriptors
Forest	< 20 m (100 links), all bearing trees present	"timber," "heavy," "dense," "thick"; understory "brushy" or "ferny"
Woodland	20-40 (80) m (100-200 [400] links), most bearing trees present	"timber," "scattering timber," "thinly timbered," "sparsely timbered," "open"; understory "dense" or "brushy"
Savanna	(20) 40-80 m ([100] 200-400 links), most bearing trees present	"openings," "scattering timber," "thinly timbered," "sparsely timbered," "open"; understory "open" or with shrubs, with "good grazing," "good for stock," "grass in abundance," or not described
Prairie	> 40-161 (352) m (200-800 [1,750] links), bearing trees often absent	"prairie," "plains," "fern prairie;" "grass"; understory lacking shrubs, or not described

To improve information for the interiors of sections, we supplemented the survey notes with GLO township plat maps, U.S. Coast Survey maps, modern soils data, and in some cases, 1930s aerial photography. GLO plat maps drawn before 1870 provided the best detail for prairie boundaries, but later plat maps usually lacked these features. U.S. Coast Survey maps, based on field work done between 1870 and 1887, provided highly detailed and accurate depictions of vegetation and water features for nearshore areas along the Columbia River at the north end of the study area (Graves et al. 1995). We used hydric soil units from the Natural Resources Conservation Service (NRCS) digital soils layer (SSURGO) to delineate the extent of wetlands crossed by survey lines, and to segregate upland prairie from wet prairie. The latter was necessary because dry-season surveys did not consistently differentiate wet prairie from dry prairie. Where survey lines were absent, topography was used to make breaks between upland and wetland vegetation, xeric and mesic vegetation on contrasting slopes, and the borders of historical burns. Air photo coverage from 1936, the earliest available, was used to corroborate the extent of some savanna and woodland stands in the southern part of the valley.

Where survey notes or plat maps indicated the presence of farm fields or towns, we used adjacent historical vegetation polygons, topography, and NRCS soils data to interpret what the presettlement composition of these areas might have been. In most cases, settlers located their fields and towns in former prairies or savannas because they did not have to clear land before plowing (Bowen 1978, Boag 1992).

Map Extent

Once mapping of vegetation units was completed and digitized, for analysis in this paper we clipped the layer to the boundary of the Willamette Valley ecoregion (Thorson et al. 2003), excluding the 26,628 ha portion that occurs in the Umpqua River basin because it is not part of the Willamette Valley.

Nomenclature

Scientific names of plants follow the NRCS PLANTS database (http://plants.usda.gov/java/).

Results

Names of dominant plants recorded in the GLO survey notes are given in Table 2. We identified 10 vegetation classes in the Willamette Valley (Table 3), presented in order of diminishing areal extent: (1) prairie, (2) upland forest, (3) savanna, (4) woodland, (5) riparian and wetland forest, (6) water, (7) shrubland, (8) emergent wetlands excluding wet prairie, (9) unvegetated, and (10) herbaceous upland. Five of the ten classes (prairie, savanna, woodland, upland forest, and riparian forest) collectively covered 97.4% of the valley at the time of Euro-American settlement (Figure 1). The vegetation classes contained 66 subclasses (Table 4), including 11 forest and woodland types that were interpreted as burned facies of corresponding unburned subclasses. Stands were classified as having been burned if surveyors recorded (1) fire in progress, (2) burned trees with contrasting descriptions of "green timber," (3) areas with an abundance of standing or fallen dead timber or "stubs," or (4) mixtures of "scattering" live trees, brush fields, "openings," and groves of regenerating forest with diameters generally less than 30 cm. Timber could have been killed by fire, insects, or fungi, but given the widespread occurrence of fire in surrounding areas, we presumed fire to be the most likely cause of dead trees. Forest described as "young" was not mapped as burned unless it was noted that burned or dead trees were present.

