

Native American influences on the forest composition of the Allegheny Plateau, northwest Pennsylvania

Bryan A. Black, Charles M. Ruffner, and Marc D. Abrams

Abstract: We integrate witness tree distribution, Native American archaeological sites, and geological and topographic variables to investigate the relationships between Native American populations and pre-European settlement forest types on the Allegheny Plateau, northwest Pennsylvania. Detrended correspondence analysis of witness tree data separated the presettlement forests into oak–hickory–chestnut and beech–hemlock–maple communities. Oak, hickory, and chestnut forests were centered on Native American village sites. Using archaeological data, an index of Native American influence (NAI) was derived to reflect the intensity of Native American land use across the landscape. In a comparison among species, mean NAI value of oak, hickory, and chestnut trees was significantly higher than that of beech, maple, and hemlock. Logistic regression demonstrated that among geology type, landform, elevation, aspect, slope, and NAI, NAI was by far the most significant predictor of oak, hickory, and chestnut distribution. Although cause and effect of this relationship cannot be tested, we suggest that long-term Native American activity selected for the disturbance-adapted oak, hickory, and chestnut. We contend that Native American agriculture, burning, and resource extraction could have converted maple–beech–hemlock to oak–hickory–chestnut, or at least reinforced the dominance of this forest type.

Résumé : Les auteurs ont intégré la distribution des arbres témoins, les sites archéologiques autochtones et les variables géologiques et topographiques pour étudier les relations entre les populations autochtones et les types de forêt qui existaient avant la colonisation par les européens sur le plateau de l'Allegheny, dans le nord-ouest de la Pennsylvanie. L'analyse des correspondances redressée des données sur les arbres témoins a divisé les forêts présentes avant la colonisation en associations de chêne – caryer – châtaignier et de hêtre – pruche – érable. Les forêts de chêne, de caryer et de châtaignier étaient concentrées dans les sites occupés par des villages autochtones. À l'aide de données archéologiques, ils ont dérivé un indice d'influence autochtone (IA) pour refléter l'intensité de l'utilisation du territoire par les autochtones partout dans le paysage. Dans une comparaison entre les espèces, la valeur moyenne de IA du chêne, du caryer et du châtaignier était significativement plus élevée que celle du hêtre, de l'érable et de la pruche. Parmi les types géologiques, la forme de relief, l'altitude, l'orientation, la pente et IA, la régression logistique a démontré que IA était de loin la variable prédictive la plus significative pour le chêne, le caryer et le châtaignier. Bien qu'on ne puisse pas tester le lien de causalité de cette relation, ils suggèrent que l'activité à long terme des autochtones a favorisé le chêne, le caryer et le châtaignier qui sont adaptés aux perturbations. Ils prétendent que l'agriculture autochtone, le brûlage et l'extraction des ressources pourraient avoir entraîné la conversion des forêts d'érable – hêtre – pruche en forêts de chêne – caryer – châtaignier, ou à tout le moins accentué la dominance de ce type de forêt.

[Traduit par la Rédaction]

Introduction

Despite considerable study over the past 50 years, the extent and degree of Native American influence on pre-European settlement forest remains a controversial subject

among forest historians, cultural ecologists, and anthropologists. Estimates of Native American impacts on forests range from broad landscape-level alterations in composition and structure (Day 1953; Pyne 1983; Delcourt 1987; Hammett 1992) to localized effects that did not extend far beyond major population centers (Russell 1983; Krech 1999). Previous attempts to elucidate native influences on vegetation have utilized a variety of data sources, yet the most commonly relied upon are anecdotal accounts of early travelers and settlers. According to many of these qualitative descriptions at the time of first European settlement, natives regularly burned the woods to drive game, improve visibility, facilitate travel, and provide browse for deer and cattle (Day 1953). However, the possibility of biases in many of these accounts has called their validity into question (Forman and Russell 1983; Russell 1983). In a more quantitative approach, a number of paleoecological analyses of native sites have revealed concomitant variations in vegetation and Na-

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tive American populations over time (Chapman et al. 1982; Patterson and Sassman 1988; Clark and Royall 1995; Delcourt et al. 1998). On a shorter yet higher resolution temporal scale, dendrochronological studies of fire scars and tree cores have proven useful for relating disturbance regimes at native sites with archaeological data (Batek et al. 1999; Ruffner and Abrams 2002). Indeed, both quantitative methodologies have yielded valuable insight into native disturbances and their impacts on vegetation over long periods of time. Yet palynological studies are largely restricted to areas adjacent to a catchment site, while dendrochronological studies are restricted to old-growth patches that predate European settlement. Consequently, a weakness of these methodologies is that they can only be applied at very specific sites and are not well suited to characterizing native influences at broad spatial scales (Batek et al. 1999).

