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# A Vegetation Reconstruction of Union County, Pennsylvania During the Early Historical Period (1755-1855)

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# A VEGETATION RECONSTRUCTION OF UNION COUNTY, PENNSYLVANIA DURING THE EARLY HISTORICAL PERIOD (1755-1855)

By

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**Abstract**

This thesis assesses relationships between vegetation and topography and the impact of human tree-cutting on the vegetation of Union County during the early historical era (1755-1855). I use early warrant maps and forestry maps from the Pennsylvania historical archives and a warrantee map from the Union County courthouse depicting the distribution of witness trees and non-tree surveyed markers (posts and stones) in early European settlement land surveys to reconstruct the vegetation and compare vegetation by broad scale (mountains and valleys) and local scale (topographic classes with mountains and valleys) topography. I calculated marker density based on 2 km x 2 km grid cells to assess tree-cutting impacts. Valleys were mostly forests dominated by white oak (*Quercus alba*) with abundant hickory (*Carya* spp.), pine (*Pinus* spp.), and black oak (*Quercus velutina*), while pine dominated what were mostly pine-oak forests in the mountains. Within the valleys, pine was strongly associated with hilltops, eastern hemlock (*Tsuga canadensis*) was abundant on north slopes, hickory was associated with south slopes, and riparian zones had high frequencies of ash (*Fraxinus* spp.) and hickory. In the mountains, white oak was infrequent on south slopes, chestnut (*Castanea dentata*) was more abundant on south slopes and ridgetops than north slopes and mountain coves, and white oak and maple (*Acer* spp.) were common in riparian zones. Marker density analysis suggests that trees were still common over most of the landscape by 1855. The findings suggest there were large differences in vegetation between valleys and mountains due in part to differences in elevation, and vegetation differed more by topographic classes in the valleys than in the mountains. Possible areas of tree-cutting were evenly distributed by topographic classes, suggesting Europeans settlers were clearing land and harvesting timber in most areas of Union County.

## Introduction

During the early European settlement period, land surveyors used trees to mark property boundaries, leaving behind records and maps that have made it possible to reconstruct historical vegetation (Bourdo 1956; Siccama 1971; Abrams and Ruffner 1995; Black and Abrams 2001). These reconstructions have proven invaluable for our understanding of the ecology and environmental history of the eastern United States (e.g. Cronon 1983; Nowacki and Abrams 1992; Abrams and Ruffner 1995; Black and Abrams 2001). In this study, I reconstruct the historical vegetation of Union County during the early historical era (1755-1855) to assess the relationship between topography and vegetation and the impact of European settler tree cutting on vegetation.

Pennsylvania was mostly forested at the time of European settlement. However, open vegetation types existed on xeric limestone soils (Laughlin and Uhl 2003), serpentine barrens (Arabas 2000), and shale barrens (Anderson et al 1999). In Central Pennsylvania, William Scull's 1770 map of Pennsylvania describes a portion of Centre County as the "Great Plains" (Figure 1), which Losensky (1961) identifies as approximately 0.14 square km of open vegetation and Ruffner and Arabas (2000) and Laughlin and Uhl (2003) attribute to burning. Indeed, Indians may have used fires to modify vegetation with the goal of managing food sources (e.g., promoting economically useful tree species, hunting, and clearing land for agriculture) and protection (Nowacki and Abrams 1997).

Whatever the aboriginal impact on vegetation, it was subtle in comparison to the scale in which European settlers transformed the landscape. During the early historical era, Europeans transformed the vegetation and cleared the landscape of Central Pennsylvania

with activities including agriculture, logging, and clear-cutting to support the iron industry (Nowacki and Abrams 1992; Abrams and Ruffner 1995; Snyder 2000). The questions arising from these land use practices are: What was the nature and composition of the woodlands into which Europeans settled, and to what extent did they modify it during their first century of occupancy?

I examine these questions using Union County, Pennsylvania as a case study. Located in the Ridge and Valley Physiographic Province, Union County has a diverse topography. Such topographic diversity makes it possible and essential to assess how topography influenced vegetation and early European settler clearing patterns in Union County.

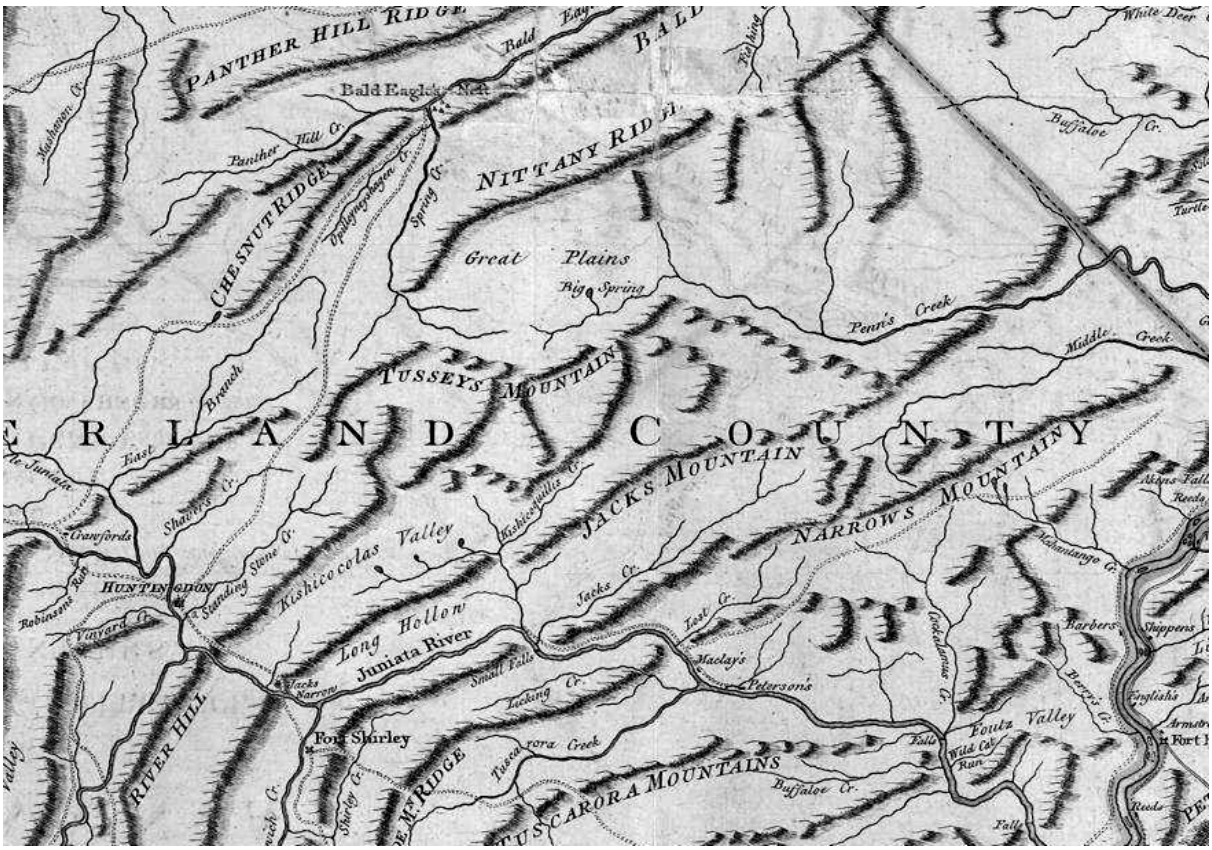


**Figure 1:** The portion of William Scull's 1770 map of Pennsylvania showing the "Great Plains" in Centre County, Pennsylvania (Scull 1770).

## Study Area

*Physical description*

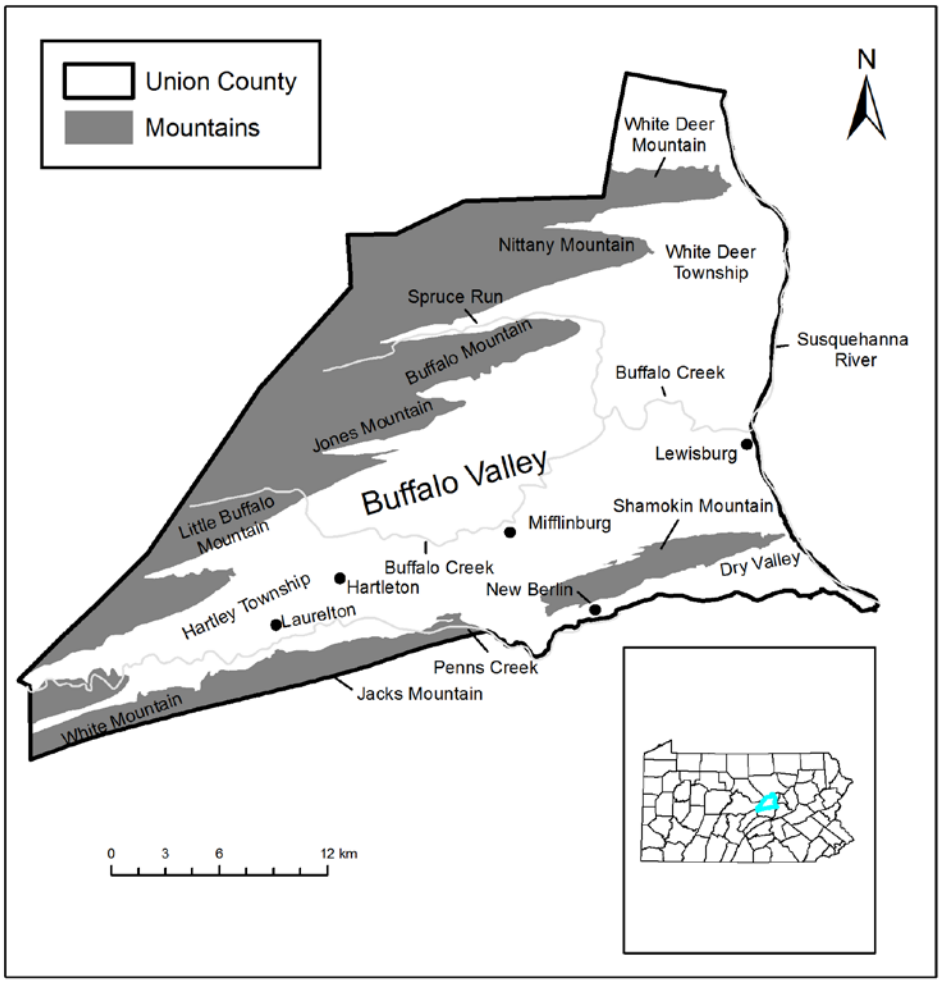


**Figure 2.** Towns, valleys, creeks, and other geographical features in Union County, Pennsylvania.

Union County, Pennsylvania is approximately 826 square km and located in the Ridge and Valley Physiographic Province (Figure 2). Bedrock was formed in the Ordivician, Silurian, and Devonian periods, and glacial till was deposited during the Pleistocene period (Eckenrode 1985). Topography is almost evenly divided between mountainous uplands with a maximum elevation of 662 m and hilly, broad valleys with a minimum elevation of 129 m (Figure 2; USGS 2000). The mountains are made of sandstone with deep, mostly coarse-

grained and well-drained soils separated by mountain valleys ("coves") formed in weaker sandstones and shale (Eckenrode 1985). The hilly valleys are composed of shale and carbonate with mostly fine-grained, shallow to deep, well-drained soils (Eckenrode 1985). The county has a humid-continental climate with an average temperature of -2 º C in the winter and 21 º C in the summer. Average annual precipitation is 990 mm with 55 % falling from April to September (Eckenrode 1985).

Topographical differences create microclimates. Higher elevations in mountains are cooler than lower elevations, and south slopes receive more direct sunlight and are drier than north slopes (Macdonald 2002). According to the Natural Areas Inventory of Union County (Davis et al 1993), the combination of topography, climate, soils, and other factors support a present-day vegetation in the valleys that includes mixed-oak communities associated with red maple (*Acer rubrum*; nomenclature follows Rhoads and Block 2000), tulip poplar (*Liriodendron tuilipifera*), and white pine (*Pinus strobus*); and contemporary vegetation in the ridges probably reflects the abundant white pine, white oak (*Quercus alba*), red oak (*Quercus rubra*), and chestnut oak (*Quercus prinus*) that Abrams and Ruffner (1995) found in the ridges of the Ridge and Valley Physiographic province of Centre County, Pennsylvania.

*Human settlement history*

Archeological evidence suggests that Indians arrived in the Susquehanna River Valley 11,000 years ago (Minderhout and Dowsett 2009). At the time of European settlement, Indians in Union County had settled in small villages. The major tribes living in these villages were the Muncy-Minsi and Lenni-Lenape, both offshoots of the Delaware. According to historical accounts, Indians used the Buffalo Valley (Figure 2) as a hunting

ground (Linn 1877) and cultivated squash (*Cucurbita* spp.), beans (*Phaseolus vulgaris*), corn (*Zea mays*), and tobacco (*Nicotiana* spp.) around their settlements (Meginess 1853), which included Muncy Town (or Shikellamy), Gordon, and an "unnamed village" (Figure 3; Linn 1877; Bitely 2010). There is also archeological evidence of a temporary village to the north of Buffalo Creek (Figure 2; B. Marsh personal communication, April 27, 2011). Commercial activity flowed from Shamokin, located at the confluence of the West and North Branches of the Susquehanna River, along Penns Creek path and the Great Island path (Wallace 1993; Figure 3).

The first land surveys in Union County were completed in 1755 when Europeans made a failed attempt at settling along Penns Creek (Figure 2). Permanent European settlement began in 1769 along the Susquehanna River and Penns Creek and grew quickly to the west and north until the mid-nineteenth century when population growth declined (Snyder 2000). In 1769, William Maclay employed his brother Samuel to execute a survey of the Buffalo Valley (Figure 2), which succeeded in parceling most of the arable land (Snyder 2000). That same year, John Lee settled at Winfield (Snyder 2000), possibly forming the first clearing in the Dry Valley (Figure 2), and Ludwig Derr settled on land next to Limestone Run (now Bull Run) and built a mill on his plot a year later (Snyder 2000). By 1776, 4,323 acres were under cultivation in Union County by 215 landowners (Snyder 2000). In 1785, Ludwig Derr laid out the town of Lewisburg on his land (Figure 2). Mifflinburg was established in 1792 (Figure 2). In 1813, Union County was established from part of Northumberland County (Snyder 2000). During the early historical era, Europeans cleared land for agriculture, logging, and charcoal to fuel iron furnaces (Snyder 2000; Whitney

1994). In the 1820s, Berlin Iron Works was founded along Penns Creek to the south of Laurelton (Figure 2; Snyder 2000).

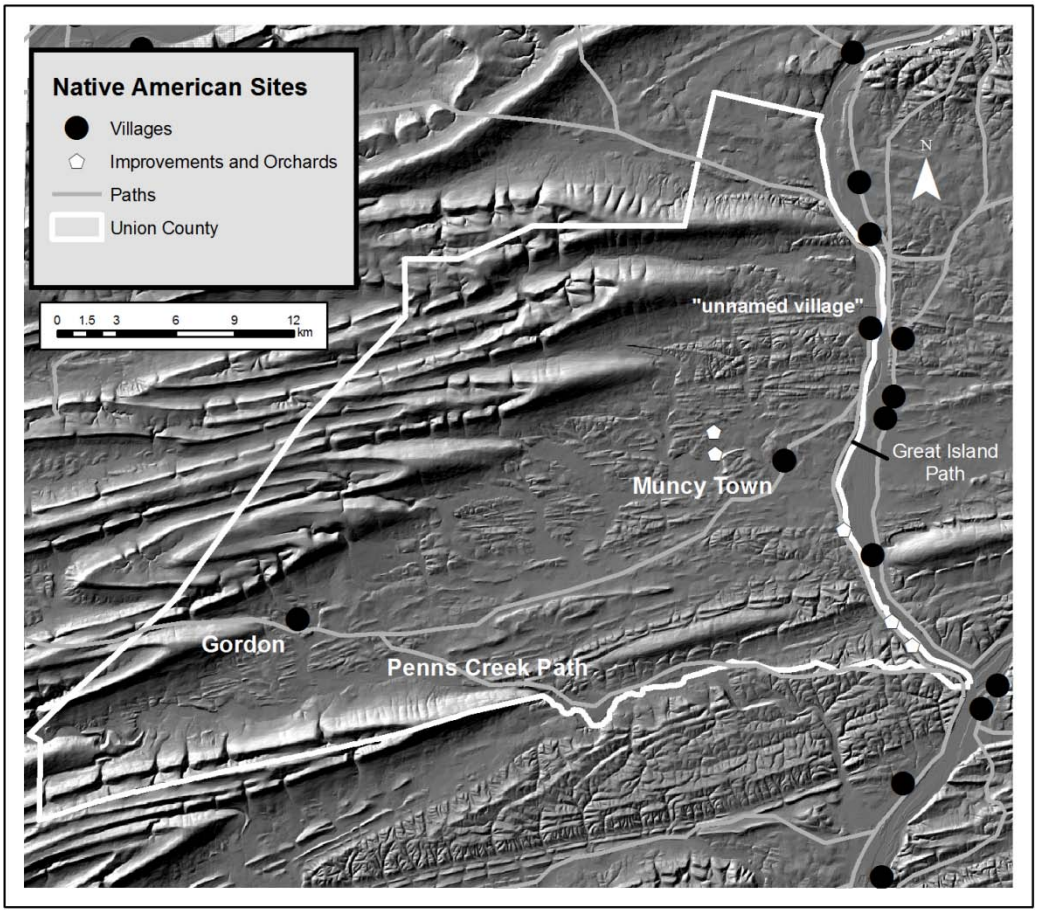


**Figure 3.** Native American paths and settlements in Union County immediately preceding European settlement (Bitely 2010).

## Methods

To reconstruct the vegetation of Union County and assess the relationship between early historical era vegetation and topography and the extent of European settler tree-cutting, I used the following three methods. First, I classified the county into broad scale (mountains and valleys) and into local scale (topographic classes within the mountains and valleys) topography. Next, I reconstructed vegetation with land survey records from 1755 to 1855 to

analyze tree composition by topographic classes. Finally, I used marker density analysis, where I quantified the uneven distribution of posts and stones[1] found in the land survey record to determine where European tree-cutting was most intensive in the county.

*Classifying topography*

Using ArcGIS, I delineated topographic classes (valley hilltops and mountain ridgetops, north slopes, south slopes, valley floors and mountain coves, and riparian zones) based on a 10 m digital elevation models of Union County (DEMs; USGS 2000; Figure 6). First, I differentiated mountains and valleys by rendering mountainous areas based on hillshades of the 10 m DEM. Next, based on calculations of slopes and aspect, I differentiated north slopes from south slopes (Table 1). I then differentiated hilltops/ridgetops from valley floors/mountain coves by smoothing the 10 m DEM to obtain local mean elevation and then subtracted the original 10 m DEM from the smoothed 10 m DEM. Based on this calculation, I defined all positive values as valley hilltops and mountain ridgetops and all negative values as valley floors and mountains coves (Table 1). Finally, I overlaid riparian zones based on 100 year floodplains as calculated by the Penn State University Office of Remote Sensing for Earth Resources (Penn State University 1996; Table 1).

[1] I refer to post and stones as "markers."

| Topographic Classes | Definition | Valley, Mountain, or Both |
|---|---|---|
| North Slope | Gradient > 10 % and aspect between 0 and 90 degrees and > 270 | Both |
| South Slope | Gradient > 10 % and aspect between 90 and 270 degrees | Both |
| Hilltops | Gradient < 10 % and positive variation from mean smoothed DEM elevation | Valley |
| Ridgetop | Gradient < 10 % and positive variation from mean smoothed DEM elevation | Mountain |
| Valley Floor | Gradient < 10 % and negative variation from mean smoothed DEM elevation | Valley |
| Mountain Cove | Gradient < 10 % and negative variation from mean smoothed DEM elevation | Mountain |
| Riparian Zone | 100-year floodplain | Both |

**Table 1.** The definitions of topographic classes in Union County, Pennsylvania.

*Tree species composition analysis*

To reconstruct the vegetation composition, I used warrant maps and forestry maps from the Pennsylvania State Archives as well as a warrantee maps from the Union County Courthouse (Table 2). These maps depict land surveys dating from 1755 to 1916, although the vast major of land surveys were recorded before 1855. It is at this date the Pennsylvania State Archives warrant map survey records end and population growth declined in Union County (Snyder 2000). In addition, the data contains fewer than 10 points dating after 1867.

Warrant maps represent land surveyed by surveyors as Europeans settled the Eastern United States (Abrams and Ruffner 1995). These maps contain the bearings and distances linking each property corner, which surveyors identified by marking with a witness tree[2] or marker. Warrants were issued to citizens and soldiers on demand. After surveying the land, maps were produced, which included trees, posts, and stones, Indian paths, streams, and

[2] Witness trees are trees blazed by surveyors representing property corners in early European land surveys of the eastern United States.

other prominent geographical features. Warrants were then patented and issued to the property owner, and were made official after the first tax payment (Abrams and Ruffner 1995).Warrant maps have limitations, as surveyors may have misidentified tree species, misrepresented the frequency of larger tree species (Black and Abrams 2001), and tended to record only genus names for some groups—e.g. pines (*Pinus* spp.), birches (*Betula* spp.), and maples (*Acer* spp.). Despite these limitations, warrant maps depict a large number of tree species and generally agree with qualitative descriptions (Abrams and Ruffner 1995; Black and Abrams 2001). Forestry maps and warrantee maps are also useful in reconstructing historical vegetation as they are updated versions of warrant maps that include depictions of the original warrants and property corners and later property subdivisions (Figure 4; Figure 5).