Prairie

Prairie covered 424,606 ha, or 31.4% of the study area (Table 3). It was the most extensive vegetation class in the valley, particularly in the central and southern portions of the study area. Surveyors characterized it as open grassland with at least some bearing trees absent or too distant for convenient use (Table 1). They universally described this vegetation type as "prairie," "plains," or "grass." We included as prairie any agricultural fields existing at the time of survey, because most settlers established their fields in prairie to avoid the labor of clearing forest, woodland, or shrubland (Bowen 1978, Boag 1992). Though prairies are thought to have been maintained in most cases by fire, surveyors did not record any signs of fire in these habitats, presumably because such evidence was short-lived and routine burning by Native Americans had ceased at least 10 years earlier. Despite the lack of physical fire evidence in prairies, historical accounts and interviews with Native peoples indicate that the fire return interval in this habitat may have been as frequent as every 1-2 years (Boyd 1999a; Storm and Shebitz 2006).

Prairie occupied a variety of landscape positions, but was best represented on the valley floor and on south facing slopes of lower foothills. Smaller isolated prairies occurred as patches within a forest or woodland matrix, either on floodplains of major rivers, or on exposed rocky slopes in the higher foothills. Prairie was often

TABLE 2. Plant species most frequently cited in General Land Office survey notes from the Willamette Valley, ca. 1850.

Surveyors' name	Modern name	Scientific name	Layer
Alder	Alder	*Alnus* (unspecified)	tree
Arrowwood	Ocean spray	*Holodiscus discolor*	shrub
Ash, White ash	Oregon ash	*Fraxinus latifolia*	tree
Balm Gilead, Balm	Black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	tree
Black oak	California Black oak	*Quercus kelloggii*	tree
Cedar	Western red cedar	*Thuja plicata*	tree
Cherry	Bitter cherry	*Prunus emarginata*	tree
Chittam, Chittem, Shittim	Cascara	*Frangula purshiana*	tree
Chinquapin, Bur willow	Chinquapin	*Chrysolepis chrysophylla*	tree
Crab apple, Crab	Oregon crabapple	*Malus fusca*	shrub
Dogwood	Dogwood	*Cornus nuttallii*	tree
Elderberry, Elder	Elderberry	*Sambucus* (unspecified)	shrub
Fern	Fern	(unspecified)	herb
Fir, Red fir	Douglas-fir	*Pseudotsuga menziesii*	tree
Grape	Oregon grape	*Mahonia* (unspecified)	shrub
Grass	Grass	(unspecified)	herb
Hackbrush, Hardbush	Douglas spiraea	*Spiraea douglasii*	shrub
Hawthorn, Thorn, Haw	Hawthorn	*Crataegus* (unspecified)	shrub
Hazel	Beaked hazelnut	*Corylus cornuta* var. *californica*	shrub
Hemlock	Western hemlock	*Tsuga heterophylla*	tree
Huckleberry	Huckleberry	*Vaccinium* (unspecified)	shrub
Laurel	Madrone	*Arbutus menziesii*	tree
Manzanita	Manzanita	*Arctostaphylos* (unspecified)	shrub
Maple	Bigleaf maple	*Acer macrophyllum*	tree
Ninebark	Ninebark	*Physocarpus capitatus*	shrub
Pea vine	Pea or vetch	*Lathyrus* or *Vicia* (unspecified)	herb
Quillwood	Oregon grape	*Mahonia* (unspecified)	shrub
Redwood	Incense cedar	*Calocedrus decurrens*	tree
Rose	Rose	*Rosa* (unspecified)	shrub
Salal	Salal	*Gaultheria shallon*	shrub
Vine maple	Vine maple	*Acer circinatum*	shrub
White oak	Oregon White oak, Garry oak	*Quercus garryana*	tree
Willow	Willow	*Salix* (unspecified)	tree, shrub
White fir, Balsam fir	Grand fir	*Abies grandis*	tree
Yellow pine	Ponderosa pine	*Pinus ponderosa*	tree
Yew	Pacific yew	*Taxus brevifolia*	tree

TABLE 3. Classes of historical vegetation in Willamette Valley, ca. 1850s, based on General Land Office survey data.