In contrast to pollen or dendrochronology, original land surveys contain the data necessary to describe the effects of Native American populations on the landscape level. During the period of early European settlement in the eastern United States, land surveyors marked and recorded witness (warrant, bearing, and (or) corner) trees to identify property corners and boundaries (Lutz 1930; Spurr 1951; Bourdo 1956). Throughout the eastern and midwestern United States these witness trees have been compiled from surveyors' notes to reconstruct forest composition and structure (Lutz 1930; Bourdo 1956; Marks and Gardescu 1992; Black and Abrams 2001). In many studies, reconstructed patterns of vegetation have been attributed to edaphic conditions such as topography, soils, slope class, or drainage classes (Gordon 1940). Yet other more recent studies have taken a more integrative approach and recognized the potential influence of native populations. In documenting pre-European vegetation of central New York State, Marks and Gardescu (1992) identified old Native American clearings and reported oak–hickory–pine growing in areas previously inhabited by peoples of the Iroquois Confederacy. In western New York, on lands surveyed for the Holland Land Company (including Gordon's (1940) area), Seischab (1990) reported that most oak communities occurred in southern portions of the study area along the Allegheny River and its tributaries, dominating a landscape formerly inhabited by Seneca people of the Iroquois Confederacy. Whitney and DeCant (2003) suggested that Iroquois may be associated with oak–chestnut forests in their witness tree study across northwestern Pennsylvania, including the Allegheny Plateau. Overall, an increasing number of witness tree studies indicate that Native Americans had at least some association with forest composition, though the degree of the relationship is not quantified.

In this study, we attempt to more directly link Native Americans with forest composition on the Allegheny Plateau of northwestern Pennsylvania. Detailed archaeological records demonstrate that Native peoples have almost continuously occupied the Allegheny River region for the past 10 000 years (USDA Forest Service Cultural Resources archives, Warren, Pennsylvania). Also, the study area contains a relatively high concentration of witness trees, including dominant species American beech (*Fagus grandifolia* Ehrh.) (30%) and eastern hemlock (*Tsuga canadensis* L.) (27%), with sugar maple (*Acer saccharum* Marsh.), birch (*Betula* spp.), white pine (*Pinus strobus* L.), and chestnut (*Castanea*

dentata (Marsh.) Borkh.) as subordinates (Lutz 1930; Whitney 1990). Such a forest type is well suited for studying the effects of altered disturbance regimes. Historically, the hemlock – northern hardwood forests of the Allegheny Plateau were characterized by a very low disturbance frequency, with disturbances being almost exclusively windstorms (Whitney 1990). Any increases in anthropogenic disturbance, especially fire, could have a dramatic impact on forest composition, with expected decreases in sugar maple and hemlock and increases in oak (*Quercus* spp.), hickory (*Carya* spp.), and chestnut. Thus, the Allegheny Plateau provides a unique combination of a disturbance-sensitive forest type and long-term Native American occupation in which to evaluate the relationships between indigenous peoples and their environment. Our objectives for this study were to (i) use known Iroquois village sites, travel corridors, and archaeological data to derive a spatially explicit index of Native American habitation on the landscape, (ii) assess the ability of this index of Native American habitation to predict the distribution of oak, hickory, and chestnut in comparison to various topographic and edaphic variables, and (iii) discuss the possibility that Native American activities at least in part influenced vegetation patterns.

