Using General Land Office Survey Notes to Characterize Historical Vegetation Conditions for the Umatilla National Forest

David C. Powell
Forest Silviculturist

Umatilla National Forest
2517 SW Hailey Avenue
Pendleton, OR 97801

FEBRUARY 2008

INTRODUCTION. The original public land survey for the Umatilla National Forest was completed primarily between 1879 and 1887. Notes and other records (such as planimetric maps) from these General Land Office (GLO) surveys provide the earliest systematically recorded information about species composition for national forest system lands in the Blue Mountains of northeastern Oregon and southeastern Washington.

The survey notes contain comments about vegetation and other conditions (recently burned areas, Indian trails and wagon roads, rivers and streams, etc.) encountered along each of the survey (section) lines. Tree species and size, along with distance and direction to the corner, were provided for up to four bearing trees at each section corner (fig. 1). If bearing trees were not available, the surveyors selected a non-tree reference monument.

Notes from the public land surveys (PLS) provide valuable information for an era predating widespread settlement by Euro-American emigrants. The fact that the PLS predates settlement is no accident because land surveys were a prerequisite before public lands could be conveyed into private ownership via homestead acts. The references section provides literature describing the general land office survey notes and their ecological uses.

Although GLO survey notes are used extensively in the Lake States region of this country, particularly for Michigan and Minnesota (see literature section), they receive relatively limited use in the interior Pacific Northwest where analysts are generally unfamiliar with their possibilities. This document describes how GLO survey notes were interpreted and analyzed for the Umatilla National Forest.

BACKGROUND. In January 1993, Don Wood, forest silviculturist for the Ochoco National Forest, prepared a short review of a GLO survey-note project and presented it at a silviculture business meeting in Portland, Oregon (Wood 1993). Don described how information from GLO notes was used to estimate presettlement vegetation conditions and to serve as a validation data source for their Viable Ecosystems Management process and guidebook (Simpson et al. 1994).

As a result of Don's presentation at the silviculture meeting, I recognized that GLO survey notes could serve as a scientifically credible data source for characterizing presettlement vegetation conditions; for the interior Pacific Northwest, the presettlement era is generally defined as the mid to late 1800s (USDA Forest Service 1996).

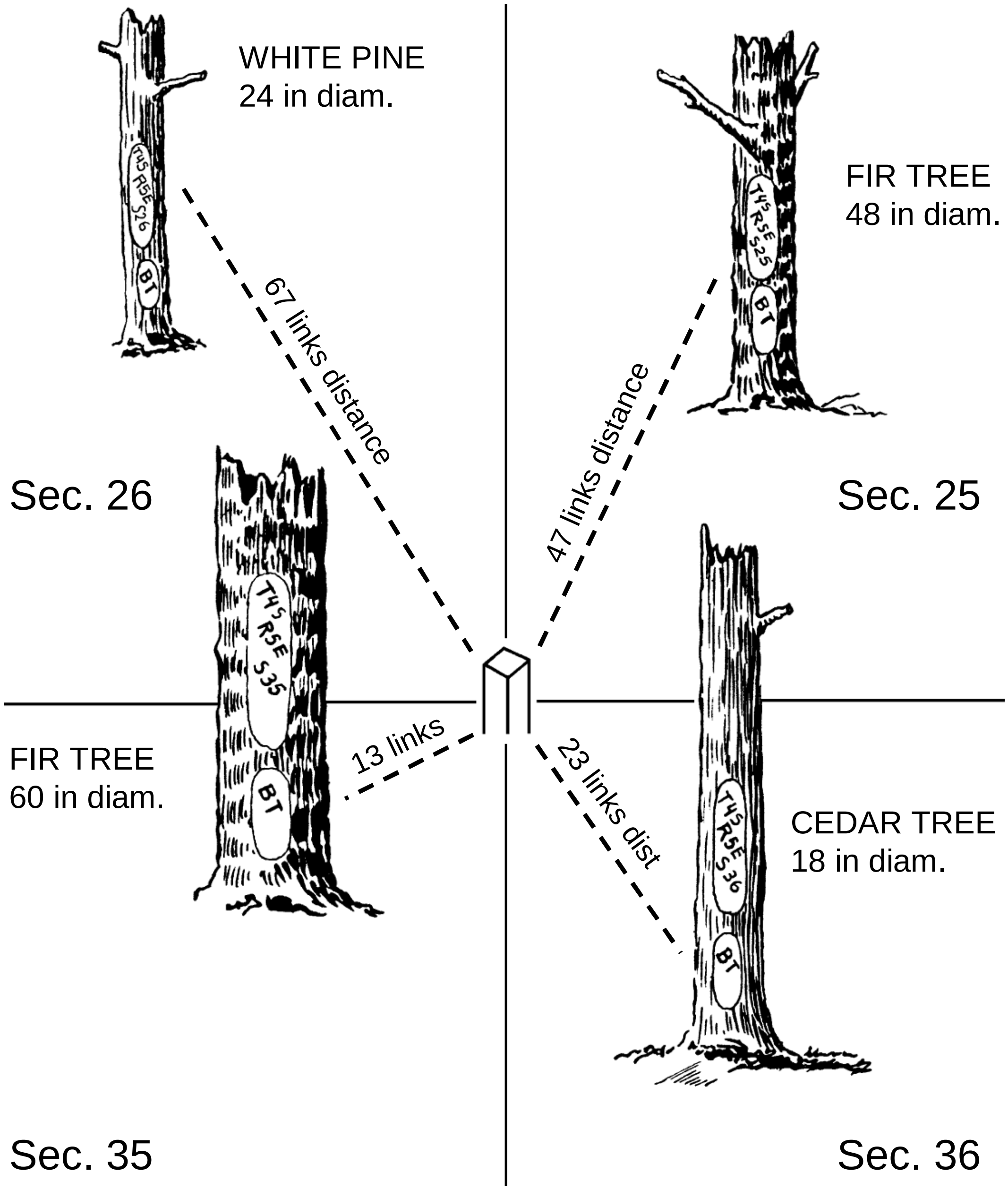


Figure 1–Schematic of a section corner, showing four bearing trees and their characteristics (species, diameter, and distance from corner expressed in links). This diagram shows a section corner post (in the center and greatly enlarged to show its location) and four bearing trees, each of which is designated as such (BT) on the lowermost blaze on the stem. The upper blaze on each bearing tree provides the pertinent public land survey information (township number, range number, section number) for the section in which it occurs. As shown in this diagram, each corner post is adjoined by four individual sections. Since section lines were surveyed using true north-south and east-west cardinal directions, each section forms a 90° quadrant around the corner post. This diagram shows all four quadrants occupied with a bearing tree; note that not all quadrants have a bearing tree because a land surveyor was not required to designate one if an acceptable tree could not be located within 300 links (198 feet) of the corner post (also see fig. 3).

Other data sources for characterizing presettlement conditions are scarce. Aerial photographs were not available until the late 1930s, and although diaries from Oregon Trail settlers (Evans 1991) and early scientists such as Captain John C. Fremont, Henry Gannett, and Thornton T. Munger are useful sources (Gannett 1902, Jackson and Spence 1970, Munger 1917), they often contain inherent biases (Forman and Russell 1983) and are seldom comprehensive in terms of their geographical scope.

BRIEF DESCRIPTION OF THE PUBLIC LAND SURVEY. The public land survey followed a consistent and standardized process when it was used to subdivide lands in the western United States. First, an initial starting point was selected. For the states of Oregon and Washington, this starting point is located a short distance west of the city of Portland, Oregon.

A true north and south line was surveyed through the starting point, which became the principal meridian to which all other north and south subdivision lines are oriented. It is called the Willamette Meridian. At approximately six mile intervals on both sides of the Willamette Meridian, secondary north and south lines were surveyed parallel to the principal meridian.

The secondary north and south lines are called range lines. The six-mile wide areas between the range lines are called ranges and are designated numerically both east and west of the principal meridian – Range 1 East, Range 1 West, Range 2 East, Range 2 West, and so forth.

A true east and west line was surveyed through the initial starting point and this became the principal base line to which all other east and west lines are oriented. It is called the Willamette Base Line. At approximately six mile intervals on both sides of the base line, secondary east and west lines were surveyed parallel to the base line.

The secondary east and west lines are called township lines. The six-mile wide areas between these lines are called townships and are designated numerically both north and south of the principal base line – Township 1 North, Township 1 South, Township 2 North, Township 2 South, and so forth.

This process of establishing township and range lines resulted in the landscape being divided into grid cells measuring 6 × 6 miles (36 square miles per cell). The area within each individual six-mile-on-a-side cell is called a township.

A full township was then subdivided into grid cells measuring 1 × 1 mile. The area within each individual one-mile-on-a-side cell is called a section.

Townships having fewer than 36 sections frequently occur, and this is due to error in early-day surveys, to the presence of large bodies of water, to the joining of adjacent surveys where different principal meridians or base lines were used, or for other reasons.

Due to surveying corrections made for convergence of meridian lines or to compensate for errors in surveying, some townships with the normal number of sections cover more or less than 36 square miles of area, resulting in one or two outside tiers of sections being oversized or undersized. In the Pacific Northwest region of the country, the oversized or undersized sections are usually the north and west tiers of sections (a tier is a strip of six sections).

When a township was surveyed by the General Land Office, the work was typically performed under contract. Surveys were completed using two contracts – one for the township exterior lines and another for the subdivisions establishing section lines within a township.

Township lines were surveyed first and then later subdivided into sections. Although there was typically little time separating the two surveys, it was not unusual for the exterior and subdivision surveys to be completed in different years and by different surveyors.

Surveyors set a post at each section corner (at 1-mile intervals) and at each quarter-section corner (at ½-mile intervals). This means that a quarter-section corner (typically referred to as quarter corners) is located midway between each section corner (fig. 2).

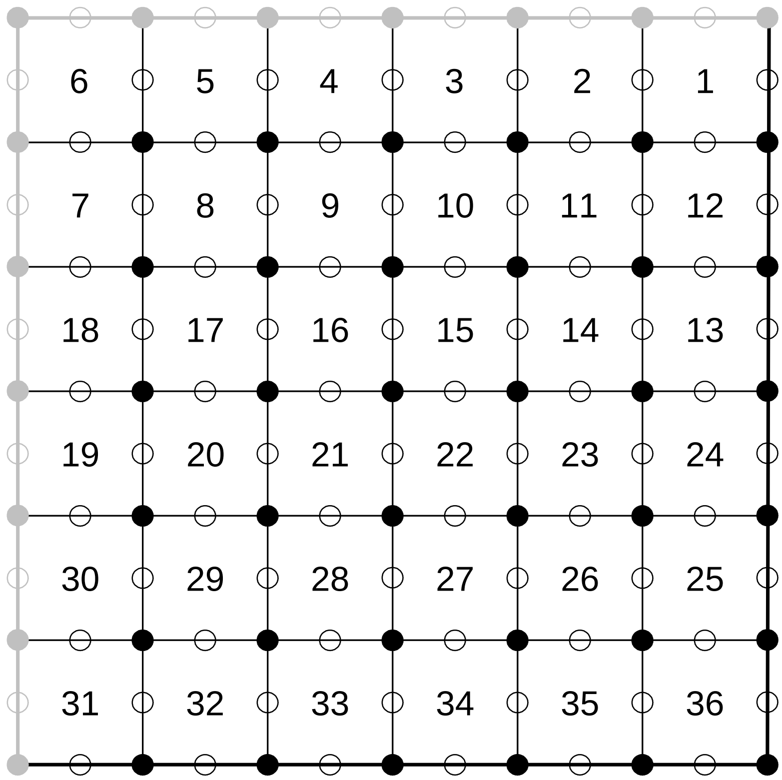


Figure 2–Schematic of a square 6 × 6 mile township, showing section corners (the filled circles), quarter-corners located midway between each section corner (the open circles), and the geometric pattern created by grid cells occurring on a 1 × 1 mile spacing. Each numbered grid cell is referred to as a section, and the 36 sections in a standard township are numbered using the sinuous scheme shown here. Note that the west and north township lines are shown in a gray color to connote that the exterior township lines are shared with adjacent townships; all four township lines are shown with thicker lines to separate them from interior section lines. Township lines also function as section lines, so they have section corners and quarter corners established along them. Each section corner and quarter-corner spatial location was assigned a unique identification (ID) number in a GLO analysis theme created in the Forest's GIS. The ID number was stored in the GLO survey notes database for each data record corresponding to a particular corner or quarter-corner. Corners (the filled circles) had up to 4 bearing trees recorded; quarter-corners (the open circles) had up to 2 bearing trees. See the "Compiling a GLO Survey Notes Database" section later in this document for more information about the ID numbers and how they were used when deriving a GLO-based map for the Umatilla National Forest.

INTERPRETING THE GLO SURVEY NOTES. Critical to any interpretation of GLO data is an understanding of how surveyors selected bearing trees (Bourdo 1956, Grimm 1984, Nelson 1997).[1]

Because the primary purpose of bearing trees was to simplify the relocation of posts, proximity to corners and quarter-corners was an important consideration for bearing tree selection. However, words such as "adjacent" and "nearly" in the surveying instructions should not be construed as implying that bearing trees were always the closest individuals to a corner.

Other criteria for bearing tree selection included tree size, vigor, and conspicuousness in the stand. The blaze made upon bearing trees had to be of sufficient size to inscribe the section, township, and range numbers (fig. 1) and, as such, GLO surveyors often preferred medium size trees that generally ranged between 10 and 14 inches (Nelson 1997).

GLO survey instructions often included phrases such as this: "You will select for bearing trees those which are the soundest and most thrifty in appearance, and of the size and kinds of trees experience teaches will be the most permanent and lasting" (Habeck 1994, Nelson 1997). Due to the importance of this criterion, a guide was produced dealing exclusively with the durability of bearing trees (White, Date unknown).

Some investigators have noted occasional surveyor bias in the selection of bearing trees. When White (1976) was working with GLO data for western Montana, he detected surveyor bias against both small-diameter and large-diameter trees, and this bias is understandable given the tree selection criteria: small trees were not viewed as meeting the permanency standard (perhaps they were too ephemeral to survive fire and other disturbances) and large trees did not fit the longevity standard (because large trees were perceived to be old and expected to die soon).

Many different land surveyors were involved in establishing the General Land Office survey system across the Umatilla National Forest. These surveyors are listed in table 1. At this point, not enough analysis of the Umatilla NF GLO survey notes has occurred to indicate whether any particular surveyor-based bias might exist in the data.

Table 1: Frequency of GLO surveys by surveyor name.

GLO Surveyors	Frequency	Percent
unknown surveyor	2	1%
A. H. Simmons	2	1%
Aaron F. York	8	3%
Alfred A. Morrill	2	1%
Alonzo Gesner	5	2%
Banford Robb & Hermon Gradon	4	1%
Charles L. Campbell	6	2%
Daniel P. Thompson & Daniel Chaplin	1	0%
David P. Thompson	1	0%
Dudley S.B. & John D. Henry	2	1%
E. A. Thatcher	1	0%
Edson D. Briggs	2	1%

[1] Some GLO sources refer to trees identified at the section corner as witness trees, trees falling on the section line as line trees, and trees identified at the quarter-corners (midway between section corners) as bearing trees. To avoid confusion, this document will generally refer to all these trees as bearing trees.

GLO Surveyors	Frequency	Percent
Edward B. Dobbs	1	0%
Edward W. Sanderson	18	6%
Edwin S. Clark	4	1%
Eugene P. McCormack	4	1%
Everett A. Thatcher	2	1%
Francis Loehr	5	2%
Frank W. Campbell	35	11%
George R. Campbell	1	0%
George S. Pershin	28	9%
George Williams	2	1%
Henry Meldrum	10	3%
Herman D. Gradon	32	10%
Jacob C. Cooper	8	3%
James E. Noland	1	0%
James P. Currin	2	1%
James P. Currin & James E. Noland	9	3%
John A. Hurlburt	1	0%
John G. Collins & Clyde N. Carey	4	1%
John W. Kimbrell	5	2%
Lew A. Wilson	2	1%
Loehr & Knowlton	2	1%
Manius Buchanan	3	1%
Mark A. Fullerton	1	0%
Otis O. Gould	13	4%
Robert A. Farmer	2	1%
Robert F. Omeg	3	1%
Roy T. Campbell	21	7%
Rufus S. Moore	29	9%
Sewall Fruax? Fruix?	5	2%
Timothy W. Davenport	2	1%
W. B. Barr	3	1%
Walter D. Long	5	2%
William E. and George R. Campbell	4	1%
William E. Campbell	2	1%
William H. Odell	5	2%
William M. Bushey	2	1%
William R. Gradon	2	1%
William T. Evans	2	1%
Z. F. Moody	3	1%
Total	319	100%

Sources/Notes: Accounting for year of survey was based on the original worksheet for a township (which lists the surveyor's name, year of survey, and the township and range that the survey covered). Each instance of either an exterior or subdivision survey was tallied. For example, if Simmons completed both surveys for a township (exterior and subdivisions), then they were tallied as 2 surveys even if both were done under the same contract.

BEARING TREES. The surveyor was required to establish on-the-ground references to each section and quarter corner. In forested lands, nearby trees were selected and blazed as bearing trees to identify corners. They were called bearing trees because the surveyor was required to take a compass bearing between the corner post and the center of the bearing tree. Bearing trees were used to help recover a corner after its post was lost, decayed, or destroyed (fig. 3).

When sufficient trees were available, section corners were referenced by four bearing trees and quarter corners by two bearing trees. According to the survey manual used as a standard reference after 1855, a surveyor was required to establish bearing trees using these rules:

- For all section corners, four bearing trees were required to be established, one in each quadrant adjacent to the corner post;
- For all quarter corners, two bearing trees were required to be established, one in each section on either side of the corner;
- Bearing trees needed to be within 300 links[2] (198 feet or 60 m) of the corner (Habeck 1994), and there was no requirement to establish a bearing tree if none was available within that distance; and
- A bearing tree was supposed to have a minimum diameter of 2½ inches.

The following information was required for each bearing tree:

- Species (local common name);
- Diameter, ostensibly as a diameter at breast height, but GLO data analyses indicate that diameter might have been estimated near the tree base (see White 1976 and Habeck 1994); tree diameter was probably just a visual estimate rather than an actual measurement;
- Compass bearing from the corner post; and
- Distance from corner to center of the tree (no documentation if this was slope or horizontal distance, but it is assumed to be uncorrected slope distance).

In addition to bearing-tree information, surveyors recorded the common names and diameters of line trees used to mark the section line between section corners (but no distances from the line were recorded for these trees).

At each section corner, the surveyor noted the type of terrain, soil, undergrowth vegetation, timber, agricultural potential, and any unusual features. Surveyors also recorded major vegetation changes along section lines (such as when entering and leaving wetlands, recently burned areas, and clearings).

As section lines were traversed, surveyors made note of the line entering or leaving forest cover with phrases such as “heavily timbered,” “heavy open timber,” or “scattering timber.” GLO analyses indicate that when surveyors used words such as heavy, they may have had a different connotation than what we would give them today. In GLO usage, heavy was apparently used to note the presence of large-sized trees rather than a dense or heavy-stocking condition (Habeck 1994).

[2] A link is one-hundredth of a chain and since a chain is 66 feet, then one link is .66 feet (i.e., there are 100 links per chain).

Figure 3–A quaking aspen designated as a bearing tree. A General Land Office surveyor was required to designate one tree in each of four 90° quadrants around a section corner as bearing trees (unless no trees were available within 3 chains, in which case the quadrant would not have a bearing tree). Selection of bearing trees was directed by contract requirements relating to tree size and tree durability; it was unusual for an aspen to be selected unless no other suitable species were available because aspen was not viewed as a “durable” tree species.

After 1850, survey instructions explicitly required that incidences of certain disturbance processes such as windthrow and fire be recorded in the survey notes, along with certain natural phenomena such as river and stream widths.

This requirement allows GLO survey notes to be used, with some confidence, for analyzing a wide variety of ecosystem characteristics (Bourdo 1956, Schulte and Mladenoff 2001):

- Presettlement river widths (Beckham 1995a, b);
- Presettlement fire location and size (Batek et al. 1999, Grimm 1984, Maclean and Cleland 2003, Zhang et al. 1999);
- Presettlement windthrow patterns (Canham and Loucks 1984, Schulte and Mladenoff 2005);
- Presettlement vegetation composition and structure (Abrams and McCay 1996; Abrams and Ruffner 1995; Bragg 2002; Brown 1998; Comer et al. 1995; Cornett 1994; Galatowitsch 1990; Gordon 1969; Habeck 1961, 1962, 1964; Leitner et al. 1991; Nelson 1997; Radeloff et al.