Vegetation class	Area (ha)	Percent study area
Upland prairie and wet prairie	424,606	31.36
Forest, upland	355,636	26.27
Savanna	245,742	18.15
Woodland	194,890	14.40
Forest, riparian and wetland	97,477	7.20
Water	26,168	1.93
Shrubland	5,216	0.39
Emergent wetland, excluding wet prairie	3,592	0.27
Unvegetated, excluding water	374	0.03
Herbaceous, upland	94	0.01
Total	1,353,795	100.00

surrounded by concentric zones of savanna or woodland where, presumably, fire frequency diminished. Because surveyors were not required to record herbs and graminoids, there are very few records of species from this vegetation layer, though in prairies some surveyors recorded "camas" (*Camassia quamash* ssp. *maxima* and *Camassia leichtlinii* ssp. *suksdorfii*), "grass" (various species, see following paragraphs), or "fern" (presumably *Pteridium aquilinum* var. *pubescens*).

Upland Prairie—Of three prairie subclasses (Table 4), upland prairie was the most extensive, covering 2/3 of the total prairie area. It occurred on well-drained soils in a variety of upland settings, and probably encompassed a range of plant communities along gradients of soil depth and seasonal soil moisture. Today, scattered remnants of high quality native upland prairie contain various combinations of grasses that presumably were

TABLE 4. Subclasses of historical vegetation in Willamette Valley, ca. 1850s, based on General Land Office survey data. Figures in parentheses indicate burned facies of subclass.

Vegetation subclass	Area (ha)	Percent study area
Forest, upland		
Douglas-fir - chinquapin - madrone on S to W aspects and ridgetops; Douglas-fir - red cedar - western hemlock on N aspects and bottoms	36,091 (285)	2.67 (0.02)
Douglas-fir	105,496 (7,264)	7.79 (0.54)
Douglas-fir - western hemlock - red cedar - grand fir	124,985 (26,985)	9.23 (1.99)
Same, storm damaged	23	0.002
Ponderosa pine - Douglas-fir - red cedar - western hemlock	424 (458)	0.03 (0.03)
Douglas-fir - white oak, or oak species unspecified	43,563 (304)	3.22 (0.02)
Douglas-fir - ponderosa pine	1,549 (121)	0.11 (0.01)
Douglas-fir, young	1,621	0.12
White oak, "oak brush," "oak and hazel brush"	3,251	0.24
White oak - black oak	86	0.01
White oak - Douglas-fir - ponderosa pine	2,995 (48)	0.22 (0.004)
Ponderosa pine	43	0.003
Storm-damaged forest, species unspecified	44	0.003
Forest, riparian and wetland		
Oregon ash "swamp" or "swale"	1,982	0.15
Oregon ash - alder - willow swamp	2,479	0.18
Oregon ash - willow swamp	4,062	0.30
Bigleaf maple - Oregon ash - black cottonwood - alder - white oak - willow riparian	67,655 (28)	5 (0.002)
Red alder - red cedar - grand fir - Douglas-fir - western hemlock - bigleaf maple - black cottonwood - Oregon ash riparian	12,430 (38)	0.92 (0.003)
Red alder swamp	48	0.004
White oak - Oregon ash riparian	7,036	0.52
Black cottonwood - willow riparian	1,719	0.13
Woodland		
Douglas-fir - western hemlock - red cedar - grand fir	4,403 (87)	0.33 (0.01)
Douglas-fir - black and/or white oak - madrone, often with ponderosa pine	4,342	0.32
White oak - Douglas-fir - ponderosa pine	6,608	0.49
Douglas-fir - white oak, or oak species unspecified	99,802	7.37
Douglas-fir	54,490 (2,309)	4.02 (0.17)
White oak, "oak brush," "oak and hazel brush"	22,849	1.69
Savanna		
Oregon ash	111	0.01
Douglas-fir	26,331	1.94
Douglas-fir - ponderosa pine	437	0.03
White oak	108,086	7.98
White oak - Oregon ash riparian	1,818	0.13
White oak - black oak	6,109	0.45
White oak - black oak - Douglas-fir	2,291	0.17
White oak - black oak - Douglas-fir - ponderosa pine	5,874	0.43
White oak - black oak - ponderosa pine	4,096	0.30
Douglas-fir - white oak, or oak species unspecified	67,541	4.99
White oak - Douglas-fir - ponderosa pine	14,188	1.05
White oak-ponderosa pine	8,818	0.65
Ponderosa pine	42	0.003
Shrubland		
Maple thicket, maple species unspecified	33	0.002
Rose or briar thickets, "briar brush"	136	0.01
Spiraea or hardhack "brush" or "swamp"	13	0.001
"Brushy swamp," "marshy thicket," "swampy thicket," composition unknown	464	0.03
"Brush," composition unknown	306	0.02
Vine maple swamp	5	0.0004
Willow swamp or "willow swale"	4,144	0.31
Hazel "brush" or "thicket"	115	0.01