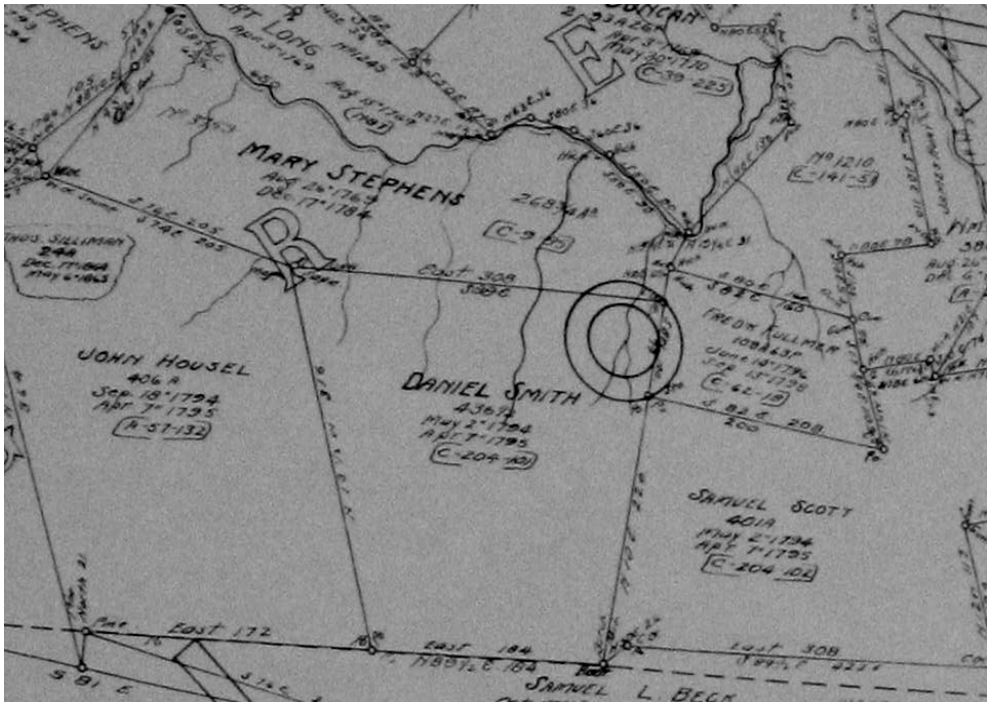


**Figure 4.** A forestry map showing Daniel Smith's property in Greggs Township, Union County, Pennsylvania including the warrant date and witness trees and markers on property corner (Pennsylvania Department of Forestry 1916; Table 2).

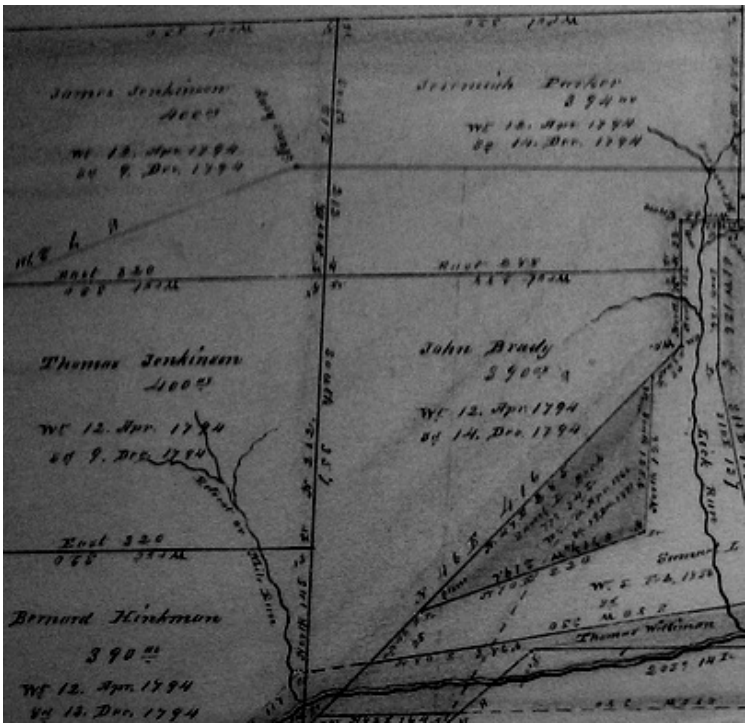


**Figure 5.** A portion of a warrantee map showing John Brady's property in West Buffalo Township, Union County, Pennsylvania including the warrant date and witness trees and markers on property corners. Photograph taken at Union County, Pennsylvania Courthouse (Pomeroy and Beer 1868; Table 2).

| Map Type | Author | Year | Dates of Original Drafts | Name | Source |
|---|---|---|---|---|---|
| Reconstructed Warrant Map | Munger, D. B | 1989 | 1770-1873 | White Deer Township Warrant Map | Pennsylvania Historical and Museum Commission |
| Forestry Map | | 1916 | 1916 | Map F-7 | Pennsylvania Department of Forestry |
| Forestry Map | | 1916 | 1916 | Map G-5 | Pennsylvania Department of Forestry |
| Forestry Map | | 1916 | 1916 | Map G-7 | Pennsylvania Department of Forestry |
| Warrantee Map | Pomeroy and Beers | 1868 | 1868 | Union County Warrantee Map | The Atlas of Union County and Snyder Counties, PA |

**Table 2.** Sources for warrant maps, forestry maps, and warrantee maps used in reconstructing the vegetation of Union County during the early historical era.

I georeferenced warrant maps to modern parcel boundaries and digitized 1,783 witness trees and markers (Appendix B) using ArcGIS (ESRI, Redland, CA). In some cases, it was difficult to digitize points based on modern parcel boundaries. To address problems with geographical precision, I assigned digitized points with a confidence value of 1 (highest confidence in geographical precision) to 4 (lowest confidence in geographical precision) (Appendix C). In addition to confidence score, I recorded each witness tree or marker's species or genus and township.

For tree species composition analysis, I overlaid the warrant map survey data over mountains, valleys, and each local topographic class in ArcGIS. I then summarized tree species occurrence and marker total to obtain tree species frequencies and counts by topographic class (Table 1).

*Marker density analysis*

To assess geographical patterns of European tree-cutting, I conducted marker density analysis. First, I identified areas where Europeans were most likely cutting trees. Markers counts were uneven across the county. Thus, I needed to quantify makers by percent to identify areas where tree-cutting was most intensive. To obtain the distribution of markers by percent, I resampled the trees and markers data in ArcGIS and then arbitrarily placed a grid of 2 km x 2 km cells onto a map of Union County to identify areas with high (50% to 100%), medium, (20% to 50%), and low (0% to 20%) densities of markers. Only cells with marker counts of $n > 4$ were included. Second, I assessed whether European settlers preferred some topographical site types over others. As a result, I constructed contingency tables for chi-

square analysis to assess these possible differences in marker distribution by topographic classes.

**Results**

Counts and frequencies for all tree species and markers in each topographic class are found in Appendices D, E, and F. In the valleys, white oak (*Quercus alba*; 43 %) was the dominant tree species, and pine (11.3 %), black oak (*Quercus velutina*; 11.2 %), and hickory (*Carya* spp; 10.1 %) were abundant (Figure 7; Appendix D). In contrast, mountains were dominated by pine (31.9 %) and had a high frequency of chestnut oak (*Quercus prinus*; 13.7 %), white oak (12.2 %), and black oak (7.6 %).

At finer scales, valley floors composed most of the extent of the valley (Figure 6). On valley floors, white oak was dominant (45.3 %). White oak was also frequent on south slopes (49 %) and on north slopes (45.3 %) (Figure 8; Appendix E). On hilltops, pine (28.6 %) was more abundant than on other topographic classes. Eastern hemlock (*Tsuga canadensis*) was abundant on north slopes (10.7 %) but absent on south slopes (0 %). In contrast, hickory was abundant on south slopes (9.8 %) but absent on north slopes (0 %) (Figure 9). Hickory (14.4 %) and ash (*Fraxinus* spp.; 7.4 %) were more frequent in riparian zones than elsewhere in the valley.

In the mountains, pine was dominant on all topographic classes except riparian zones (6.7 %) and most abundant in mountain coves (37.7 %) and on ridgetops (32.6 %) (Figure 10; Appendix F). On ridgetops, white oak (32.6 %) scarlet oak (*Quercus coccinea*; 7.2 %) were also more abundant than on other topographic classes. On north slopes, white oak (15.4 %) and chestnut oak were abundant (21.2 %). Chestnut (*Castanea dentata*) was most

abundant on south slopes (11.8 %). Riparian zones had a lower samples size (*n*= 15) than other classes and was dominated by white oak was dominant (20 %) with abundant maple (13.3 %).

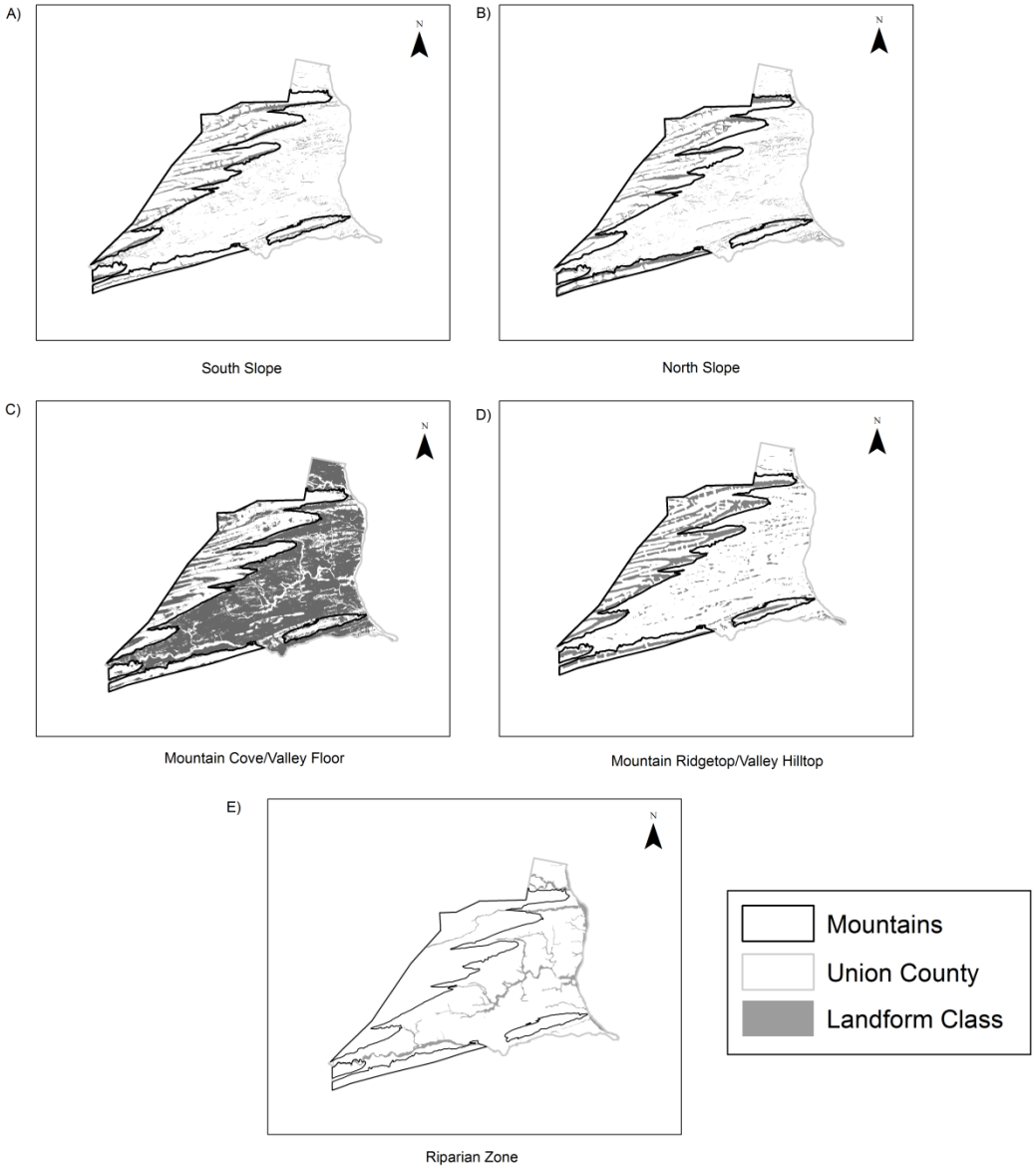


**Figure 6.** The distribution of topographic classes in Union County. The maps identifies: A) South Slope; B) North Slope; C) Mountain Cove/Valley Floors; D) Mountain Ridgetops/Valley Hilltops; E) Riparian Zones. All topographic classes are defined in Table 1.

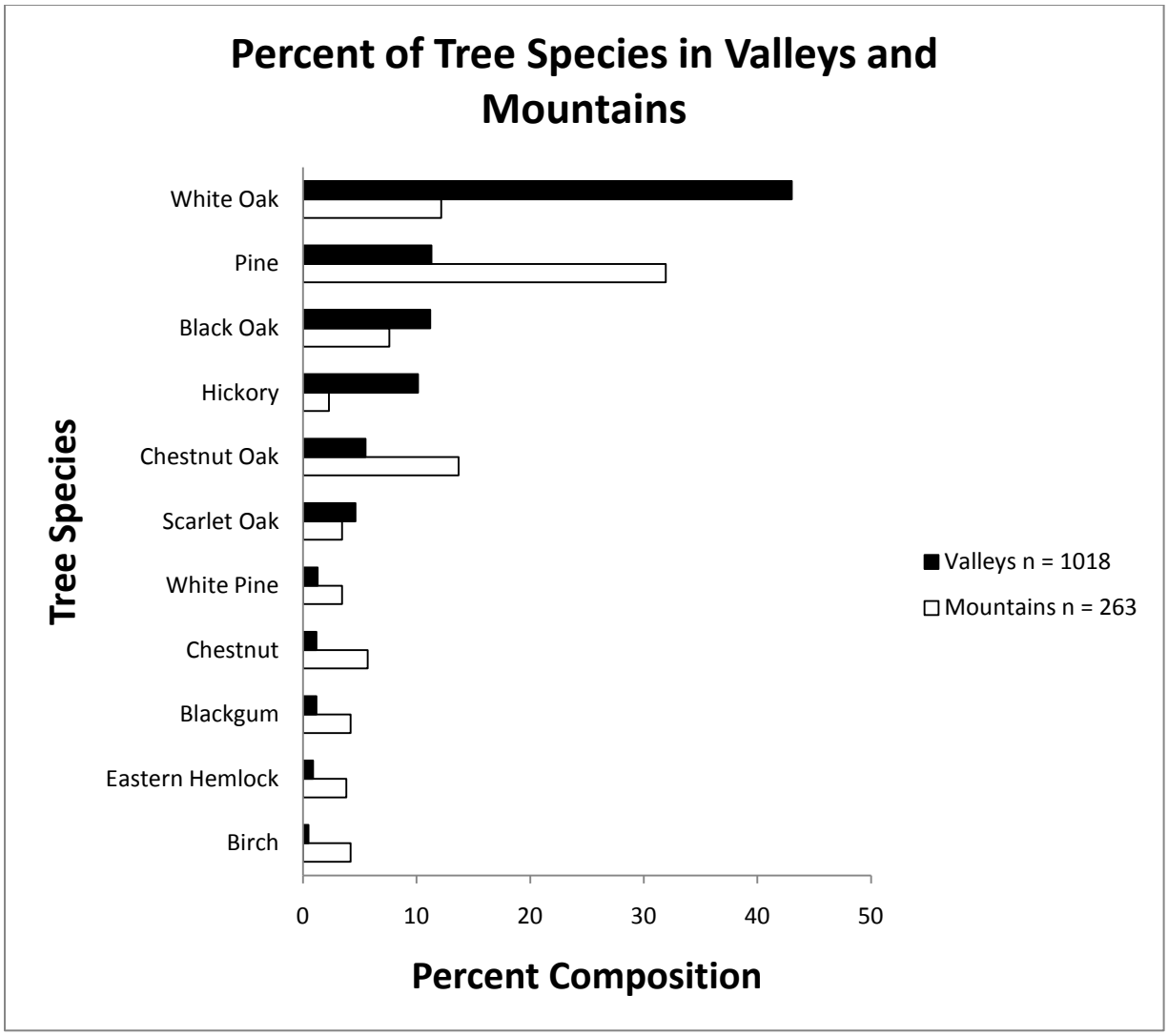


**Figure 7.** The frequency of tree species in the valleys and in the mountains of Union County based on land survey data from 1755 to 1855.

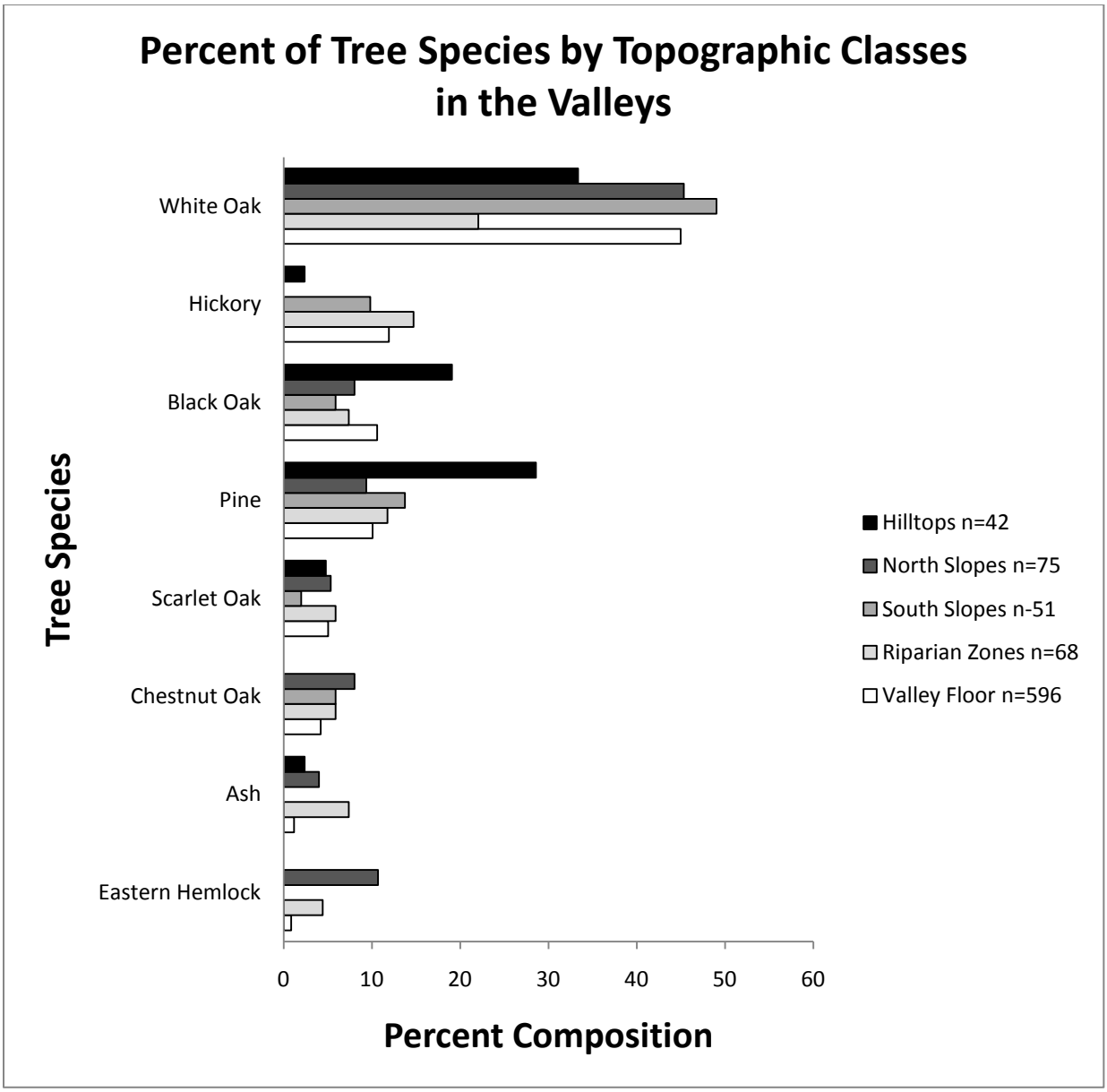


**Figure 8.** Tree species frequency by topographic classes in the valleys of Union County based on land survey data.

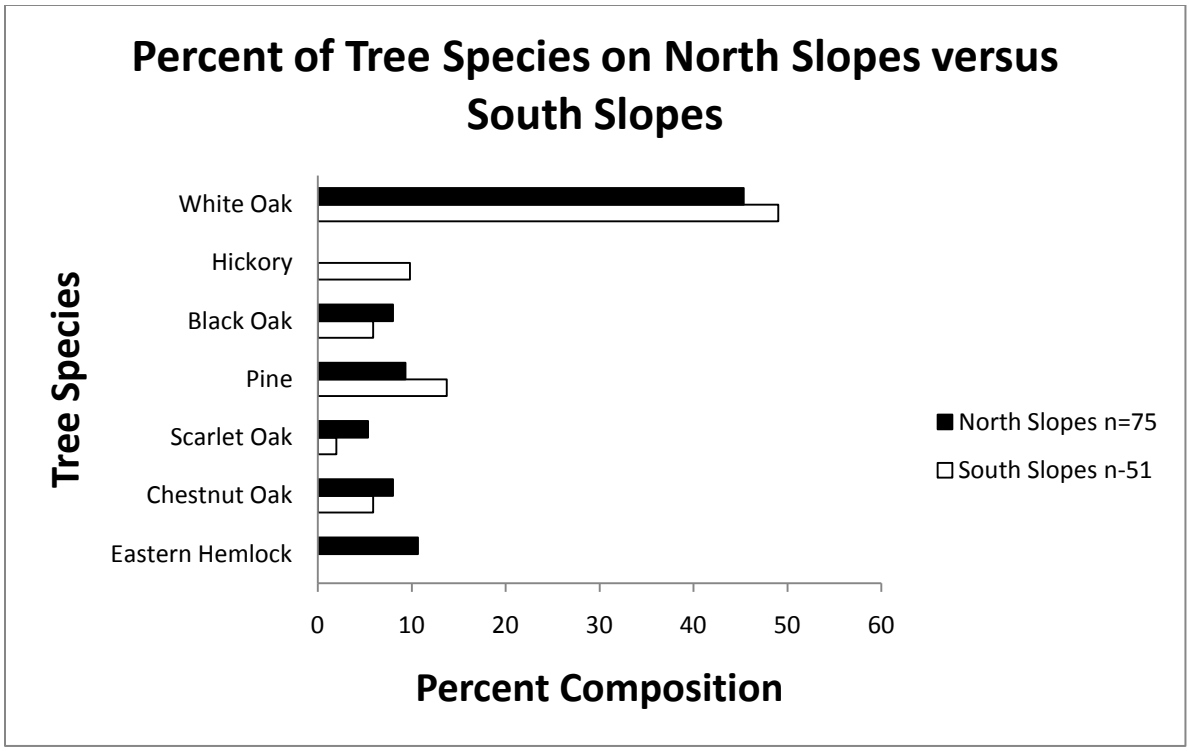


**Figure 9.** The frequency of tree species on north slopes versus south slopes in the valleys of Union County based on land survey data.