1998, 1999; Schulte et al. 2002; Stearns 1949; Teensma et al. 1991; White 1976; White and Mladenoff 1994).

COMPILING A GLO SURVEY NOTES DATABASE. In November 1995, Martha King and I met with Gean Davidson, a volunteer who was interpreting the GLO survey notes for both the Deschutes and Ochoco National Forests. Gean provided examples of their database structure and some GLO-derived maps produced for the Metolius watershed analysis, Deschutes National Forest.

After meeting with Gean Davidson and reviewing her GLO examples for the Ochoco and Deschutes national forests, we decided to interpret GLO survey notes for the Umatilla National Forest, starting with the Umatilla-Meacham watershed analysis.

After discussing analysis objectives and potential uses of the GLO data, we decided to record more information from the notes than the Ochoco and Deschutes national forests had done. We believed that the additional information would make the GLO data more useful for a wider variety of resource specialists.

Funding was obtained from traditional sources and after Gean Davidson and the Forest's land surveyor (Dennis Gaylord) provided training, Martha King began interpreting GLO survey notes during the winter of 1995-1996.

The first step was to determine which quadrangle maps occurred within the Umatilla-Meacham watershed; full-sized paper copies were made of these quads. We then consulted with a geographical information system (GIS) specialist (Mike Hines) to discuss the objectives and potential uses for GLO data.

After considering examples from other national forests, Mike created a GIS theme assigning unique ID numbers for each section corner, and for the midpoint of each section line, occurring within the Umatilla National Forest administrative boundary (see fig. 2). The ID numbers provide a link between the database records and the geographical coordinates of their corresponding nodes (section corners) or line segments (section lines).

The next task was to acquire hard copies of the GLO survey notes. Dennis Gaylord, land surveyor for the Umatilla National Forest (now retired), maintained these notes on microfiche. Dennis explained procedures that the GLO land surveyors were supposed to follow; he described how the microfiche files were organized; and he served as a technical advisor throughout the GLO notes project (at least until his retirement).

Paper copies of the microfiche files for all townships within the Umatilla National Forest boundary were then made using the office's microfiche reader and copier. At this point, Martha began interpreting and summarizing the survey notes and entering the information into a non-normalized Paradox database (single-record or flat-file format). This initial interpretation was for the Umatilla/Meacham watershed analysis area.

After finishing Umatilla/Meacham, the GLO work progressed to the next analysis area: Desolation watershed. After that was the Tower wildfire area, followed by the Middle Grande Ronde subbasin. After completing the Middle Grande Ronde database, we decided to quit interpreting for individual analysis areas, and to begin a systematic process for interpreting the GLO notes for the entire Umatilla National Forest.

The Umatilla National Forest has approximately 1.4 million acres included on 95 primary base series quadrangle maps (1:24,000 scale). The GIS theme was used to print paper copies of all 95 quad maps showing ID numbers for corner nodes and section lines. An accordion-style, legal-size folder was then prepared for each of 120 townships occurring on the Forest. These folders, which contain printed copies of the notes, are stored in a 5-drawer file cabinet located at the FS warehouse and shop compound on Byers Avenue in Pendleton, Oregon.

Processing the microfiche copies of the survey notes and plotting out the GIS maps required between one and two months time. Producing paper copies of the notes (from microfiche) required several toner cartridges and many reams of paper.

Reading and interpreting the survey notes was the most time consuming part of the process, requiring over 100, 8-hour workdays for approximately 120 townships. The notes for some townships were relatively easy to process and took, on average, a day to finish; others took longer. Some notes were typed up while others were handwritten. It was found that paper printouts from microfiche records could be hard to read.

Since some surveyors included more information in their notes than others, it took more time to process townships with longer notes. A few townships were actually surveyed in a different pattern and order than they were supposed to be, so these notes also took longer to process.

For some townships, only a quarter or a half of them contained national forest system (NFS) lands and, in some instances, GLO information was interpreted for the NFS portions only. Generally, however, an entire township was entered into the database even if it contained a relatively small portion of NFS lands. Based on our experience, a reasonable time estimate for the transcription portion of the process is to allow one full workday per full township.

Finally, printing out a hard copy of the GLO database and checking it for inconsistencies and errors, while paying particular attention that the correct legal description was matched to the correct ID number (from the GIS theme), required several days for a large analysis area such as the Umatilla National Forest.

It is important that the interpreter understand the basic survey process, and how the GLO survey notes are filed and organized. For example, it is common to have multiple surveys available for the same area, with some of the surveys taking place after 1930. We also found that it is not necessary to copy everything on the fiche files; the microfiche notes should be reviewed before printing them.

DERIVING THE GLO VEGETATION MAPS. The previous section described how GLO survey notes for the Umatilla National Forest were located, copied, and then interpreted to create a GLO survey notes database. Appendix A provides a short description for each field in the GLO database.

Because each record in the GLO survey notes database corresponds to a unique spatial location (the ID number assigned to each section corner and quarter-corner; see fig. 2), a GLO data set can be easily imported into a GIS as a point coverage. These data points can then be plotted to provide a quick visual estimate of species distribution patterns (and this is often how GLO data was being used on the Deschutes and Ochoco national forests in the mid to late 1990s).

A point coverage, however, is often inappropriate for describing the distribution of a continuously varying landscape feature such as vegetation, so more relevant data forms (such as grid (raster) or polygon coverages) are generally viewed as desirable. To derive either of the non-point data forms, some form of spatial interpolation is required, which often involves sophisticated and complex analytical techniques such as kriging or cokriging (Chang 2002).[3]

After compiling the GLO survey notes database and checking it for errors, the GLO data was provided to a contractor (Titan Corporation) for additional analysis, including spatial interpolation. Titan Corporation then subcontracted with the Oregon Natural Heritage Information Center (ONHIC), an organization affiliated with The Nature Conservancy, because they had previous experience analyzing GLO data by using a spatial interpolation methodology (see appendix B).

ONHIC performed a wide array of sophisticated and complicated spatial analyses such as cokriging and maximum entropy modeling to produce a map depicting historical vegetation conditions for the Umatilla National Forest. Map units consist of ecological systems, a classification framework developed by a non-profit organization called NatureServe (Comer et al. 2003).

"Ecological systems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding" (Comer et al. 2003). The Umatilla National Forest GLO vegetation map includes 15 different ecological systems, and they are described in a separate document because their descriptions are too lengthy to include here. Appendix C describes how to access the ecological systems document.

The Umatilla GLO map is available in two forms: as a GIS theme in grid format that is usable with ArcMap software, and as a color PDF file that can be printed like a small poster (17" × 22" format; see figure 13 in appendix B).

To what timeframe does the Umatilla GLO map refer? For the color PDF version of the GLO map, a time period of 1879 to 1887 is shown in the annotations because approximately 62% of the original GLO surveys occurred during this 9-year period (table 2).

Appendix B, which is based on metadata materials supplied by ONHIC, describes how ONHIC prepared the Umatilla's GLO map. Titan Corporation also produced a poster (34" × 44" format) providing an abbreviated summary of the map preparation process described in appendix B; the poster is available from the History website along with other GLO materials.

As described in appendix B, the tree species occurring at section corners or quarter-corners were analyzed individually (by species) during the cokriging and maximum entropy phases of the map preparation process. This process generated maps for 18 individual tree and shrub species; these species maps are available from the GLO section of the Forest's history website (but only as color PDF files in 8½" × 11" format; no GIS format is available for the tree species maps).

[3] Kriging, a spatial interpolation technique, assumes that the spatial variation of an attribute is neither totally random nor deterministic. Cokriging uses one or more secondary variables, which are correlated with the primary variable of interest, during the interpolation process. Landform position or other variables derived from a digital elevation model, for example, can be used during cokriging to help limit the distribution of riparian vegetation types to valley bottoms (Chang 2002).

Table 2: Frequency of GLO surveys by year of survey.

Year of Survey	Frequency	Percent
1863	2	1%
1864	2	1%
1866	5	2%
1871	4	2%
1872	3	1%
1873	5	2%
1874	1	0%
1876	2	0%
1877	6	2%
1878	2	1%
1879	21	6%
1880	13	5%
1881	46	16%
1882	47	15%
1883	16	6%
1884	35	10%
1885	3	1%
1887	10	3%
1889	4	1%
1891	2	0%
1895	3	1%
1897	1	0%
1898	2	0%
1899	8	3%
1900	2	0%
1901	5	1%
1903	2	0%
1904	3	1%
1905	2	0%
1907	2	1%
1910	2	0%
1915	4	1%
1931	9	2%
1932	6	2%
1933	4	1%
1934	2	0%
1935	2	0%
1881-82	1	0%
1882-83	3	1%
1884-85	2	1%
1901-02	2	0%
1902-03	3	1%
1909-10	1	0%
1920-21	2	0%
1931-32	2	0%

Year of Survey	Frequency	Percent
1931-33	5	1%
1932-1935	4	1%
1932-33	4	1%
1933-34	2	0%
Total	319	100%

Sources/Notes: Year of survey was based on the worksheet for a township (listing surveyor's name, survey year, and township/range covered by survey). Each instance of an exterior or subdivision survey was tallied. If a township had both surveys in the same year, it would be tallied as 2 even if completed under the same contract. Surveys started in one year but not finished until the next are listed separately.

APPENDIX A

Description of Database Fields

Survey Year: This is the year a survey was completed, not the year a contract was signed. This date is recorded on the contract page, listed as “date survey started” and “date survey completed.” The date a survey was signed (by the head surveyor) is sometimes the same as one of these, but not always.

Some surveys were started in one year but not finished until the following year due to weather, fire or for other reasons. When this occurred, both years were recorded in the master list. The master database contains the recorded survey year for each subdivision of the township.

Quad: This is the number of the primary base series quadrangle map.

TRSD: This refers to the Township, Range, Section and Description of the type of survey. For example, 01N3506E means it is Township 01N, Range 35 East, Section 06, and East Node (midpoint of the East line of Section 01). The survey notes for T01N, R35E, Section 06, for the North Line boundary would be referenced as 01N3506NL.

Nontree Ref: A non-tree reference point was used when there weren’t any trees at all, or when trees were not close enough to use as bearing trees, either at the corner of a section or at the mid-point of a line survey.

Spec# / Diam# / Dist#: The species, diameter of the tree, and the distance from the corner or mid-point of the line for the bearing trees. Section corners could have up to four trees, and mid-lines could have two (one tree in each section adjoining the line).

Line#Spec and Line#Diam: The species and diameter of any tree found along the section line or exterior boundary line during the survey.

Creek# and Creek# Size and Creek# Course: A river, stream, creek, branch or ditch found along a survey line would be referenced with a description and name if it was known, the size of the feature and the direction it was flowing.

Cult Imp#: Any other feature (cultural improvement) noted along the survey line by the surveyor is listed here. We included only four columns in an attempt to keep the database from getting too large. If there were more items, they were listed in the comment field. Cultural improvements include railroads, Indian trails, wagon roads, stock trails, homesteads, burns and others.

Timber Density and Timb Spec#: At the end of the paragraph for each section, there is an accounting of any timber species seen along the survey route. The surveyors often make note of the overall density of the timber found (such as dense, heavy or scattered).

Soil Type A-B: At the end of each section paragraph, the surveyor makes note of the soil types, referencing them as #1-4. They might also use a descriptive term such as rocky or loamy.

Undergrow#: At the end of the section paragraph, the surveyor lists the different species of shrubs noted along the survey line. Some surveyors were more descriptive than others, and referenced up to 24 different types of plants observed.

Node and Line: The node is a unique GIS-created number identifying each section corner and the mid-point of each section line. A node is a point coordinate referencing a section corner or the mid-point of a section line usually located at 40 chains. The line is also a unique GIS-based number used to identify each section line across the forest.

Each node and line ID number is linked to a TRSD identifier in the database. There is a GIS map showing the node and line ID numbers for each section in the analysis area. Note that all of the node/line GIS maps are currently hanging in a map case at the Supervisor's Office.

Comments: This field was used for listing any additional tree species found along the survey lines, for other cultural improvements, for other water features and for any extra undergrowth species not included in another field.

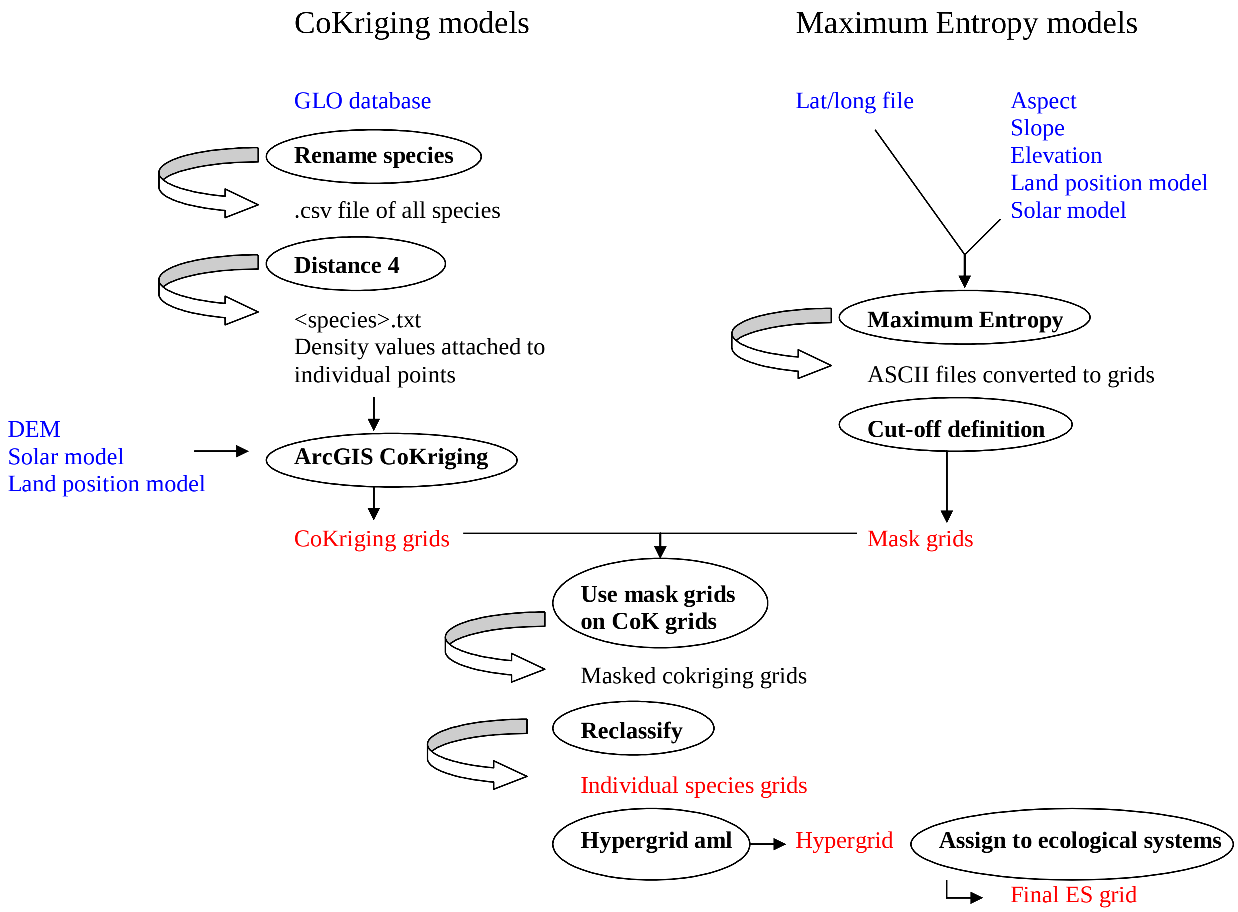
At the end of each survey, there was usually a General Description paragraph providing summary information from the surveyor. This general description was reviewed for interesting information that could then be included in the comments field.

APPENDIX B

GLO Umatilla Models[4]

Summary

Using tree data from the Umatilla GLO survey, two types of grids were generated on a species-by-species basis: a CoKriging model based on density values, and a Maximum Entropy model used as a mask to limit the distribution of the CoKriging grids. The final species grids were combined into a "hypergrid" and the unique combinations of tree species were reclassified into ecological systems. This diagram summarizes the analysis process in a flow-chart format (red text shows intermediate steps):



1. Data preparation

A frequency was run in the CornerTrees table of the GLO database to list the different species; this list was crosswalked to current tree names by vegetation specialists (Jimmy Kagan and John Christy) as follows (species count in parentheses):

ALDER: Mountain alder (63)
ALPINE FIR: Subalpine fir (4)
B--RBERY: Bearberry (1)

[4] The information in this appendix, dated February 2005, was provided by the Oregon Natural Heritage Information Center as metadata to Titan Corporation (Geospatial Services Division) during completion of task order 1 for contract 53-84N8-0-001 between the USDA Forest Service and Titan Corporation.

BALM: Black cottonwood (11)
BALSAM FIR: Grand fir (4)
BIRCH: Birch (7)
BLACK PINE: Lodgepole pine (454)
BULL PINE: Lodgepole pine (3)
CHERRY: Cherry (5)
COTTONWOOD: Black cottonwood (11)
DEAD FIR: Douglas-fir (1)
DEAD PINE: Ponderosa pine (1)
DOUBLE FIR: Douglas fir (10)
DOUBLE PINE: Ponderosa pine (1)
DOUBLE SPRUCE: Engelmann spruce (1)
DOUBLE WHITE PINE: Western white pine (1)
FIR: Douglas fir (7352)
HEMLOCK: Mountain hemlock (16)
JUNIPER: Western juniper (85)
LARCH: Western larch (3)
LODGEPOLE PINE: Lodgepole pine (65)
MAHOGANY: Mountain mahogany (15)
MESQUITE: Mesquite (3)
PINE: Ponderosa pine (7965)
POPLAR: Black cottonwood (1)
QUAKING ASH: Quaking aspen (2)
QUAKING ASPEN: Quaking aspen (8)
RED FIR: Douglas fir (283)
ROCKY MTN MAPLE: Rocky Mountain maple (10)
SILVER FIR: Grand fir (1)
SPRUCE: Englemann spruce (851)
SPRUCE PINE: Lodgepole pine (12)
WESTERN LARCH: Western larch (2044)
WHITE FIR: Grand fir : (130)
WHITE PINE: Western white pine (8)
WILLOW: Willow (23)
YELLOW FIR: Grand fir (3)
YELLOW PINE: Ponderosa pine (707)
YEW: Yew (10)

After renaming, 21 species remained, for a total of 20,175 trees at 8232 corner points:[5]

Bearberry (1) (not modeled – not enough points)
Birch (7)
Black cottonwood (23)
Cherry (5)
Douglas-fir (7646)
Engelmann spruce (852)
Grand fir (138)
Lodgepole pine (534)
Mesquite (3) (not modeled – not enough points)
Mountain alder (63)

[5] After accounting for the fact that bearberry, mesquite, and western white pine were not modeled for various reasons, this means that 18 tree or shrub species were actually used for the modeling. The GLO website includes separate maps showing the modeled distribution for these 18 species individually.

Mountain hemlock (16)
Mountain mahogany (15)
Ponderosa pine (8674)
Quaking aspen (10) (no CoKriging model – only Maximum Entropy)
Rocky Mountain maple (10)
Subalpine fir (4)
Western juniper (85)
Western larch (2047)
Western white pine (9) (not included in the hypergrid – all density values smaller than 1)
Willow (23)
Yew (10)

2. Distance 4 analysis

The GLO CornerTrees table (with the new names) was imported into a computer program called Distance 4 (http://www.ruwpa.st-and.ac.uk/distance/) (Figure B-1). Distance sampling and analysis is explained in a book by Buckland et al. (2001).

