The Original US Public Land Survey Records

Courtesy of State Historical Society of Wisconsin

Their Use and Limitations in Reconstructing Presettlement Vegetation

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ABSTRACT

Studies of pre-European-settlement vegetation frequently use the original Public Land Survey (PLS) records from the US General Land Office. Like all other sources of data, this historical source poses both advantages and limitations. We review spatial and temporal issues concerning the quality of the PLS data for vegetation studies, including surveyor preference for witness tree characteristics and the duration of survey data collection. We present methods to capitalize on the advantages of the PLS data while minimizing their limitations.

Keywords: data quality; historical vegetation; restoration

Natural variability and ecosystem management have been embraced in the past decade as frameworks for understanding and managing dynamic ecological systems. Both concepts rely heavily on knowledge of historical ecosystem conditions, and in an effort to apply them to northern forested ecosystems, the Wisconsin Department of Natural Resources and the USDA Forest Service have participated in developing a historical data set for Wisconsin—the original US Public Land Survey (PLS) records. Not all scientists or managers agree on the utility of these data, however, and questions raised include how well these data portray the pre-European landscape and what they tell us about ecosystem processes over longer time frames.

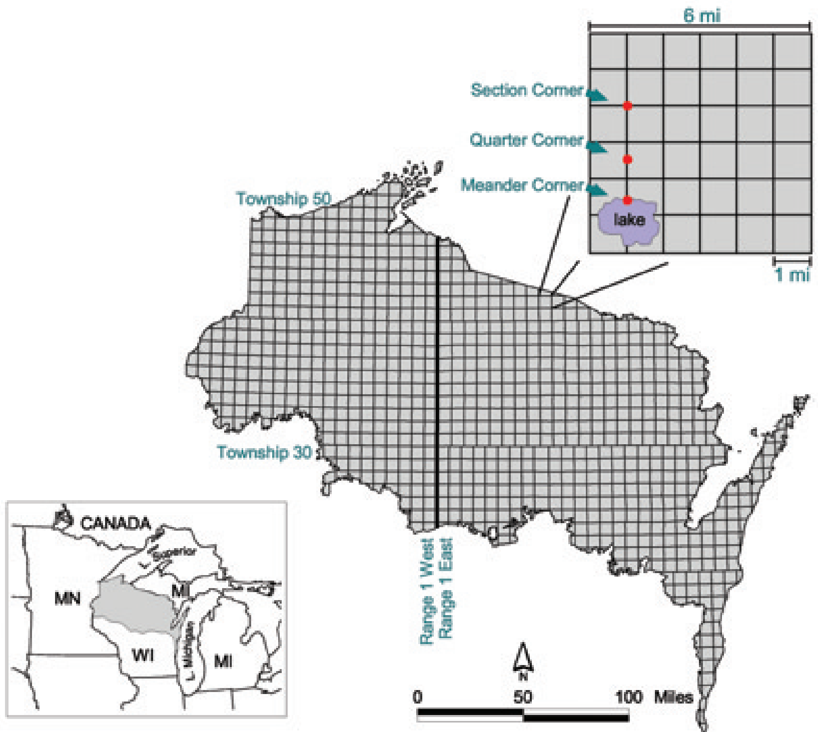
Our objectives here are to review these concerns within the context of the following questions: (1) How does variation in data quality associated with the PLS records affect vegetation studies? (2) What does the vegetation represented by the PLS records mean in a broader temporal context? and (3) How can PLS data best be used in scientific studies and in forest management?