Materials and methods

Study area

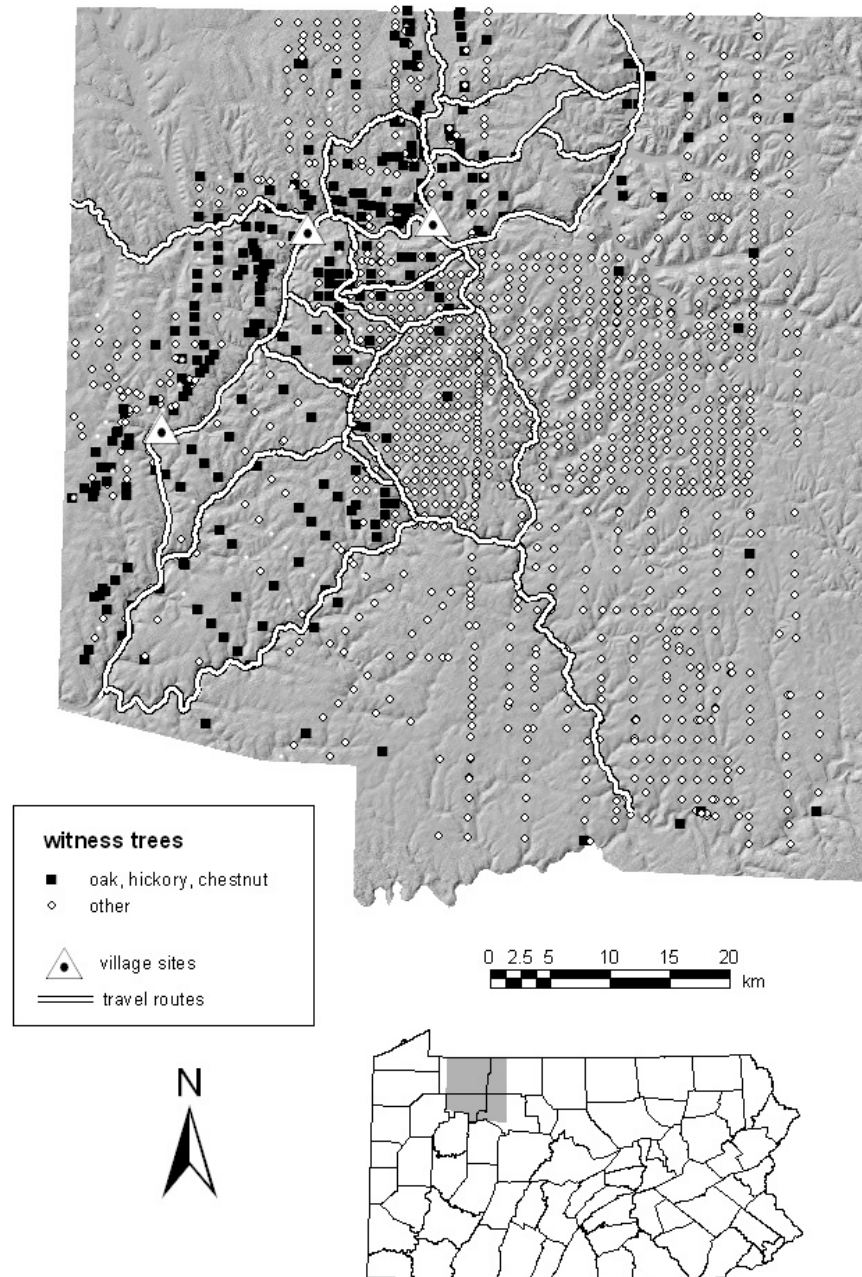
The study area in northwestern Pennsylvania represents much of the unglaciated Allegheny High Plateau and is characterized by broad flat-topped ridges deeply dissected by dendritic drainages (Fenneman 1938; Cuff et al. 1989) (Fig. 1). Soils of the High Plateau are fairly homogeneous Inceptisols formed in residuum and colluvium from Mississippian- and Pennsylvanian-aged sandstones and shales (Cerutti 1985; Ciolkosz et al. 1989). Hazleton–Cookport soils occur on plateau uplands, while Hazleton–Gilpin–Ernest soils dominate sideslopes. Both are characterized as deep, well drained to moderately well drained, sloping to moderately steep soils formed from acidic sandstone and shale. Alluvial floodplains and glacial outwash terraces comprise deep, very poorly drained Wayland–Chenango–Braceville soils derived from acid sandstone and shale (Cerutti 1985).

The climate of the region is cool and humid. Temperature and frost-free periods vary across the Plateau with elevation, which rises from 540 m at the top of the Allegheny River Gorge in the west, to 620 m near Sheffield, and then decreases again to 430 m towards the headwaters of the Clarion River, a major tributary of the Allegheny River. Average temperatures range from 20 °C in the summer to –2 °C in the winter. Total annual precipitation is 109 cm, with 61 cm falling during the growing season between April and September (Cerutti 1985).