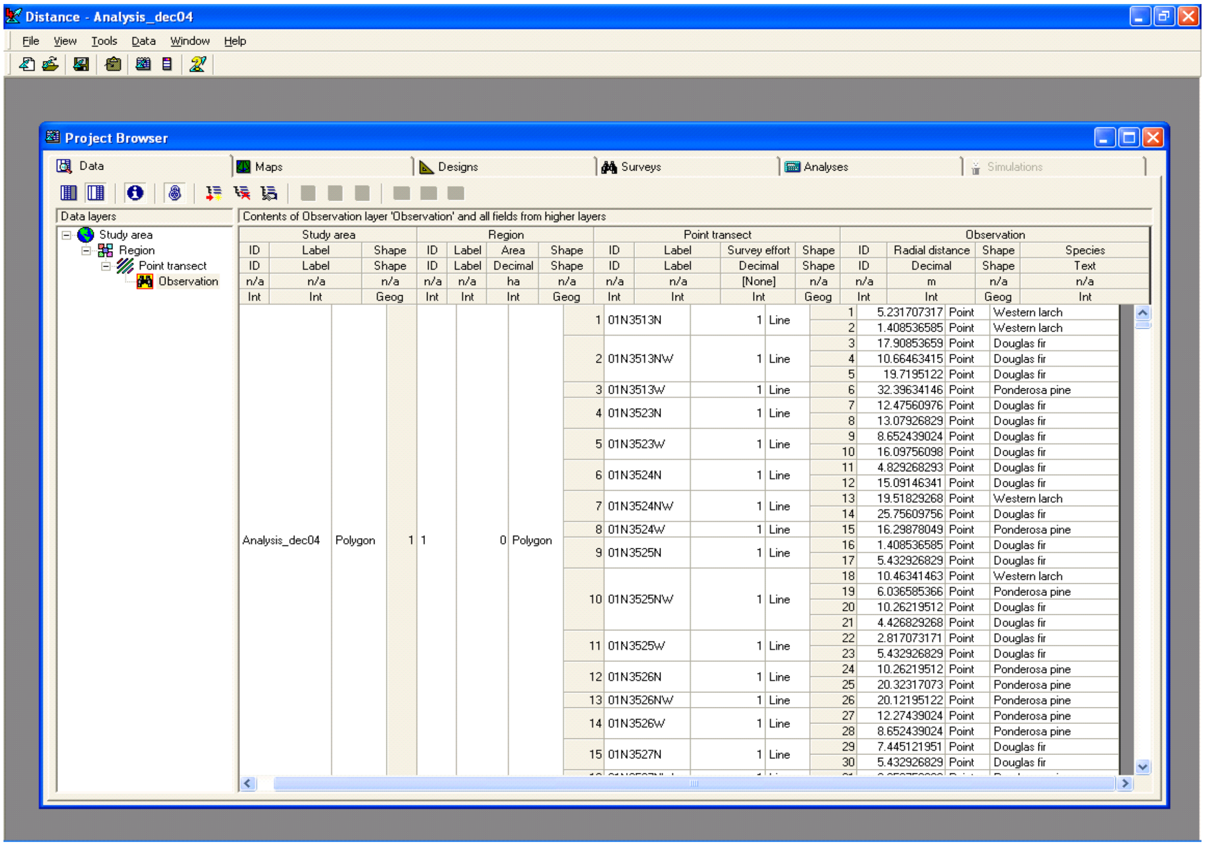


Figure B-1–Example showing Distance 4 input data.

Analysis was run on a species-by-species basis (minus bearberry and mesquite), using Distance 4 conventional distance sampling, with a half-normal key function and a cosine series expansion (the program's default settings). Output statistics were saved to a text file (one per species), and density values were attached to corner tree points (Figure B-2).

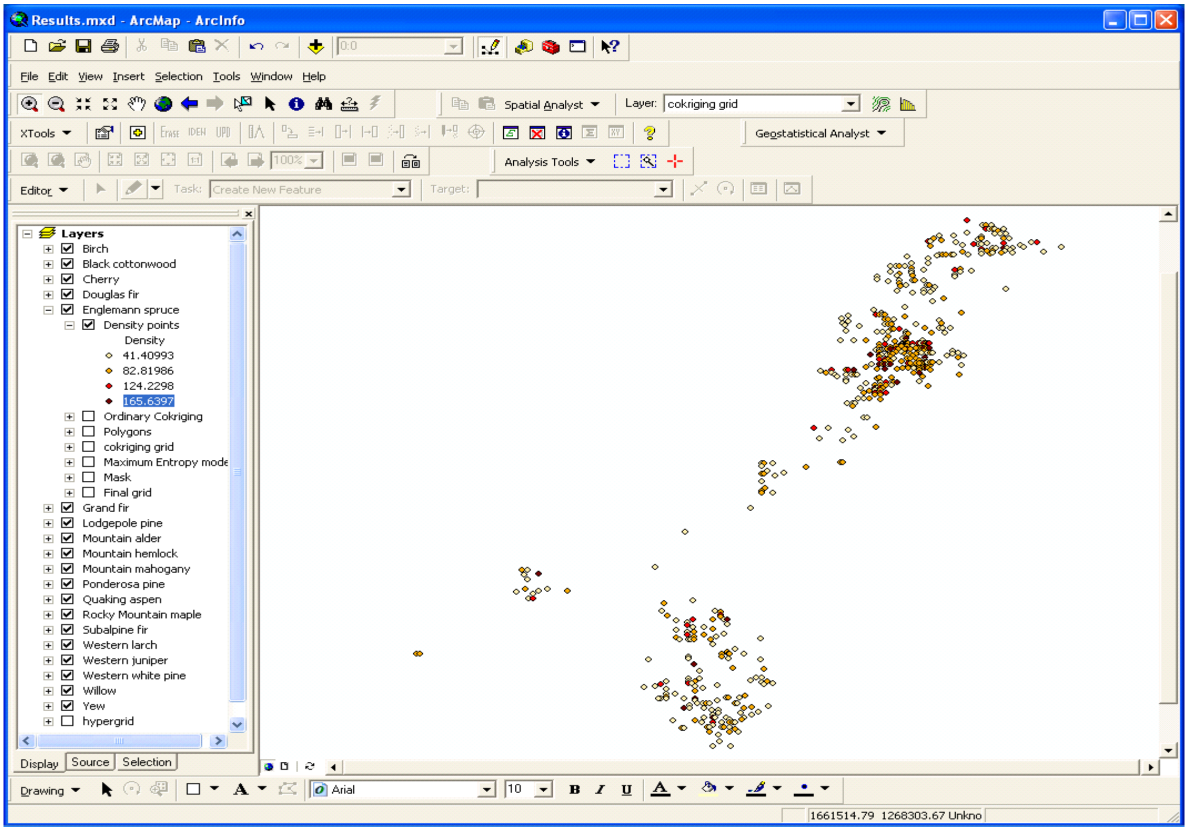


Figure B-2–Example showing distribution of density values for Engelmann spruce.

For an unknown reason, Distance 4 refused to output a model for quaking aspen (the programmers of Distance 4 were contacted but could not fix the problem). Instead of a CoKriging model, the 8 corner tree points where aspen were located were buffered by 9000' (approximately the size of cokriging value patches around single points) and assigned a density class of 1.

3. CoKriging

We used the CoKriging option of the Geostatistical Analyst in ArcGIS 8.3.

The models used three co-variables: elevation (extracted directly from a 10-meter DEM; figure B-3), a landform model (figure B-4), and a solar model (figure B-5). The 10-m digital elevation model was generated by piecing together data from Oregon (http://buccaneer.geo.orst.edu/dem/data/dem10oregon.html) and Washington (http://www.or.blm.gov/gis/resources/dataset.asp?cid=102).

The landform model was derived from the DEM and describes the landscape as one of 13 base components of cliffs → coved → wet flat areas. The inclusion of the solar index model is based upon work done by NatureServe, and ORNHIC, in which the "south-westerness" of a cell is derived from the amount of potential illumination a cell receives on the two solstice and equinox dates.

Inclusion of three co-variables allow a sample site density to be describe based upon its spatial auto-correlation with other points, and to be filtered based upon where in a landscape the point is. For example, a dry site such as a high elevation SW-facing ridgeline would have substantially different vegetation composition when compared to a low elevation N-facing coved sloped.

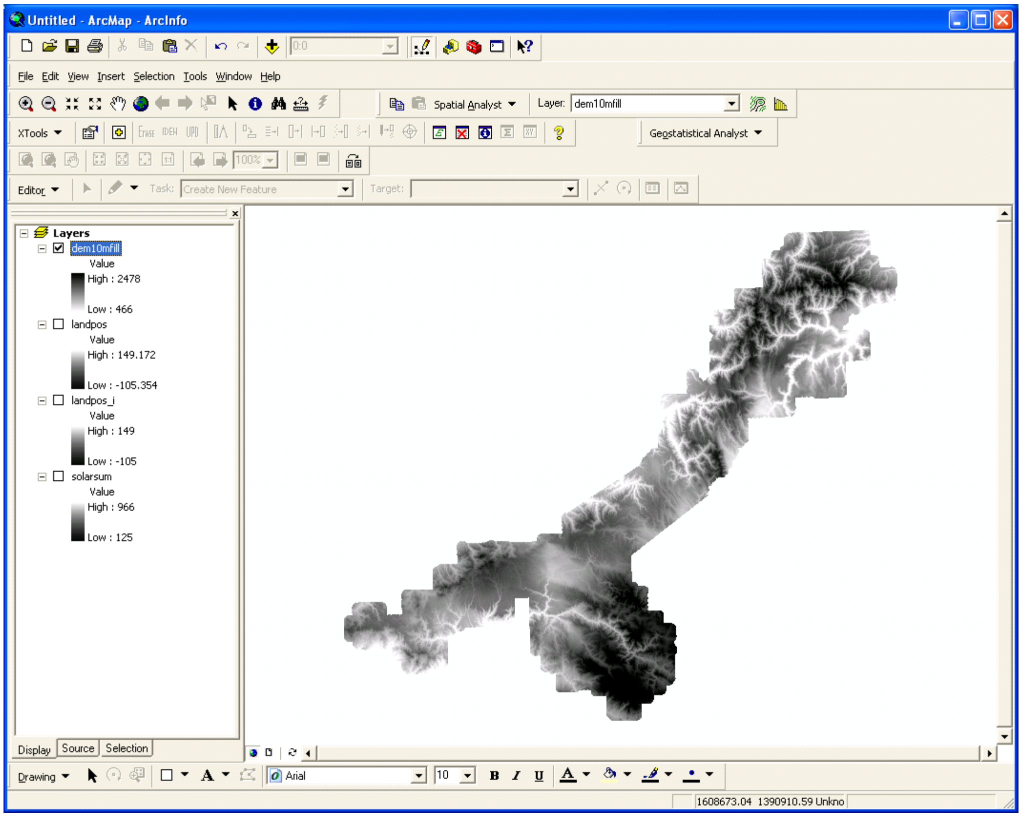


Figure B-3–Example showing ten-meter digital elevation model.

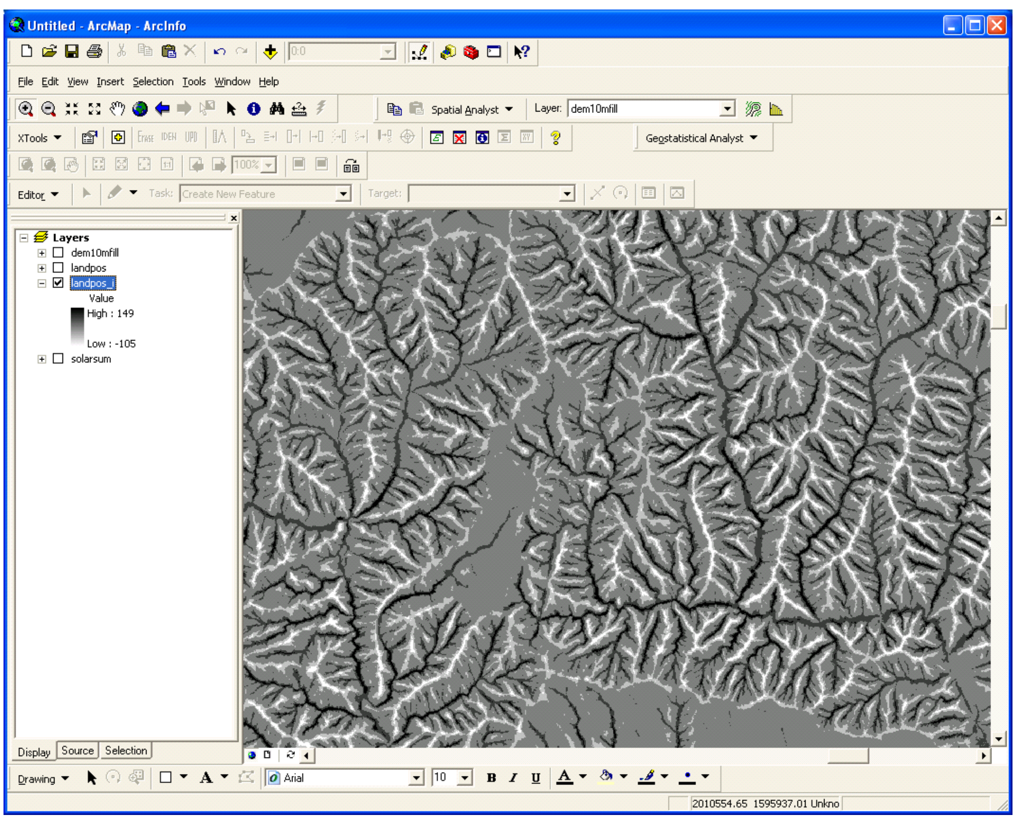


Figure B-4–Example of the land position model.

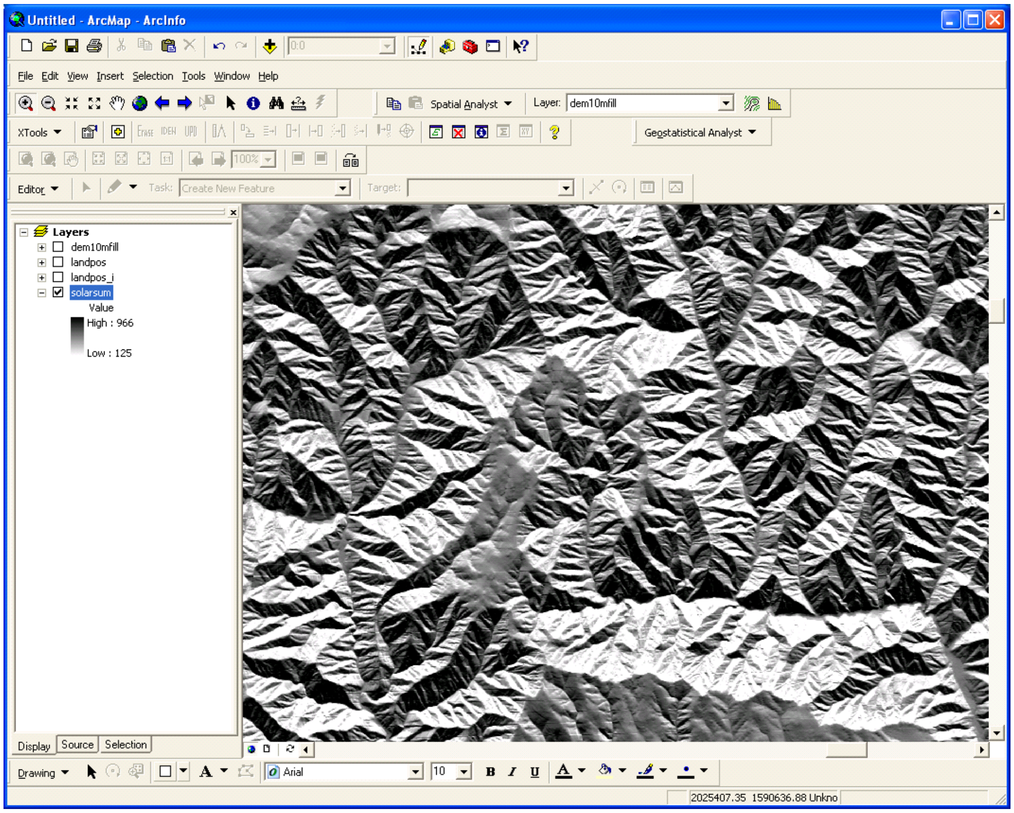


Figure B-5–Example of the solar index model.

Co-kriging analyses were performed for each species individually. The Geostatistical Analyst extension allows the user to choose among different semivariogram models (spherical, exponential, Gaussian, etc…); the model providing the best fit was chosen visually. The modeling output was displayed by classifying filled contours to 100 values (smart quantile method) and choosing the Presentation quality (Figure B-6).

ArcGIS offers a direct conversion from model output to Arc/Info grid; this process is time-consuming however, taking 24 to 48 hours per model. Because of time constraints, we opted for a different approach, first exporting the models to vector files (Figure B-7), and then converting those to grids (Figure B-8). Because of model complexity, this was not possible for western larch, for which the direct conversion from model to grid was used.

4. Maximum Entropy models

One drawback of CoKriging models is the impossibility to limit the extent of the model, leading to weird "spikes" where the model extrapolates beyond the range of density points. To limit this problem, environmental models were generated and used as masks over the CoKriging models.

The original GLO data were used to extract a file for each species, listing the species' name, latitude, and longitude of the corner points where that species was censused. This file was used as input into a Maximum Entropy model (software MaxEnt.bat from ATTLabs), along with five environmental variables: aspect, elevation, landform, slope, and the solar model.

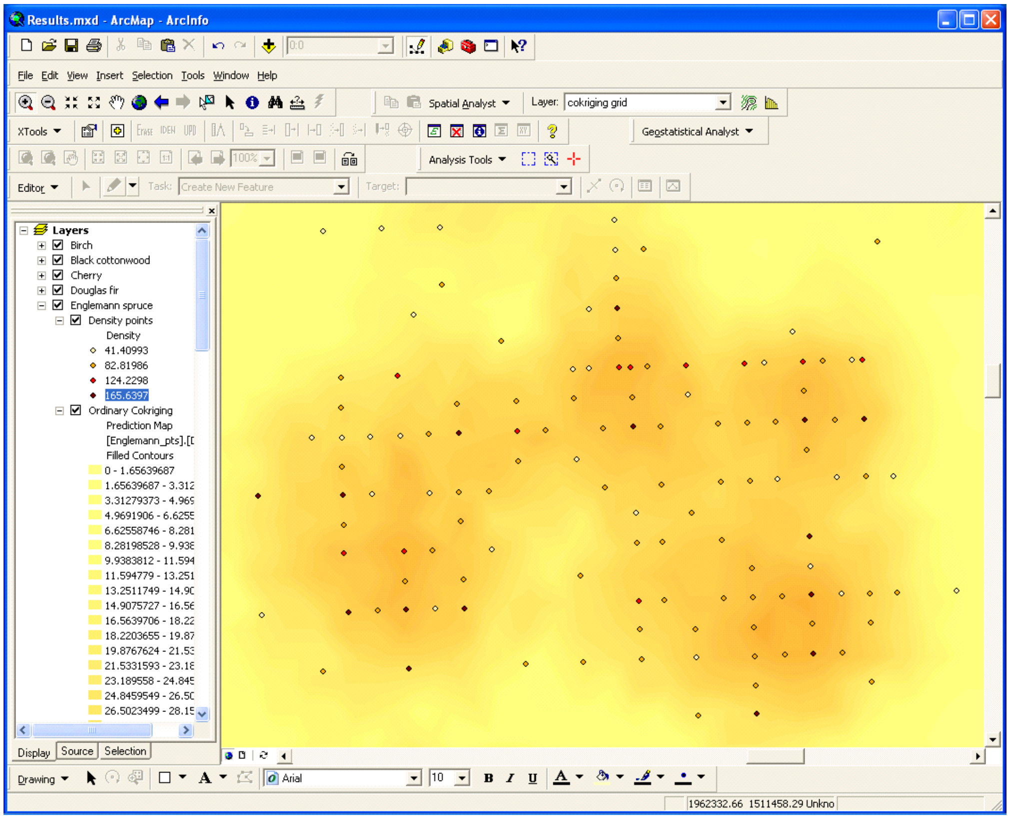


Figure B-6–Example of cokriging model (and density values) for Engelmann spruce.