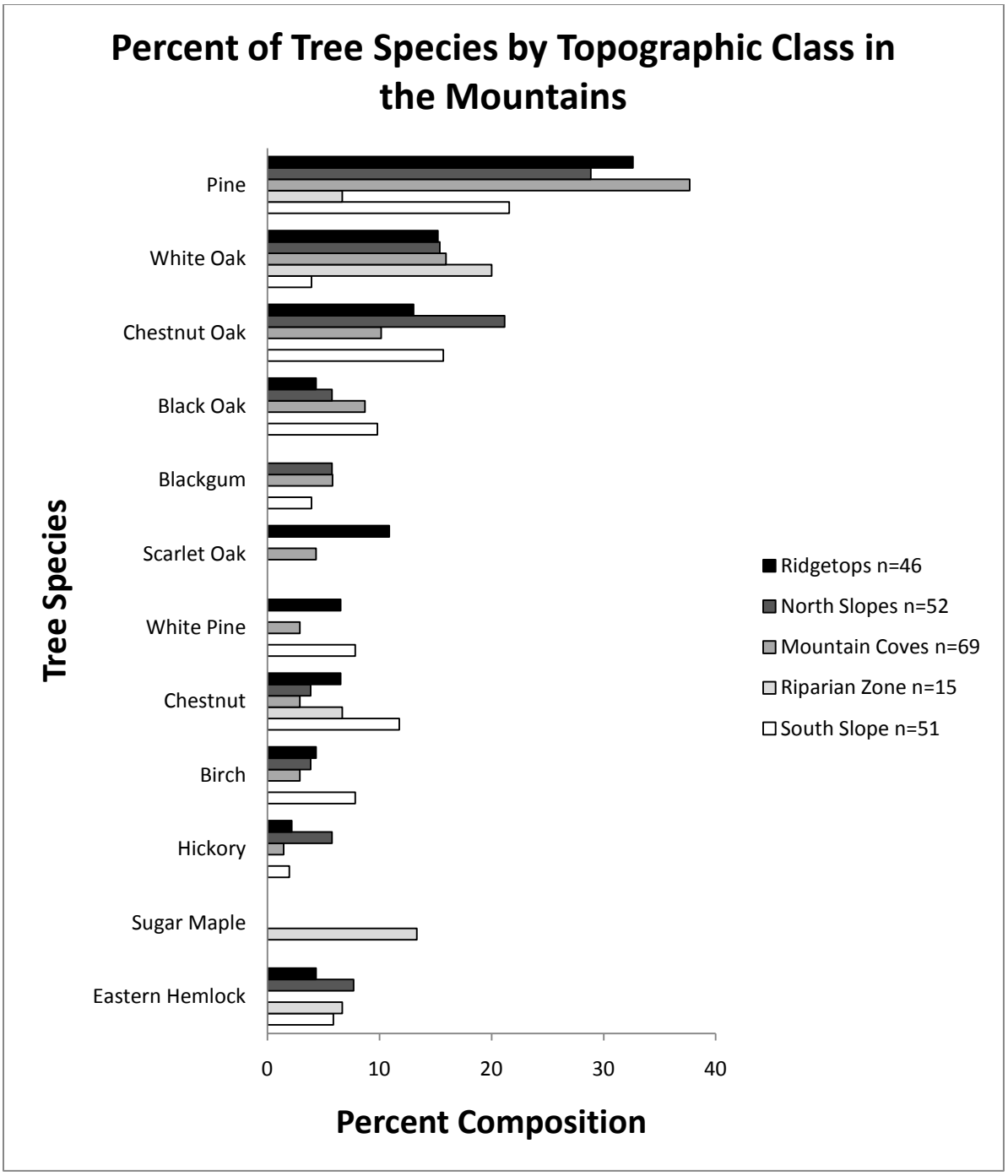


**Figure 10:** The frequency of tree species by topographic classes in the mountains of Union County based on land survey data.

*Marker Density Analysis*

Marker density analysis indicates that the majority of the 2 km x 2 km cells had a medium density of markers (46 %) or low density of markers (38.9 %). High density markers were only found in 15 % of cells (Figure 11). There was no strong pattern of high density marker distribution except along the eastern edge of Union County (Figure 11). Chi-square tests of markers in the valleys $\{X^2(4, N = 1198) = 6.023, p = 0.197\}$ and the mountains $\{X^2(3, N = 334) = 4.000, p = 0.261\}$ indicate no significant relationship between marker frequencies and topographic classes (Appendix E; Appendix F).

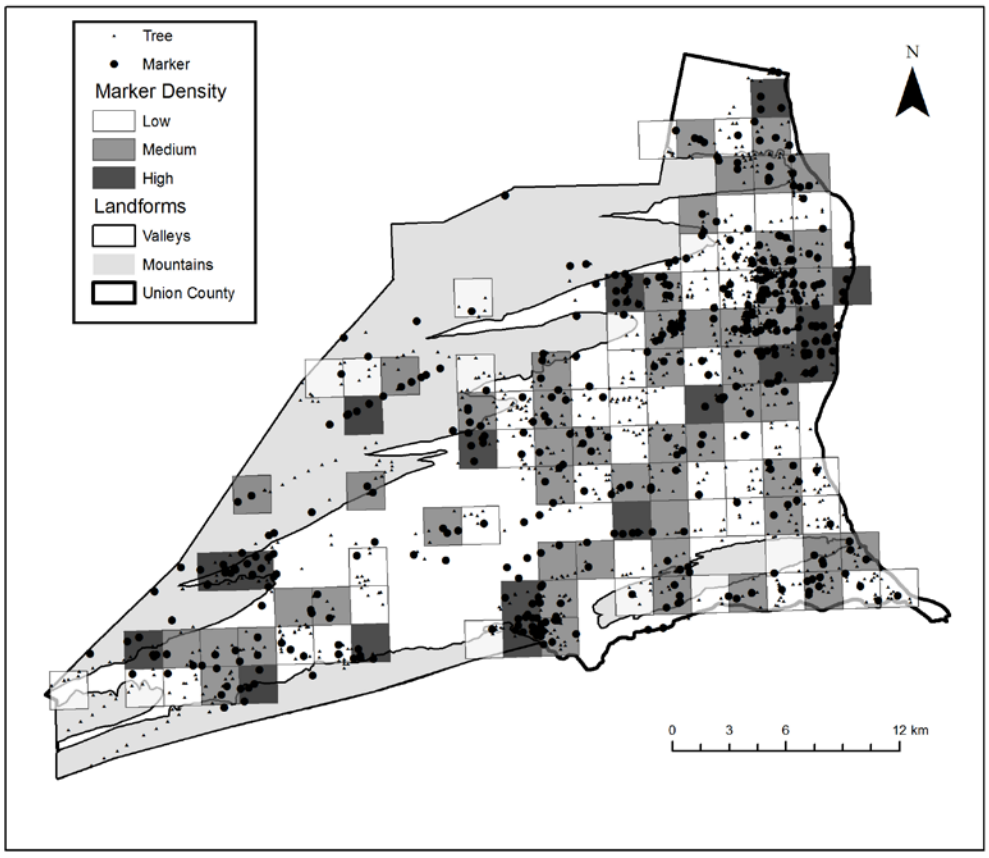


**Figure 11.** The distribution of areas with low (0 to 20 %), medium (20 to 50 %), and high (50 to 100%) marker densities based on 2 km x 2 km cells in Union County during the early historical period. Only cells with marker count $n > 4$ are shown.

## Discussion

### *Vegetation and topography*

The most dramatic vegetation composition differences in Union County during the early historical era were between the valleys and the mountain. The valleys were dominated by white oak with abundant pine, and hickory and a surprisingly large frequency of scarlet oak (Figure 7). In the mountains, pine was dominant, chestnut oak was more abundant, and white oak and hickory decreased in abundance. These compositional changes may reflect an association between white oak and hickory and slightly warmer conditions at lower elevations. Nowacki and Abrams (1992) conducted an analysis of historical and edaphic changes in tree species compositions of Central Pennsylvania Ridge and Valley forests in Centre County. Their findings in contemporary Central Pennsylvania forests explain tree species trends related to elevation change in Union County. According to Nowacki and Abrams (1992), white oak also decreases as elevation increased, scarlet oak is unexpectedly found in the valleys, and chestnut oak is restricted to ridges (mountains) as it favors growth on coarse-textured soils.

At finer scales, topographic classes within valleys supported different vegetation in Union County. Hilltops had substantially different vegetation than valley floors. Pine was more abundant on hilltops than valleys floors, and white oak showed the opposite association (Figure 8). These differences probably reflect better drainage on hilltops than any large variation in microclimates. In comparison, differences in vegetation between south slopes and north slopes were consistent with their different microclimates. On north slopes, conditions are cooler and soil temperature fluctuate less than on south slopes (Nowacki and Abrams 1992). In Union County, north slopes tended to support trees with more northern

ranges (such as eastern hemlock), and more southern species (such as hickory) thrived on warmer and drier south slopes (Figure 9; cf. Nowacki and Abrams 1992). Riparian zones supported dramatically different vegetation than other topographic classes, which is probably more related to soil composition, drainage, and moisture than climate.

In Union County, vegetation differences among topographic classes in mountains were less dramatic. Though small in sample size, riparian zones probably had a set of soil, drainage, and moisture conditions that supported a unique set of vegetation (white oak and maple) compared to other topographic classes (Figure 10). The microclimate effect between north slopes and south slopes was less recognizable in the mountains of Union County. However, south slopes supported a greater abundance of chestnut than north slopes, and white oak was more frequent on north slopes. These results suggest that chestnut favors growth in condition exposed to more direct sunlight. Infrequent white oak on south slopes may reflect the fact that steeper slopes are less favorable to white oak development (Nowacki and Abrams 1992). On mountain coves in Union County, eastern hemlocks were absent (Appendix F). This is a surprising result as coves receive both solar protection and cold air drainage, which should promote trees more abundant in areas with cooler climates than Pennsylvania, such as eastern hemlock.

*Timber cutting by early European settlers*

In the early historical period, tree-cutting in Union County was associated with different economic activities in the mountains and the in valleys. Charcoal demanded to fuel iron furnaces led to timbering in the mountains of Union County. In the 1820s, an iron furnace opened in Hartley Township that was fueled by charcoal from wood from nearby

Jacks Mountain (Figure 2; Snyder 2000). There is also evidence of timbering for charcoal in the mountains near spruce run (Figure 2; Marsh, personal communication, April 27, 2011). According to Nowacki and Abrams (1997), the demand for charcoal was so intensive in early European settlement ridges forests of Central Pennsylvania that forest were converted from dense oak, pine, and chestnut to young stands of oak and chestnut. By 1860, the rising price of charcoal and high production cost brought a decline to charcoal-fueled iron furnaces, and coal became the less expensive alternative (Snyder 2000). In contrast, logging and agriculture were the major tree-cutting activities in Union County valleys (Snyder 2000).

In Union County, marker distribution was relatively equal in valleys and in the mountains (Appendix D), and a chi-square analysis showed no relationship between marker frequencies and topographic classes (Appendix E; Appendix F). This relatively equal distribution of markers across topographic classes indicates that tree-cutting was widespread in Union County regardless of topography. In the mountains, there is evidence of tree-cutting in the high marker density areas near Berlin Iron Works and Spruce Run (Figure 2; Figure 11). Marker density analysis suggests the most intensive agriculture and logging occurred along the Susquehanna River in White Deer Township (Figure 2; Figure 11).

*Fires and clearing prior to European settlement*

The high density marker areas in Union County valleys may also reflect open vegetation that predated European settlement. Allen (1877: 485) quotes a description of the Buffalo Valley's eighteenth century vegetation (attributed to Colonel John Kelly) as "wooded…with large scattered trees so that the grass grew abundantly to furnish good pasturage for the buffalo." This account describes an oak savanna. The Illinois Natural Area

inventory defines savanna as a grassy environment with 5 to 80 percent canopy cover (Anderson et al 1999). Union County also has a large number of "Buffalo" place names including the Buffalo Valley, Buffalo Mountain, Buffalo Crossroads, Buffalo Creek, and Buffalo Township (Figure 2; Wagner and Shellenberger 2007). Although there is no archeological evidence of buffalo in Union County, the high concentration of "Buffalo" place names likely reflects the presence of bison in the area at the time of European settlement. As grass-eating generalists, bison habitats tend to be areas with plentiful grass (Platou and Tueller 1985)—in other words, savannas. One piece of direct evidence for a savanna is the open growth form white oak included in the original land survey of Lewisburg[3] (Figure 12; Figure 13). Open growth form is more characteristic of trees in savannas than dense forests. These three lines of evidence are consistent with historical descriptions of open vegetation prior to European settlement in Eastern United States forests (Denevan 1992) and the Great Plains in Centre County, Pennsylvania (Losensky 1961; Ruffner and Arabas 2000; Laughlin and Uhl 2003).

[3] Open growth form reflects a tree that receives maximum sunlight from having little competition with neighboring trees (Srivastiva 2001).

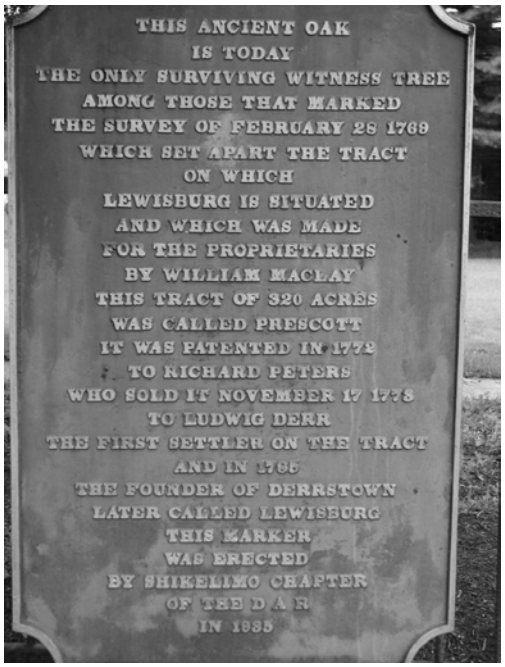


**Figure 12.** The Daughters of the American Revolution (DAR) plaque in front a surveyed white oak tree in Lewisburg, Pennsylvania claiming the tree was part of the original land survey.

**Figure 13.** The open growth form white oak that the Daughter's of the American Revolution Plaque memorializes at Lewisburg, Pennsylvania.

The most likely explanation for these clearings is fire. Indeed, fire is a key component in retarding tree development in savannas, but shallow soils and extreme climates or microclimates are also important factors (Anderson et al 1999). Although paleoecological evidence such as charcoal would make these findings more robust, the tree species composition of Union county reflects regular fires prior to and during early European settlement. The dominant tree species in Union County—white oak and pine—were highly dependent on fire to maintain (Peet 1984; Abrams 1992; Abrams and Ruffner 1995). In contrast, fire intolerant species, such as sugar maple (*Acer saccharum*), red maple, tulip poplar, and red oak, had relatively low frequencies (Appendix D), a surprising result considering their present-day prominence in Central Pennsylvania Ridge and Valley forests (Abrams and Ruffner 1995). The scarcity of red oak may be misleading as surveyors would have not been able to distinguish red oak from black oak without acorns present.

Fire ignition sources were either natural (lightning) or anthropogenic (Indians or early European settlers). Humid conditions may have made lightning fires too rare in Eastern United States forests to explain the high frequency of fire-resistant vegetation (Abrams and Nowacki 2008), though Pennsylvania has relatively hot and dry summers. Fire-resistant vegetation may reflect frequent Indian fires in Union County as fires would have been useful in maintaining the aboriginal hunting grounds and agricultural land clearings described in historical accounts of Union County (Linn 1877; Meginess 1853). In the mountains, this vegetation may be related to the Union County iron industry. Elsewhere in Central Pennsylvania, early European settler tree-cutting for charcoal to fuel iron furnaces was associated with uncontrolled fires (Abrams and Ruffner 1995).

*A comparison of vegetation in Union County to other studies and historical accounts*

Vegetation composition during the early historical period in Union County was consistent with other vegetation reconstructions (Nowacki and Abrams 1992; Abrams and Ruffner 1995) and historical accounts (Bartram Vol. 11; Linn 1877) of Central Pennsylvania Ridge and Valley forests. There are some exceptions. First, Nowacki and Abrams (1992) found chestnut to be one of the dominant ridge tree species (mountains) in their reconstruction of eighteenth century forests in Centre County. Chestnuts were not found to be as abundant in mountains of Union County. Second, in the mid 1700s, John Bartram described vegetation along the West Branch of the Susquehanna River near Lewisburg as "spruce[4], and white pine, oak, beach [*sic*], plane trees…hickory, walnut, locust, and pitch pine" (Bartram Vol. 11: 26). This study found no plane trees (*Platanus occidentalis*) or pitch pine (*Pinus rigida*) and only a small number of walnut (*Juglans* spp.), locust (*Robinia pseudoacacia*), and beech (*Fagus* spp.) in Union County (Appendix A). Third, the nearby Middle Creek Valley of Snyder County appears to have had different vegetation than Union County. Linn (1877: 6) quotes Captain McHenry describing the Middle Creek Valley in 1774 as "well timbered-walnut, black oak, and maple." The account provides an incomplete description of vegetation, but it mentions maples and walnuts, which were not abundant tree species in Union County. These vegetation differences probably reflect different human land uses in Union County and the Middle Creek Valley prior to European settlement.

[4] For early European settlers, spruce was *Tsuga Canadensis*, now known as eastern hemlock, and should not be confused with the *Picea* genus.

## Conclusions

Union County was mostly forested during the early historical era. The valleys were mixed-oak, hickory, and pine forests dominated by white oak, and the ridges were pine-oak forests dominated by pine and with abundant chestnut oak and white oak. A stronger relationship existed between vegetation compositions and topographic classes in the valley than in the mountains.

In the valleys, white oaks were more frequent on valley floors than hilltops, and pines were more abundant in hilltops than on valley floors. Dramatic vegetation shifts on north slopes versus south slopes reflected distinct microclimates. An inverse relationship existed between abundant eastern hemlock on north slopes and the high frequency of hickory on south slopes. In the mountains, microclimate relationships were weaker. Chestnut was associated with south slopes, where it received more direct sunlight. In contrast, white oak was frequent on north slopes but excluded on south.

Tree-cutting was probably common and widespread in Union County during the early historical period. In the mountains, tree-cutting may have been associated with providing charcoal for the iron industry. In the valleys, European tree-cutting activities, such agriculture and logging, are difficult to distinguish from possible aboriginal fires and agriculture clearings.

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**Appendix A:** Nomenclature for Tree Species in Pennsylvania

| Binomial | Family | Common Names |
|---|---|---|
| *Fraxinus* spp. | Oleaceae | Ash |
| *Fagus* spp. | Fagaceae | Beech |
| *Betula* spp. | Betulaceae | Birch |
| *Quercus velutina* | Fagaceae | Sourgum, Black oak |
| *Nyssa sylvatica* | Nyssaceae | Blackgum |
| *Castanea dentata* | Fagaceae | Chestnut |
| *Quercus prinus, Quercus Montana* | Fagaceae | Chestnut oak |
| *Cornus* spp. | Cornaceae | Dogwood |
| *Tsuga canadensis* | Pinaceae | Canada hemlock, Eastern hemlock, spruce |
| *Ulmus* spp. | Ulmaceae | Elm |
| *Carya* spp. | Juglandaceae | Hickory |
| | | Ironwood |
| *Tilia* spp. | Tiliaceae | Linden |
| *Robinia* spp. | Fabaceae | Locust |
| *Acer* spp. | Aceraceae | Maple |
| *Pinus* spp. | Pinaceae | Pine |
| *Pinus resinosa* | Pinaceae | Red pine |
| *Quercus rubra* | Fagaceae | Northern red oak, Red oak |
| *Sassafras albidum* | Lauraceae | Sassafras |
| *Quercus coccinea* | Fagaceae | Scarlet oak, Spanish oak |
| *Acer saccharum* | Aceraceae | Sugar maple |
| *Quercus bicolor* | Fagaceae | Swamp white oak, Swamp oak |
| *Liriodendron tulipifera* | | Tulip Poplar |
| *Juglans* spp. | Juglandaceae | Walnut |
| *Quercus alba* | Fagaceae | White oak |
| *Pinus strobus* | Pinaceae | White pine |
| *Hamamelis* spp. | Hamamelidaceae | Witch hazel |

**Table 3**. The scientific binomials, families, and common names for trees found in Union County at the time of European settlements (Rhoads and Block 2000).

## Appendix B: A Description of Witness Tree Analysis Methods

Due to imagery constraints, the property corner markers on warrant maps, forestry maps, and Union County Courthouse warrantee map were not always legible. On the original warrant maps and most forestry maps, each property was labeled with a registry numbers referencing the location of the map in the original survey books, which can be found on the Pennsylvania Historical Archives website (http://www.portal.state.pa.us/portal/).