Original US Public Land Survey

In the late 1700s, the United States instituted the PLS to demarcate its territories for sale, grant, and settlement. Initially, the territories were divided into square townships, measuring 36 square miles, which were further sub-

Above: **European settlement introduced new disturbances to the northern Lake States, including broadscale removal of forest vegetation and tilling of the soil. This photograph was taken in Chippewa County, Wisconsin, in 1895, at the height of the lumbering era in this region.**

Figure 1. **Government Land Office surveyors first surveyed township and range lines, which together divided the land into townships, measuring 36 square miles. Townships were divided into one-square-mile units, called sections, and survey data were collected along section boundaries. Surveyors marked and recorded witness trees at section corners, quarter corners, and meander corners.**



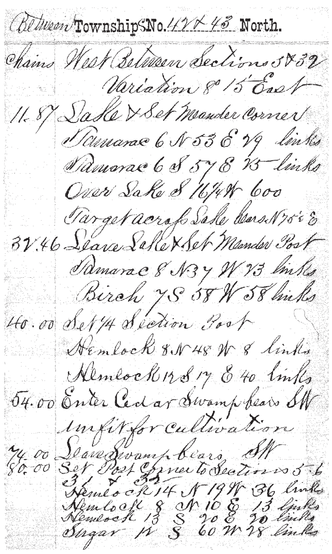
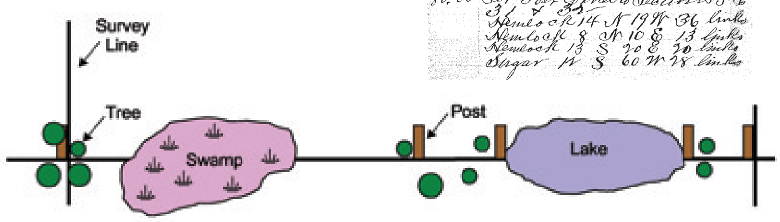

Between Townships No. 47 & 48 North.
Chains West Between Sections 5 & 32
Variation 8° 15' East
11.87 Lake & Set Meander Corner
Tamarac 6 N 53 E 49 links
Tamarac 6 S 57 E 75 links
Over Lake S 1/4 W 600
Target across Lake bears N 75 E
37.46 Leave Lake & Set Meander Post
Tamarac 8 N 37 W 73 links
Birch 7 S 58 W 58 links
40.00 Set 1/4 Section Post
Hemlock 8 N 48 W 8 links
Hemlock 12 S 17 E 40 links
54.00 Enter Cedar Swamp bears SW
unfit for cultivation
74.00 Leave Swamp bears SW
80.00 Set Post Corner to Sections 5 & 6
31 & 32
Hemlock 14 N 19 W 36 links
Hemlock 8 N 10 E 13 links
Hemlock 13 S 70 E 20 links
Sugar 14 S 60 W 28 links

Figure 2. **Page of notes recorded by a surveyor of the original US Public Land Survey. A schematic of data collected runs right to left along the bottom.**



divided into 36 one-square-mile sections (Stewart 1935) *(fig. 1).* Surveyors traversed the boundaries between all sections and, in so doing, marked the intersection of section lines (section corners) and the midpoint between section corners (quarter corners), using a wooden post set into the ground, a mound of earth, or stones. Surveyors also marked the locations where section lines crossed navigable rivers, bayous, or lakes (meander corners) *(fig. 2).*

At section, quarter, and meander corners, surveyors "blazed" two to four nearby trees as "witness" or "bearing" trees. Blazing consisted of inscribing the corner identification and coordinates on the tree, so that given locations could subsequently be relocated. Tree species, diameter, compass bearing, and distance from the corner were then recorded in surveyor notebooks. Other data recorded by surveyors, which are frequently used in studies of historical vegetation, include (1) the location of abrupt boundaries between distinct vegetation types (e.g., swamp versus upland forest); (2) incidences of visible fire or wind disturbance; and (3) line and township descriptions of dominant over- and understory species, agricultural suitability of the soils, topography, and Native American and early Euro-American settlements. Thorough reviews of the survey technique, changes over time in survey instructions, and consistency between the actual survey and the instructions provided can be found in Bourdo (1956).