Table 4 continued, next page

TABLE 4, continued

Vegetation subclass	Area (ha)	Percent study area
Herbaceous upland		
"Fern opening," "fern land," or "open fern hill"	94	0.01
Upland prairie and wet prairie		
Mounded prairie	932	0.07
Upland and xeric prairie	286,397	21.15
Seasonally wet prairie, "prairie marsh," "swamp prairie"	137,277	10.14
Emergent wetland, excluding wet prairie		
Marsh or "wet meadow," composition unknown	1,843	0.14
Pond lily aquatic bed, sometimes with skunk cabbage	70	0.01
Swamp, composition unknown	1,193	0.09
Wetland, composition unknown	347	0.03
Wapato marsh	139	0.01
Water		
Water body > 1 chain across, including river, slough, pond, beaver pond, lake, "marshy lake," and "bayou"	25,947	1.92
Seasonally-flooded lake, pond or slough > 1 chain across, including "shoal lake"	221	0.02
Unvegetated, excluding water		
Gravel bar	194	0.01
Rock outcrop, talus, exposed bedrock, scree slope, rocky scabland	19	0.001
Sand bar	161	0.01
TOTAL	**1,315,868 (37,927)**	**97.20 (2.80)**

the primary species present historically: Roemer's fescue (*Festuca idahoensis* ssp. *roemeri*), Sandberg bluegrass (*Poa secunda*), prairie Junegrass (*Koeleria macrantha*), Lemmon's needlegrass (*Achnatherum lemmonii*), wheatgrass (*Elymus trachycaulus*), and California oatgrass (*Danthonia californica*). A diversity of native perennial forbs also occur in high quality upland prairie remnants.

Wet Prairie—The second most extensive prairie subclass was wet prairie, covering about 1/3 of the total prairie area. It occurred primarily on heavy clay soils of the valley floor that were perennially saturated or flooded during the winter and early spring. GLO surveyors were nearly universal in calling all this vegetation "prairie" or "plains," but they used "wet prairie" only in cases where standing water was evident during a winter survey. Wet prairies often occupied swales or drainages occurring within a larger matrix of upland prairie, but in areas of extensive heavy clay soils, wet prairie was the primary vegetation type. Wet prairie presumably included a range of communities varying along gradients of soil texture and seasonal hydrology. Small areas of mounded prairie resembling the Mima Mounds of western Washington (Washburn 1988) occurred within the larger wet prairie matrix in Lane County. These were mapped based on 1936 aerial photography and current field knowledge, but were not mentioned in the GLO survey notes. Wet prairie also occurred along the floodplain of the Columbia River, covering about 9,545 ha, or about 7% of the subclass within the study area. These floodplain prairies were subject to inundation in June and July by the annual Columbia River freshets.

Wet prairie in most of the valley was dominated by tufted hairgrass (*Deschampsia cespitosa*), rushes (*Juncus* spp.), and sedges (*Carex* spp.). A great diversity of perennial and annual forbs were present in both upland and wet prairies. GLO surveyors occasionally described wet prairie as "camas prairie" because of the abundance of camas (*Camassia quamash* ssp. *maxima* and *Camassia leichtlinii* ssp. *suksdorfii*). Wet prairies along the Columbia River were dominated, at least in part, by extensive stands of *Carex aperta* (Howell 1897-1903, Piper and Beattie 1915, Gorman 1916-1917).