However, the forestry maps and the warrantee map did not show these registry numbers on every property, but they did note the property owner as well as the date the warrantees were commissioned and the date that the patents were completed. Each county has a list of warrant registries chronologically ordered by their date of commission and include a reference to where the surveys are recorded, which can be found at the Pennsylvania Historical Archives website (http://www.portal.state.pa.us/portal/). Thus in the warrant registry, it was possible use the warrant commission date to locate the correct property and corresponding registry number of its survey map in the warrant registry.

## Appendix C: Georeferencing Confidence Points

Georeferencing confidence points denote the geographical precision of property markers. I used streams, contemporary township boundaries, and contemporary parcel boundaries to georeference photos of warrant maps, forestry maps, and Union County courthouse warrantee map. Even after multiple edits of these georeferenced photos and then digitized witness trees and markers based on these georeferenced maps, not all witness trees and markers aligned to contemporary parcel boundaries, which are subdivided versions of the original property boundaries. This limitation was especially true on the north and northwest ridges of Union County, where most of the territory is in state-owned Bald Eagle State Forest.

To account for the possible error in the placement of witness trees and markers, I created a scale of 1 to 4 to show confidence in their alignment with contemporary parcel boundaries and streams. Each number in the scale means the following.

**1** There is little doubt that the point is geographically precise based on contemporary parcel boundaries and streams.

**2** The point aligns to a contemporary parcel boundary, but it is not close enough to another known landscape feature to verify its geographical precision.

**3** The point does not align to a contemporary parcel boundary or stream, but it is based on a precisely georeferenced photo.

**4** The point does not align to a contemporary parcel boundary or stream, and it is based on a geoferenced photo with an uncertain geographical location—there were few streams, contemporary parcels, or township lines on which to georeference the photo.

**Appendix D:** Tree species and marker distribution in valleys and mountains of Union County, Pennsylvania during the early historical period

| | | Mountains | | Valleys | |
|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | 5 | 1.9 | 18 | 1.8 |
| Beech | *Fagus* spp. | | 0.0 | 1 | 0.1 |
| Birch | *Betula* spp. | 11 | 4.2 | 5 | 0.5 |
| Black Oak | *Quercus velutina* | 20 | 7.6 | 114 | 11.2 |
| Blackgum | *Nyssa sylvatica* | 11 | 4.2 | 12 | 1.2 |
| Chestnut | *Castanea dentata* | 15 | 5.7 | 12 | 1.2 |
| Chestnut Oak | *Quercus prinus* | 36 | 13.7 | 56 | 5.5 |
| Dogwood | *Cornus* spp. | 2 | 0.8 | 13 | 1.3 |
| Eastern Hemlock | *Tsuga Canadensis* | 10 | 3.8 | 9 | 0.9 |
| Elm | *Ulmus* spp. | 1 | 0.4 | 9 | 0.9 |
| Hickory | *Carya* spp. | 6 | 2.3 | 103 | 10.1 |
| Linden | *Tilia* spp. | 1 | 0.4 | | 0.0 |
| Ironwood | | | 0.0 | 9 | 0.9 |
| Locust | *Robinia pseudoacacia* | 1 | 0.4 | 2 | 0.2 |
| Maple | *Acer* spp. | 3 | 1.1 | 24 | 2.4 |
| Pine | *Pinus* spp. | 84 | 31.9 | 115 | 11.3 |
| Red Oak | *Quercus rubra* | 1 | 0.4 | 1 | 0.1 |
| Sassafras | *Sassafras albidum* | | 0.0 | 2 | 0.2 |
| Red Pine | *Pinus rubrum* | 1 | 0.4 | | 0.0 |
| Scarlet Oak | *Quercus coccinea* | 9 | 3.4 | 47 | 4.6 |
| Sugar Maple | *Acer saccharum* | 2 | 0.8 | 4 | 0.4 |
| Swamp Oak | *Quercus bicolor* | | 0.0 | 1 | 0.1 |
| Tulip Poplar | *Liriodendron tulipifera* | 2 | 0.8 | 7 | 0.7 |
| Walnut | *Juglans* spp. | 1 | 0.4 | 2 | 0.2 |
| White Oak | *Quercus alba* | 32 | 12.2 | 438 | 43.0 |
| White Pine | *Pinus strobus* | 9 | 3.4 | 13 | 1.3 |
| Witch Hazel | *Hamamelis* | | 0.0 | 1 | 0.1 |
| | | 263 | | 1018 | |

**Table 4.** The counts and frequencies of tree species in valleys and in mountains of Union County, Pennsylvania based on early European settlement surveys.

| | | Mountains | | Valleys | |
|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | 5 | 1.3 | 18 | 1.2 |
| Beech | *Fagus* spp. | | | 1 | 0.1 |
| Birch | *Betula* spp. | 11 | 2.8 | 5 | 0.3 |
| Black Oak | *Quercus velutina* | 20 | 5.0 | 114 | 7.7 |
| Blackgum | *Nyssa sylvatica* | 11 | 2.8 | 12 | 0.8 |
| Chestnut | *Castanea dentata* | 15 | 3.8 | 12 | 0.8 |
| Chestnut Oak | *Quercus prinus* | 36 | 9.0 | 56 | 3.8 |
| Dogwood | *Cornus spp.* | 2 | 0.5 | 13 | 0.9 |
| Eastern Hemlock | *Tsuga Canadensis* | 10 | 2.5 | 9 | 0.6 |
| Elm | *Ulmus* spp. | 1 | 0.3 | 9 | 0.6 |
| Hickory | *Carya* spp. | 6 | 1.5 | 103 | 7.0 |
| Linden | *Tilia* spp. | 1 | 0.3 | | |
| Ironwood | | | | 9 | 0.6 |
| Locust | *Robinia pseudoacacia* | 1 | 0.3 | 2 | 0.1 |
| Markers | | 135 | 33.9 | 455 | 30.8 |
| Maple | *Acer* spp. | 3 | 0.8 | 24 | 1.6 |
| Pine | *Pinus* spp. | 84 | 21.1 | 115 | 7.8 |
| Red Oak | *Quercus rubra* | 1 | 0.3 | 1 | 0.1 |
| Sassafras | *Sassafras albidum* | | | 2 | 0.1 |
| Red Pine | *Pinus rubrum* | 1 | 0.3 | | |
| Scarlet Oak | *Quercus coccinea* | 9 | 2.3 | 47 | 3.2 |
| Stump | | | | 2 | 0.1 |
| Sugar Maple | *Acer saccharum* | 2 | 0.5 | 4 | 0.3 |
| Swamp Oak | *Quercus bicolor* | | | 1 | 0.1 |
| Tulip Poplar | *Liriodendron tulipifera* | 2 | 0.5 | 7 | 0.5 |
| Walnut | *Juglans* spp. | 1 | 0.3 | 2 | 0.1 |
| White Oak | *Quercus alba* | 32 | 8.0 | 438 | 29.7 |
| White Pine | *Pinus strobus* | 9 | 2.3 | 13 | 0.9 |
| Witch Hazel | *Hamamelis* spp. | | | 1 | 0.1 |
| | **Total** | 398 | | 1475 | |

**Table 5.** The counts and frequencies of tree species and markers in the valleys and in the mountains of Union County, Pennsylvania based on early European settlement survey

**Appendix E:** Tree species and marker distribution by topographic class in valleys and chi-square test for difference

| | | Valley Floor | | Riparian Zone | | South Slope | | North Slope | | Hilltop | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | 7 | 1.2 | 5 | 7.4 | | | 3 | 4.0 | 1 | 2.4 |
| Beech | *Fagus* spp. | 1 | 0.2 | | 0.0 | | | | 0.0 | | 0.0 |
| Birch | *Betula* spp. | 1 | 0.2 | 3 | 4.4 | | | | 0.0 | | 0.0 |
| Black Oak | *Quercus velutina* | 63 | 10.6 | 5 | 7.4 | 3 | 5.9 | 6 | 8.0 | 8 | 19.0 |
| Blackgum | *Nyssa sylvatica* | 10 | 1.7 | 1 | 1.5 | | 0.0 | 1 | 1.3 | | 0.0 |
| Chestnut | *Castanea dentata* | 6 | 1.0 | 2 | 2.9 | | 0.0 | 1 | 1.3 | 2 | 4.8 |
| Chestnut Oak | *Quercus prinus* | 25 | 4.2 | 4 | 5.9 | 3 | 5.9 | 6 | 8.0 | | 0.0 |
| Dogwood | *Cornus* spp. | 9 | 1.5 | | 0.0 | 1 | 2.0 | 1 | 1.3 | | 0.0 |
| Eastern Hemlock | *Tsuga Canadensis* | 5 | 0.8 | 3 | 4.4 | | 0.0 | 8 | 10.7 | | 0.0 |
| Elm | *Ulmus* spp. | 8 | 1.3 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Hickory | *Carya* spp. | 71 | 11.9 | 10 | 14.7 | 5 | 9.8 | | 0.0 | 1 | 2.4 |
| Ironwood | | 4 | 0.7 | 1 | 1.5 | | 0.0 | 1 | 1.3 | 1 | 2.4 |
| Locust | *Robinia pseudoacacia* | | 0.0 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Maple | *Acer* spp. | 13 | 2.2 | 1 | 1.5 | 2 | 3.9 | 2 | 2.7 | | 0.0 |
| Pine | *Pinus* spp. | 60 | 10.1 | 8 | 11.8 | 7 | 13.7 | 7 | 9.3 | 12 | 28.6 |
| Red Oak | *Quercus rubra* | | 0.0 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Sassafras | *Sassafras albidum* | 1 | 0.2 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Scarlet Oak | *Quercus coccinea* | 30 | 5.0 | 4 | 5.9 | 1 | 2.0 | 4 | 5.3 | 2 | 4.8 |
| Swamp Oak | *Quercus bicolor* | 1 | 0.2 | | 0.0 | 1 | 2.0 | | 0.0 | | 0.0 |
| Sugar Maple | *Acer saccharum* | | 0.0 | 2 | 2.9 | 1 | 2.0 | | 0.0 | 1 | 2.4 |
| Tulip Poplar | *Liriodendron tulipifera* | 6 | 1.0 | | 0.0 | | 0.0 | | 0.0 | | 0.0 |
| Walnut | *Juglans* spp. | 2 | 0.3 | | 0.0 | | 0.0 | | 0.0 | | 0.0 |
| White Oak | *Quercus alba* | 268 | 45.0 | 15 | 22.1 | 25 | 49.0 | 34 | 45.3 | 14 | 33.3 |
| White Pine | *Pinus strobus* | 4 | 0.7 | | 0.0 | 2 | 3.9 | 1 | 1.3 | | |
| Witch Hazel | *Hamamelis* | 1 | 0.2 | | 0.0 | | | | | | |
| | **Total** | 596 | | 68 | | 51 | | 75 | | 42 | |

**Table 6.** Counts and frequencies of tree species by topographic classes in the valleys based on early European settler surveys of Union County, Pennsylvania.

| | | Valley Floor | | Riparian Zone | | South Slope | | North Slope | | Hilltop | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Markers | | 262 | 30.5 | 31 | 31.3 | 25 | 32.9 | 21 | 21.9 | 27 | 39.1 |
| Ash | *Fraxinus* spp | 7 | 0.8 | 5 | 5.1 | | | 3 | 3.1 | 1 | 1.4 |
| Beech | *Fagus* spp. | 1 | 0.1 | | | | | | | | |
| Birch | *Betula* spp. | 1 | 0.1 | 3 | 3.0 | | | | | | |
| Black Oak | *Quercus velutina* | 63 | 7.3 | 5 | 5.1 | 3 | 3.9 | 6 | 6.3 | 8 | 11.6 |
| Blackgum | *Nyssa sylvatica* | 10 | 1.2 | 1 | 1.0 | | | 1 | 1.0 | | |
| Chestnut | *Castanea dentata* | 6 | 0.7 | 2 | 2.0 | | | 1 | 1.0 | 2 | 2.9 |
| Chestnut Oak | *Quercus prinus* | 25 | 2.9 | 4 | 4.0 | 3 | 3.9 | 6 | 6.3 | | |
| Dogwood | *Cornus* spp. | 9 | 1.0 | | | 1 | 1.3 | 1 | 1.0 | | |
| Eastern Hemlock | *Tsuga Canadensis* | 5 | 0.6 | 3 | 3.0 | | | 8 | 8.3 | | |
| Elm | *Ulmus* spp. | 8 | 0.9 | 1 | 1.0 | | | | | | |
| Hickory | *Carya* spp. | 71 | 8.3 | 10 | 10.1 | 5 | 6.6 | | | 1 | 1.4 |
| Ironwood | | 4 | 0.5 | 1 | 1.0 | | | 1 | 1.0 | 1 | 1.4 |
| Locust | *Robinia pseudoacacia* | | | 1 | 1.0 | | | | | | |
| Maple | *Acer* spp. | 13 | 1.5 | 1 | 1.0 | 2 | 2.6 | 2 | 2.1 | | |
| Pine | *Pinus* spp. | 60 | 7.0 | 8 | 8.1 | 7 | 9.2 | 7 | 7.3 | 12 | 17.4 |
| Red Oak | *Quercus rubra* | | | 1 | 1.0 | | | | | | |
| Sassafras | *Sassafras albidum* | 1 | 0.1 | 1 | 1.0 | | | | | | |
| Scarlet Oak | *Quercus coccinea* | 30 | 3.5 | 4 | 4.0 | 1 | 1.3 | 4 | 4.2 | 2 | 2.9 |
| Swamp Oak | *Quercus bicolor* | 1 | 0.1 | | | 1 | 1.3 | | | | |
| Sugar Maple | *Acer saccharum* | | | 2 | 2.0 | 1 | 1.3 | | | 1 | 1.4 |
| Tulip Poplar | *Liriodendron tulipifera* | 6 | 0.7 | | | | | | | | |
| Walnut | *Juglans* spp. | 2 | 0.2 | | | | | | | | |
| White Oak | *Quercus alba* | 268 | 31.2 | 15 | 15.2 | 25 | 32.9 | 34 | 35.4 | 14 | 20.3 |
| White Pine | *Pinus strobus* | 4 | 0.5 | | | 2 | 2.6 | 1 | 1.0 | | |
| Witch Hazel | *Hamamelis* | 1 | 0.1 | | | | | | | | |
| | **Total** | 858 | | 99 | | 76 | | 96 | | 69 | |

**Table 7**. The counts and frequencies of tree species and markers by topographic classes in the valleys based on early European settlement surveys of Union County, Pennsylvania.

**Chi-Square Test: Markers, Contingency**

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Markers  Contingency  Total
    1      262          596    858
         262.13       595.87
          0.000        0.000

    2       31           68     99
          30.25        68.75
          0.019        0.008

    3       25           51     76
          23.22        52.78
          0.137        0.060

    4       21           75     96
          29.33        66.67
          2.365        1.040

    5       27           42     69
          21.08        47.92
          1.662        0.731

Total      366          832   1198

Chi-Sq = 6.023, DF = 4, P-Value = 0.197
```

**Conclusion:** There is not enough evidence that there is a relationship between local scale topography and markers in the valleys.

**Table 8.** Chi-square test for marker frequency difference by topographic classes in the valleys.

**Appendix F:** Tree species and marker distribution by topographic classes on mountains and chi-square test for difference

| | | Ridgetop | | North Slope | | South Slope | | Riparian Zone | | Coves | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | | | 1 | 1.9 | 2 | 3.9 | 1 | 6.7 | 1 | 1.4 |
| Birch | *Betula* spp. | 2 | 4.3 | 2 | 3.8 | 4 | 7.8 | | 0.0 | 2 | 2.9 |
| Black Oak | *Quercus velutina* | 2 | 4.3 | 3 | 5.8 | 5 | 9.8 | | 0.0 | 6 | 8.7 |
| Blackgum | *Nyssa sylvatica* | | 0.0 | 3 | 5.8 | 2 | 3.9 | | 0.0 | 4 | 5.8 |
| Chestnut | *Castanea dentata* | 3 | 6.5 | 2 | 3.8 | 6 | 11.8 | 1 | 6.7 | 2 | 2.9 |
| Chestnut Oak | *Quercus prinus* | 6 | 13.0 | 11 | 21.2 | 8 | 15.7 | | 0.0 | 7 | 10.1 |
| Dogwood | *Cornus* spp. | | 0.0 | | 0.0 | 1 | 2.0 | | 0.0 | 1 | 1.4 |
| Eastern Hemlock | *Tsuga Canadensis* | 2 | 4.3 | 4 | 7.7 | 3 | 5.9 | 1 | 6.7 | | 0.0 |
| Elm | *Ulmus* spp. | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Linden | | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Locust | *Robinia pseudoacacia* | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Hickory | *Carya* spp. | 1 | 2.2 | 3 | 5.8 | 1 | 2.0 | | 0.0 | 1 | 1.4 |
| Maple | *Acer* spp. | | 0.0 | | 0.0 | 1 | 2.0 | 1 | 6.7 | 1 | 1.4 |
| Pine | *Pinus* spp. | 15 | 32.6 | 15 | 28.8 | 11 | 21.6 | 1 | 6.7 | 26 | 37.7 |
| Red Oak | *Quercus rubra* | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Red Pine | *Pinus rubrum* | | 0.0 | | 0.0 | | 0.0 | | 0.0 | 1 | 1.4 |
| Sugar Maple | *Acer saccharum* | | 0.0 | | 0.0 | | 0.0 | 2 | 13.3 | | 0.0 |
| Scarlet Oak | *Quercus coccinea* | 5 | 10.9 | | 0.0 | | 0.0 | | 0.0 | 3 | 4.3 |
| Tulip Poplar | *Liriodendron tulipifera* | | 0.0 | | 0.0 | 1 | 2.0 | | 0.0 | 1 | 1.4 |
| Walnut | *Juglans* spp. | | 0.0 | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| White Oak | *Quercus alba* | 7 | 15.2 | 8 | 15.4 | 2 | 3.9 | 3 | 20.0 | 11 | 15.9 |
| White Pine | *Pinus strobus* | 3 | 6.5 | | | 4 | 7.8 | | | 2 | 2.9 |
| | **Total** | 46 | | 52 | | 51 | | 15 | | 69 | |

**Table 9.** Counts and frequencies of tree species by topographic classes in the mountains based on early European settler surveys of Union County, Pennsylvania.

| | | Ridgetop | | North Slope | | South Slope | | Riparian Zone | | Mountain Cove | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Marker | | 23 | 33.3 | 33 | 38.8 | 34 | 40.0 | 4 | 21.1 | 26 | 27.4 |
| Ash | *Fraxinus* spp | | | 1 | 1.2 | 2 | 2.4 | 1 | 5.3 | 1 | 1.1 |
| Birch | *Betula* spp. | 2 | 2.9 | 2 | 2.4 | 4 | 4.7 | | | 2 | 2.1 |
| Black Oak | *Quercus velutina* | 2 | 2.9 | 3 | 3.5 | 5 | 5.9 | | | 6 | 6.3 |
| Blackgum | *Nyssa sylvatica* | | | 3 | 3.5 | 2 | 2.4 | | | 4 | 4.2 |
| Chestnut | *Castanea dentata* | 3 | 4.3 | 2 | 2.4 | 6 | 7.1 | 1 | 5.3 | 2 | 2.1 |
| Chestnut Oak | *Quercus prinus* | 6 | 8.7 | 11 | 12.9 | 8 | 9.4 | | | 7 | 7.4 |
| Dogwood | *Cornus* spp. | | | | | 1 | 1.2 | | | 1 | 1.1 |
| Eastern Hemlock | *Tsuga Canadensis* | 2 | 2.9 | 4 | 4.7 | 3 | 3.5 | 1 | 5.3 | | |
| Elm | *Ulmus* spp. | | | | | | | 1 | 5.3 | | |
| Linden | | | | | | | | 1 | 5.3 | | |
| Locust | *Robinia pseudoacacia* | | | | | | | 1 | 5.3 | | |
| Hickory | *Carya* spp. | 1 | 1.4 | 3 | 3.5 | 1 | 1.2 | | | 1 | 1.1 |
| Maple | *Acer* spp. | | | | | 1 | 1.2 | 1 | 5.3 | 1 | 1.1 |
| Pine | *Pinus* spp. | 15 | 21.7 | 15 | 17.6 | 11 | 12.9 | 1 | 5.3 | 26 | 27.4 |
| Red Oak | *Quercus rubra* | | | | | | | 1 | 5.3 | | |
| Red Pine | *Pinus rubrum* | | | | | | | | | 1 | 1.1 |
| Sugar Maple | *Acer saccharum* | | | | | | | 2 | 10.5 | | |
| Scarlet Oak | *Quercus coccinea* | 5 | 7.2 | | | | | | | 3 | 3.2 |
| Tulip Poplar | *Liriodendron tulipifera* | | | | | 1 | 1.2 | | | 1 | 1.1 |
| Walnut | *Juglans* spp. | | | | | | | 1 | 5.3 | | |
| White Oak | *Quercus alba* | 7 | 10.1 | 8 | 9.4 | 2 | 2.4 | 3 | 15.8 | 11 | 11.6 |
| White Pine | *Pinus strobus* | 3 | 4.3 | | | 4 | 4.7 | | | 2 | 2.1 |
| | **Total** | **69** | | **85** | | **85** | | **19** | | **95** | |

**Table 10:** Counts and frequencies of tree species and markers by topographic classes mountains based on early European settler surveys of Union County.

**Chi-Square Test: Markers, Contingency**

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Markers  Contingency  Total
    1       34           51     85
         29.52        55.48
         0.680        0.362

    2       26           69     95
         32.99        62.01
         1.483        0.789

    3       33           52     85
         29.52        55.48
         0.410        0.218

    4       23           46     69
         23.96        45.04
         0.039        0.021

Total      116          218    334

Chi-Sq = 4.000, DF = 3, P-Value = 0.261
```

There is not enough evidence that a relationship exists between markers and local scale topography in the mountains.