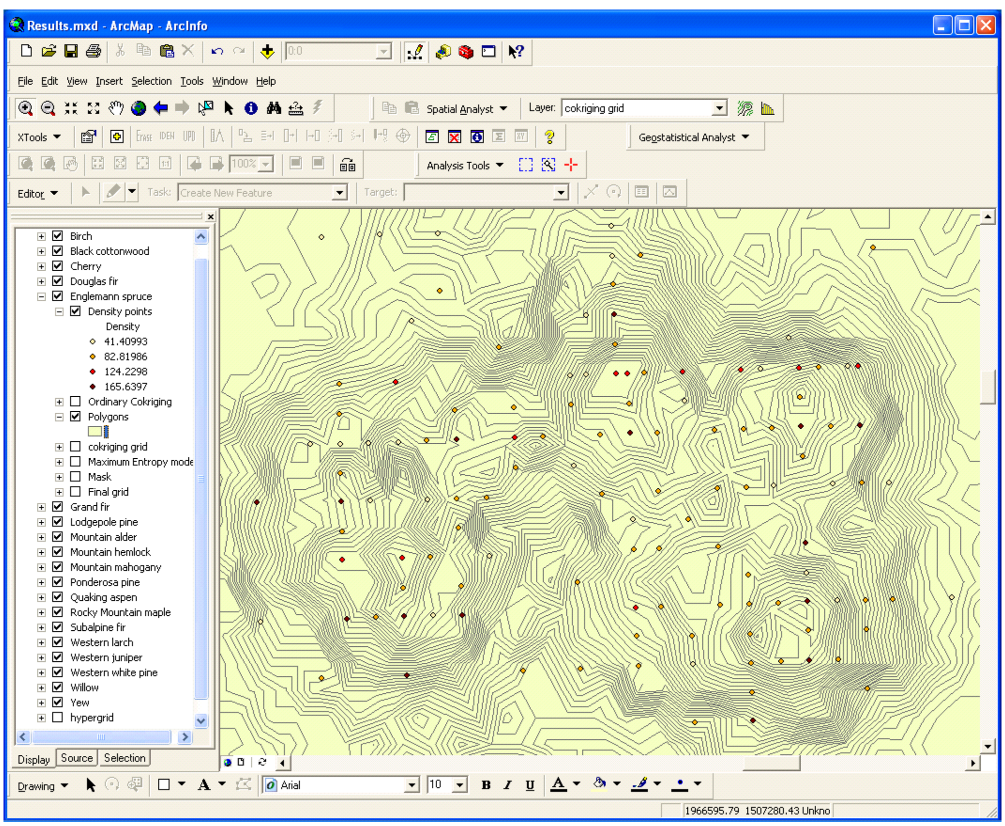


Figure B-7–Example of polygons derived from cokriging model of Engelmann spruce.

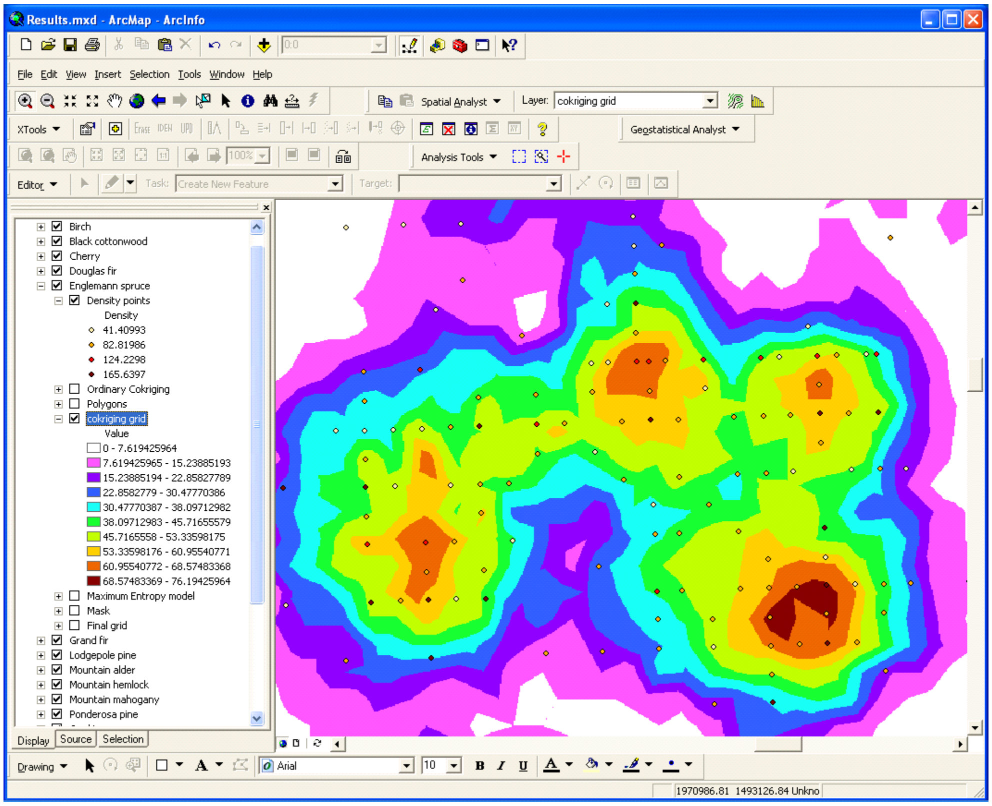


Figure B-8–Example of grid developed from polygon shapefile for Engelmann spruce.

Maximum Entropy was selected over other types of models (such as CART or DOMAIN models) because of its better performance with small sample sizes. An overlay with corner trees with model results demonstrates that good results can be obtained, even with only a few corner trees (Figure B-9).

The resulting ASCII file for each species was converted to a floating-point grid and used as a mask over the CoKriging grids. The maximum entropy modeling output is probabilistic, i.e., the grid represents the distribution of probability of presence of the species; a cut-off probability has to be selected to generate masks. This cut-off was determined in one of two ways. For species with few corner trees (less than 50), the determination was visual and based on the species' site characteristics, after displaying the grid of probabilities in 10% increments.

The solar model was often displayed in the background as a visual aid. For example, cut-off points for riparian species such as cottonwood or birch were selected to limit distribution to valley bottoms. The entropy model for willow did not limit that species to valley bottoms; a mask of buffered streams was first applied (streams buffered by 1 cell, i.e., 90-m buffer) over the entropy model, and only cokriging cells within that mask and with a probability value greater than 0 were retained.

For the seven remaining species, the probability value was obtained at each point (see table below, page 23); the cut-off was the probability value above which 75% of the points were correctly predicted, with the exception of western juniper. The grid was then reclassified and used as a mask over the cokriging model grid (Figure B-10).

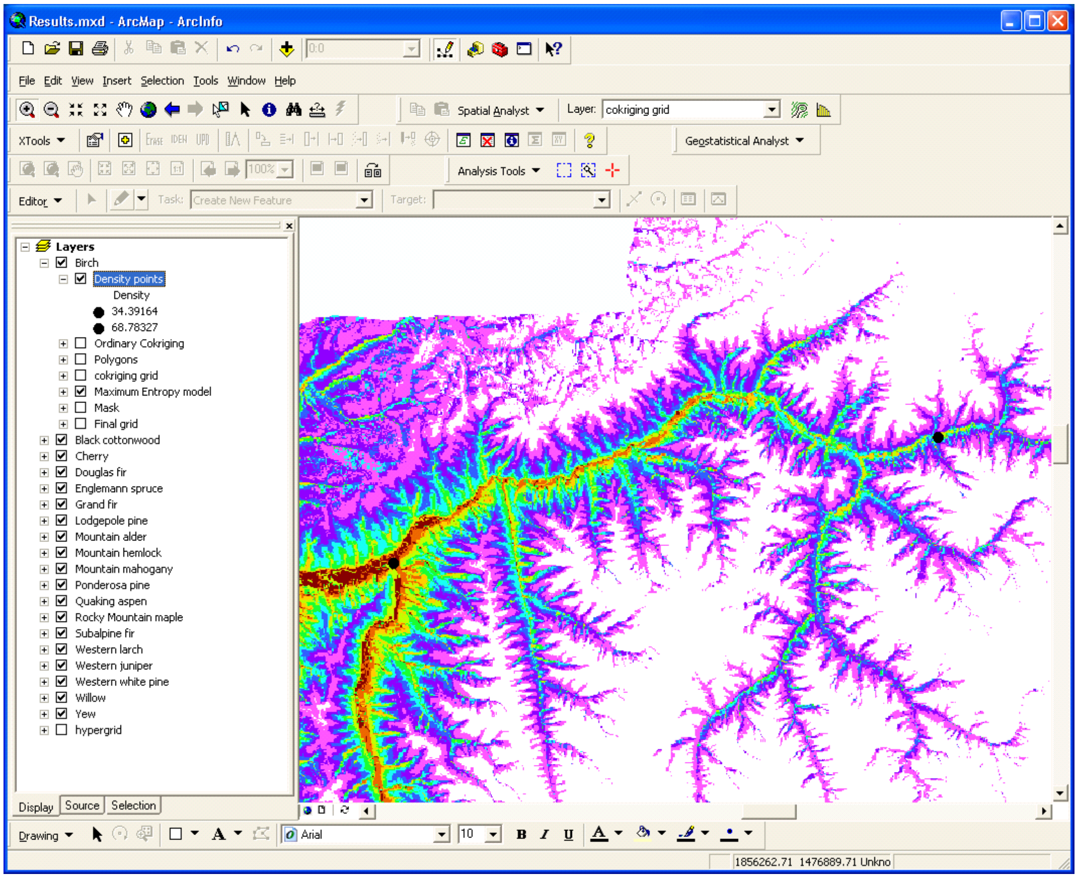


Figure B-9–Example of entropy model for birch.

Species	**Points**	**75% points**	**Cut-off probability**
Douglas fir	4106	3080	27
Englemann spruce	514	386	28
Grand fir	87	65	30
Lodgepole pine	281	211	33
Ponderosa pine	4516	3387	26
Western juniper	67	60% points = 41	40
Western larch	1406	1055	25
Birch	6		60
Black cottonwood	18		60
Cherry	5		40
Mountain alder	41		50
Mountain hemlock	11		40
Mountain mahogany	11		50
Quaking aspen	6		50
Rocky Mountain maple	8		40
Subalpine fir	4		50
Willow	19		Stream buffer
Yew	8		40

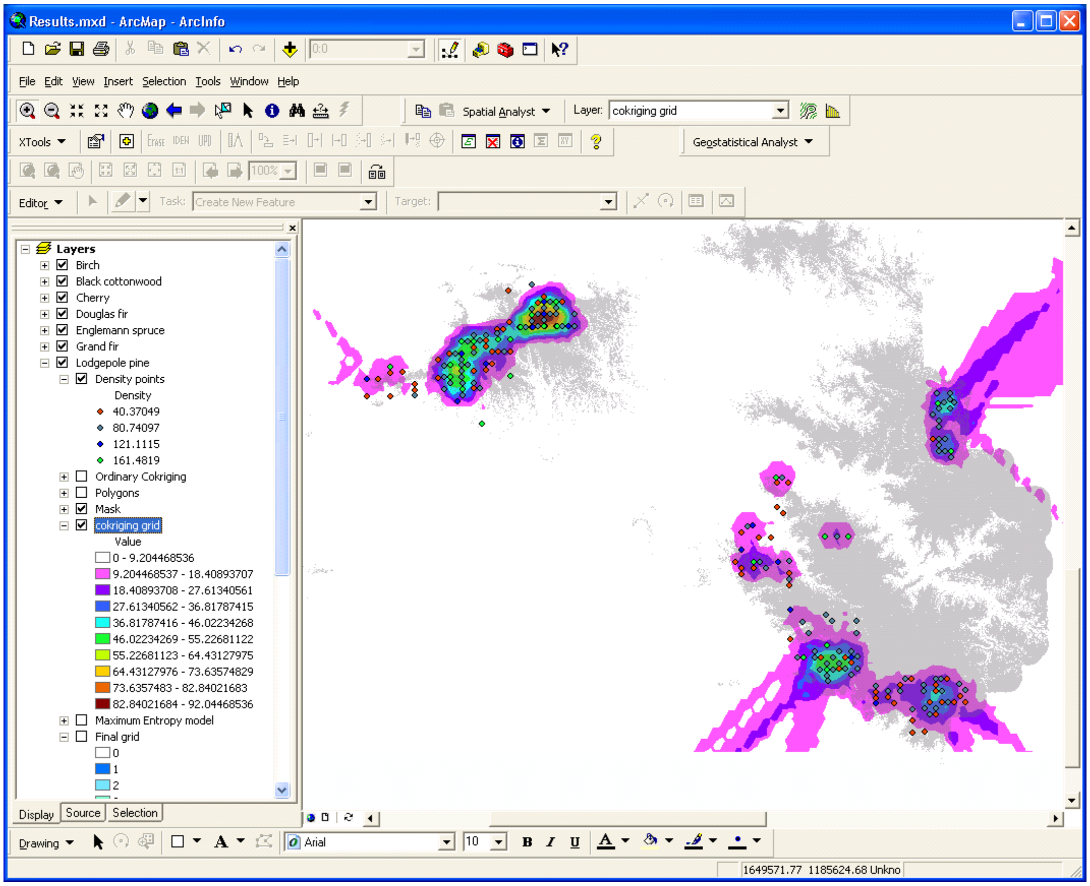


Figure B-10–Example of lodgepole pine cokriging model with maximum entropy mask (gray).

5. Ecological systems grid

To obtain a unique grid of ecological systems, each final cokriging grid was converted to an integer grid, and then reclassified as follows:

Density value	Class
0	0
1-9	1
10-19	2
20-29	3
30-39	4
40-49	5
50-59	6
60-69	7
70-79	8
80-89	9
90-100	10

An Arc/Info aml originally developed by Jason Karl (Idaho Cooperative Fish & Wildlife Research Unit) for Gap Analysis was used to combine the 18 grids into a unique “hypergrid” presenting density classes for each species in a column format. This hypergrid was examined by Jimmy Kagan who converted combinations of individual species into forest ecological systems (Figure B-11, NatureServe 2003).

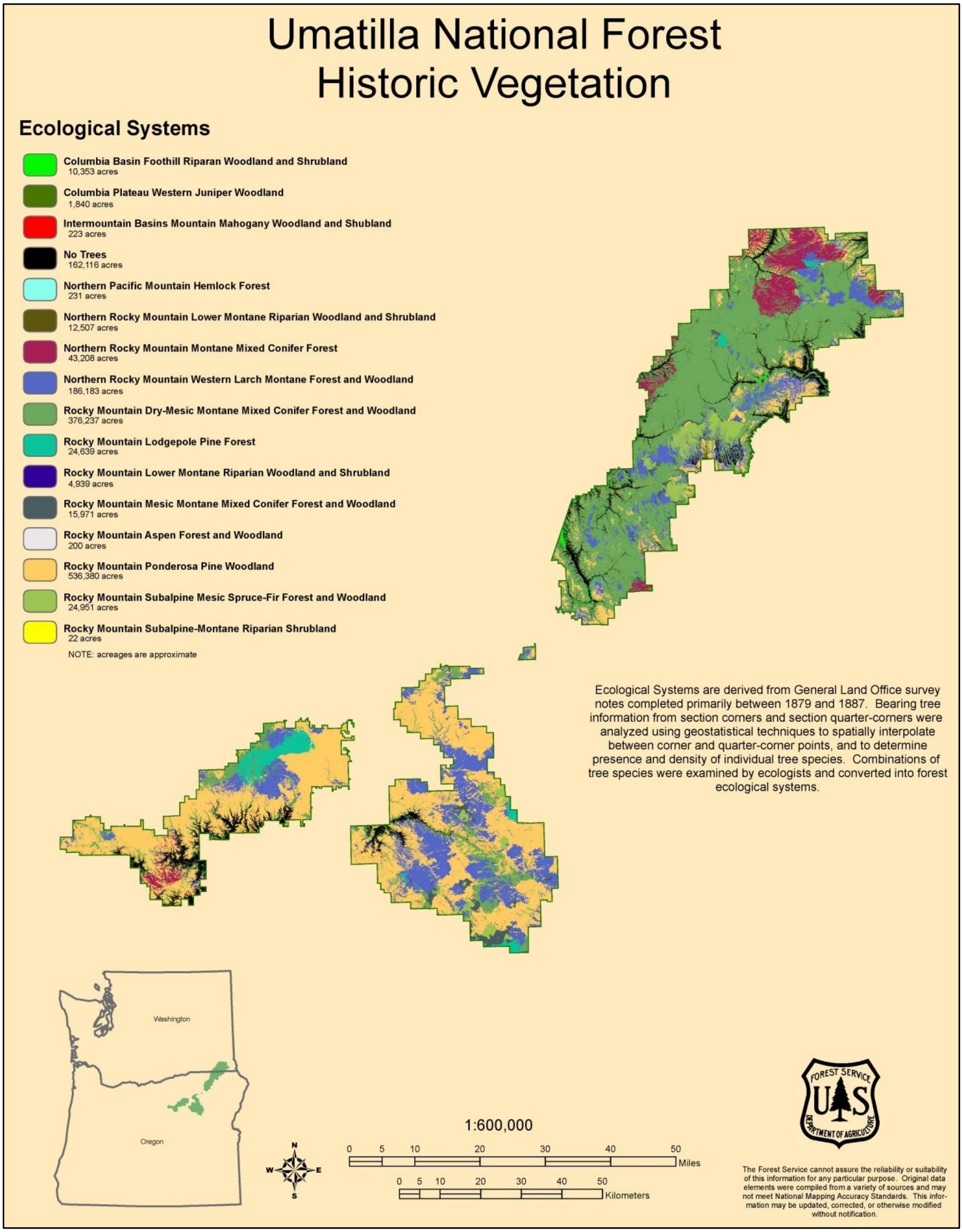


Figure B-11–Final map depicting ecological systems (Comer et al. 2003) within the boundary of the Umatilla National Forest, as derived for spatial analyses of GLO survey notes acquired primarily between 1879 and 1887. Appendix C provides a description of each ecological system. A larger version of this map (17" × 22" format), and formatted like a poster with supplementary annotations, is available from the Umatilla National Forest History website along with other GLO materials.

APPENDIX C

Description of Ecological Systems

"Ecological systems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding" (Comer et al. 2003). The Umatilla National Forest GLO vegetation map includes 15 different ecological systems, and other systems are believed to exist on the Forest but were too limited to include on the map.

Descriptions of the ecological systems included on the Umatilla GLO map were extracted from Natural Heritage Central Databases (NatureServe 2003). Since the descriptions are somewhat lengthy, they are included in a separate document (Umatilla Ecological Systems Description.pdf) that can be accessed from the GLO section of the Umatilla National Forest history website: http://www.fs.fed.us/r6/uma/publications/history/maps.shtml

Note that unmapped types occurring in the Umatilla National Forest are also described in the ecological systems document referenced above, beginning on page 29 of that source.

APPENDIX D

Maps for 18 Individual Tree and Shrub Species

As described in appendix B, the tree species occurring at section corners or quarter-corners were analyzed individually (by species) during the cokriging and maximum entropy phases of the map preparation process. This process generated maps for 18 individual tree and shrub species; these species maps are available from the GLO section of the Forest's history website (but only as color PDF files in 8½" × 11" format; no GIS format is available for the tree species maps).