Data Quality

The intention of the PLS was legal rather than scientific; although surveyors were provided general instructions on how to conduct the survey, lack of expertise and care meant they often did not apply methods consistently. Preference for or discrimination against certain tree species, sizes, and locations has been documented, as well as cases of fraud, which contemporary surveyors usually uncovered and resurveyed (Bourdo 1956). Despite inconsistencies, data collection was largely systematic, quantitative, and statistically representative. PLS records also provide the broadest coverage (Ohio to the

West Coast) and finest spatial resolution (one square mile) of any presettlement data source. The first question then is, To what degree does variability in data quality limit their use in scientific studies of historical vegetation? Methods to investigate this include statistical examination of the original survey data, survey re-creation, and corroboration of PLS-derived vegetation patterns with vegetation data gathered from independent sources.

Statistical examination. Statistical comparison has been the most commonly used mechanism to understand variation within the PLS data. Bourdo (1956), Delcourt and Delcourt (1996), and Manies et al. (in press) all used statistical procedures to test variability among surveyors. Their results show that surveyors working in forested environments were remarkably consistent in the values recorded for distance and direction of the witness tree from the corner post; distances are relatively short and locations were usually in the middle of quadrants. This suggests that preferred witness trees were usually those easiest to locate. Close trees were likely preferred because surveyors were compensated according to each mile of line completed. Written accounts left by surveyors describe survey work as arduous; traveling farther than necessary to obtain witness trees would have required more time, allowing fewer lines to be completed. Survey instructions also required that witness trees at a given point be established in different quadrants (i.e., NW, NE, SE, or SW). Trees obviously located in the center of a quadrant would not have required the compass work that trees near the edge would. Consistent preference for tree distance and direction likely constrained surveyor choice for other ecologically important witness tree characteristics.

In contrast, differences have been found in tree species and diameter characteristics as recorded across surveyors. Manies et al. (in press) showed that some surveyors recorded certain tree species and tree sizes more frequently than others; however, a consistent bias among all surveyors for a specific species or size has not been detected. It is important to point out that most of the statistical tests used here assume that tree species and sizes are randomly distributed in nature. This assumption is not usually met, as the placement of trees on the landscape is constrained by environmental factors. Thus, variability in recording rates for tree species and diameters as uncovered by statistical comparisons may be due to broadscale variation in climatic, soil, topographic, disturbance, and competitive conditions rather than surveyor preferences. In any case, environmental patterning likely tempered surveyor choice through reduced availability of tree species and sizes in the environment surrounding the corner.

Survey reconstruction. Because statistical comparisons cannot answer the question of how well the original PLS records approximate "true" vegetation patterning, Manies and Mladenoff (2000) expanded on statistical analyses by re-creating the PLS on a modern landscape. They surveyed the Sylvania Wilderness Area in the Upper Peninsula of Michigan first by approximating the surveyors' techniques (Stewart 1935) and then by using random sampling at each corner. Sylvania was chosen as a study area because this region is dominated by forests of old-growth hemlock *(Tsuga canadensis)* and northern hardwoods (predominantly *Acer saccharum* and *Betula alleghaniensis*) that approximate presettlement conditions. Comparing the PLS reconstruction and random datasets showed that the PLS sampling method slightly underestimates tree species richness and the range of diameter classes (fewer small and fewer large trees). Despite these underestimates, the PLS data can still represent broadscale vegetation patterns. Subsequent mapping of the PLS data and comparison of resultant patterning to aerial photos showed that the data collected using the PLS sampling method accurately estimated relative species composition and the order of dominance of land cover types at broad spatial scales (Manies and Mladenoff 2000). Of all witness tree characteristics, surveyor preference for or discrimination against tree species is most likely to affect the mapping of vegetation patterning, yet Manies and Mladenoff (2000) showed that this factor did not strongly influence the accuracy of their maps.

Corroborating with other sources. Independently gathered data can also be used to corroborate the general quality of PLS survey. Journals kept by the early explorers, such as 19th century explorer Henry Rowe Schoolcraft (1855) in the Midwest, contain information on the physiognomy of vegetation and generally agree with patterns displayed by the PLS records. Lumber receipts and shipping records support the PLS notes in regard to the dominance of species, such as white pine *(Pinus strobus)* and eastern hemlock, in different parts of the northern Lake States (Williams 1989). Palynological studies using fossil pollen and charcoal corroborate presettlement species range boundaries (Davis 1981) and fire frequencies (Clark and Royall 1996).