**Table 11.** Chi-square test for marker frequency difference by topographic classes in the mountains of Union County.

# A VEGETATION RECONSTRUCTION OF UNION COUNTY, PENNSYLVANIA DURING THE EARLY HISTORICAL PERIOD (1755-1855)

By

**Nicholas P. Gonsalves**

A Thesis Submitted to the Honors Council

For Honors in Geography

May, 9 2011

Date
Approved by:

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Adviser: Duane Griffin

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**Abstract**

This thesis assesses relationships between vegetation and topography and the impact of human tree-cutting on the vegetation of Union County during the early historical era (1755-1855). I use early warrant maps and forestry maps from the Pennsylvania historical archives and a warrantee map from the Union County courthouse depicting the distribution of witness trees and non-tree surveyed markers (posts and stones) in early European settlement land surveys to reconstruct the vegetation and compare vegetation by broad scale (mountains and valleys) and local scale (topographic classes with mountains and valleys) topography. I calculated marker density based on 2 km x 2 km grid cells to assess tree-cutting impacts. Valleys were mostly forests dominated by white oak (*Quercus alba*) with abundant hickory (*Carya* spp.), pine (*Pinus* spp.), and black oak (*Quercus velutina*), while pine dominated what were mostly pine-oak forests in the mountains. Within the valleys, pine was strongly associated with hilltops, eastern hemlock (*Tsuga canadensis*) was abundant on north slopes, hickory was associated with south slopes, and riparian zones had high frequencies of ash (*Fraxinus* spp.) and hickory. In the mountains, white oak was infrequent on south slopes, chestnut (*Castanea dentata*) was more abundant on south slopes and ridgetops than north slopes and mountain coves, and white oak and maple (*Acer* spp.) were common in riparian zones. Marker density analysis suggests that trees were still common over most of the landscape by 1855. The findings suggest there were large differences in vegetation between valleys and mountains due in part to differences in elevation, and vegetation differed more by topographic classes in the valleys than in the mountains. Possible areas of tree-cutting were evenly distributed by topographic classes, suggesting Europeans settlers were clearing land and harvesting timber in most areas of Union County.

## Introduction

During the early European settlement period, land surveyors used trees to mark property boundaries, leaving behind records and maps that have made it possible to reconstruct historical vegetation (Bourdo 1956; Siccama 1971; Abrams and Ruffner 1995; Black and Abrams 2001). These reconstructions have proven invaluable for our understanding of the ecology and environmental history of the eastern United States (e.g. Cronon 1983; Nowacki and Abrams 1992; Abrams and Ruffner 1995; Black and Abrams 2001). In this study, I reconstruct the historical vegetation of Union County during the early historical era (1755-1855) to assess the relationship between topography and vegetation and the impact of European settler tree cutting on vegetation.

Pennsylvania was mostly forested at the time of European settlement. However, open vegetation types existed on xeric limestone soils (Laughlin and Uhl 2003), serpentine barrens (Arabas 2000), and shale barrens (Anderson et al 1999). In Central Pennsylvania, William Scull's 1770 map of Pennsylvania describes a portion of Centre County as the "Great Plains" (Figure 1), which Losensky (1961) identifies as approximately 0.14 square km of open vegetation and Ruffner and Arabas (2000) and Laughlin and Uhl (2003) attribute to burning. Indeed, Indians may have used fires to modify vegetation with the goal of managing food sources (e.g., promoting economically useful tree species, hunting, and clearing land for agriculture) and protection (Nowacki and Abrams 1997).

Whatever the aboriginal impact on vegetation, it was subtle in comparison to the scale in which European settlers transformed the landscape. During the early historical era, Europeans transformed the vegetation and cleared the landscape of Central Pennsylvania

with activities including agriculture, logging, and clear-cutting to support the iron industry (Nowacki and Abrams 1992; Abrams and Ruffner 1995; Snyder 2000). The questions arising from these land use practices are: What was the nature and composition of the woodlands into which Europeans settled, and to what extent did they modify it during their first century of occupancy?

I examine these questions using Union County, Pennsylvania as a case study. Located in the Ridge and Valley Physiographic Province, Union County has a diverse topography. Such topographic diversity makes it possible and essential to assess how topography influenced vegetation and early European settler clearing patterns in Union County.

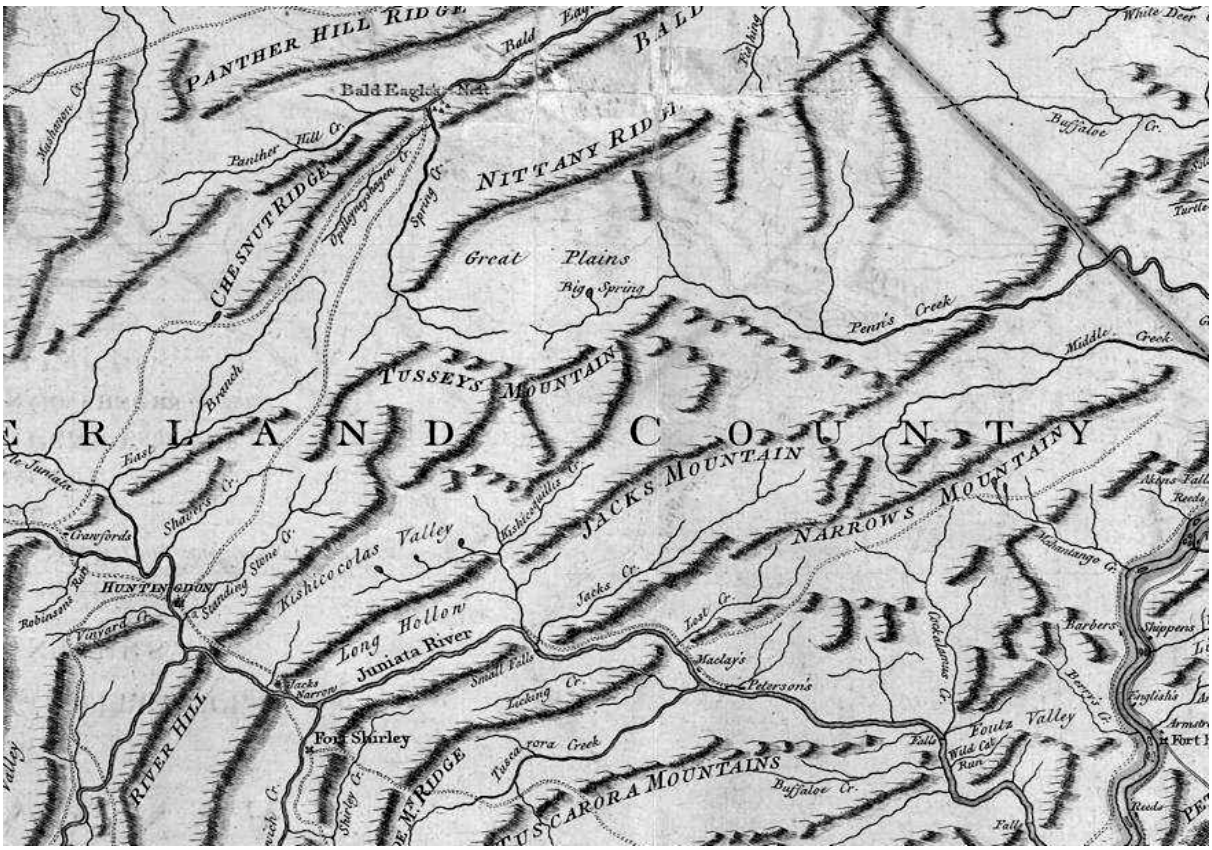


**Figure 1:** The portion of William Scull's 1770 map of Pennsylvania showing the "Great Plains" in Centre County, Pennsylvania (Scull 1770).

## Study Area

*Physical description*

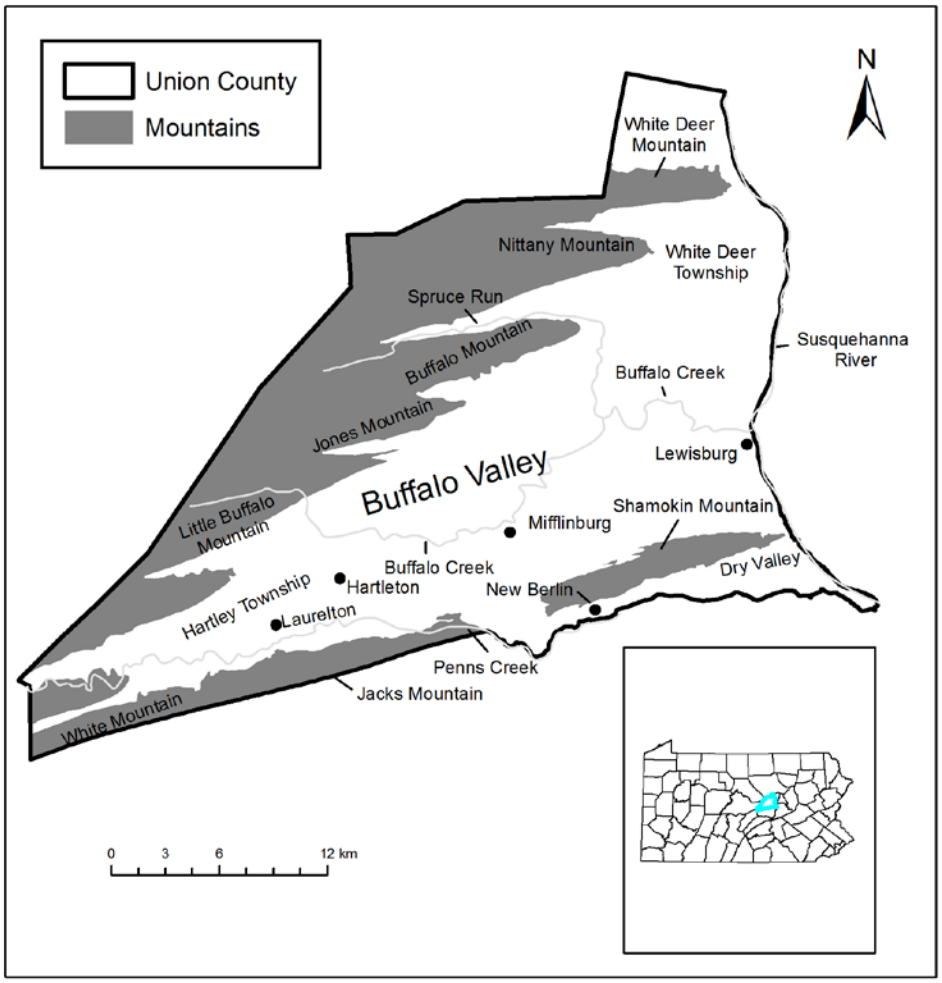


**Figure 2.** Towns, valleys, creeks, and other geographical features in Union County, Pennsylvania.

Union County, Pennsylvania is approximately 826 square km and located in the Ridge and Valley Physiographic Province (Figure 2). Bedrock was formed in the Ordivician, Silurian, and Devonian periods, and glacial till was deposited during the Pleistocene period (Eckenrode 1985). Topography is almost evenly divided between mountainous uplands with a maximum elevation of 662 m and hilly, broad valleys with a minimum elevation of 129 m (Figure 2; USGS 2000). The mountains are made of sandstone with deep, mostly coarse-

grained and well-drained soils separated by mountain valleys ("coves") formed in weaker sandstones and shale (Eckenrode 1985). The hilly valleys are composed of shale and carbonate with mostly fine-grained, shallow to deep, well-drained soils (Eckenrode 1985). The county has a humid-continental climate with an average temperature of -2 º C in the winter and 21 º C in the summer. Average annual precipitation is 990 mm with 55 % falling from April to September (Eckenrode 1985).

Topographical differences create microclimates. Higher elevations in mountains are cooler than lower elevations, and south slopes receive more direct sunlight and are drier than north slopes (Macdonald 2002). According to the Natural Areas Inventory of Union County (Davis et al 1993), the combination of topography, climate, soils, and other factors support a present-day vegetation in the valleys that includes mixed-oak communities associated with red maple (*Acer rubrum*; nomenclature follows Rhoads and Block 2000), tulip poplar (*Liriodendron tuilipifera*), and white pine (*Pinus strobus*); and contemporary vegetation in the ridges probably reflects the abundant white pine, white oak (*Quercus alba*), red oak (*Quercus rubra*), and chestnut oak (*Quercus prinus*) that Abrams and Ruffner (1995) found in the ridges of the Ridge and Valley Physiographic province of Centre County, Pennsylvania.

*Human settlement history*

Archeological evidence suggests that Indians arrived in the Susquehanna River Valley 11,000 years ago (Minderhout and Dowsett 2009). At the time of European settlement, Indians in Union County had settled in small villages. The major tribes living in these villages were the Muncy-Minsi and Lenni-Lenape, both offshoots of the Delaware. According to historical accounts, Indians used the Buffalo Valley (Figure 2) as a hunting

ground (Linn 1877) and cultivated squash (*Cucurbita* spp.), beans (*Phaseolus vulgaris*), corn (*Zea mays*), and tobacco (*Nicotiana* spp.) around their settlements (Meginess 1853), which included Muncy Town (or Shikellamy), Gordon, and an "unnamed village" (Figure 3; Linn 1877; Bitely 2010). There is also archeological evidence of a temporary village to the north of Buffalo Creek (Figure 2; B. Marsh personal communication, April 27, 2011). Commercial activity flowed from Shamokin, located at the confluence of the West and North Branches of the Susquehanna River, along Penns Creek path and the Great Island path (Wallace 1993; Figure 3).

The first land surveys in Union County were completed in 1755 when Europeans made a failed attempt at settling along Penns Creek (Figure 2). Permanent European settlement began in 1769 along the Susquehanna River and Penns Creek and grew quickly to the west and north until the mid-nineteenth century when population growth declined (Snyder 2000). In 1769, William Maclay employed his brother Samuel to execute a survey of the Buffalo Valley (Figure 2), which succeeded in parceling most of the arable land (Snyder 2000). That same year, John Lee settled at Winfield (Snyder 2000), possibly forming the first clearing in the Dry Valley (Figure 2), and Ludwig Derr settled on land next to Limestone Run (now Bull Run) and built a mill on his plot a year later (Snyder 2000). By 1776, 4,323 acres were under cultivation in Union County by 215 landowners (Snyder 2000). In 1785, Ludwig Derr laid out the town of Lewisburg on his land (Figure 2). Mifflinburg was established in 1792 (Figure 2). In 1813, Union County was established from part of Northumberland County (Snyder 2000). During the early historical era, Europeans cleared land for agriculture, logging, and charcoal to fuel iron furnaces (Snyder 2000; Whitney

1994). In the 1820s, Berlin Iron Works was founded along Penns Creek to the south of Laurelton (Figure 2; Snyder 2000).

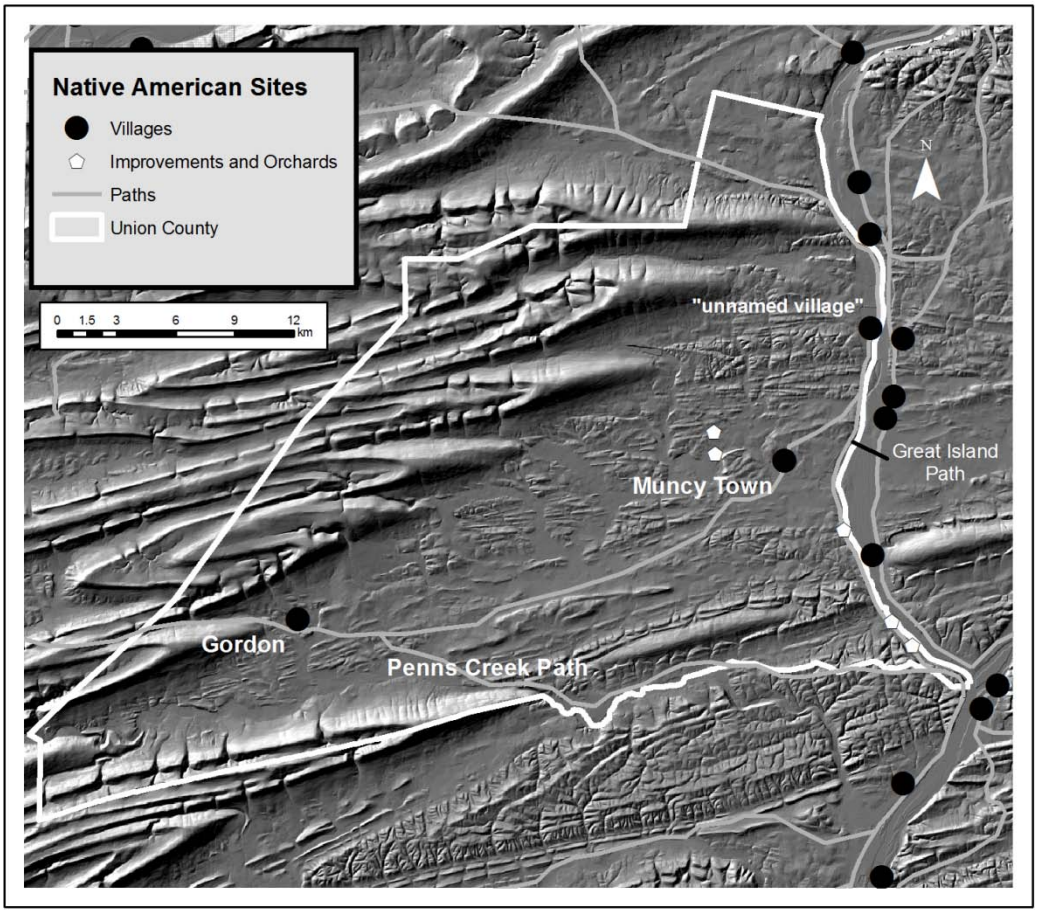


**Figure 3.** Native American paths and settlements in Union County immediately preceding European settlement (Bitely 2010).

## Methods

To reconstruct the vegetation of Union County and assess the relationship between early historical era vegetation and topography and the extent of European settler tree-cutting, I used the following three methods. First, I classified the county into broad scale (mountains and valleys) and into local scale (topographic classes within the mountains and valleys) topography. Next, I reconstructed vegetation with land survey records from 1755 to 1855 to

analyze tree composition by topographic classes. Finally, I used marker density analysis, where I quantified the uneven distribution of posts and stones[1] found in the land survey record to determine where European tree-cutting was most intensive in the county.

*Classifying topography*

Using ArcGIS, I delineated topographic classes (valley hilltops and mountain ridgetops, north slopes, south slopes, valley floors and mountain coves, and riparian zones) based on a 10 m digital elevation models of Union County (DEMs; USGS 2000; Figure 6). First, I differentiated mountains and valleys by rendering mountainous areas based on hillshades of the 10 m DEM. Next, based on calculations of slopes and aspect, I differentiated north slopes from south slopes (Table 1). I then differentiated hilltops/ridgetops from valley floors/mountain coves by smoothing the 10 m DEM to obtain local mean elevation and then subtracted the original 10 m DEM from the smoothed 10 m DEM. Based on this calculation, I defined all positive values as valley hilltops and mountain ridgetops and all negative values as valley floors and mountains coves (Table 1). Finally, I overlaid riparian zones based on 100 year floodplains as calculated by the Penn State University Office of Remote Sensing for Earth Resources (Penn State University 1996; Table 1).

[1] I refer to post and stones as "markers."

| Topographic Classes | Definition | Valley, Mountain, or Both |
|---|---|---|
| North Slope | Gradient > 10 % and aspect between 0 and 90 degrees and > 270 | Both |
| South Slope | Gradient > 10 % and aspect between 90 and 270 degrees | Both |
| Hilltops | Gradient < 10 % and positive variation from mean smoothed DEM elevation | Valley |
| Ridgetop | Gradient < 10 % and positive variation from mean smoothed DEM elevation | Mountain |
| Valley Floor | Gradient < 10 % and negative variation from mean smoothed DEM elevation | Valley |
| Mountain Cove | Gradient < 10 % and negative variation from mean smoothed DEM elevation | Mountain |
| Riparian Zone | 100-year floodplain | Both |

**Table 1.** The definitions of topographic classes in Union County, Pennsylvania.

*Tree species composition analysis*

To reconstruct the vegetation composition, I used warrant maps and forestry maps from the Pennsylvania State Archives as well as a warrantee maps from the Union County Courthouse (Table 2). These maps depict land surveys dating from 1755 to 1916, although the vast major of land surveys were recorded before 1855. It is at this date the Pennsylvania State Archives warrant map survey records end and population growth declined in Union County (Snyder 2000). In addition, the data contains fewer than 10 points dating after 1867.

Warrant maps represent land surveyed by surveyors as Europeans settled the Eastern United States (Abrams and Ruffner 1995). These maps contain the bearings and distances linking each property corner, which surveyors identified by marking with a witness tree[2] or marker. Warrants were issued to citizens and soldiers on demand. After surveying the land, maps were produced, which included trees, posts, and stones, Indian paths, streams, and

[2] Witness trees are trees blazed by surveyors representing property corners in early European land surveys of the eastern United States.

other prominent geographical features. Warrants were then patented and issued to the property owner, and were made official after the first tax payment (Abrams and Ruffner 1995).Warrant maps have limitations, as surveyors may have misidentified tree species, misrepresented the frequency of larger tree species (Black and Abrams 2001), and tended to record only genus names for some groups—e.g. pines (*Pinus* spp.), birches (*Betula* spp.), and maples (*Acer* spp.). Despite these limitations, warrant maps depict a large number of tree species and generally agree with qualitative descriptions (Abrams and Ruffner 1995; Black and Abrams 2001). Forestry maps and warrantee maps are also useful in reconstructing historical vegetation as they are updated versions of warrant maps that include depictions of the original warrants and property corners and later property subdivisions (Figure 4; Figure 5).