This appendix provides image files derived from the GIS presentation maps (PDF format) as they were prepared for the history website:
http://www.fs.fed.us/r6/uma/publications/history/glo/index.shtml

Image-file maps are provided for these species:

Birch

Black cottonwood

Cherry

Douglas-fir

Engelmann spruce

Grand fir

Lodgepole pine

Mountain alder

Mountain hemlock

Mountain mahogany

Ponderosa pine

Quaking aspen

Rocky Mountain maple

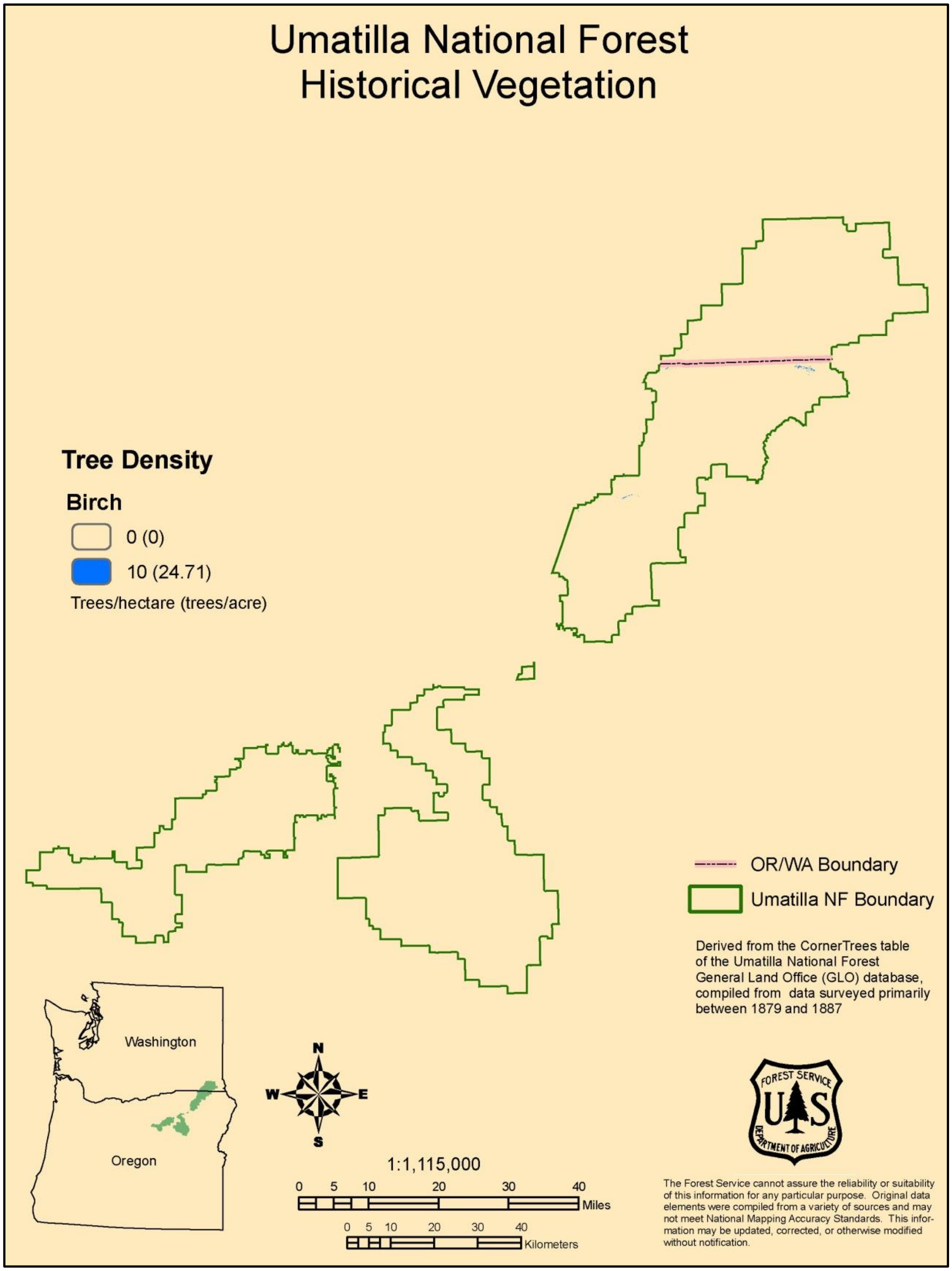
Subalpine fir

Western juniper

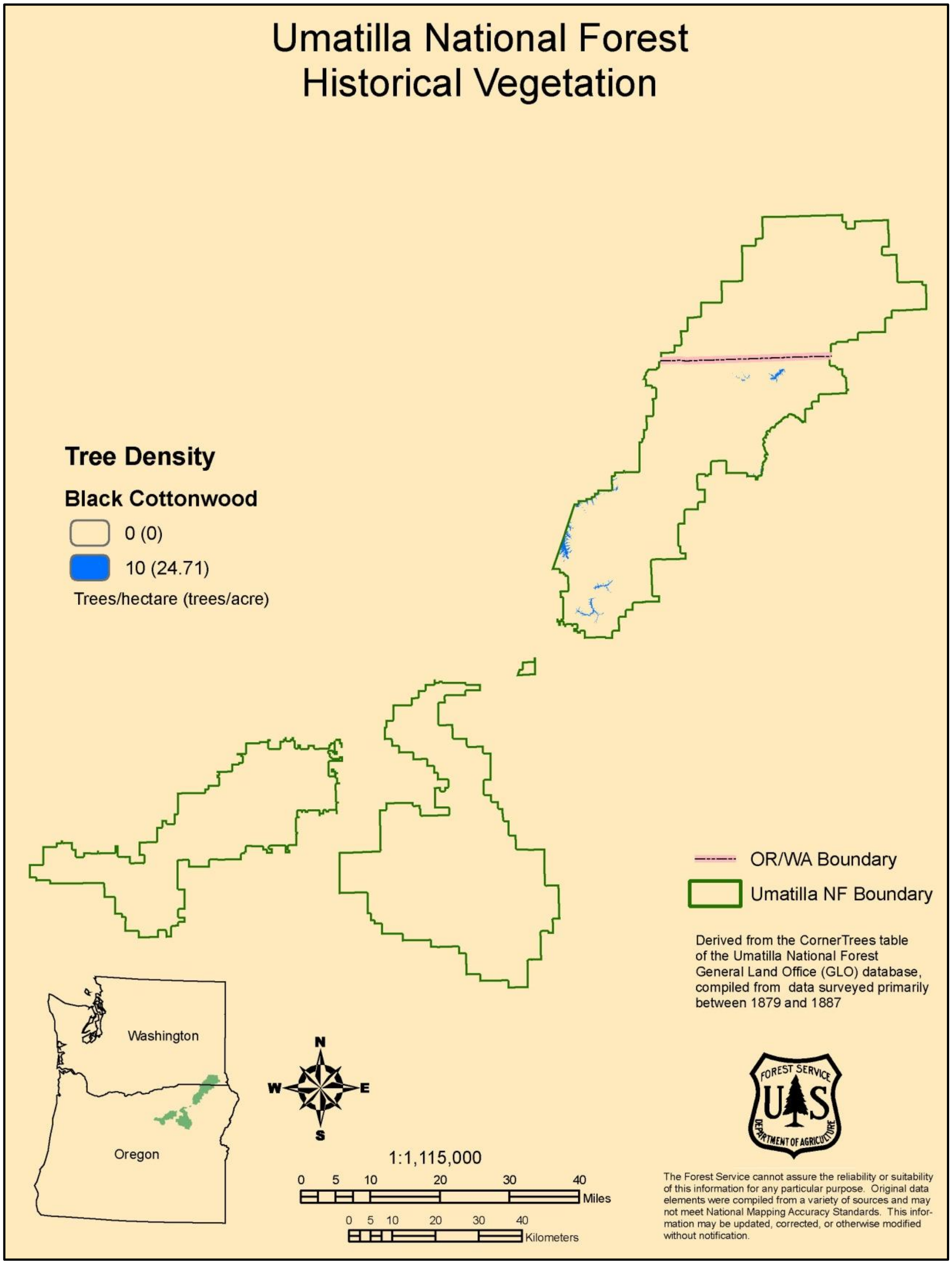
Western larch

Willow

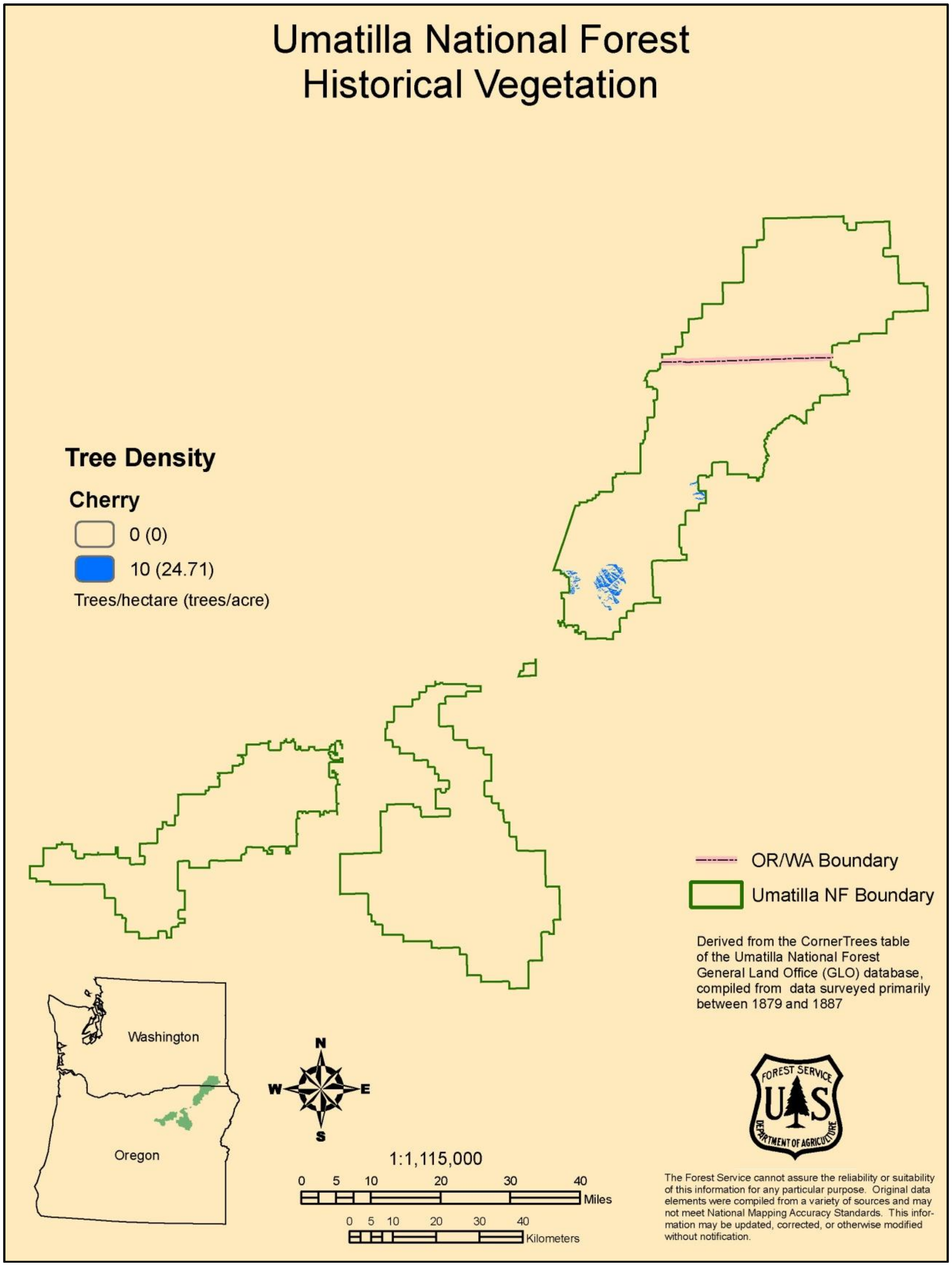
Yew



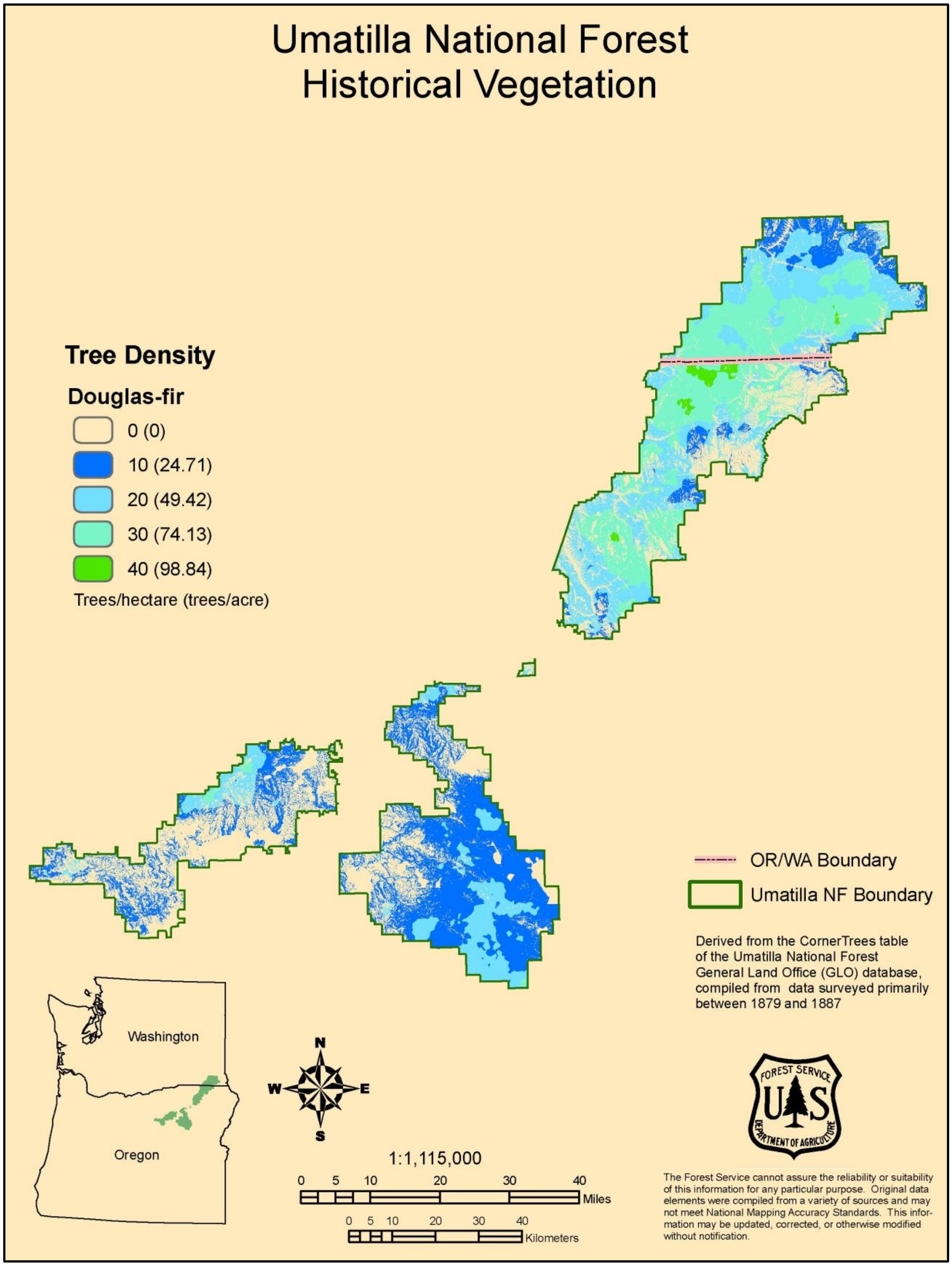
Interpolated tree density for birch



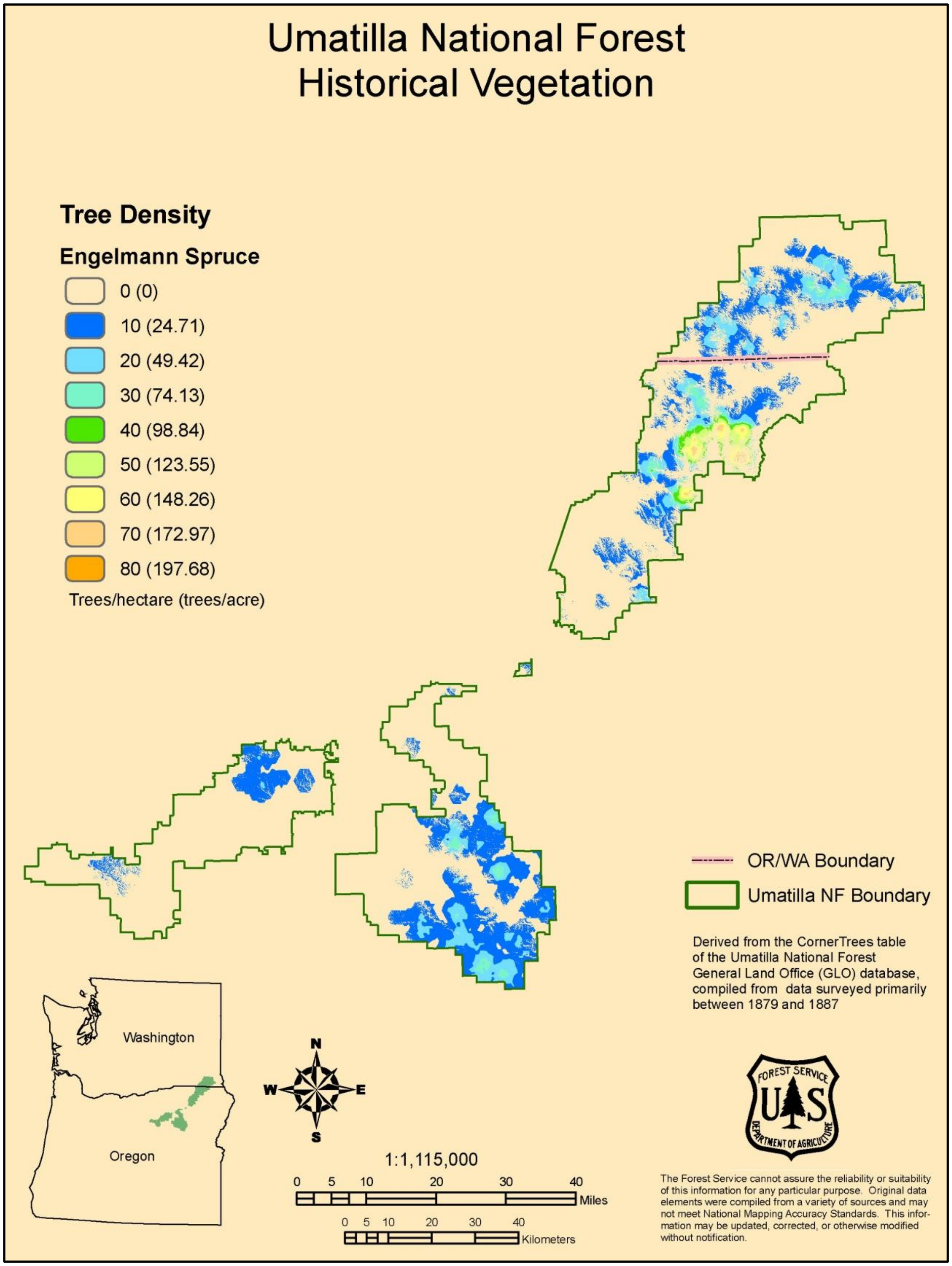
Interpolated tree density for black cottonwood