Temporal Context

As a record of historical vegetation, the PLS notes have the advantage of covering a broad spatial extent at a relatively fine resolution, but what do they mean temporally?

Survey data were not all gathered within the same year. In Wisconsin, the majority of the survey occurred over a 34-year period (1832–66), and when measured on a human scale, this window of time seems large. Vegetation differences between adjacent townships, where several years may have passed between surveys, could have been caused by various temporal processes, both natural (e.g., disturbance, competition, or predation) and anthropogenic (e.g., burning, hunting, or harvesting), rather than by differences in site conditions. Although these factors can make patterns more difficult to interpret, in many regions the data still effectively represent a single ecological period—a period in which human impacts on the land were very different from the impacts associated with European settlement.

Within portions of North America, the shift from Native American to European land stewardship was rapid and largely occurred within the lifetime of the dominant tree species (Williams 1989). Pre-Colombian Native American population levels, a topic germane to discussions of the naturalness of pre-European vegetation, are continually debated without clear resolution. It is likely safe to conclude, however, that

- Native peoples affected the ecosystems they inhabited through their use of fire, game, and agriculture (Russell 1983).
- The impact of native peoples was heterogeneous at several scales, local to continental, much like other ecological phenomena (Vale 1998).
- The impact of native peoples on vegetation patterning was less pronounced in regions of marginal agriculture due to lower population levels (Cronon 1983).
- In many areas the impact of Native Americans was much lighter than that of the Europeans who followed them (Cole et al. 1998).

Although broadly useful in documenting the ecological conditions of a specific period, for studies of natural variability the PLS data are likely most useful in regions of marginal agriculture, where Native American populations and impacts were relatively lower. This includes much of our present-day forestlands.

The PLS data may also functionally represent vegetation patterning over longer time frames. Palynological research suggests that vegetation in the Midwest may have been stable for as long as 2,000 to 3,000 years prior to settlement (Davis 1981; Cole et al. 1998). The spatial scale to which this generalization may pertain, however, requires further research.

Scientific Use of the PLS Records

Given the strengths and limitations of PLS data, how can we use them to answer current-day questions regarding historical vegetation? The purpose and scale of investigation should be considered first; quantitative hypothesis testing requires a different set of techniques than general, descriptive work. Delcourt and Delcourt (1996) provide guidelines on the use of PLS data at fine spatial extents (tens of square miles), and Grimm (1984) successfully uses them at intermediate extents (hundreds of square miles). Our lab is currently researching how PLS data might best be analyzed over broad spatial scales (thousands of square miles) (Schulte et al., in review) *(fig. 3).*

In a relative way. When comparing across regions, we recommend first normalizing the quantitative witness tree data over a relative scale. In cases where a local sample deviates from broader averages, a relative estimate reduces the magnitude of error. For instance, a researcher interested in the pre-European patterning of aspen *(Populus tremuloides* and *P. grandidentata)* basal area should relativize absolute basal area over a scale of zero to 100 percent, to form a measure of relative dominance. Whereas absolute basal area may be called into question, as several studies have shown strong surveyor preference for trees 8 to 16 inches in diameter, aspen's superior colonization and competitive ability on recently burned sites left few other species for the surveyor to choose from. Bias against small or large aspen trees may have occurred, but the relative dominance of aspen in comparison to other tree species should remain representative.

Placing data into classes can also help reduce the effects of some errors. Using the example of witness tree diameter data, surveyors estimated diameters by eye and usually showed strong preferences for even-numbered sizes (e.g., 10 inches, 12 inches). Because it was uncommon for surveyors to record odd-numbered diameters, although they were likely distributed on the landscape with similar frequencies as even-numbered ones, most users of the PLS records group witness trees into two-inch diameter classes (e.g., 9–10 inches, 11–12 inches).