Both Native Americans and Euro-Americans used prairies intensively for habitation and food production, and this vegetation class has a long history of human influence. Important Native American food plants included bulbs of camas, brodiaea (*Brodiaea* spp., *Triteleia* spp.), and checker lily (*Fritillaria affi-*

nis), roots of biscuitroot (*Lomatium* spp.) and yampah (*Perideridia* spp.), and seeds of tarweed (*Madia* spp.) and balsamroot (*Balsamorhiza* spp) (Boyd 1999a; Storm and Shebitz 2006). GLO records and the 1850 census showed that over 90 percent of the population of settlers was concentrated in prairies (Bowen 1978). Though detailed habitat mapping of today's prairie remnants has not been performed for the entire study area, less than 4,047 ha of moderate- to high-quality upland prairie, and less than 2,024 ha of wet prairie, are estimated to remain in the Willamette Valley today—less than 2 percent of the former extent of these ecosystems (Alverson, unpublished data).

Upland Forest

Upland forest covered 355,635 ha, or 26.3% of the study area (Table 3), and was the second most extensive vegetation class in the valley. Trees were spaced up to 20 m apart, but usually less than half that distance (Table 1). Surveyors described stands as "timber," "heavy," "dense," or "thick," with a brushy or ferny understory.

Coniferous Forest—Nine subclasses of upland coniferous forest (Table 4) comprised 85% of upland forest vegetation, and formed the major vegetation cover in the northern portion of the valley and around the margins of the valley adjoining the Cascade Range and Coast Range. Stands of all ages and diameters were present, and were not dominated by large old-growth trees. Drier sites supported monotypic stands of Douglas-fir, or mixtures of Douglas-fir, incense cedar, ponderosa pine, chinquapin, and madrone. Mesic sites in the northern part of the valley and at higher elevations supported mixed conifer forest with various combinations of Douglas-fir, western hemlock, western red cedar, grand fir, bigleaf maple, dogwood, white oak, and red alder. Ten percent of the area occupied by all upland forest subclasses was described as having been recently burned, reflecting the widespread influence of fire in this ecosystem. Fires could have resulted from lightning, Native American burning, or burning by settlers (Morris 1934). Fire suppression has enabled forest vegetation to expand its extent in the valley dramatically since 1850 (Sprague and Hansen 1946).

Oak-Pine Forest—Seven subclasses of upland forest vegetation were dominated or co-dominated by white oak, black oak, or ponderosa pine (Table 4), covering 52,842 ha. Forests of oak and pine were uncommon on the valley floor and foothills, and occupied only 14.9% of the forested landscape of the study area. They bordered more widespread prairie, woodland, or savanna vegetation in topographic positions protected from frequent fire. Depending on site and fire history, forests dominated by oak and pine included various combinations of Douglas-fir, western red cedar, western hemlock, bigleaf maple, white oak, red alder, Oregon ash, and dogwood. Burned stands were infrequent, comprising only 1.8% of the total area occupied by pine or oak forest classes, presumably because fire evidence in this habitat was short-lived and seldom recorded by surveyors.