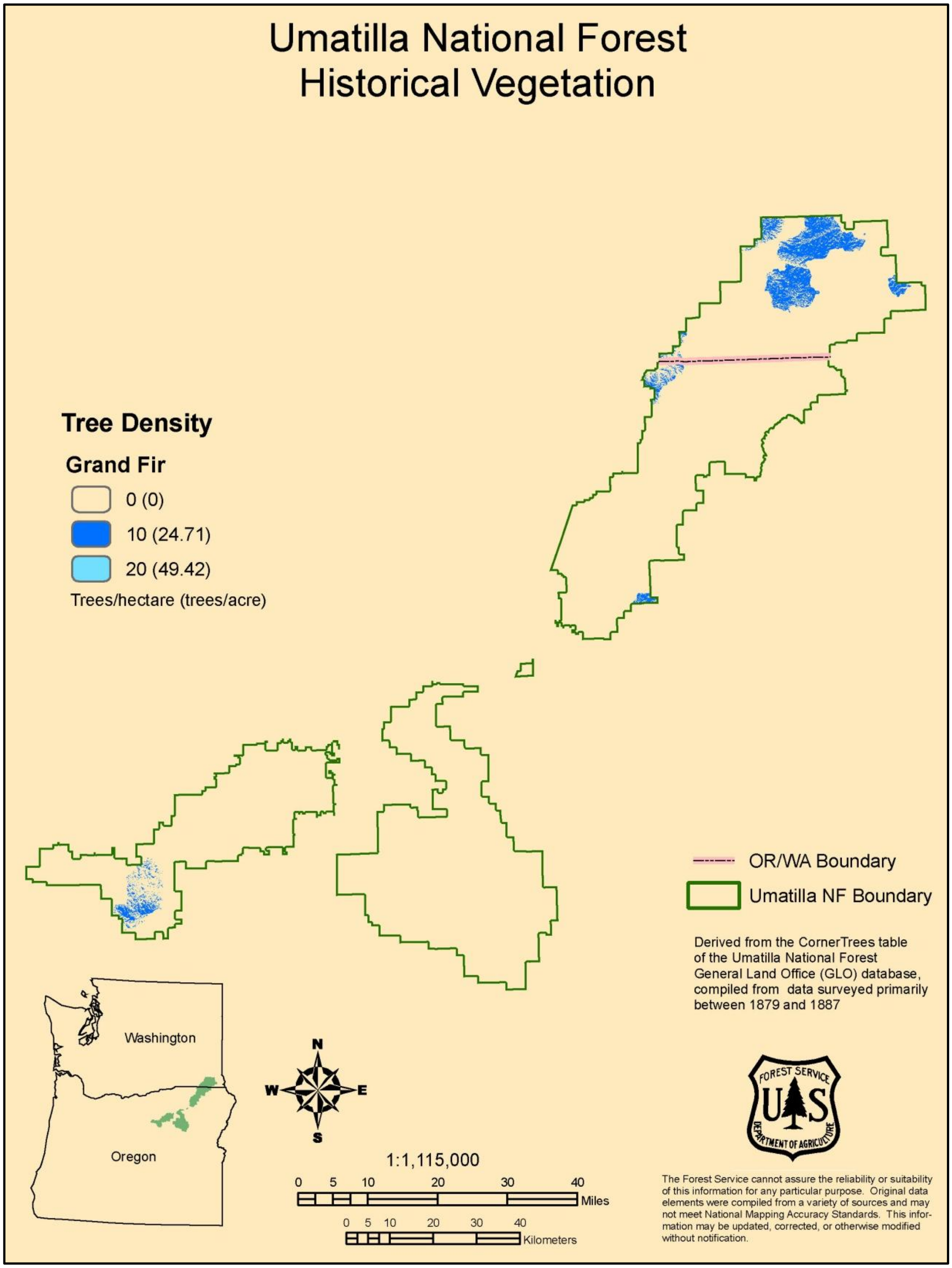
Interpolated tree density for cherry



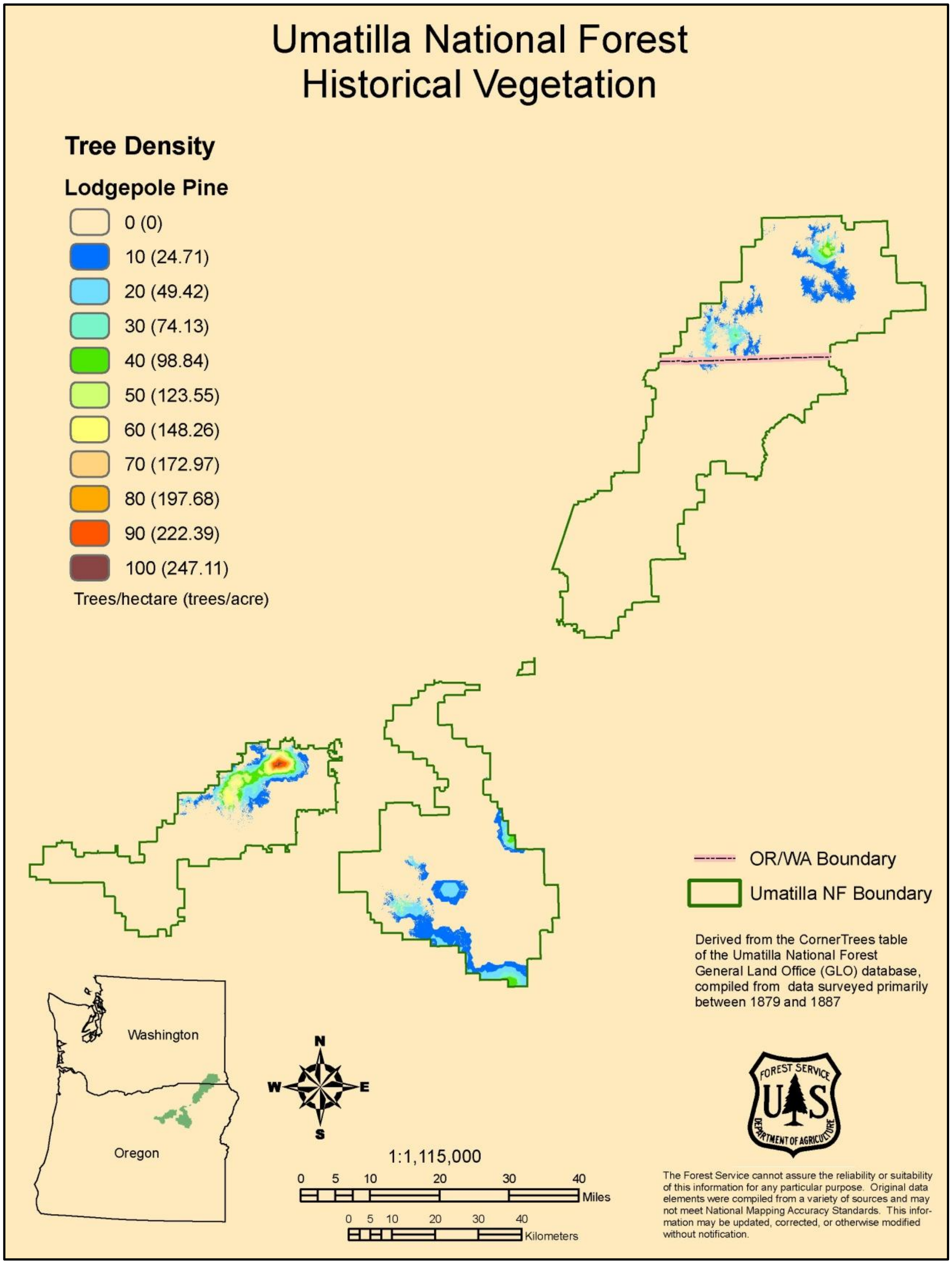
Interpolated tree density for Douglas-fir



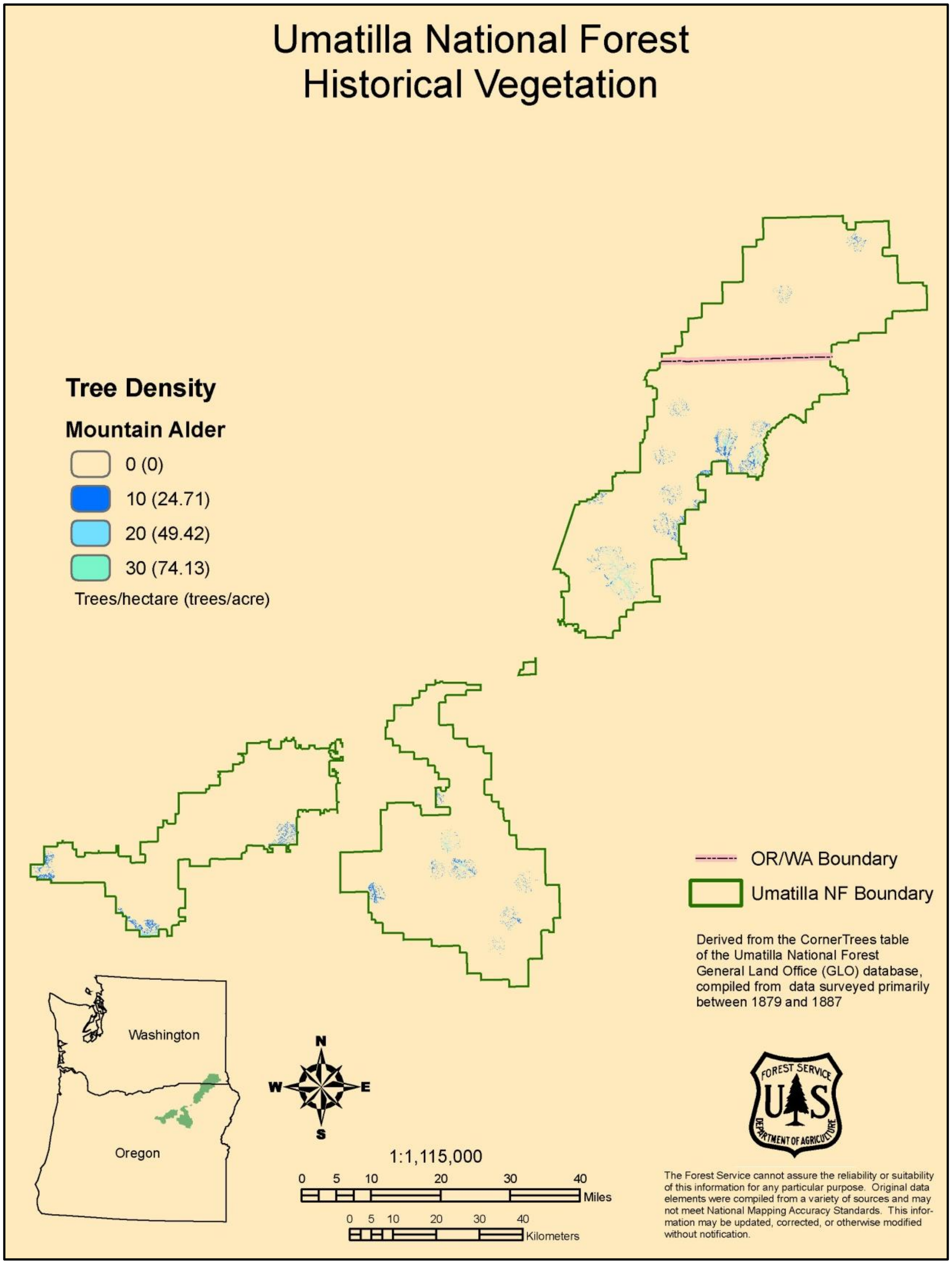
Interpolated tree density for Engelmann spruce



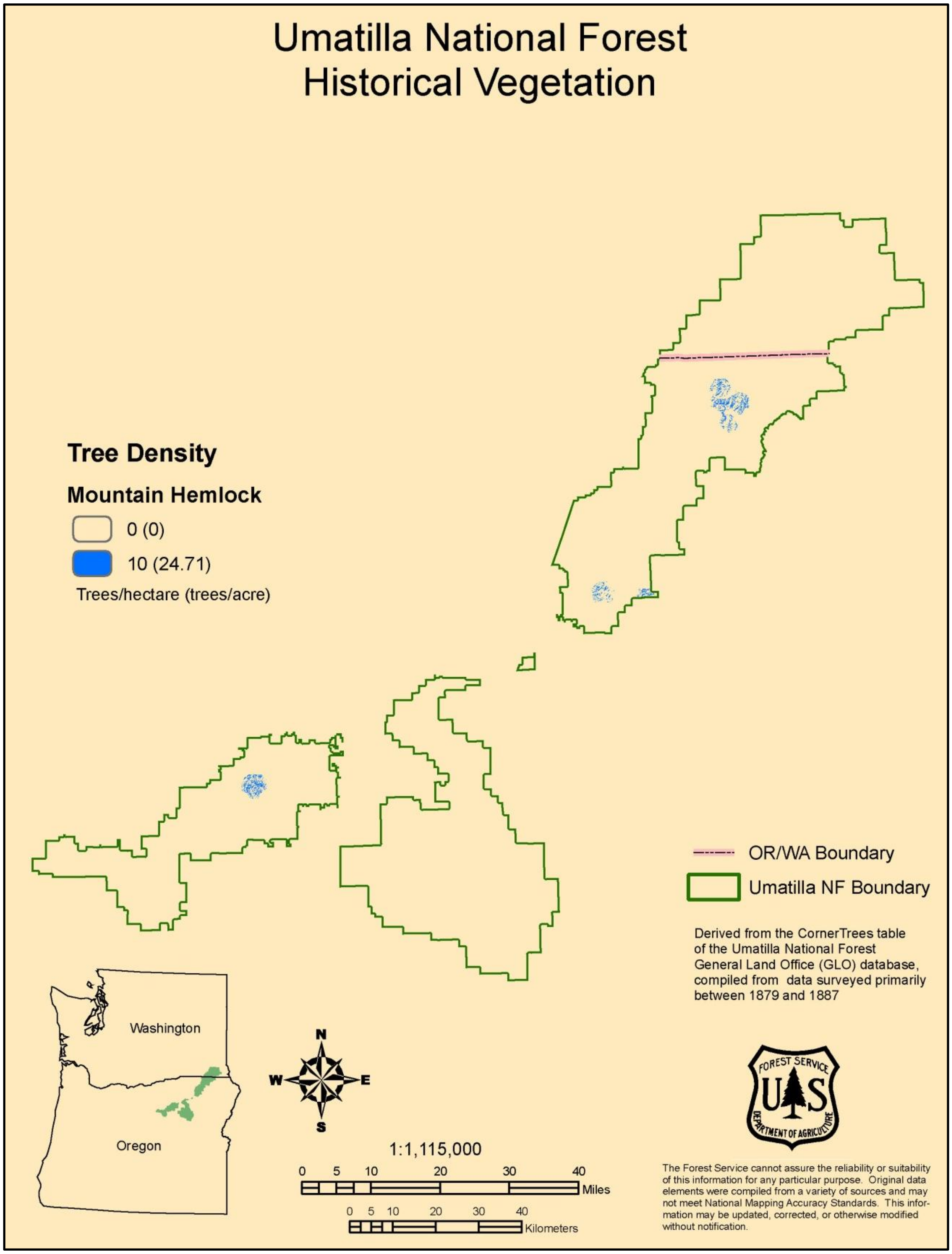
Interpolated tree density for grand fir



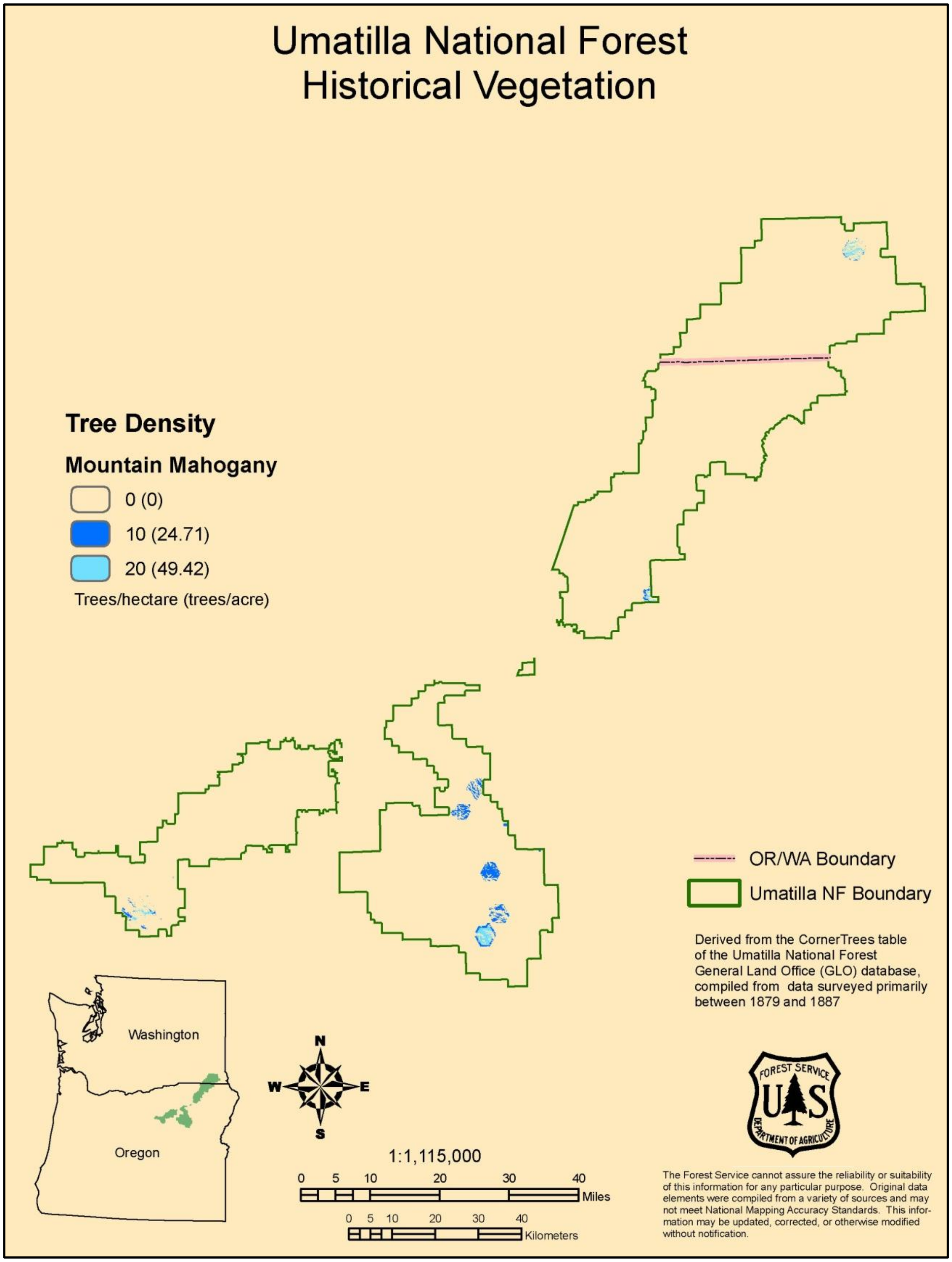
Interpolated tree density for lodgepole pine



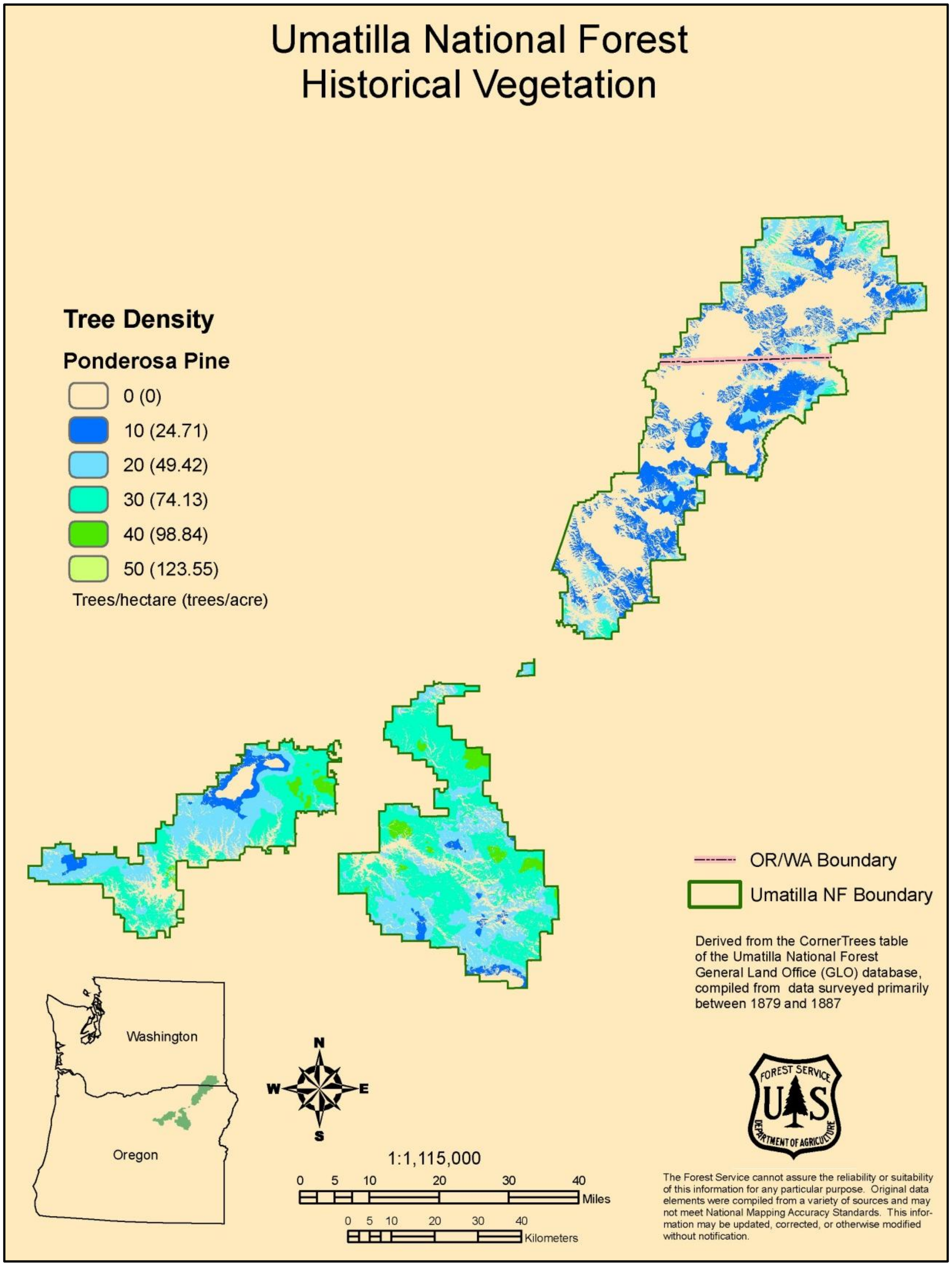
Interpolated tree density for mountain alder