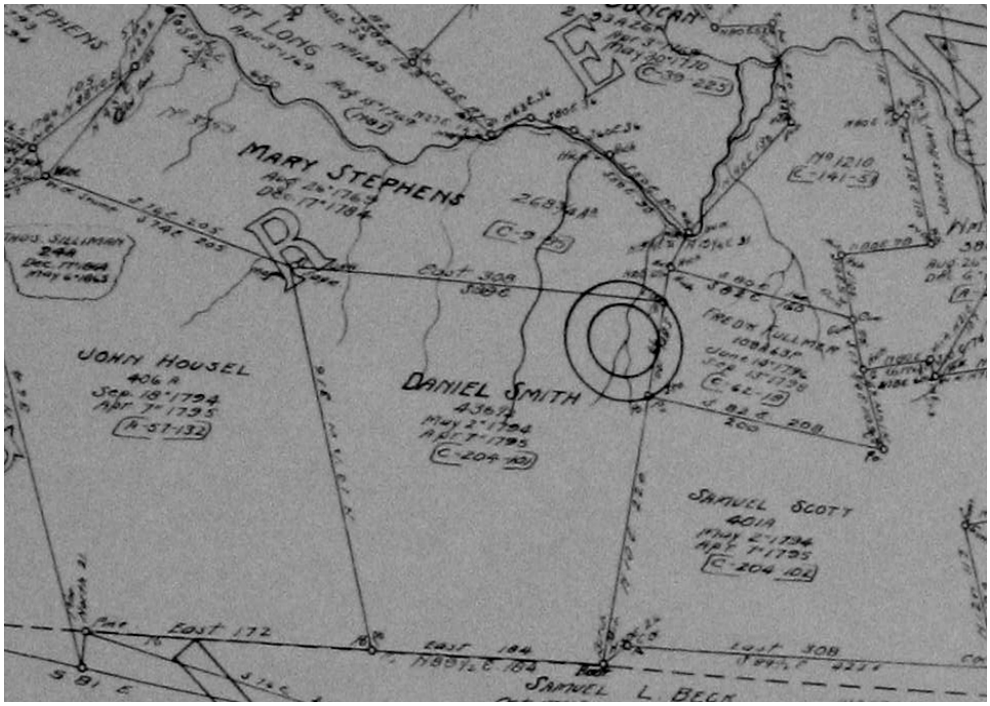


**Figure 4.** A forestry map showing Daniel Smith's property in Greggs Township, Union County, Pennsylvania including the warrant date and witness trees and markers on property corner (Pennsylvania Department of Forestry 1916; Table 2).

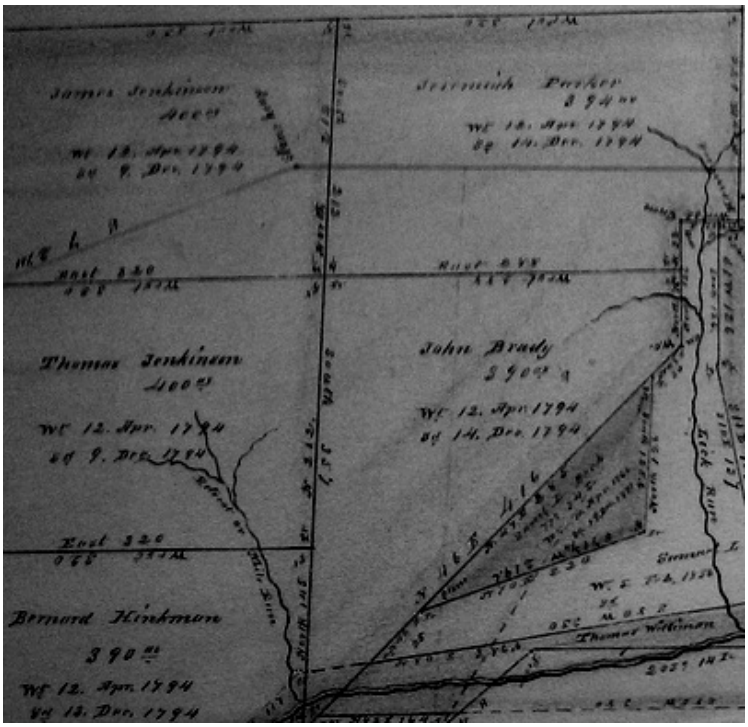


**Figure 5.** A portion of a warrantee map showing John Brady's property in West Buffalo Township, Union County, Pennsylvania including the warrant date and witness trees and markers on property corners. Photograph taken at Union County, Pennsylvania Courthouse (Pomeroy and Beer 1868; Table 2).

| Map Type | Author | Year | Dates of Original Drafts | Name | Source |
|---|---|---|---|---|---|
| Reconstructed Warrant Map | Munger, D. B | 1989 | 1770-1873 | White Deer Township Warrant Map | Pennsylvania Historical and Museum Commission |
| Forestry Map | | 1916 | 1916 | Map F-7 | Pennsylvania Department of Forestry |
| Forestry Map | | 1916 | 1916 | Map G-5 | Pennsylvania Department of Forestry |
| Forestry Map | | 1916 | 1916 | Map G-7 | Pennsylvania Department of Forestry |
| Warrantee Map | Pomeroy and Beers | 1868 | 1868 | Union County Warrantee Map | The Atlas of Union County and Snyder Counties, PA |

**Table 2.** Sources for warrant maps, forestry maps, and warrantee maps used in reconstructing the vegetation of Union County during the early historical era.

I georeferenced warrant maps to modern parcel boundaries and digitized 1,783 witness trees and markers (Appendix B) using ArcGIS (ESRI, Redland, CA). In some cases, it was difficult to digitize points based on modern parcel boundaries. To address problems with geographical precision, I assigned digitized points with a confidence value of 1 (highest confidence in geographical precision) to 4 (lowest confidence in geographical precision) (Appendix C). In addition to confidence score, I recorded each witness tree or marker's species or genus and township.

For tree species composition analysis, I overlaid the warrant map survey data over mountains, valleys, and each local topographic class in ArcGIS. I then summarized tree species occurrence and marker total to obtain tree species frequencies and counts by topographic class (Table 1).

*Marker density analysis*

To assess geographical patterns of European tree-cutting, I conducted marker density analysis. First, I identified areas where Europeans were most likely cutting trees. Markers counts were uneven across the county. Thus, I needed to quantify makers by percent to identify areas where tree-cutting was most intensive. To obtain the distribution of markers by percent, I resampled the trees and markers data in ArcGIS and then arbitrarily placed a grid of 2 km x 2 km cells onto a map of Union County to identify areas with high (50% to 100%), medium, (20% to 50%), and low (0% to 20%) densities of markers. Only cells with marker counts of $n > 4$ were included. Second, I assessed whether European settlers preferred some topographical site types over others. As a result, I constructed contingency tables for chi-

square analysis to assess these possible differences in marker distribution by topographic classes.

**Results**

Counts and frequencies for all tree species and markers in each topographic class are found in Appendices D, E, and F. In the valleys, white oak (*Quercus alba*; 43 %) was the dominant tree species, and pine (11.3 %), black oak (*Quercus velutina*; 11.2 %), and hickory (*Carya* spp; 10.1 %) were abundant (Figure 7; Appendix D). In contrast, mountains were dominated by pine (31.9 %) and had a high frequency of chestnut oak (*Quercus prinus*; 13.7 %), white oak (12.2 %), and black oak (7.6 %).

At finer scales, valley floors composed most of the extent of the valley (Figure 6). On valley floors, white oak was dominant (45.3 %). White oak was also frequent on south slopes (49 %) and on north slopes (45.3 %) (Figure 8; Appendix E). On hilltops, pine (28.6 %) was more abundant than on other topographic classes. Eastern hemlock (*Tsuga canadensis*) was abundant on north slopes (10.7 %) but absent on south slopes (0 %). In contrast, hickory was abundant on south slopes (9.8 %) but absent on north slopes (0 %) (Figure 9). Hickory (14.4 %) and ash (*Fraxinus* spp.; 7.4 %) were more frequent in riparian zones than elsewhere in the valley.

In the mountains, pine was dominant on all topographic classes except riparian zones (6.7 %) and most abundant in mountain coves (37.7 %) and on ridgetops (32.6 %) (Figure 10; Appendix F). On ridgetops, white oak (32.6 %) scarlet oak (*Quercus coccinea*; 7.2 %) were also more abundant than on other topographic classes. On north slopes, white oak (15.4 %) and chestnut oak were abundant (21.2 %). Chestnut (*Castanea dentata*) was most

abundant on south slopes (11.8 %). Riparian zones had a lower samples size (*n*= 15) than other classes and was dominated by white oak was dominant (20 %) with abundant maple (13.3 %).

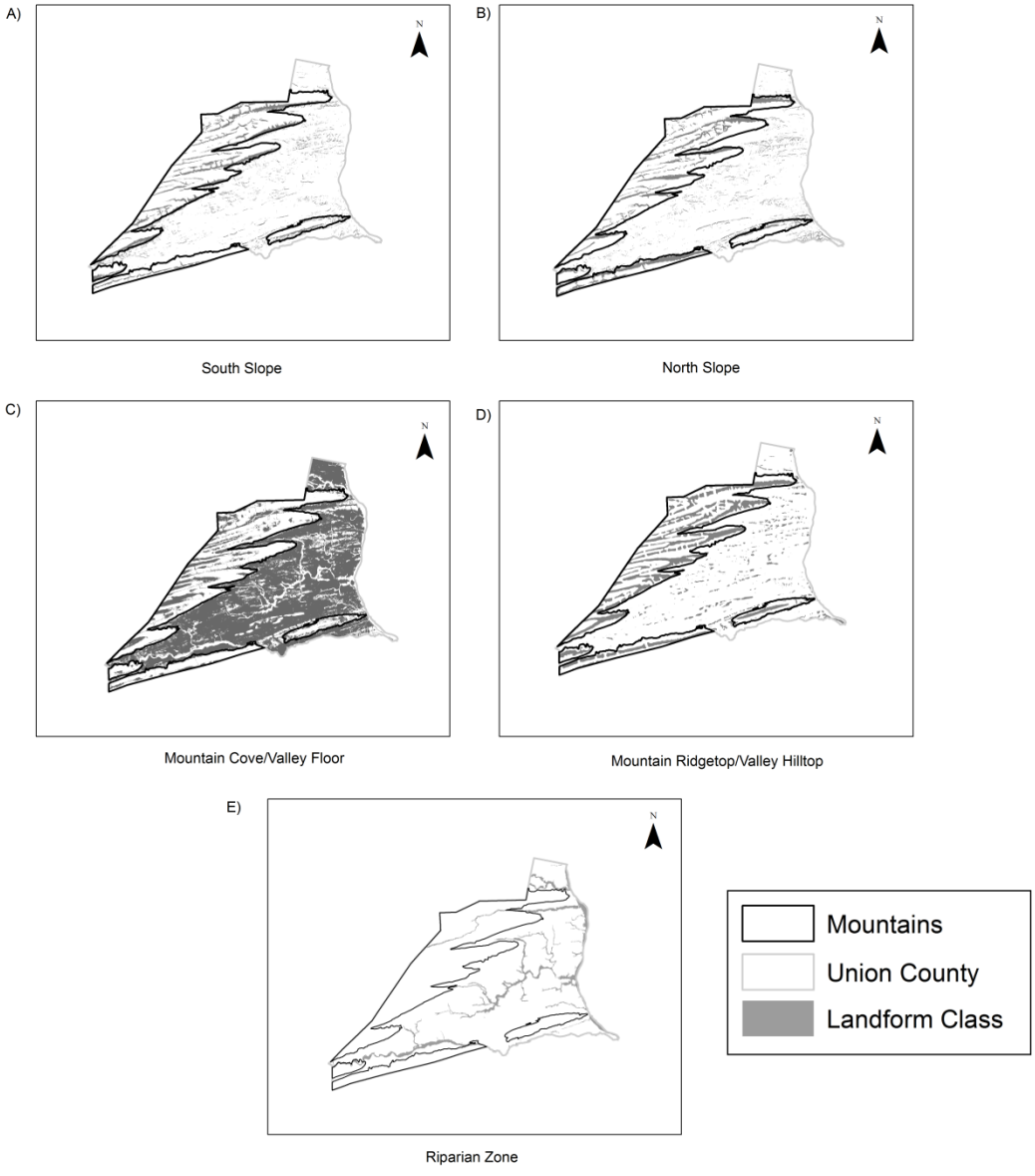


**Figure 6.** The distribution of topographic classes in Union County. The maps identifies: A) South Slope; B) North Slope; C) Mountain Cove/Valley Floors; D) Mountain Ridgetops/Valley Hilltops; E) Riparian Zones. All topographic classes are defined in Table 1.

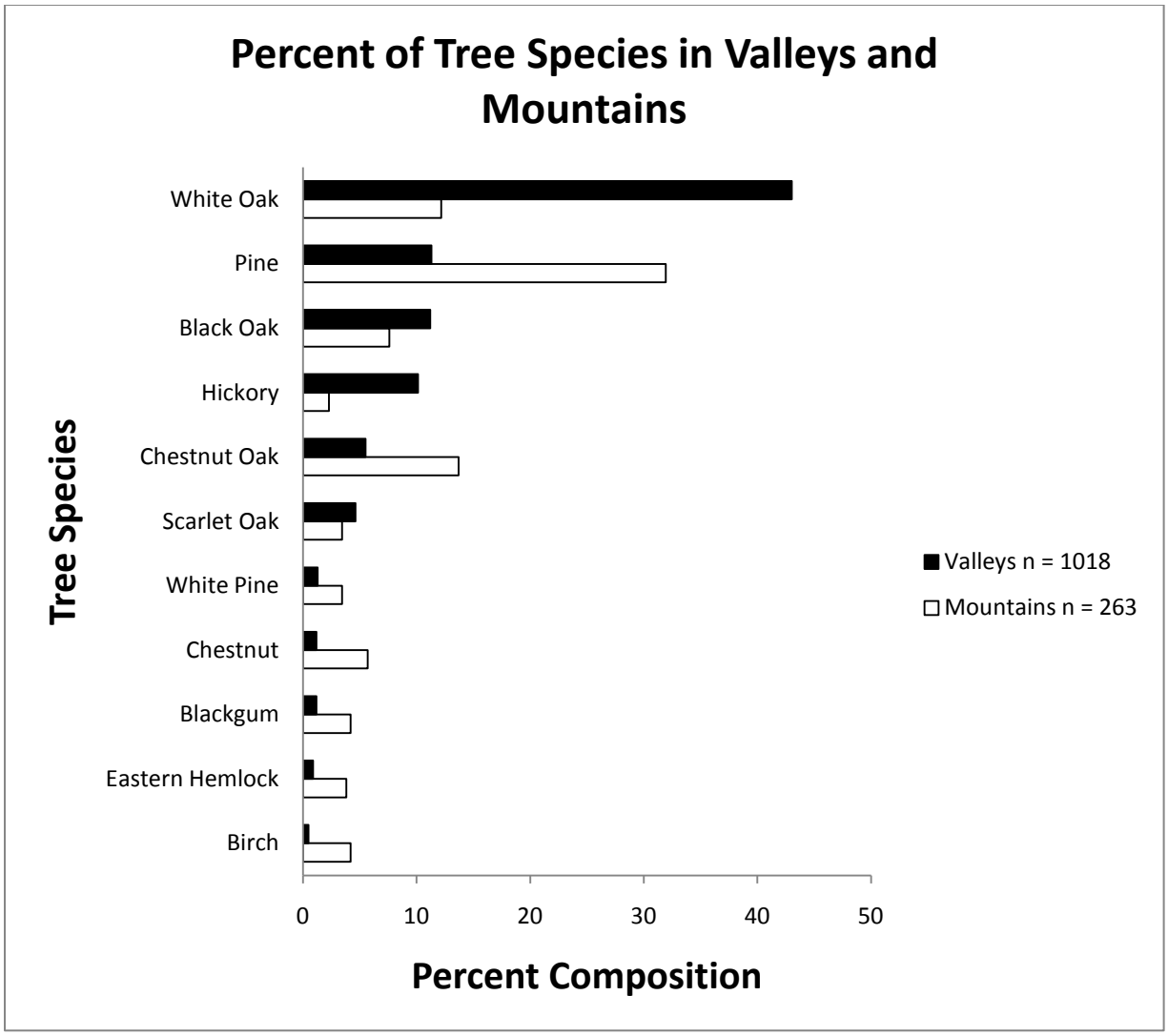


**Figure 7.** The frequency of tree species in the valleys and in the mountains of Union County based on land survey data from 1755 to 1855.

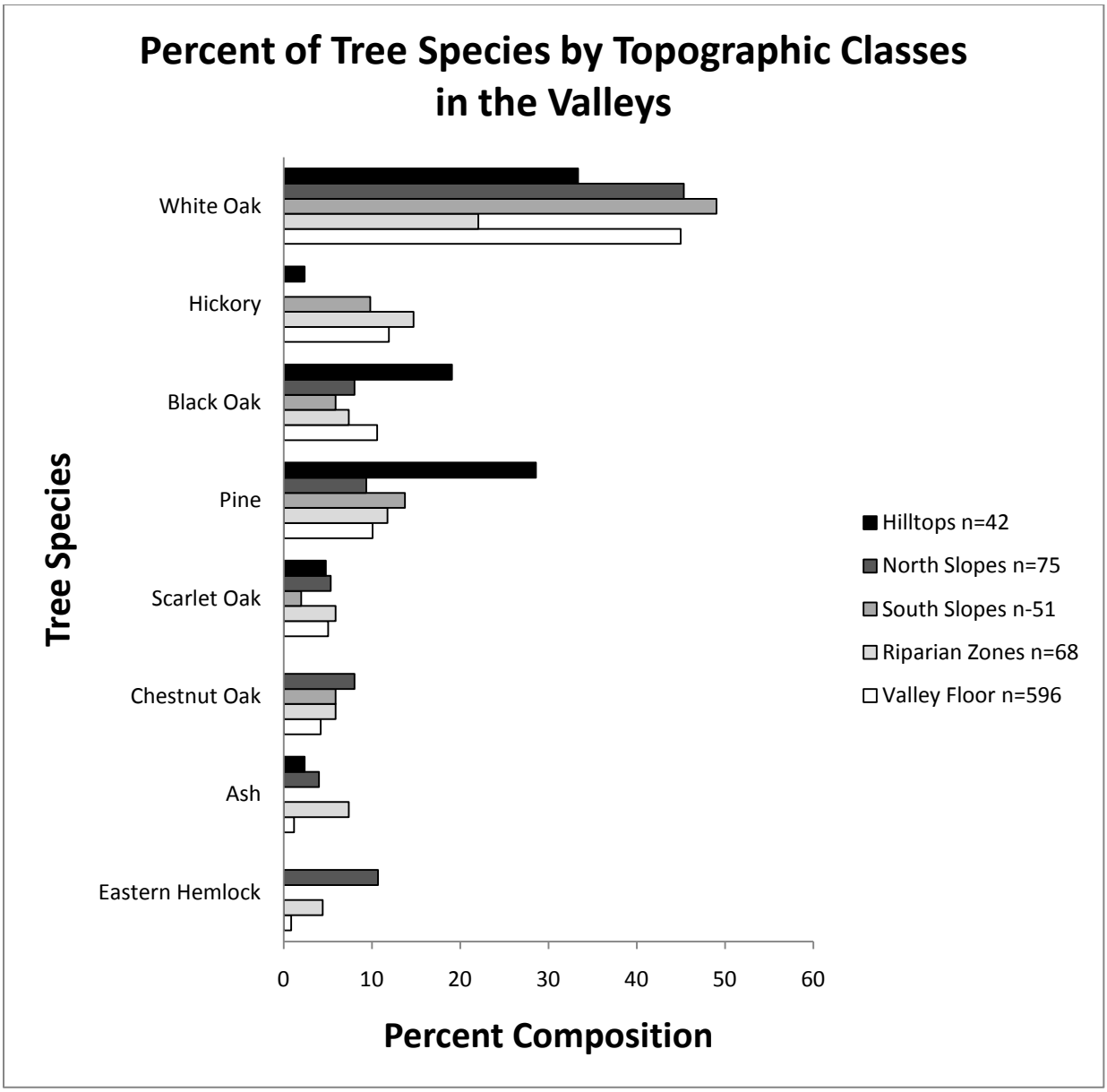


**Figure 8.** Tree species frequency by topographic classes in the valleys of Union County based on land survey data.

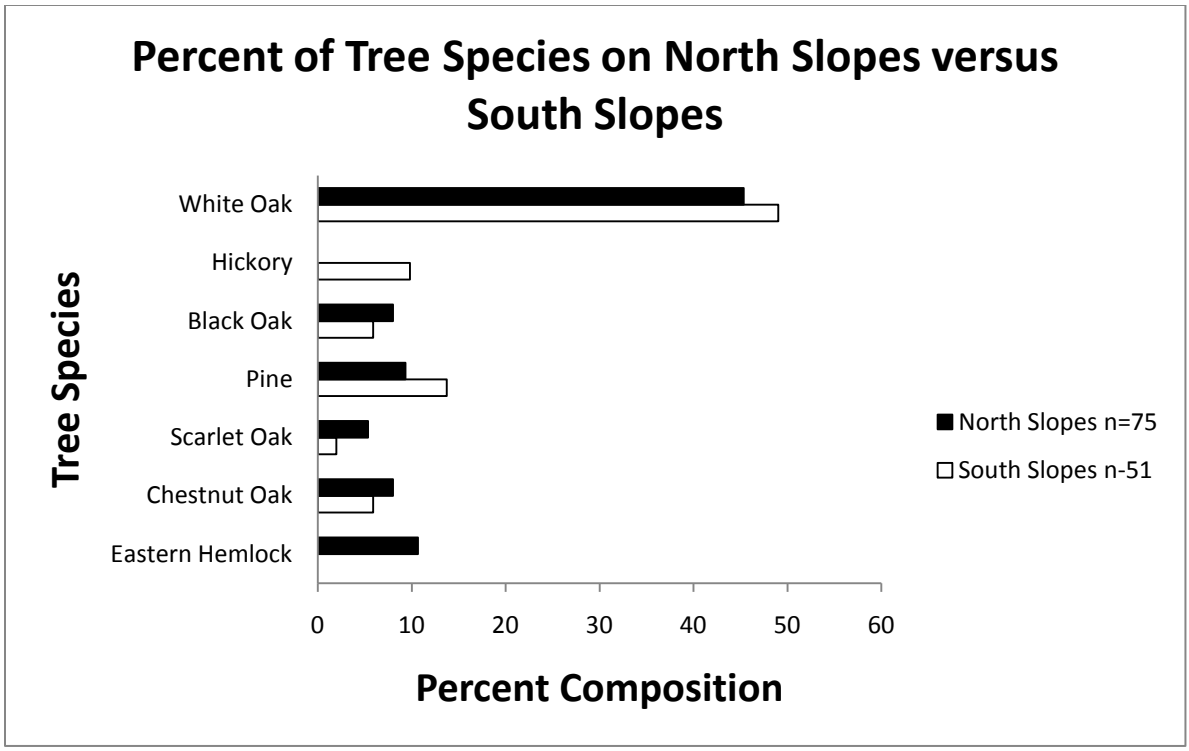


**Figure 9.** The frequency of tree species on north slopes versus south slopes in the valleys of Union County based on land survey data.