Under certain circumstances, however, information measured on an absolute scale can offer insights that relativized or generalized data cannot. For example, Anderson and Anderson (1975) used the distance from corners to witness trees to distinguish between prairie, savanna, open forest, and closed forest ecosystems.

At broad spatial scales. When used by themselves, the PLS witness tree data are best applied at broad spatial extents and using coarse resolutions. Broadening the window over which the records are studied does two things. First, it increases the chance of incorporating data from a greater number of surveyors, thus reducing the chance of basing an entire study on the preferences of a single person. Second, it is likely to incorporate greater environmental heterogeneity, providing greater context for interpretations (e.g., where aspen was dominant). In terms of resolution, the witness tree data are inadequate in representing stand-level composition and patterning by themselves, because of the coarse sampling density at which they were gathered (only one point with two to four trees per one-half mile). In the mapping of PLS reconstruction data from the Sylvania Wilderness Area, Manies and Mladenoff (2000) showed that the ability of mapped PLS data to approximate vegetation at the resolution of the aerial photo (164 square feet) was poor (< 50 percent). Both Manies and Mladenoff (2000) and Delcourt and Delcourt (1996) recommend using the PLS data at coarser resolutions (approximately one square mile).

We find that many researchers, however, are interested in tackling questions that require a finer resolution than that obtained via witness tree data alone. Several mechanisms have been proposed to obtain finer scale patterning. One option includes using additional information derived from the PLS notes, including the location of ecotones and the relative abundance of tree species provided in the section line descriptions. This technique was applied qualitatively by Finley (1976) for Wisconsin, but it is time-intensive, requires subjective decisionmaking, cannot be replicated, and has its own set of shortcomings (e.g., surveyors only recorded abrupt ecotones, no data for center of sections). Another option is to supplement the PLS data with information on soils and topography as also performed qualitatively by Finley (1976) or applied quantitatively by Brown (1998). Again, the qualitative approach is time-intensive, requires subjective decisionmaking, and is not repeatable. In both cases, maps derived must bear the label "potential" vegetation, because mapping involves extrapolation of relationships to regions where no data are present. Importantly, such uses of ancillary data preclude their use as independent variables for subsequent analysis of species-environment relationships.

A finer approach may be necessary to answer some questions, despite potential problems with using the data at this scale. In tackling questions of vegetation-site relationships, Whitney (1986) used PLS data at a point level to understand the relationship between presettlement pine forests and their substrates in Michigan. If the patterning of the independent variables exists at a finer resolution than the PLS data, using a PLS dataset that has been generalized over a coarser resolution will occlude most potential effects. Fine-scale analyses may also be necessary if the vegetation type in question never achieved the status of dominant cover type at one-square-mile resolution, as is the case with small, patchy, or linear riparian and forested wetland ecosystems in northern Wisconsin. The patterning of these vegetation types cannot be accurately represented at a coarse scale and, hence, treatment of these systems requires techniques that are more intensive. Given the spatial limitations of the witness tree data, these approaches may not be valid; we urge care and thorough investigation of potential errors or biases within the data prior to analysis.

In conjunction with other data sources. Cross-validation of results using multiple independent data sources can make a stronger case for a particular set of vegetation patterns. When possible, PLS data should be used in conjunction with other data sources, or at least interpreted in the context of other independent studies. Additional sources of information include other historical records, lake sediment cores of pollen and charcoal, and dendroecological data, as well as information gathered from current-day reference areas. It is important to recognize, however, that these sources of information, like the PLS records, pose their own strengths and limitations. Andersen et al. (1996) provide a successful example of a multi–data source approach in the lower St. Croix river valley of Wisconsin and Minnesota. They use data gathered from the PLS records, federal censuses, lumber and agricultural records, accounts of early settlers and historians, scientific reports, maps, and photographs to paint a clear picture of landscape change between presettlement and the present.