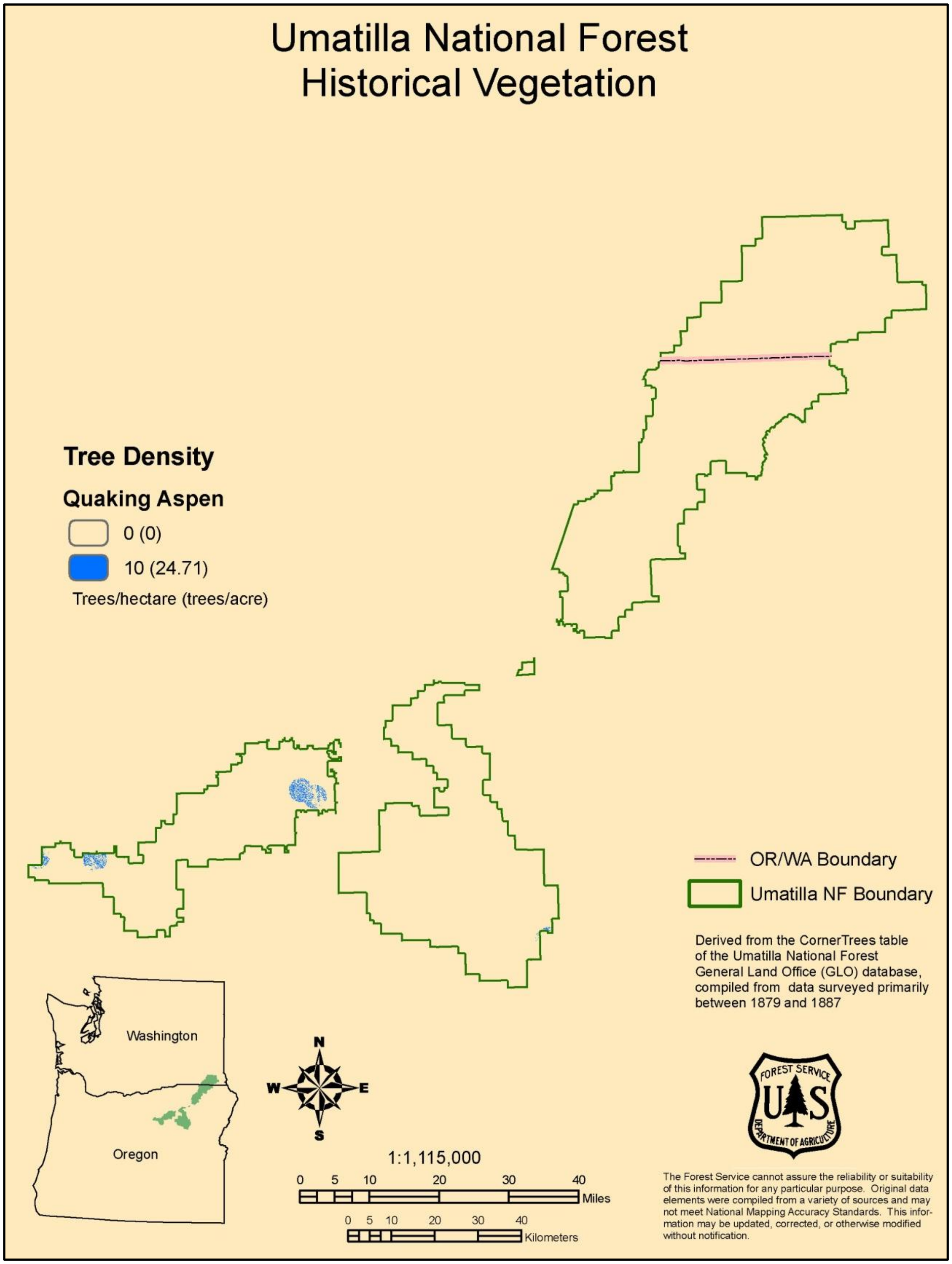
Interpolated tree density for mountain hemlock



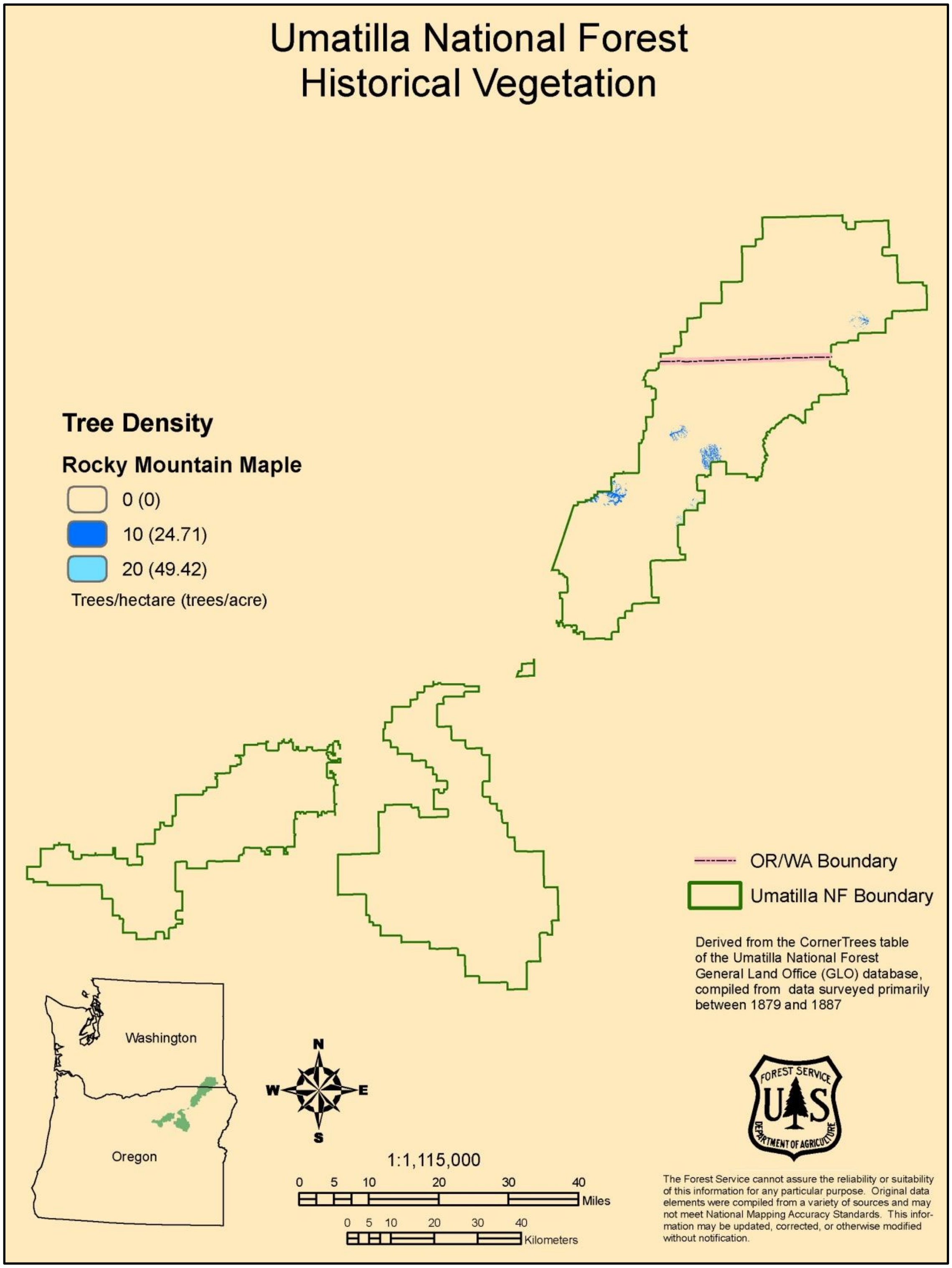
Interpolated tree density for mountain mahogany



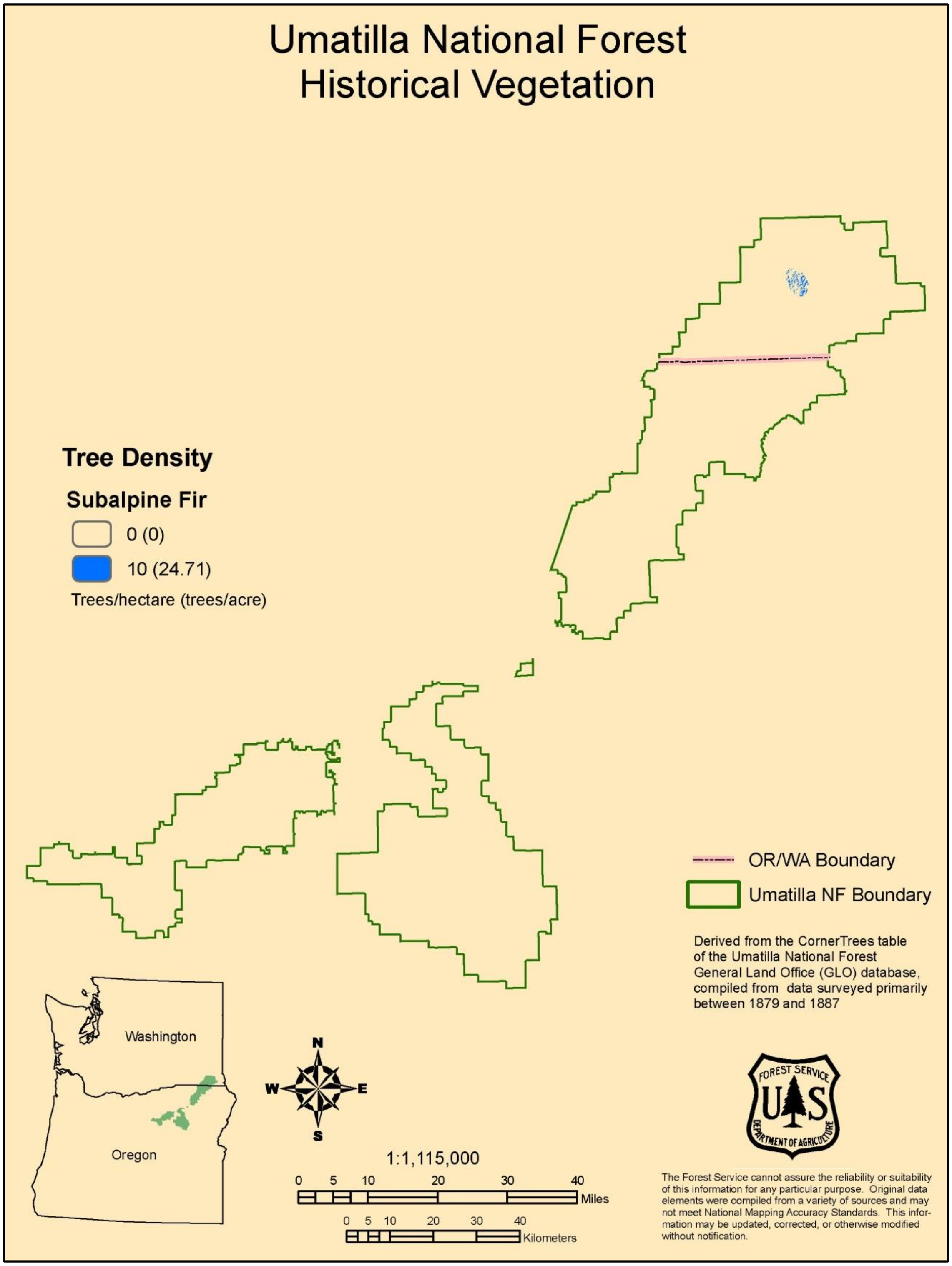
Interpolated tree density for ponderosa pine



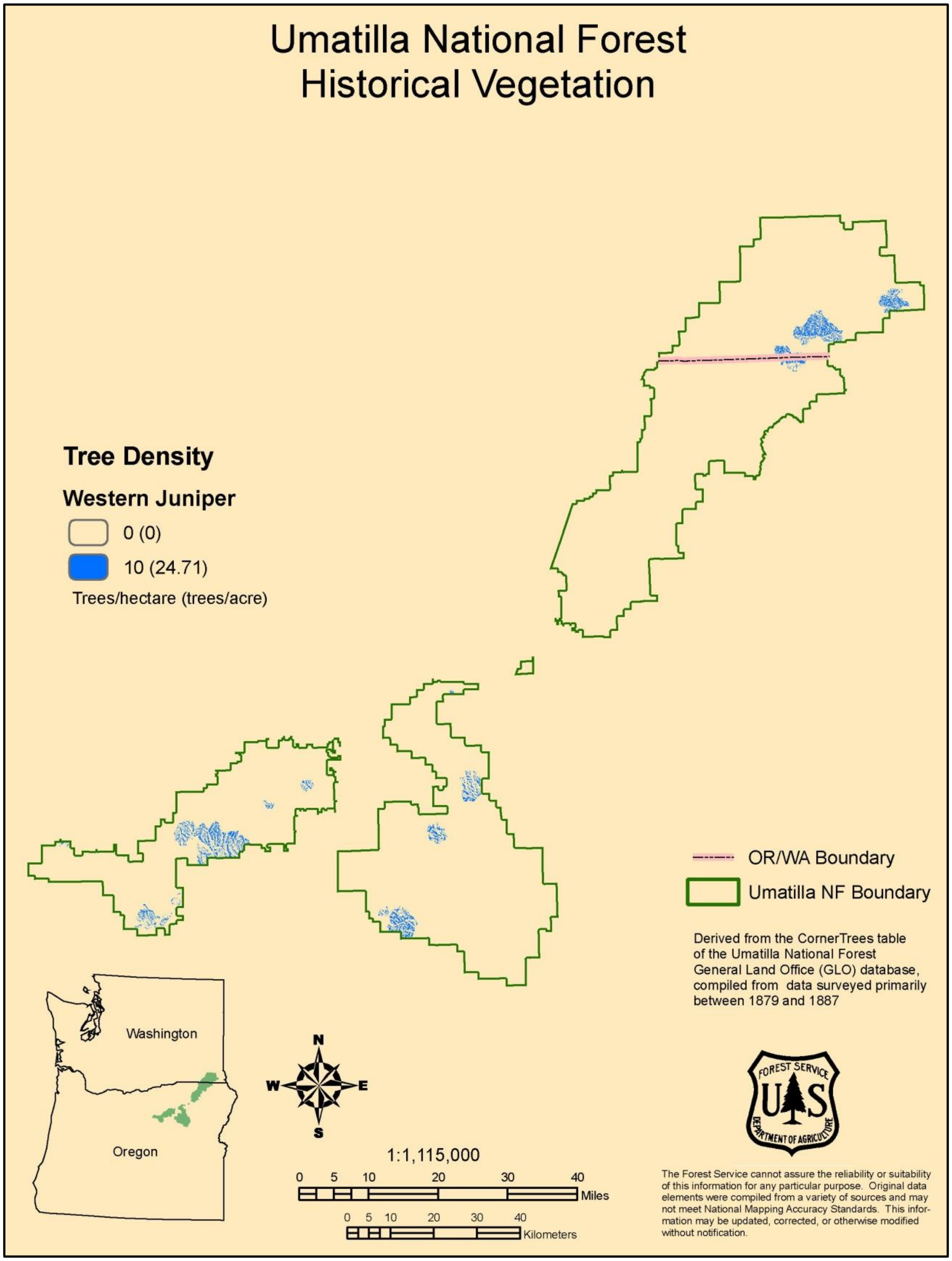
Interpolated tree density for quaking aspen



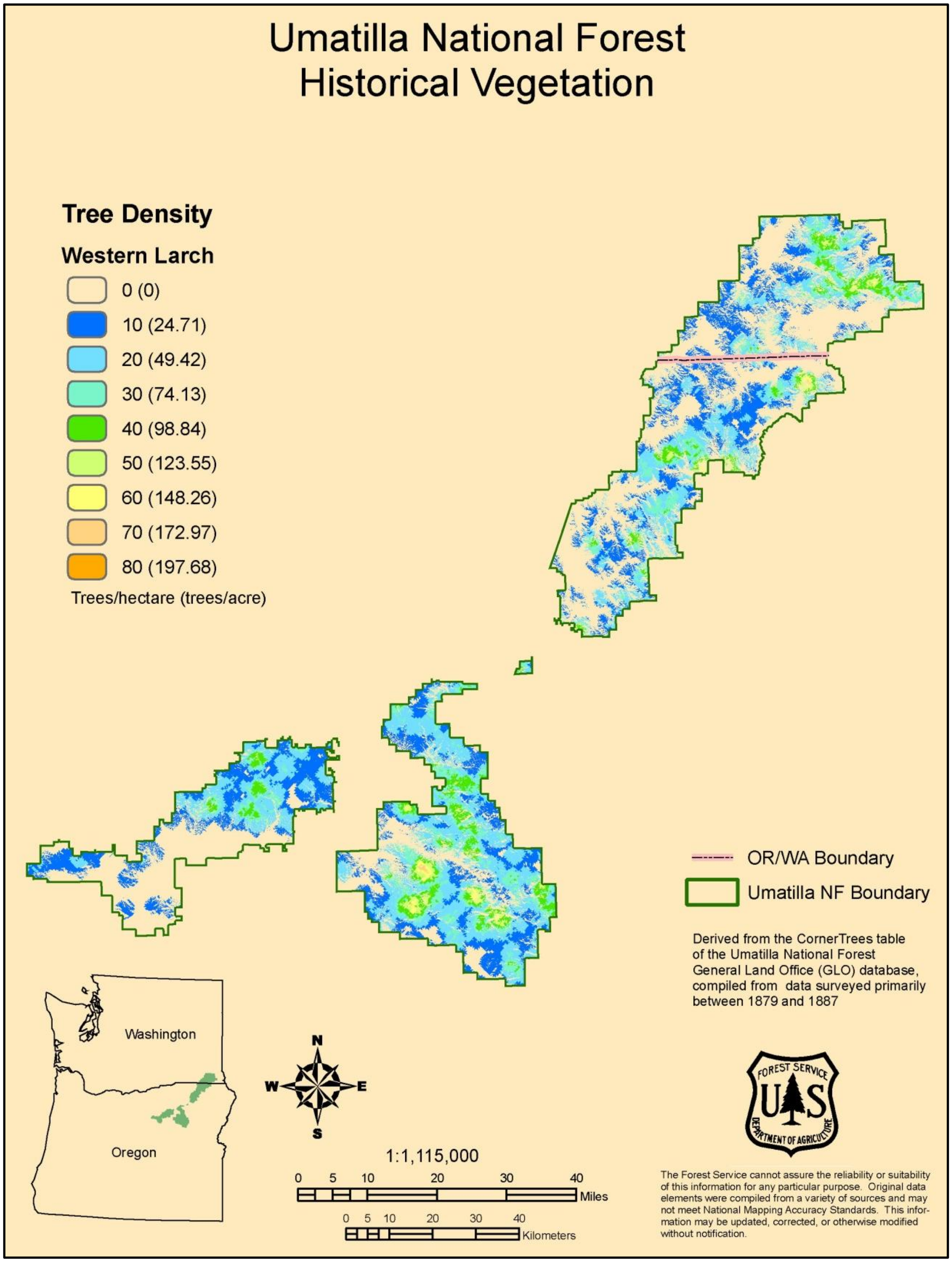
Interpolated tree density for Rocky Mountain maple