Historical context

Throughout the Holocene, the Allegheny River watershed served as a major transportation, trade, and communication artery for Archaic (8500–1000 BC) and Woodland (1000 BC – AD 1600) cultures. The Late Woodland (AD 1000–1600) Allegheny Valley Iroquois and the Historic (AD 1600–1800) Seneca Iroquois occupied base camps on river terraces surrounded by large catchment areas from which

Fig. 1. Topography of the study area and its location within Pennsylvania. Native American village sites and major travel corridors are shown, as well as the location of each witness tree used in the study.



raw materials were procured at ancillary sites (Flannery 1976; Quinn and Adovasio 1996; Ruffner 1999). These native groups were semisedentary horticulturists practicing swidden agriculture, whereby forests were cleared and burned to create open areas in which sunflower (*Helianthus annuus*), maize (*Zea mays*), squash (*Curcubita pepo*), and beans (*Phaseolus vulgaris*) were cultivated (Parker 1968; Sykes 1980; Snow 1994). By AD 1500, settlements were large, palisaded villages with longhouses and garden plots capable of supporting up to 250–300 people (Snow 1994; Quinn and Adovasio 1996). Based on archaeological reconstructions, the prehistoric landscape resembled a mosaic pattern of (i) active croplands near palisaded settlements, (ii) abandoned clearings with early-successional taxa, and

(iii) open-forest stands dominated by fire-adapted species such as oak and hickory (Kent et al. 1981; Snow 1994; Quinn and Adovasio 1996).

The Historic period witnessed the greatest population surges of Native peoples beginning with the expansion of the Seneca Iroquois out of their Genessee Valley homeland into the upper Allegheny River drainage (Snow 1994). They established numerous villages along the Allegheny River including Buckaloons, Conewango, and Tidioute (Kent et al. 1981). Then between 1700 and 1780, these sites (and others) apparently supported a large population of emigrant natives pushed westward by European pressure in eastern Pennsylvania and were continually inhabited through the French and Indian War and the American Revolution (McConnell 1992).

Table 1. Native American village sites used for catchment area analysis.

Village site	Occupation period	Size (ha)	References
Buckaloons	Early Archaic – Contact	125	Donehoo 1928; Kent et al.1981; Quinn and Adovasio 1996
Conewango	Early Archaic – Contact	140	Schenck 1887; Donehoo 1928
Tidioute	Early Archaic – Historic	40	USDA Forest Service Cultural Resources archives

Note: See text for selection criteria. Reported village size based on estimates from Pennsylvania archaeological site surveys archived at Pennsylvania Historical and Museum Commission, Harrisburg, Pennsylvania.

During the latter conflict, the Seneca supported the British, and in 1779 a punitive expedition under Colonel Brodhead was dispatched to the Seneca villages on the upper Allegheny River. Brodhead recorded in his journal that his army destroyed Seneca villages at Cornplanter, Conewango, and Buckaloons. He estimated that over 500 acres (202 ha) of cropland were burned along with 150 longhouses and corn stores (Donehoo 1928). The native village at Buckaloons was never rebuilt, and European settlement of the Allegheny River area began after the purchase of northwestern Pennsylvania in 1789.