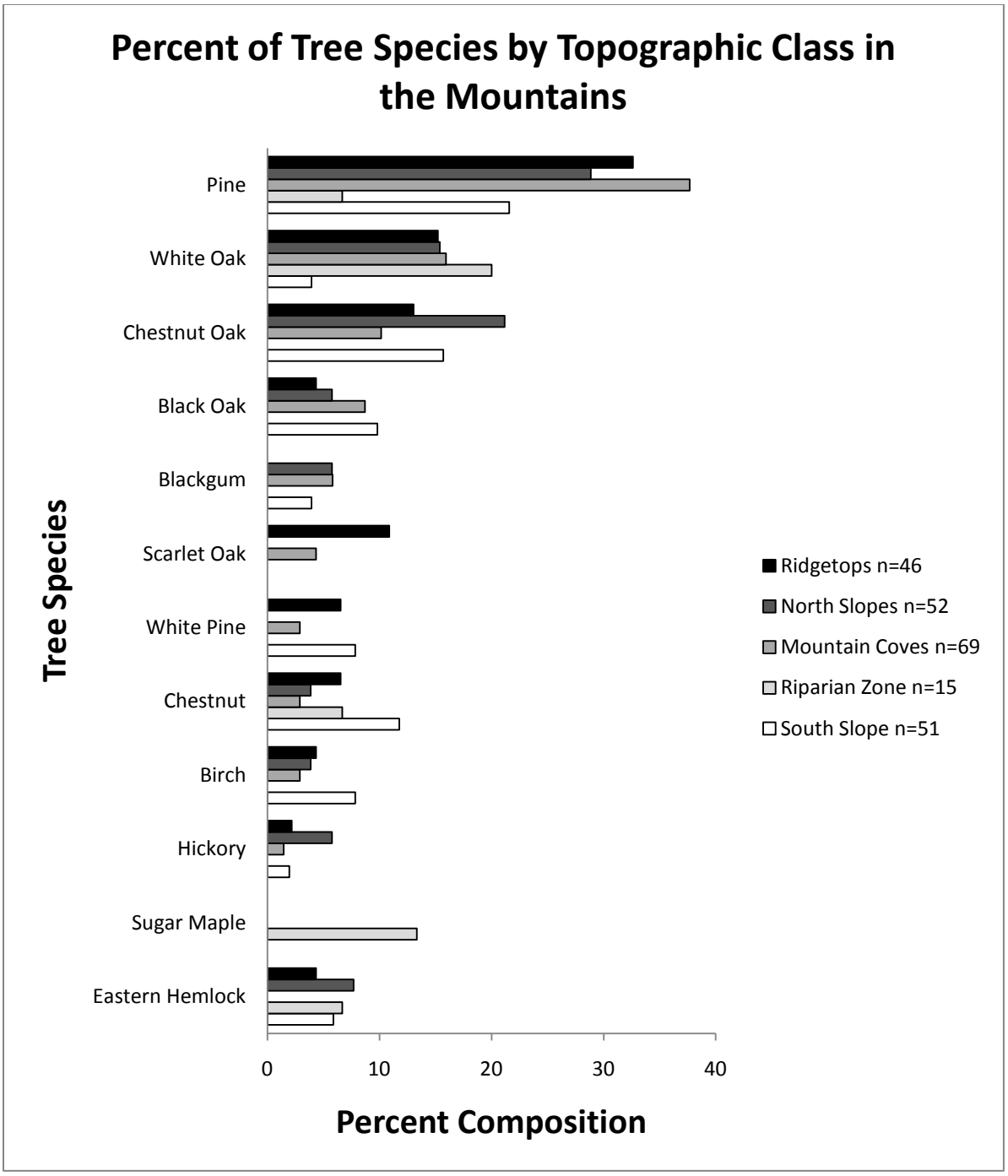


**Figure 10:** The frequency of tree species by topographic classes in the mountains of Union County based on land survey data.

*Marker Density Analysis*

Marker density analysis indicates that the majority of the 2 km x 2 km cells had a medium density of markers (46 %) or low density of markers (38.9 %). High density markers were only found in 15 % of cells (Figure 11). There was no strong pattern of high density marker distribution except along the eastern edge of Union County (Figure 11). Chi-square tests of markers in the valleys $\{X^2(4, N = 1198) = 6.023, p = 0.197\}$ and the mountains $\{X^2(3, N = 334) = 4.000, p = 0.261\}$ indicate no significant relationship between marker frequencies and topographic classes (Appendix E; Appendix F).

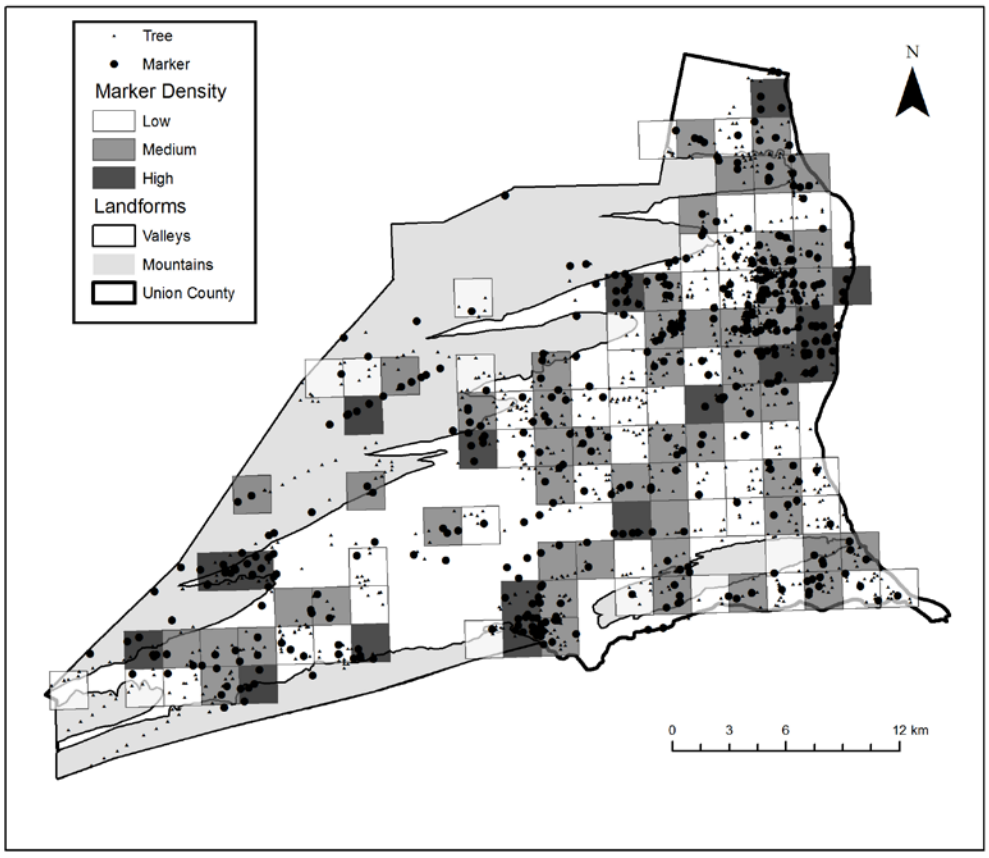


**Figure 11.** The distribution of areas with low (0 to 20 %), medium (20 to 50 %), and high (50 to 100%) marker densities based on 2 km x 2 km cells in Union County during the early historical period. Only cells with marker count $n > 4$ are shown.

## Discussion

### *Vegetation and topography*

The most dramatic vegetation composition differences in Union County during the early historical era were between the valleys and the mountain. The valleys were dominated by white oak with abundant pine, and hickory and a surprisingly large frequency of scarlet oak (Figure 7). In the mountains, pine was dominant, chestnut oak was more abundant, and white oak and hickory decreased in abundance. These compositional changes may reflect an association between white oak and hickory and slightly warmer conditions at lower elevations. Nowacki and Abrams (1992) conducted an analysis of historical and edaphic changes in tree species compositions of Central Pennsylvania Ridge and Valley forests in Centre County. Their findings in contemporary Central Pennsylvania forests explain tree species trends related to elevation change in Union County. According to Nowacki and Abrams (1992), white oak also decreases as elevation increased, scarlet oak is unexpectedly found in the valleys, and chestnut oak is restricted to ridges (mountains) as it favors growth on coarse-textured soils.

At finer scales, topographic classes within valleys supported different vegetation in Union County. Hilltops had substantially different vegetation than valley floors. Pine was more abundant on hilltops than valleys floors, and white oak showed the opposite association (Figure 8). These differences probably reflect better drainage on hilltops than any large variation in microclimates. In comparison, differences in vegetation between south slopes and north slopes were consistent with their different microclimates. On north slopes, conditions are cooler and soil temperature fluctuate less than on south slopes (Nowacki and Abrams 1992). In Union County, north slopes tended to support trees with more northern

ranges (such as eastern hemlock), and more southern species (such as hickory) thrived on warmer and drier south slopes (Figure 9; cf. Nowacki and Abrams 1992). Riparian zones supported dramatically different vegetation than other topographic classes, which is probably more related to soil composition, drainage, and moisture than climate.

In Union County, vegetation differences among topographic classes in mountains were less dramatic. Though small in sample size, riparian zones probably had a set of soil, drainage, and moisture conditions that supported a unique set of vegetation (white oak and maple) compared to other topographic classes (Figure 10). The microclimate effect between north slopes and south slopes was less recognizable in the mountains of Union County. However, south slopes supported a greater abundance of chestnut than north slopes, and white oak was more frequent on north slopes. These results suggest that chestnut favors growth in condition exposed to more direct sunlight. Infrequent white oak on south slopes may reflect the fact that steeper slopes are less favorable to white oak development (Nowacki and Abrams 1992). On mountain coves in Union County, eastern hemlocks were absent (Appendix F). This is a surprising result as coves receive both solar protection and cold air drainage, which should promote trees more abundant in areas with cooler climates than Pennsylvania, such as eastern hemlock.

*Timber cutting by early European settlers*

In the early historical period, tree-cutting in Union County was associated with different economic activities in the mountains and the in valleys. Charcoal demanded to fuel iron furnaces led to timbering in the mountains of Union County. In the 1820s, an iron furnace opened in Hartley Township that was fueled by charcoal from wood from nearby

Jacks Mountain (Figure 2; Snyder 2000). There is also evidence of timbering for charcoal in the mountains near spruce run (Figure 2; Marsh, personal communication, April 27, 2011). According to Nowacki and Abrams (1997), the demand for charcoal was so intensive in early European settlement ridges forests of Central Pennsylvania that forest were converted from dense oak, pine, and chestnut to young stands of oak and chestnut. By 1860, the rising price of charcoal and high production cost brought a decline to charcoal-fueled iron furnaces, and coal became the less expensive alternative (Snyder 2000). In contrast, logging and agriculture were the major tree-cutting activities in Union County valleys (Snyder 2000).

In Union County, marker distribution was relatively equal in valleys and in the mountains (Appendix D), and a chi-square analysis showed no relationship between marker frequencies and topographic classes (Appendix E; Appendix F). This relatively equal distribution of markers across topographic classes indicates that tree-cutting was widespread in Union County regardless of topography. In the mountains, there is evidence of tree-cutting in the high marker density areas near Berlin Iron Works and Spruce Run (Figure 2; Figure 11). Marker density analysis suggests the most intensive agriculture and logging occurred along the Susquehanna River in White Deer Township (Figure 2; Figure 11).

*Fires and clearing prior to European settlement*

The high density marker areas in Union County valleys may also reflect open vegetation that predated European settlement. Allen (1877: 485) quotes a description of the Buffalo Valley's eighteenth century vegetation (attributed to Colonel John Kelly) as "wooded…with large scattered trees so that the grass grew abundantly to furnish good pasturage for the buffalo." This account describes an oak savanna. The Illinois Natural Area

inventory defines savanna as a grassy environment with 5 to 80 percent canopy cover (Anderson et al 1999). Union County also has a large number of "Buffalo" place names including the Buffalo Valley, Buffalo Mountain, Buffalo Crossroads, Buffalo Creek, and Buffalo Township (Figure 2; Wagner and Shellenberger 2007). Although there is no archeological evidence of buffalo in Union County, the high concentration of "Buffalo" place names likely reflects the presence of bison in the area at the time of European settlement. As grass-eating generalists, bison habitats tend to be areas with plentiful grass (Platou and Tueller 1985)—in other words, savannas. One piece of direct evidence for a savanna is the open growth form white oak included in the original land survey of Lewisburg[3] (Figure 12; Figure 13). Open growth form is more characteristic of trees in savannas than dense forests. These three lines of evidence are consistent with historical descriptions of open vegetation prior to European settlement in Eastern United States forests (Denevan 1992) and the Great Plains in Centre County, Pennsylvania (Losensky 1961; Ruffner and Arabas 2000; Laughlin and Uhl 2003).

[3] Open growth form reflects a tree that receives maximum sunlight from having little competition with neighboring trees (Srivastiva 2001).

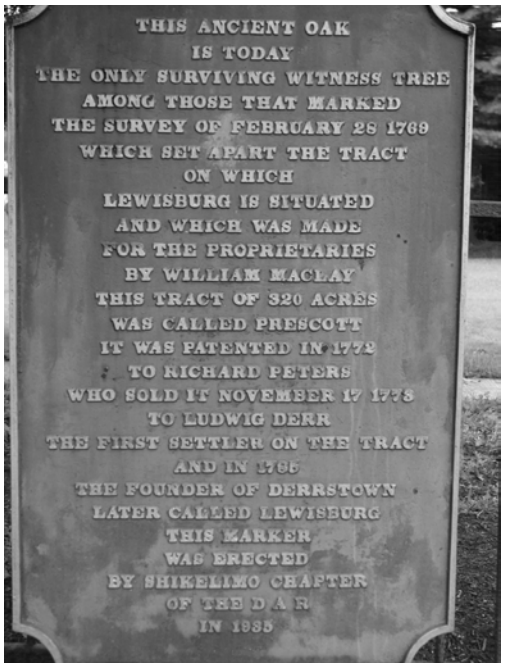


**Figure 12.** The Daughters of the American Revolution (DAR) plaque in front a surveyed white oak tree in Lewisburg, Pennsylvania claiming the tree was part of the original land survey.

**Figure 13.** The open growth form white oak that the Daughter's of the American Revolution Plaque memorializes at Lewisburg, Pennsylvania.

The most likely explanation for these clearings is fire. Indeed, fire is a key component in retarding tree development in savannas, but shallow soils and extreme climates or microclimates are also important factors (Anderson et al 1999). Although paleoecological evidence such as charcoal would make these findings more robust, the tree species composition of Union county reflects regular fires prior to and during early European settlement. The dominant tree species in Union County—white oak and pine—were highly dependent on fire to maintain (Peet 1984; Abrams 1992; Abrams and Ruffner 1995). In contrast, fire intolerant species, such as sugar maple (*Acer saccharum*), red maple, tulip poplar, and red oak, had relatively low frequencies (Appendix D), a surprising result considering their present-day prominence in Central Pennsylvania Ridge and Valley forests (Abrams and Ruffner 1995). The scarcity of red oak may be misleading as surveyors would have not been able to distinguish red oak from black oak without acorns present.

Fire ignition sources were either natural (lightning) or anthropogenic (Indians or early European settlers). Humid conditions may have made lightning fires too rare in Eastern United States forests to explain the high frequency of fire-resistant vegetation (Abrams and Nowacki 2008), though Pennsylvania has relatively hot and dry summers. Fire-resistant vegetation may reflect frequent Indian fires in Union County as fires would have been useful in maintaining the aboriginal hunting grounds and agricultural land clearings described in historical accounts of Union County (Linn 1877; Meginess 1853). In the mountains, this vegetation may be related to the Union County iron industry. Elsewhere in Central Pennsylvania, early European settler tree-cutting for charcoal to fuel iron furnaces was associated with uncontrolled fires (Abrams and Ruffner 1995).

*A comparison of vegetation in Union County to other studies and historical accounts*

Vegetation composition during the early historical period in Union County was consistent with other vegetation reconstructions (Nowacki and Abrams 1992; Abrams and Ruffner 1995) and historical accounts (Bartram Vol. 11; Linn 1877) of Central Pennsylvania Ridge and Valley forests. There are some exceptions. First, Nowacki and Abrams (1992) found chestnut to be one of the dominant ridge tree species (mountains) in their reconstruction of eighteenth century forests in Centre County. Chestnuts were not found to be as abundant in mountains of Union County. Second, in the mid 1700s, John Bartram described vegetation along the West Branch of the Susquehanna River near Lewisburg as "spruce[4], and white pine, oak, beach [*sic*], plane trees…hickory, walnut, locust, and pitch pine" (Bartram Vol. 11: 26). This study found no plane trees (*Platanus occidentalis*) or pitch pine (*Pinus rigida*) and only a small number of walnut (*Juglans* spp.), locust (*Robinia pseudoacacia*), and beech (*Fagus* spp.) in Union County (Appendix A). Third, the nearby Middle Creek Valley of Snyder County appears to have had different vegetation than Union County. Linn (1877: 6) quotes Captain McHenry describing the Middle Creek Valley in 1774 as "well timbered-walnut, black oak, and maple." The account provides an incomplete description of vegetation, but it mentions maples and walnuts, which were not abundant tree species in Union County. These vegetation differences probably reflect different human land uses in Union County and the Middle Creek Valley prior to European settlement.

[4] For early European settlers, spruce was *Tsuga Canadensis*, now known as eastern hemlock, and should not be confused with the *Picea* genus.

## Conclusions

Union County was mostly forested during the early historical era. The valleys were mixed-oak, hickory, and pine forests dominated by white oak, and the ridges were pine-oak forests dominated by pine and with abundant chestnut oak and white oak. A stronger relationship existed between vegetation compositions and topographic classes in the valley than in the mountains.

In the valleys, white oaks were more frequent on valley floors than hilltops, and pines were more abundant in hilltops than on valley floors. Dramatic vegetation shifts on north slopes versus south slopes reflected distinct microclimates. An inverse relationship existed between abundant eastern hemlock on north slopes and the high frequency of hickory on south slopes. In the mountains, microclimate relationships were weaker. Chestnut was associated with south slopes, where it received more direct sunlight. In contrast, white oak was frequent on north slopes but excluded on south.

Tree-cutting was probably common and widespread in Union County during the early historical period. In the mountains, tree-cutting may have been associated with providing charcoal for the iron industry. In the valleys, European tree-cutting activities, such agriculture and logging, are difficult to distinguish from possible aboriginal fires and agriculture clearings.

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**Appendix A:** Nomenclature for Tree Species in Pennsylvania

| Binomial | Family | Common Names |
|---|---|---|
| *Fraxinus* spp. | Oleaceae | Ash |
| *Fagus* spp. | Fagaceae | Beech |
| *Betula* spp. | Betulaceae | Birch |
| *Quercus velutina* | Fagaceae | Sourgum, Black oak |
| *Nyssa sylvatica* | Nyssaceae | Blackgum |
| *Castanea dentata* | Fagaceae | Chestnut |
| *Quercus prinus, Quercus Montana* | Fagaceae | Chestnut oak |
| *Cornus* spp. | Cornaceae | Dogwood |
| *Tsuga canadensis* | Pinaceae | Canada hemlock, Eastern hemlock, spruce |
| *Ulmus* spp. | Ulmaceae | Elm |
| *Carya* spp. | Juglandaceae | Hickory |
| | | Ironwood |
| *Tilia* spp. | Tiliaceae | Linden |
| *Robinia* spp. | Fabaceae | Locust |
| *Acer* spp. | Aceraceae | Maple |
| *Pinus* spp. | Pinaceae | Pine |
| *Pinus resinosa* | Pinaceae | Red pine |
| *Quercus rubra* | Fagaceae | Northern red oak, Red oak |
| *Sassafras albidum* | Lauraceae | Sassafras |
| *Quercus coccinea* | Fagaceae | Scarlet oak, Spanish oak |
| *Acer saccharum* | Aceraceae | Sugar maple |
| *Quercus bicolor* | Fagaceae | Swamp white oak, Swamp oak |
| *Liriodendron tulipifera* | | Tulip Poplar |
| *Juglans* spp. | Juglandaceae | Walnut |
| *Quercus alba* | Fagaceae | White oak |
| *Pinus strobus* | Pinaceae | White pine |
| *Hamamelis* spp. | Hamamelidaceae | Witch hazel |

**Table 3**. The scientific binomials, families, and common names for trees found in Union County at the time of European settlements (Rhoads and Block 2000).

## Appendix B: A Description of Witness Tree Analysis Methods

Due to imagery constraints, the property corner markers on warrant maps, forestry maps, and Union County Courthouse warrantee map were not always legible. On the original warrant maps and most forestry maps, each property was labeled with a registry numbers referencing the location of the map in the original survey books, which can be found on the Pennsylvania Historical Archives website (http://www.portal.state.pa.us/portal/).

However, the forestry maps and the warrantee map did not show these registry numbers on every property, but they did note the property owner as well as the date the warrantees were commissioned and the date that the patents were completed. Each county has a list of warrant registries chronologically ordered by their date of commission and include a reference to where the surveys are recorded, which can be found at the Pennsylvania Historical Archives website (http://www.portal.state.pa.us/portal/). Thus in the warrant registry, it was possible use the warrant commission date to locate the correct property and corresponding registry number of its survey map in the warrant registry.