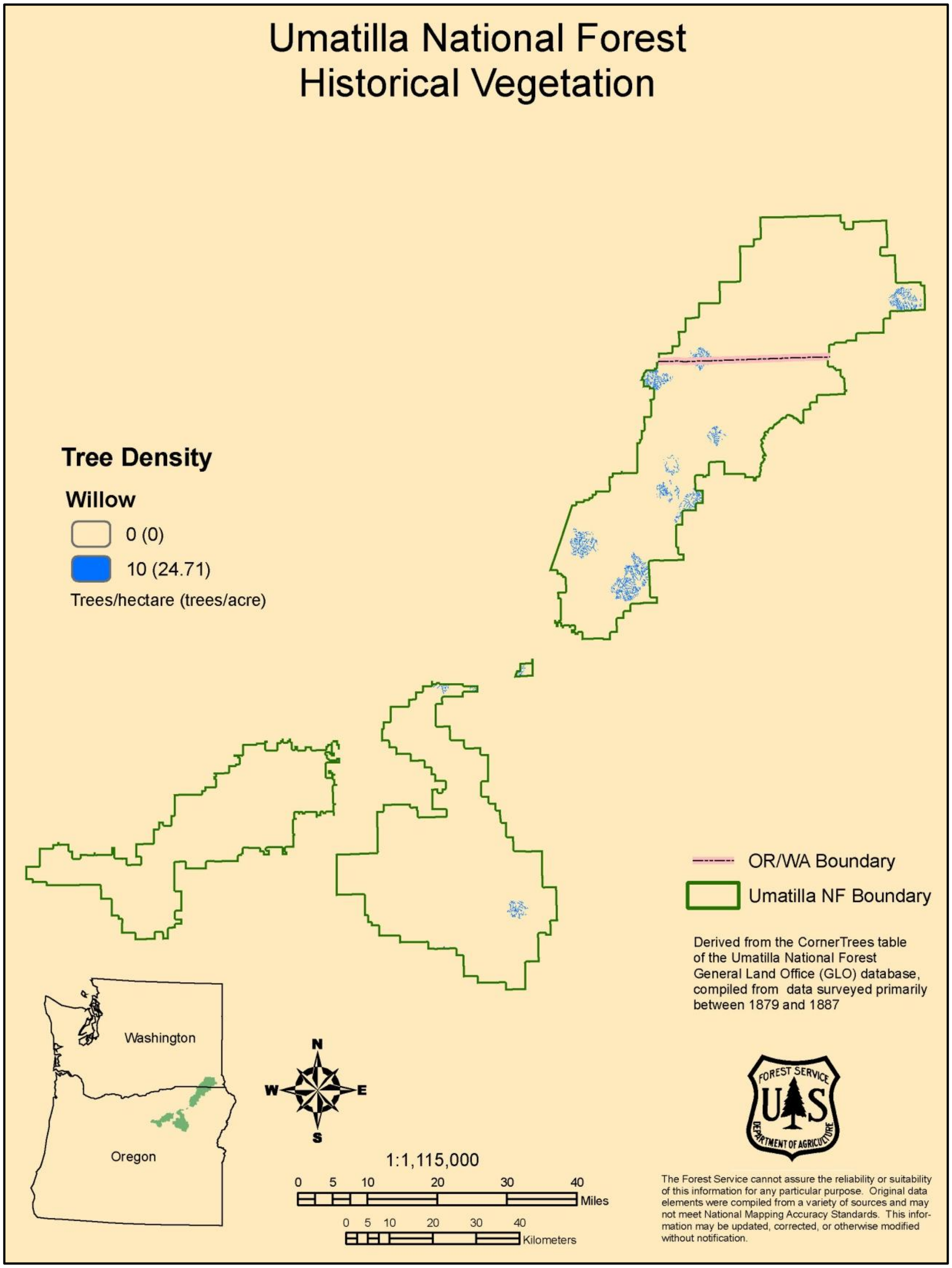
Interpolated tree density for subalpine fir



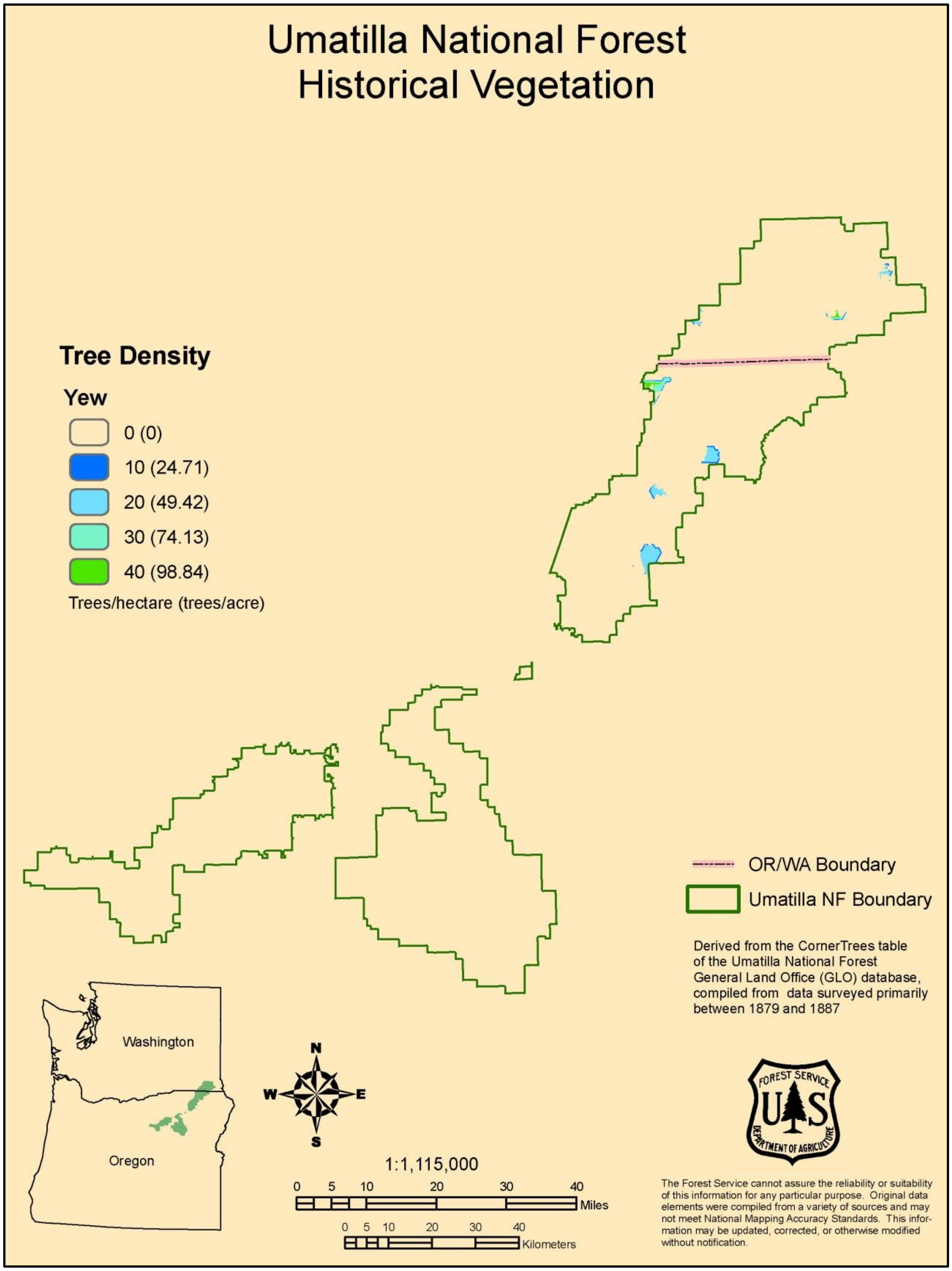
Interpolated tree density for western juniper



Interpolated tree density for western larch



Interpolated tree density for willow



Interpolated tree density for yew

REFERENCES

Abrams, M.D.; McCay, D.M. 1996. Vegetation-site relationships of witness trees (1780-1856) in the presettlement forests of eastern West Virginia. Canadian Journal of Forest Research. 26: 217-224.

Abrams, M.D.; Ruffner, C.M. 1995. Physiographic analysis of witness-tree distribution (1765-1798) and present forest cover through north central Pennsylvania. Canadian Journal of Forest Research. 25: 659-668.

Almendinger, J.C. 1996. Minnesota's bearing tree database. Biological Report No. 56. St. Paul, MN: Minnesota Department of Natural Resources, Division of Fish and Wildlife, Section of Ecological Services. 23 p.

Atwood, K. 2008. Chaining Oregon: surveying the public lands of the Pacific Northwest, 1851-1855. Blacksburg, VA: The McDonald & Woodward Publishing Company. 264 p.

Batek, M.J.; Rebertus, A.J.; Schroeder, W.A.; Haithcoat, T.L.; Compas, E.; Guyette, R.P. 1999. Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. Journal of Biogeography. 26: 397-412.

Beckham, S.D. 1995a. Grande Ronde River, Oregon: river widths, vegetative environment, and conditions shaping its condition, Imbler vicinity to headwaters. Unpublished Report. Walla Walla, WA: Eastside Ecosystem Management Project. 85 p.

Beckham, S.D. 1995b. Tucannon River, Washington: river widths, vegetative environment, and conditions shaping its condition, mouth to headwaters. Unpublished Report. Walla Walla, WA: Eastside Ecosystem Management Project. 63 p.

Black, B.A.; Foster, H.T.; Abrams, M.D. 2002. Combining environmentally dependent and independent analyses of witness tree data in east-central Alabama. Canadian Journal of Forest Research. 32: 2060-2075.

Bourdo, E.A., Jr. 1956. A review of the General Land Office survey and of its use in quantitative studies of former forests. Ecology. 37(4): 754-768.

Bragg, D.C. 2002. Checklist of major plant species in Ashley County, Arkansas noted by General Land Office surveyors. Journal of the Arkansas Academy of Science. 56: 32-41.

Brown, D.G. 1998a. Classification and boundary vagueness in mapping presettlement forest types. International Journal of Geographical Information Science. 12(2): 105-129.

Brown, D.G. 1998b. Mapping historical forest types in Baraga County Michigan, USA as fuzzy sets. Plant Ecology. 134: 97-111.

Buckland, S.T.; Anderson, D.R.; Burnham, K.P.; Laake, J.L.; Borchers, D.L.; Thomas, L. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford, UK: Oxford University Press. 432 p.

Canham, C.D.; Loucks, O.L. 1984. Catastrophic windthrow in the presettlement forests of Wisconsin. Ecology. 65(3): 803-809.

Chang, K. 2002. Introduction to geographic information systems. New York: McGraw-Hill. 348 p.

Clark, P.J.; Evans, F.C. 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology. 35(4): 445-453.

Comer, P.J.; Albert, D.A.; Wells, H.A.; Hart, B.L.; Raab, J.B.; Price, D.L.; Kashian, D.M.; Corner, R.A.; Schuen, D.W. 1995. Michigan's native landscape, as interpreted from the General Land Office surveys 1816-1856. Report to the U.S. EPA Water Division and the Wildlife Division, Michigan Department of Natural Resources. Lansing, MI: Michigan Natural Features Inventory. 76 p.

Comer, P.; Faber-Langendoen, D.; Evans, R.; Gawler, S.; Josse, C.; Kittel, G.; Menard, S.; Pyne, M.; Reid, M.; Schulz, K.; Snow, K.; Teague, J. 2003. Ecological systems of the United States: a working classification of U.S. terrestrial ecosystems. Arlington, VA: NatureServe. 75 p.

Cornett, D.R. 1994. Using General Land Office survey notes in ecosystem mapping. Wild Earth. 4(Fall): 58-60.

Cottam, G.; Curtis, J.T. 1956. The use of distance measures in phytosociological sampling. Ecology. 37(3): 451-460.

Delcourt, H.R.; Delcourt, P.A. 1996. Presettlement landscape heterogeneity: evaluating grain of resolution using General Land Office survey data. Landscape Ecology. 11 (6): 363-381.

Dodds, J.S.; McKean, J.P.; Stewart, L.O.; Tigges, G.F. 1943. Original instructions governing public land surveys of Iowa. Ames, IA: Iowa Engineering Society. 564 p.

Egan, D.; Howell, E.A., editors. 2001. The historical ecology handbook: a restorationist's guide to reference ecosystems. Washington, DC: Island Press. 457 p.

Evans, J.W. 1991. Powerful rockey: the Blue Mountains and the Oregon Trail, 1811-1883. Enterprise, OR: Eastern Oregon State College; Pika Press. 374 p.

Forman, R.T.T.; Russell, E.W.B. 1983. Commentary: evaluation of historical data in ecology. Bulletin of the Ecological Society of America. 64: 5-7.

Galatowitsch, S.M. 1990. Using the original land survey notes to reconstruct presettlement landscapes in the American west. Great Basin Naturalist. 50(2): 181-191.

Gordon, R.B. 1969. The natural vegetation of Ohio in pioneer days. Bulletin of the Ohio Biological Survey. 3(2): 1-113.

Grimm, E.C. 1984. Fire and other factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. Ecological Monographs. 54(3): 291-311.

Habeck, J.R. 1961. The original vegetation of the mid-Willamette Valley, Oregon. Northwest Science. 35(2): 65-77.

Habeck, J.R. 1962. Forest succession in Monmouth township, Polk County, Oregon since 1850. Proceedings of the Montana Acadamy of Sciences. 21: 7-17.

Habeck, J.R. 1994. Using General Land Office records to assess forest succession in ponderosa pine/Douglas-fir forests in western Montana. Northwest Science. 68(2): 69-78.

He, H.S.; Mladenoff, D.J.; Sickley, T.A.; Guntenspergen, G.G. 2000. GIS interpolations of witness tree records (1839-1866) for northern Wisconsin at multiple scales. Journal of Biogeography. 27(4): 1031-1042.

Hutchison, M. 1988. A guide to understanding, interpreting, and using the public land survey field notes in Illinois. Natural Areas Journal. 8(4): 245-255.

Jackson, D.; Spence, M.L., editors. 1970. The expeditions of John Charles Fremont; volume 1: travels from 1838 to 1844. Urbana, IL: University of Illinois Press. 854 p.

Leitner, L.A.; Dunn, C.P.; Guntenspergen, G.R.; Stearns, F.; Sharpe, D.M. 1991. Effects of site, landscape features, and fire regime on vegetation patterns in presettlement southern Wisconsin. Landscape Ecology. 5(4): 203-217.

Lutz, H.J. 1930. Original forest composition in northwestern Pennsylvania as indicated by early land survey notes. Journal of Forestry. 28(8): 1098-1103.

Maclean, A.L.; Cleland, D.T. 2003. Determining the spatial extent of historical fires with geostatistics in northern lower Michigan. In: Omi, P.N.; Joyce, L.A., technical editors. Fire, fuel treatments, and ecological restoration: conference proceedings. Proceedings RMRS-P-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 289-300.

Manies, K.L.; Mladenoff, D.J. 2000. Testing methods to produce landscape-scale presettlement vegetation maps from the U.S. public land survey records. Landscape Ecology. 15: 741-754.

Manies, K.L.; Mladenoff, D.J.; Nordheim, E.V. 2001. Assessing large-scale surveyor variability in the historic forest data of the original U.S. public land survey. Canadian Journal of Forest Research. 31: 1719-1730.

McAllister, L.S. 2008. Reconstructing historical riparian conditions of two river basins in eastern Oregon, USA. Environmental Management. 42(3): 412-425.

Mladenoff, D.J.; Dahir, S.E.; Nordheim, E.V.; Schulte, L.A.; Guntenspergen, G.G. 2002. Narrowing historical uncertainty: probabilistic classification of ambiguously identified tree species in historical forest survey data. Ecosystems. 5: 539-553.

NatureServe. 2003. International ecological classification standard: terrestrial ecological systems of the United States. Natural Heritage Central Databases. Arlington, VA and Boulder, CO: NatureServe, and Natureserve Western Regional Office. 54 p.

Nelson, J.C. 1997. Presettlement vegetation patterns along the 5th principal meridian, Missouri Territory, 1815. American Midland Naturalist. 137(1): 79-94.

Noss, R.F. 1985. On characterizing presettlement vegetation: how and why. Natural Areas Journal. 5 (1): 5-19.

Radeloff, V.C.; Mladenoff, D.J.; He, H.S.; Boyce, M.S. 1999. Forest landscape change in the northwestern Wisconsin pine barrens from pre-European settlement to the present. Canadian Journal of Forest Research. 29: 1649-1659.

Radeloff, V.C.; Mladenoff, D.J.; Manies, K.L.; Boyce, M.S. 1998. Analyzing forest landscape restoration potential: pre-settlement and current distribution of oak in the northwest Wisconsin pine barrens. Transactions. 86: 189-206.

Schulte, L.A.; Mladenoff, D.J. 2001. The original US public land survey records: their use and limitations in reconstructing presettlement vegetation. Journal of Forestry. 99(10): 5-10.

Schulte, L.A.; Mladenoff, D.J. 2005. Severe wind and fire regimes in northern forests: historical variability at the regional scale. Ecology. 86(2): 431-445.

Schulte, L.A.; Mladenoff, D.J.; Nordheim, E.V. 2002. Quantitative classification of a historic northern Wisconsin (U.S.A.) landscape: mapping forests at regional scales. Canadian Journal of Forest Research. 32: 1616-1638.

Simpson, M.; Zalunardo, D.; Eglitis, A.; Wood, D.C.; Roy, D.; Johnson, S. 1994. Viable ecosystems management guide. Prineville, OR: U.S. Department of Agriculture, Forest Service, Ochoco National Forest. 142 p.

Stearns, F.W. 1949. Ninety years change in a northern hardwood forest in Wisconsin. Ecology. 30(3): 350-358.

Stewart, L.O. 1935. Public land surveys: history, instructions, methods. Ames, IA: Collegiate Press, Inc. 202 p.

Teensma, P.D.A.; Rienstra, J.T.; Yeiter, M.A. 1991. Preliminary reconstruction and analysis of change in forest stand age classes of the Oregon Coast Range from 1850-1940. T/N OR-9. Filing Code:

9217. Portland, OR: U.S. Department of the Interior, Bureau of Land Management. 9 p.

Townsend, J.K.; Jobanek, G.A. 1999. Narrative of a journey across the Rocky Mountains, to the Columbia River, and a visit to the Sandwich Islands, Chili, &c., with a scientific appendix. Corvallis, OR: Oregon State University Press. 290 p.

U.S. Department of Agriculture, Forest Service. 1996. Status of the interior Columbia basin: summary of scientific findings. General Technical Report PNW-GTR-385. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 144 p.

U.S. Department of the Interior, Bureau of Land Management. 1959. The public land records...footnotes to American history. Washington, DC: U.S. Department of the Interior, Bureau of Land Management. Not paginated.

White, A.S. 1976. Evaluating land survey notes to determine the pre-settlement structure of the Lubrecht Forest, Montana. Missoula, MT: University of Montana. 62 p. Master of Science thesis.

White, C.A. [Date unknown]. Durability of bearing trees. Portland, OR: U.S. Department of the Interior, Bureau of Land Management, Cadastral Survey Training Staff. 89 p.

White, M.A.; Mladenoff, D.J. 1994. Old-growth forest landscape transitions from pre-European settlement to present. Landscape Ecology. 9(3): 191-205.

Whitney, G.G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. Ecology. 67(6): 1548-1559.

Whitney, G.G.; DeCant, J.P. 2001. Government land office surveys and other early land surveys. In: Egan, D.; Howell, E.A., editors. The historical ecology handbook: a restorationist's guide to reference ecosystems. Washington, DC: Island Press: 147-172.

Wood, D. 1993 (January 7). Review of land survey notes. Unpublished Report. [Prineville, OR]: [U.S. Department of Agriculture, Forest Service, Ochoco National Forest]. 3 p.

Zhang, Q.; Pregitzer, K.S.; Reed, D.D. 1999. Catastrophic disturbance in the presettlement forests of the upper peninsula of Michigan. Canadian Journal of Forest Research. 29: 106-114.