Savanna

The total area mapped as savanna was 245,742 ha, or 18.2% of the study area (Table 3). This was the third most extensive vegetation class in the valley. Day (2005) documented savannas with as few as 17 trees per ha. The understory was usually open, with grassy or herbaceous vegetation but few or no shrubs. Surveyors described savanna as "openings," "open," "scattering timber," "thinly" or "sparsely" timbered, and "barrens" on rare occasions. Grass or "ferns" were occasionally documented as part of the undergrowth, as well as descriptors such as "good grazing," "grass in abundance," or "good for stock." Savanna occupied an ecotone between prairie and woodland. Because low-intensity fires leave little direct evidence, it is difficult to demonstrate fire return intervals in savanna. Agee (1993) estimated an interval of 5-10 yr for these stands, but historical accounts indicate that portions of savannas could have burned annually (Boyd 1999a). However, surveyors did not record any burned savanna, presumably because fire evidence was short-lived and routine burning by Native Americans had ceased 10 or more years prior to the surveys. Savanna was distributed more abundantly in drier areas such as the valley floor, while woodland tended to occur in more mesic areas in the foothills. However, much of the woodland recorded by the GLO surveys may have developed from earlier savannas, given the general decrease in fire frequency after about 1700 (Walsh et al. 2010b), caused by precipitous declines in the Native American population. If true, savanna once may have occupied as much as 440,000 ha, covering 79 percent more area than what we have mapped. This scenario seems particularly likely in the northern valley, where woodland was more extensive than savanna at the time of the GLO surveys. Five subclasses of savanna (Table 4) contained either monotypic stands of white oak or Douglas-fir, or stands containing mixtures of Douglas-fir, white oak, and ponderosa pine. While most savanna (89%) was dominated by oak, half (53%) included conifers in the canopy. Surveyors consistently distinguished

California black oak from Oregon white oak. The black oak, occurring here at the northern limit of its range, was co-dominant in savanna and covered about 12,000 ha, but was always mixed with white oak. Coniferous savanna, primarily Douglas-fir, occupied only about 11% of the savanna system. Diameters of bearing trees were typically 41-61 cm but occasionally larger.

This vegetation class has a long history of human alteration. Savanna groves were favorite homesites for Euro-American settlers. In the absence of fire it has largely converted to forest except for areas continuously grazed by livestock since the 1840s (Agee 1993). Day (2005) estimated that less than 1 percent of historical savanna remains today, and no unaltered examples are known to have survived. The GLO record indicates that most surviving stands of what had been savanna in 1850 have converted to forest, and most of today's savanna-like stands were prairie in 1850, having converted to savanna after establishment of scattered trees. The composition of the original herb layer in savanna is a matter of speculation because so few historical records exist (e.g., Christy et al. 2009), but it may have been similar to upland prairie because some remnant stands of open oak woodland contain populations of native prairie species.

Woodland

Woodland covered 194,890 ha, or 14.4% of the study area (Table 3), and was the fourth most extensive vegetation class in the valley. Surveyors typically described stands as "thinly timbered" or "scattering timber." Woodland usually had a dense shrub layer, and typically occurred along the ecotone between prairie or savanna and upland forest, in foothills and along streams in the north-central portions of the valley. Stand density and a brushy understory suggest that burning was less frequent in woodland than in prairie or savanna, but more frequent than in closed forest. As noted previously, much of the woodland may have been savanna under an earlier Native American fire regime. Alternatively, some woodland could have been created by increased fire frequency in former closed forest. Seven subclasses of woodland (Table 4) contained a mix of species similar to those found in upland forests. White oak was abundant, occurring in more than 69% of mapped woodland. It occurred in some areas as monotypic stands with an understory of beaked hazelnut or oak brush, but more commonly various combinations of Douglas-fir, ponderosa pine, and bigleaf maple were also present. Douglas-fir was even more widespread than oak, occurring in 88% of mapped woodland. A dry-site Douglas-fir monotype occurred along with beaked hazelnut in the understory. A mesic type with Douglas-fir, red cedar, and western hemlock occurred on north-facing slopes and sheltered areas, with beaked hazelnut or vine maple dominating the understory. In some areas of woodland, surveyors used large old-growth Douglas-fir as witness trees. Burned stands were recorded in woodland, but the total area was only 1.2% of the total map unit, presumably because fire evidence in this habitat was short-lived and seldom recorded by surveyors.

Woodland has disappeared from the modern landscape because of invasion by conifers or conversion to forest in the absence of fire. No examples of unaltered woodland are known to have survived, but former occurrences are evident in forests containing a component of widely scattered old "wolf trees" bearing large side branches or branch stubs, surrounded by a dense younger cohort of trees that post-date Euro-American settlement.