## Appendix C: Georeferencing Confidence Points

Georeferencing confidence points denote the geographical precision of property markers. I used streams, contemporary township boundaries, and contemporary parcel boundaries to georeference photos of warrant maps, forestry maps, and Union County courthouse warrantee map. Even after multiple edits of these georeferenced photos and then digitized witness trees and markers based on these georeferenced maps, not all witness trees and markers aligned to contemporary parcel boundaries, which are subdivided versions of the original property boundaries. This limitation was especially true on the north and northwest ridges of Union County, where most of the territory is in state-owned Bald Eagle State Forest.

To account for the possible error in the placement of witness trees and markers, I created a scale of 1 to 4 to show confidence in their alignment with contemporary parcel boundaries and streams. Each number in the scale means the following.

**1** There is little doubt that the point is geographically precise based on contemporary parcel boundaries and streams.

**2** The point aligns to a contemporary parcel boundary, but it is not close enough to another known landscape feature to verify its geographical precision.

**3** The point does not align to a contemporary parcel boundary or stream, but it is based on a precisely georeferenced photo.

**4** The point does not align to a contemporary parcel boundary or stream, and it is based on a geoferenced photo with an uncertain geographical location—there were few streams, contemporary parcels, or township lines on which to georeference the photo.

**Appendix D:** Tree species and marker distribution in valleys and mountains of Union County, Pennsylvania during the early historical period

| | | Mountains | | Valleys | |
|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | 5 | 1.9 | 18 | 1.8 |
| Beech | *Fagus* spp. | | 0.0 | 1 | 0.1 |
| Birch | *Betula* spp. | 11 | 4.2 | 5 | 0.5 |
| Black Oak | *Quercus velutina* | 20 | 7.6 | 114 | 11.2 |
| Blackgum | *Nyssa sylvatica* | 11 | 4.2 | 12 | 1.2 |
| Chestnut | *Castanea dentata* | 15 | 5.7 | 12 | 1.2 |
| Chestnut Oak | *Quercus prinus* | 36 | 13.7 | 56 | 5.5 |
| Dogwood | *Cornus* spp. | 2 | 0.8 | 13 | 1.3 |
| Eastern Hemlock | *Tsuga Canadensis* | 10 | 3.8 | 9 | 0.9 |
| Elm | *Ulmus* spp. | 1 | 0.4 | 9 | 0.9 |
| Hickory | *Carya* spp. | 6 | 2.3 | 103 | 10.1 |
| Linden | *Tilia* spp. | 1 | 0.4 | | 0.0 |
| Ironwood | | | 0.0 | 9 | 0.9 |
| Locust | *Robinia pseudoacacia* | 1 | 0.4 | 2 | 0.2 |
| Maple | *Acer* spp. | 3 | 1.1 | 24 | 2.4 |
| Pine | *Pinus* spp. | 84 | 31.9 | 115 | 11.3 |
| Red Oak | *Quercus rubra* | 1 | 0.4 | 1 | 0.1 |
| Sassafras | *Sassafras albidum* | | 0.0 | 2 | 0.2 |
| Red Pine | *Pinus rubrum* | 1 | 0.4 | | 0.0 |
| Scarlet Oak | *Quercus coccinea* | 9 | 3.4 | 47 | 4.6 |
| Sugar Maple | *Acer saccharum* | 2 | 0.8 | 4 | 0.4 |
| Swamp Oak | *Quercus bicolor* | | 0.0 | 1 | 0.1 |
| Tulip Poplar | *Liriodendron tulipifera* | 2 | 0.8 | 7 | 0.7 |
| Walnut | *Juglans* spp. | 1 | 0.4 | 2 | 0.2 |
| White Oak | *Quercus alba* | 32 | 12.2 | 438 | 43.0 |
| White Pine | *Pinus strobus* | 9 | 3.4 | 13 | 1.3 |
| Witch Hazel | *Hamamelis* | | 0.0 | 1 | 0.1 |
| | | 263 | | 1018 | |

**Table 4.** The counts and frequencies of tree species in valleys and in mountains of Union County, Pennsylvania based on early European settlement surveys.

| | | Mountains | | Valleys | |
|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | 5 | 1.3 | 18 | 1.2 |
| Beech | *Fagus* spp. | | | 1 | 0.1 |
| Birch | *Betula* spp. | 11 | 2.8 | 5 | 0.3 |
| Black Oak | *Quercus velutina* | 20 | 5.0 | 114 | 7.7 |
| Blackgum | *Nyssa sylvatica* | 11 | 2.8 | 12 | 0.8 |
| Chestnut | *Castanea dentata* | 15 | 3.8 | 12 | 0.8 |
| Chestnut Oak | *Quercus prinus* | 36 | 9.0 | 56 | 3.8 |
| Dogwood | *Cornus spp.* | 2 | 0.5 | 13 | 0.9 |
| Eastern Hemlock | *Tsuga Canadensis* | 10 | 2.5 | 9 | 0.6 |
| Elm | *Ulmus* spp. | 1 | 0.3 | 9 | 0.6 |
| Hickory | *Carya* spp. | 6 | 1.5 | 103 | 7.0 |
| Linden | *Tilia* spp. | 1 | 0.3 | | |
| Ironwood | | | | 9 | 0.6 |
| Locust | *Robinia pseudoacacia* | 1 | 0.3 | 2 | 0.1 |
| Markers | | 135 | 33.9 | 455 | 30.8 |
| Maple | *Acer* spp. | 3 | 0.8 | 24 | 1.6 |
| Pine | *Pinus* spp. | 84 | 21.1 | 115 | 7.8 |
| Red Oak | *Quercus rubra* | 1 | 0.3 | 1 | 0.1 |
| Sassafras | *Sassafras albidum* | | | 2 | 0.1 |
| Red Pine | *Pinus rubrum* | 1 | 0.3 | | |
| Scarlet Oak | *Quercus coccinea* | 9 | 2.3 | 47 | 3.2 |
| Stump | | | | 2 | 0.1 |
| Sugar Maple | *Acer saccharum* | 2 | 0.5 | 4 | 0.3 |
| Swamp Oak | *Quercus bicolor* | | | 1 | 0.1 |
| Tulip Poplar | *Liriodendron tulipifera* | 2 | 0.5 | 7 | 0.5 |
| Walnut | *Juglans* spp. | 1 | 0.3 | 2 | 0.1 |
| White Oak | *Quercus alba* | 32 | 8.0 | 438 | 29.7 |
| White Pine | *Pinus strobus* | 9 | 2.3 | 13 | 0.9 |
| Witch Hazel | *Hamamelis* spp. | | | 1 | 0.1 |
| | **Total** | 398 | | 1475 | |

**Table 5.** The counts and frequencies of tree species and markers in the valleys and in the mountains of Union County, Pennsylvania based on early European settlement survey

**Appendix E:** Tree species and marker distribution by topographic class in valleys and chi-square test for difference

| | | Valley Floor | | Riparian Zone | | South Slope | | North Slope | | Hilltop | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | 7 | 1.2 | 5 | 7.4 | | | 3 | 4.0 | 1 | 2.4 |
| Beech | *Fagus* spp. | 1 | 0.2 | | 0.0 | | | | 0.0 | | 0.0 |
| Birch | *Betula* spp. | 1 | 0.2 | 3 | 4.4 | | | | 0.0 | | 0.0 |
| Black Oak | *Quercus velutina* | 63 | 10.6 | 5 | 7.4 | 3 | 5.9 | 6 | 8.0 | 8 | 19.0 |
| Blackgum | *Nyssa sylvatica* | 10 | 1.7 | 1 | 1.5 | | 0.0 | 1 | 1.3 | | 0.0 |
| Chestnut | *Castanea dentata* | 6 | 1.0 | 2 | 2.9 | | 0.0 | 1 | 1.3 | 2 | 4.8 |
| Chestnut Oak | *Quercus prinus* | 25 | 4.2 | 4 | 5.9 | 3 | 5.9 | 6 | 8.0 | | 0.0 |
| Dogwood | *Cornus* spp. | 9 | 1.5 | | 0.0 | 1 | 2.0 | 1 | 1.3 | | 0.0 |
| Eastern Hemlock | *Tsuga Canadensis* | 5 | 0.8 | 3 | 4.4 | | 0.0 | 8 | 10.7 | | 0.0 |
| Elm | *Ulmus* spp. | 8 | 1.3 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Hickory | *Carya* spp. | 71 | 11.9 | 10 | 14.7 | 5 | 9.8 | | 0.0 | 1 | 2.4 |
| Ironwood | | 4 | 0.7 | 1 | 1.5 | | 0.0 | 1 | 1.3 | 1 | 2.4 |
| Locust | *Robinia pseudoacacia* | | 0.0 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Maple | *Acer* spp. | 13 | 2.2 | 1 | 1.5 | 2 | 3.9 | 2 | 2.7 | | 0.0 |
| Pine | *Pinus* spp. | 60 | 10.1 | 8 | 11.8 | 7 | 13.7 | 7 | 9.3 | 12 | 28.6 |
| Red Oak | *Quercus rubra* | | 0.0 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Sassafras | *Sassafras albidum* | 1 | 0.2 | 1 | 1.5 | | 0.0 | | 0.0 | | 0.0 |
| Scarlet Oak | *Quercus coccinea* | 30 | 5.0 | 4 | 5.9 | 1 | 2.0 | 4 | 5.3 | 2 | 4.8 |
| Swamp Oak | *Quercus bicolor* | 1 | 0.2 | | 0.0 | 1 | 2.0 | | 0.0 | | 0.0 |
| Sugar Maple | *Acer saccharum* | | 0.0 | 2 | 2.9 | 1 | 2.0 | | 0.0 | 1 | 2.4 |
| Tulip Poplar | *Liriodendron tulipifera* | 6 | 1.0 | | 0.0 | | 0.0 | | 0.0 | | 0.0 |
| Walnut | *Juglans* spp. | 2 | 0.3 | | 0.0 | | 0.0 | | 0.0 | | 0.0 |
| White Oak | *Quercus alba* | 268 | 45.0 | 15 | 22.1 | 25 | 49.0 | 34 | 45.3 | 14 | 33.3 |
| White Pine | *Pinus strobus* | 4 | 0.7 | | 0.0 | 2 | 3.9 | 1 | 1.3 | | |
| Witch Hazel | *Hamamelis* | 1 | 0.2 | | 0.0 | | | | | | |
| | **Total** | 596 | | 68 | | 51 | | 75 | | 42 | |

**Table 6.** Counts and frequencies of tree species by topographic classes in the valleys based on early European settler surveys of Union County, Pennsylvania.

| | | Valley Floor | | Riparian Zone | | South Slope | | North Slope | | Hilltop | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Markers | | 262 | 30.5 | 31 | 31.3 | 25 | 32.9 | 21 | 21.9 | 27 | 39.1 |
| Ash | *Fraxinus* spp | 7 | 0.8 | 5 | 5.1 | | | 3 | 3.1 | 1 | 1.4 |
| Beech | *Fagus* spp. | 1 | 0.1 | | | | | | | | |
| Birch | *Betula* spp. | 1 | 0.1 | 3 | 3.0 | | | | | | |
| Black Oak | *Quercus velutina* | 63 | 7.3 | 5 | 5.1 | 3 | 3.9 | 6 | 6.3 | 8 | 11.6 |
| Blackgum | *Nyssa sylvatica* | 10 | 1.2 | 1 | 1.0 | | | 1 | 1.0 | | |
| Chestnut | *Castanea dentata* | 6 | 0.7 | 2 | 2.0 | | | 1 | 1.0 | 2 | 2.9 |
| Chestnut Oak | *Quercus prinus* | 25 | 2.9 | 4 | 4.0 | 3 | 3.9 | 6 | 6.3 | | |
| Dogwood | *Cornus* spp. | 9 | 1.0 | | | 1 | 1.3 | 1 | 1.0 | | |
| Eastern Hemlock | *Tsuga Canadensis* | 5 | 0.6 | 3 | 3.0 | | | 8 | 8.3 | | |
| Elm | *Ulmus* spp. | 8 | 0.9 | 1 | 1.0 | | | | | | |
| Hickory | *Carya* spp. | 71 | 8.3 | 10 | 10.1 | 5 | 6.6 | | | 1 | 1.4 |
| Ironwood | | 4 | 0.5 | 1 | 1.0 | | | 1 | 1.0 | 1 | 1.4 |
| Locust | *Robinia pseudoacacia* | | | 1 | 1.0 | | | | | | |
| Maple | *Acer* spp. | 13 | 1.5 | 1 | 1.0 | 2 | 2.6 | 2 | 2.1 | | |
| Pine | *Pinus* spp. | 60 | 7.0 | 8 | 8.1 | 7 | 9.2 | 7 | 7.3 | 12 | 17.4 |
| Red Oak | *Quercus rubra* | | | 1 | 1.0 | | | | | | |
| Sassafras | *Sassafras albidum* | 1 | 0.1 | 1 | 1.0 | | | | | | |
| Scarlet Oak | *Quercus coccinea* | 30 | 3.5 | 4 | 4.0 | 1 | 1.3 | 4 | 4.2 | 2 | 2.9 |
| Swamp Oak | *Quercus bicolor* | 1 | 0.1 | | | 1 | 1.3 | | | | |
| Sugar Maple | *Acer saccharum* | | | 2 | 2.0 | 1 | 1.3 | | | 1 | 1.4 |
| Tulip Poplar | *Liriodendron tulipifera* | 6 | 0.7 | | | | | | | | |
| Walnut | *Juglans* spp. | 2 | 0.2 | | | | | | | | |
| White Oak | *Quercus alba* | 268 | 31.2 | 15 | 15.2 | 25 | 32.9 | 34 | 35.4 | 14 | 20.3 |
| White Pine | *Pinus strobus* | 4 | 0.5 | | | 2 | 2.6 | 1 | 1.0 | | |
| Witch Hazel | *Hamamelis* | 1 | 0.1 | | | | | | | | |
| | **Total** | 858 | | 99 | | 76 | | 96 | | 69 | |

**Table 7**. The counts and frequencies of tree species and markers by topographic classes in the valleys based on early European settlement surveys of Union County, Pennsylvania.

**Chi-Square Test: Markers, Contingency**

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Markers  Contingency  Total
    1      262          596    858
         262.13       595.87
          0.000        0.000

    2       31           68     99
          30.25        68.75
          0.019        0.008

    3       25           51     76
          23.22        52.78
          0.137        0.060

    4       21           75     96
          29.33        66.67
          2.365        1.040

    5       27           42     69
          21.08        47.92
          1.662        0.731

Total      366          832   1198

Chi-Sq = 6.023, DF = 4, P-Value = 0.197
```

**Conclusion:** There is not enough evidence that there is a relationship between local scale topography and markers in the valleys.

**Table 8.** Chi-square test for marker frequency difference by topographic classes in the valleys.

**Appendix F:** Tree species and marker distribution by topographic classes on mountains and chi-square test for difference

| | | Ridgetop | | North Slope | | South Slope | | Riparian Zone | | Coves | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Ash | *Fraxinus* spp | | | 1 | 1.9 | 2 | 3.9 | 1 | 6.7 | 1 | 1.4 |
| Birch | *Betula* spp. | 2 | 4.3 | 2 | 3.8 | 4 | 7.8 | | 0.0 | 2 | 2.9 |
| Black Oak | *Quercus velutina* | 2 | 4.3 | 3 | 5.8 | 5 | 9.8 | | 0.0 | 6 | 8.7 |
| Blackgum | *Nyssa sylvatica* | | 0.0 | 3 | 5.8 | 2 | 3.9 | | 0.0 | 4 | 5.8 |
| Chestnut | *Castanea dentata* | 3 | 6.5 | 2 | 3.8 | 6 | 11.8 | 1 | 6.7 | 2 | 2.9 |
| Chestnut Oak | *Quercus prinus* | 6 | 13.0 | 11 | 21.2 | 8 | 15.7 | | 0.0 | 7 | 10.1 |
| Dogwood | *Cornus* spp. | | 0.0 | | 0.0 | 1 | 2.0 | | 0.0 | 1 | 1.4 |
| Eastern Hemlock | *Tsuga Canadensis* | 2 | 4.3 | 4 | 7.7 | 3 | 5.9 | 1 | 6.7 | | 0.0 |
| Elm | *Ulmus* spp. | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Linden | | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Locust | *Robinia pseudoacacia* | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Hickory | *Carya* spp. | 1 | 2.2 | 3 | 5.8 | 1 | 2.0 | | 0.0 | 1 | 1.4 |
| Maple | *Acer* spp. | | 0.0 | | 0.0 | 1 | 2.0 | 1 | 6.7 | 1 | 1.4 |
| Pine | *Pinus* spp. | 15 | 32.6 | 15 | 28.8 | 11 | 21.6 | 1 | 6.7 | 26 | 37.7 |
| Red Oak | *Quercus rubra* | | | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| Red Pine | *Pinus rubrum* | | 0.0 | | 0.0 | | 0.0 | | 0.0 | 1 | 1.4 |
| Sugar Maple | *Acer saccharum* | | 0.0 | | 0.0 | | 0.0 | 2 | 13.3 | | 0.0 |
| Scarlet Oak | *Quercus coccinea* | 5 | 10.9 | | 0.0 | | 0.0 | | 0.0 | 3 | 4.3 |
| Tulip Poplar | *Liriodendron tulipifera* | | 0.0 | | 0.0 | 1 | 2.0 | | 0.0 | 1 | 1.4 |
| Walnut | *Juglans* spp. | | 0.0 | | 0.0 | | 0.0 | 1 | 6.7 | | 0.0 |
| White Oak | *Quercus alba* | 7 | 15.2 | 8 | 15.4 | 2 | 3.9 | 3 | 20.0 | 11 | 15.9 |
| White Pine | *Pinus strobus* | 3 | 6.5 | | | 4 | 7.8 | | | 2 | 2.9 |
| | **Total** | 46 | | 52 | | 51 | | 15 | | 69 | |

**Table 9.** Counts and frequencies of tree species by topographic classes in the mountains based on early European settler surveys of Union County, Pennsylvania.

| | | Ridgetop | | North Slope | | South Slope | | Riparian Zone | | Mountain Cove | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tree** | **Binomial** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** | **Count** | **Frequency** |
| Marker | | 23 | 33.3 | 33 | 38.8 | 34 | 40.0 | 4 | 21.1 | 26 | 27.4 |
| Ash | *Fraxinus* spp | | | 1 | 1.2 | 2 | 2.4 | 1 | 5.3 | 1 | 1.1 |
| Birch | *Betula* spp. | 2 | 2.9 | 2 | 2.4 | 4 | 4.7 | | | 2 | 2.1 |
| Black Oak | *Quercus velutina* | 2 | 2.9 | 3 | 3.5 | 5 | 5.9 | | | 6 | 6.3 |
| Blackgum | *Nyssa sylvatica* | | | 3 | 3.5 | 2 | 2.4 | | | 4 | 4.2 |
| Chestnut | *Castanea dentata* | 3 | 4.3 | 2 | 2.4 | 6 | 7.1 | 1 | 5.3 | 2 | 2.1 |
| Chestnut Oak | *Quercus prinus* | 6 | 8.7 | 11 | 12.9 | 8 | 9.4 | | | 7 | 7.4 |
| Dogwood | *Cornus* spp. | | | | | 1 | 1.2 | | | 1 | 1.1 |
| Eastern Hemlock | *Tsuga Canadensis* | 2 | 2.9 | 4 | 4.7 | 3 | 3.5 | 1 | 5.3 | | |
| Elm | *Ulmus* spp. | | | | | | | 1 | 5.3 | | |
| Linden | | | | | | | | 1 | 5.3 | | |
| Locust | *Robinia pseudoacacia* | | | | | | | 1 | 5.3 | | |
| Hickory | *Carya* spp. | 1 | 1.4 | 3 | 3.5 | 1 | 1.2 | | | 1 | 1.1 |
| Maple | *Acer* spp. | | | | | 1 | 1.2 | 1 | 5.3 | 1 | 1.1 |
| Pine | *Pinus* spp. | 15 | 21.7 | 15 | 17.6 | 11 | 12.9 | 1 | 5.3 | 26 | 27.4 |
| Red Oak | *Quercus rubra* | | | | | | | 1 | 5.3 | | |
| Red Pine | *Pinus rubrum* | | | | | | | | | 1 | 1.1 |
| Sugar Maple | *Acer saccharum* | | | | | | | 2 | 10.5 | | |
| Scarlet Oak | *Quercus coccinea* | 5 | 7.2 | | | | | | | 3 | 3.2 |
| Tulip Poplar | *Liriodendron tulipifera* | | | | | 1 | 1.2 | | | 1 | 1.1 |
| Walnut | *Juglans* spp. | | | | | | | 1 | 5.3 | | |
| White Oak | *Quercus alba* | 7 | 10.1 | 8 | 9.4 | 2 | 2.4 | 3 | 15.8 | 11 | 11.6 |
| White Pine | *Pinus strobus* | 3 | 4.3 | | | 4 | 4.7 | | | 2 | 2.1 |
| | **Total** | **69** | | **85** | | **85** | | **19** | | **95** | |

**Table 10:** Counts and frequencies of tree species and markers by topographic classes mountains based on early European settler surveys of Union County.

**Chi-Square Test: Markers, Contingency**

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       Markers  Contingency  Total
    1       34           51     85
         29.52        55.48
         0.680        0.362

    2       26           69     95
         32.99        62.01
         1.483        0.789

    3       33           52     85
         29.52        55.48
         0.410        0.218

    4       23           46     69
         23.96        45.04
         0.039        0.021

Total      116          218    334

Chi-Sq = 4.000, DF = 3, P-Value = 0.261
```

There is not enough evidence that a relationship exists between markers and local scale topography in the mountains.

**Table 11.** Chi-square test for marker frequency difference by topographic classes in the mountains of Union County.