Methods

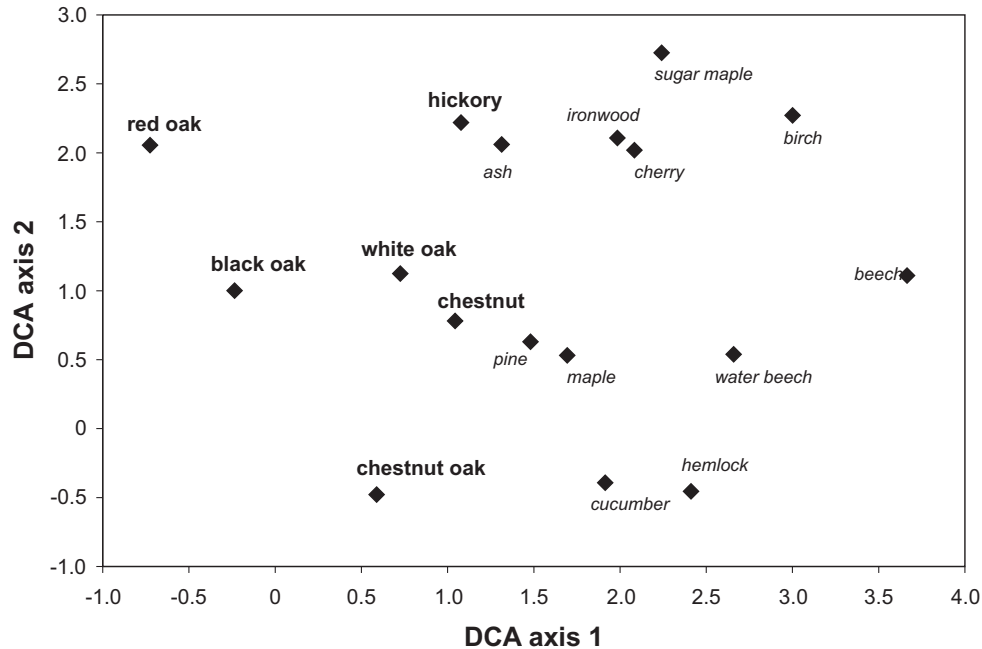
Forest conditions were characterized by tallying witness trees from original warrant maps (1790–1820) that represent a tract of land as surveyed at the time of European settlement (Munger 1991). This section of Pennsylvania was surveyed using a rectangular scheme similar to that specified by the Northwest Ordinance of 1785. Although it was not the General Land Office (GLO) township and range system utilized in the Midwest and western parts of the United States (Bourdo 1956), deputy surveyors were required to use a rectangular system to facilitate disposal of unseated lands after the Last Purchase of tribal lands in 1784 (Munger 1991). The density of witness trees (trees per unit area) varied across the study area, but these irregularities did not correspond with underlying topographic or geological features and should not influence the interpretation of these witness tree data (Ruffner 1999; Black and Abrams 2001).

Witness trees ($n = 1611$) were obtained from original warrants and connected drafts in the Pennsylvania State Archives. Many of these trees have been included in past studies of pre-European settlement forest composition (Lutz 1930; Whitney 1990), but we also added a large number of trees along the Allegheny River that had not been previously analyzed. We transcribed all trees onto USGS 7.5 min topographic quadrangles and digitized them using ArcView 3.2a (ESRI, Redlands, California). Locations of three major Iroquois village sites (Table 1) were also digitized as well as major travel routes (Donehoo 1928; Wallace 1965; Kent et al. 1981). We then summarized community structure by conducting detrended correspondence analysis (DCA) on the witness tree data. First we superimposed a 6 km \times 6 km grid over the study area using ArcGIS 9.2 and Hawth Tools extension (<http://www.spatial ecology.com/htools/tool desc.php>), which subdivided the region into a total of 130 grid cells. We then tallied all witness trees within each cell and entered the data into CANOCO 4 (Microcomputer Power, Ithaca, New York) for analysis. Species scores were plotted for the first two axes, and cell scores were imported into ArcGIS to examine spatial gradients.

To roughly quantify the intensity of Native American influence in the region, we developed a Native American index (NAI) from 0 to 100 based on known village sites and travel routes. This should represent the portion of the study area subjected to the most intense agricultural activity and forest exploitation. Archaeological evidence suggests that Native fields most likely occurred within 1 km of the village site and that the heaviest fuelwood collection and burning for berry production and defense was conducted within 4–5 km of the village (Williams 1989). Foraging and small game hunting were probably the primary land uses from approximately 6 to 8 km from a village. A final consideration was that a person carrying a load can typically travel no more than 6–10 km a day (Flannery 1976; Roper 1979; Williams 1989). To reflect these land uses and the fact that Native Americans would have minimized energy expenditures necessary to procure resources, the values of NAI decline with increasing distance from the villages. Thus, the highest NAI value of 100 was assigned to all regions within 5 km of major village sites. All regions between 5 and 7 km from a village were assigned values of 75, and regions between 7 and 9 km were assigned values of 50. NAI values were halved every 2 km increment beyond 9 km to reflect what would have been diminishing activity with increasing distance. In addition to villages, proximity to travel routes was also included in the final NAI calculation. Though these travel routes would have experienced ephemeral and less intense land uses than village sites, Native Americans would have still procured forest resources and intentionally or inadvertently increased fire frequency by their presence. Thus, regions within 500 m of a major travel route were assigned a value of 50, and the index value was halved with every additional 1 km increment in distance. The final NAI was computed by adding the village and travel route values. Travel route values beyond 9 km of a village were capped at a value of 50.