Riparian and Wetland Forest

Riparian and wetland forest covered 97,477 ha, or 7.2% of the study area (Table 3), and was the fifth most extensive vegetation class in the valley. Ten subclasses of riparian or wetland forest (Table 4) occurred in bands of varying width along floodplains of larger streams and rivers, some extending up to 8 km wide along the Willamette River. Smaller wetland and riparian stands presumably also occurred within the matrix of upland forest, but these were not mapped because of the coarse scale of GLO data. Riparian and wetland forests were composed mostly of fire-intolerant deciduous trees and shrubs, sometimes in very dense stands. Early successional species such as willow, red alder, white alder, and black cottonwood typically occurred along active channels, with Oregon ash, bigleaf maple, and white oak occurring on higher terraces. The understory in many places was described as consisting of rose and "briars", the latter presumably *Rubus ursinus*. Black cottonwood was present in most riparian forests associated with larger rivers, but only a small percentage (<2%) of the riparian forest in the valley consisted of pure stands of this species. More typically it occurred mixed with other vegetation depending on fine scale successional history. Western red cedar, grand fir, and Douglas-fir were occasional on higher stream terraces, although red cedar was mostly confined to the northern valley. White oak and Oregon ash were important along many of the smaller streams where a narrow wooded riparian corridor was bounded by open prairie, but woody species sometimes were reduced to brush or sprouts because of fire. Stands along smaller streams were described as ash or ash and willow "swales." Low-gradient sites often contained ash, alder, and willow swamps with beaver dams that were subsequently drained and cleared for their coveted "beaverdam" soils.

Extensive areas of riparian forest have been lost to agricultural and urban development, and typically only a narrow band of forest remains along larger rivers where historical stands were much wider. Most of today's riparian forest is second-growth and has been degraded by a variety of non-native species such as reed canarygrass (*Phalaris arundinacea*) and Himalaya blackberry (*Rubus armeniacus*). The herb layer of higher forested terraces of floodplains is especially rich, but the GLO data provide little information about these plants.

Water

Water covered 26,168 ha, or 1.9% of the study area, including the Willamette and Columbia rivers (Table 3). No subclasses were mapped. Water included any mappable features wider than 20 m (1 chain), and included rivers, sloughs, ponds, beaver ponds, lakes, "marshy lakes," and "bayous." Sloughs and bayous occurred mostly in the floodplains of the largest rivers, following abandoned channels and old oxbows. Much of this open water habitat has now disappeared because of channelization of the river, loss of off-channel habitat, and urban and agricultural fills (Sedell and Froggatt 1984, Benner and Sedell 1997).

Shrubland

Mappable shrubland covered 5,216 ha, less than 0.4% of the study area (Table 3). Nine subclasses included both upland and wetland shrub types and one burn facies (Table 4). Upland stands most likely originated after forest fires, while those in wetlands were generally too wet to support trees. Some shrublands were identified as monotypic stands of manzanita, rose, Douglas spiraea, vine maple, willow, or beaked hazelnut. Many stands were simply described as "brush," "swamp," or "thicket," but their species composition could be inferred from topography, soils, and descriptions of adjacent vegetation.

Emergent Wetlands, Excluding Wet Prairie

Emergent wetlands covered 3,592 ha, or just under 0.3% of the study area (Table 3). The composition of emergent wetlands usually was not described by surveyors because they were not required to record herbs or graminoids. Most were simply recorded as "marsh" or "swamp." Eight subclasses (Table 4) were based on vegetative components when known, or differences in descriptors used by the surveyors. Swamps were typically associated with smaller streams, and many contained beaver dams. Larger marshes and associated seasonal waterbodies such as Lake Labish, Lousignont Lake, and Wapato Lake were usually delineated on GLO plat maps and products developed from the plat maps (e.g., Trutch and Hyde 1856). Wapato (*Sagittaria latifolia*), skunk cabbage (*Lysichiton americanum*), pond lily (*Nuphar lutea* ssp. *polysepala*), rushes (*Juncus* spp.), and "coarse grass" (probably sedges) were recorded occasionally in such sites.