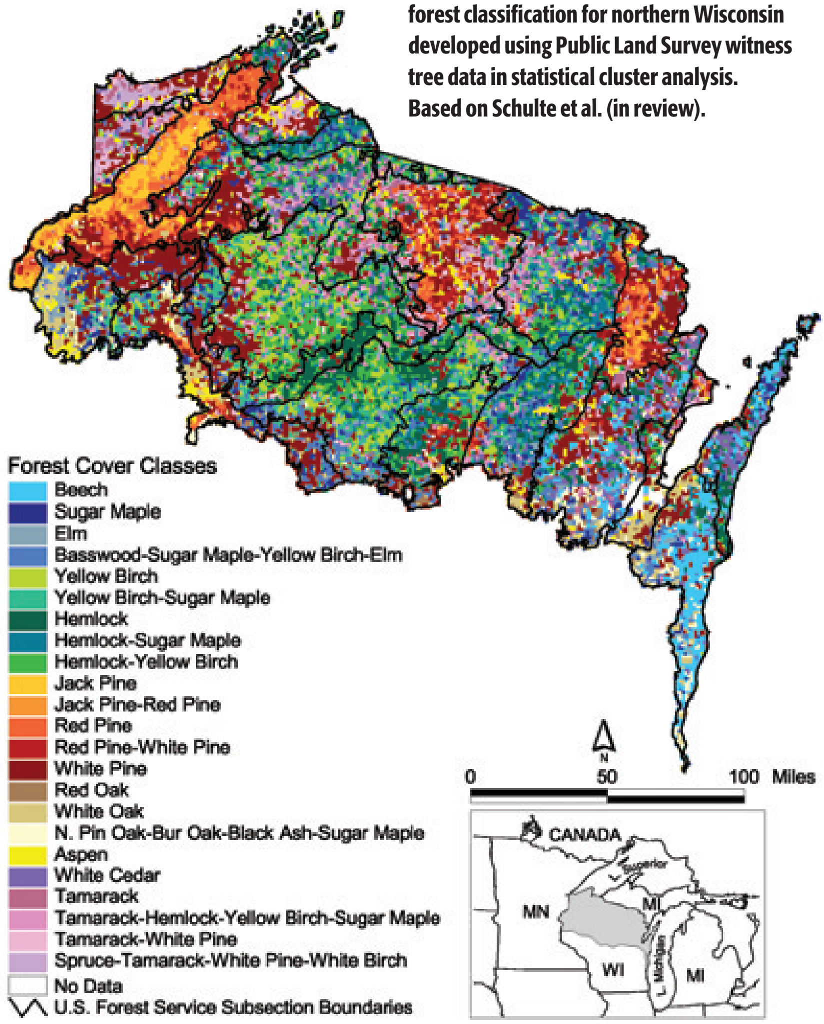


Figure 3. **A quantitative presettlement forest classification for northern Wisconsin developed using Public Land Survey witness tree data in statistical cluster analysis. Based on Schulte et al. (in review).**

Conclusion

Of historical data sources, the PLS data have the advantages of being quantitative, (possibly) statistically representative, collected over broad spatial scales, of relatively fine resolution, and representative of a discrete period. Elements of individual surveyor preferences entered the equation, but choice and possible biases were often constrained by two factors: (1) For the surveyor, the easiest tree to locate was the best tree, and (2) few tree species and sizes were available within the immediately surrounding environment. Thus, the PLS witness tree data can mirror major features of vegetation patterning.

For many regions the PLS records represent a single ecological period—a period before rapid deforestation, settlement, and conversion of the land to agriculture by peoples of European descent—although in some areas palynological research suggests that the temporal window that the records represent may be expanded to 2,000 to 3,000 years. Because of spatial and temporal inconsistencies in the way the data were collected, the PLS records generally provide their best description of presettlement vegetation when used in a relative way, analyzed over broad spatial extents and at coarse spatial resolutions, and used in conjunction with other historical data sources. This approach may not be warranted for all analyses, and researchers must consider specific study objectives, especially the scale at which questions may be best answered, when choosing methodology.

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