All larger historical emergent wetlands have been drained and converted for agricultural use. Early botanical publications and voucher specimens from sites such as Lake Labish indicate that these wetlands were important contributors to the native biodiversity of the Willamette Valley (Nelson 1918).

Unvegetated (Except Water)

Unvegetated areas, amounting to only 375 ha, were concentrated in mountainous areas and along major rivers (Table 3). Three subclasses included gravel bars, sand bars, rock outcrops, talus, exposed bedrock, scree slopes, and unvegetated or sparsely-vegetated landslides (Table 4).

Herbaceous Upland

Only 94 ha of herbaceous upland, or 0.01% of the study area, were mapped within the study area (Table 3), but more occurred in adjacent ecoregions. This class was occasional in openings within forest, woodland, or savanna. It included, "fern openings," "fern land," or "open fern hills," and sometimes contained beaked hazelnut. It was mapped only when the openings had distinct entry and exit points along survey lines. Similar habitats may have occurred more extensively in openings within polygons mapped as woodland. The ferns noted by surveyors may have included both sword fern (*Polystichum munitum*) and bracken fern (*Pteridium aquilinum* var. *pubescens*), though the latter is more often associated with open habitats that are relatively persistent on the landscape. References to dense or tall stands of fern probably refer to bracken, as this species was a widespread and important resource managed with fire by Native Americans (Storm and Shebitz 2006).

Discussion

Patterns of Vegetation

The pattern of vegetation recorded in the GLO surveys reflects the influences of topography, geomorphology, climate, and millennia of Native American land management practices (Figure 1). In contrast to other areas of the state, GLO notes for the Willamette Valley contained virtually no references to its original inhabitants other than "Indian trails." Most physical traces of aboriginal occupation had disappeared by 1851 except for the legacy of vegetation types that they had influenced with fire.

The Willamette valley was a complex mix of different vegetation types in various patch sizes. Within most townships, three or more of the major vegetation classes were represented, in contrast to adjacent ecoregions (Cascade Range, Coast Range, and portions of the Puget Trough) where coniferous forests were the dominant natural vegetation. Prairie, savanna, and woodland or forest vegetation with an oak component together formed the majority of vegetation in the valley, covering nearly 64% of the study area. Prairie and savanna dominated the southern and central valley, with woodland and forest occurring as small to large patches usually peripheral to prairie and savanna. In contrast, forest and woodland were more abundant in the northern portion of the valley, and prairie and savanna occupied a much smaller area. Mesic conifer forest that included western red cedar and western hemlock occupied only 14.7% of the study area. Varied topography in the northern valley favored more mesic conifer forest and woodland, perhaps coupled with a less intense fire regime or a longer period of abandonment by Native Americans.

Temporal Stability of Vegetation

Because the survey notes describe conditions only at the time of survey, and are colored by the personal interpretations of the original surveyors and modern-day researchers, they offer only a snapshot in time and nothing more (Noss 1985, Whitlock and Knox 2002). Vegetation patterns change over time under the influences of climate, succession, and disturbance regimes. However, it appears that the array of vegetation types in the Willamette Valley has remained relatively consistent over the last 3,000-6,000 years (Agee 1993, Boyd 1999a). This period is distinguished by widespread establishment of Oregon ash, an increase in charcoal and occupation by Native Americans, and an assemblage of other pollen taxa not dissimilar to today's flora (Barnosky 1985; Worona and Whitlock 1995; Walsh 2008; Walsh et al. 2010a, 2010b). Given the relative stability of vegetation types in the Willamette Valley over this period of time, our mapping is consistent with similar estimates of vegetation stability based on the GLO record from the upper midwestern United States (Noss 1985, Schulte and Mladenoff 2001). We know from research on rare native biota and plant associations that today's landscape does not function adequately to support ecosystems and native biota that existed prior to 1850, because of habitat fragmentation, loss of essential ecosystem processes, and presence of exotic species (Alverson 2005). Clearly it will never be possible to return to the pre-1850s Willamette Valley landscape, but knowing the historical composition of that landscape is a key step in planning restoration and best management practices to conserve biodiversity.

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