We also divided the study area into a total of four mutually exclusive landforms: north sideslope, south sideslope, hilltop–plateau, and stream valley – floodplain. Landforms were identified by analyzing 30 m digital elevation models (USGS EROS), a Warren and Forest County geological map, and a hydrography layer (Pennsylvania Spatial Data Access, <http://www.pasda.psu.edu/>). The first step in delineating landforms was to define stream valleys and floodplains. To generate this coverage, streams were buffered to 150 m on each side using ArcInfo 8.02. Given the deeply dissected topography of the region, 150 m included sites immediately adjacent to streams as well as the surrounding cove slopes. Alluvial soils were combined with the buffered stream layer, and in some cases the floodplains were extended along the Allegheny River valleys where slope was less than 1%. Sideslopes were all sites not included in the stream valley –

Fig. 2. Species scores for the first two axes of detrended correspondence analysis (DCA) of the witness tree data. Witness trees were tallied within 6 km × 6 km grid cells across the study area, and each grid cell was used as a sample in the analysis. Species separate into an oak–hickory–chestnut forest type (bold) and a beech–hemlock–maple forest type.



floodplain coverage where slope was greater than 10%. All other sites where slope was less than 10% and not already classified as stream valley – floodplain were designated hilltop–plateau.

The NAI, slope, aspect, parent material, and landform were recorded for each witness tree. Average NAI and a 95% confidence interval were calculated for each witness tree species with a sample size greater than 10. Walnut ($n = 8$) was also included because this species has been reported as associated with other Native American sites. Witness tree composition was then tallied in regions with a high NAI (>10) and low NAI (<10), and the elevation, slope, landform, and geological characteristics of the two regions were compared. Finally, all oak, hickory, and American chestnut trees were pooled into an “oak” group, and all other species were pooled into an “other” group. Logistic regression was performed using the PROC PROBIT function in SAS 9.1 (SAS Institute Inc., Cary, North Carolina) to estimate the significance of NAI, landform, slope, aspect, elevation, and geology in explaining the distribution of oak, hickory, and chestnut across the landscape. Elevation, slope, and NAI were entered as quantitative variables. Aspect (north, south, east, west), landform (valley, south sideslope, north sideslope, hilltop), and geology (11 geology types, as shown in Table 3) were entered as categorical variables.

Results

DCA separated species along a gradient of oak–chestnut–hickory to hemlock–maple–beech communities (Fig. 2). Axis 1 accounted for 50.9% of the variance and axis 2 accounted for an additional 15.3%. Axis 1 captured a gradient across the study area that corresponds with a gradient in the concentration of Native American villages and travel corridors (Fig. 3). Subdividing the region into 3 km grid cells as

Fig. 3. Scores of detrended correspondence analysis (DCA) axis 1. Witness trees were tallied within 6 km × 6 km grids cell across the study area, and each grid cell was used as a sample in the analysis. Native American village sites and major travel corridors are shown.

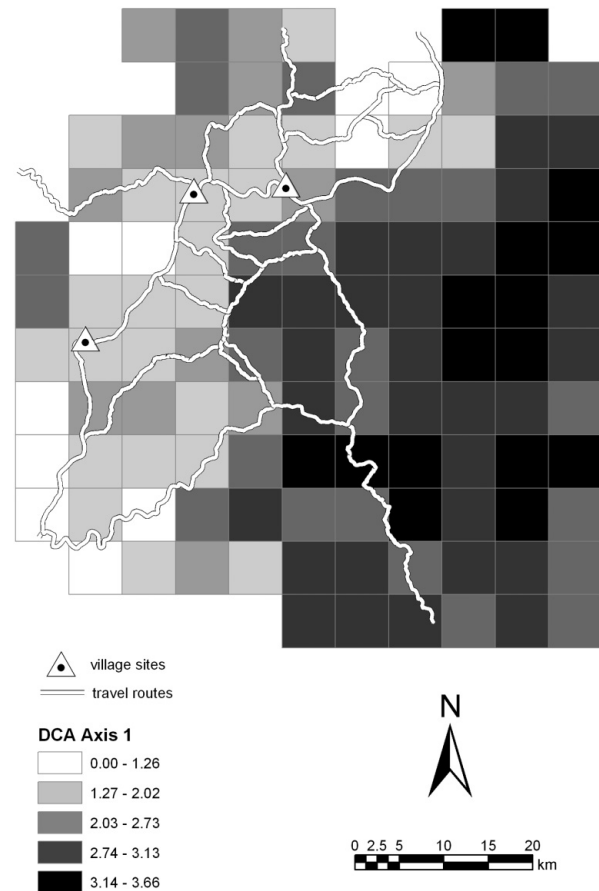
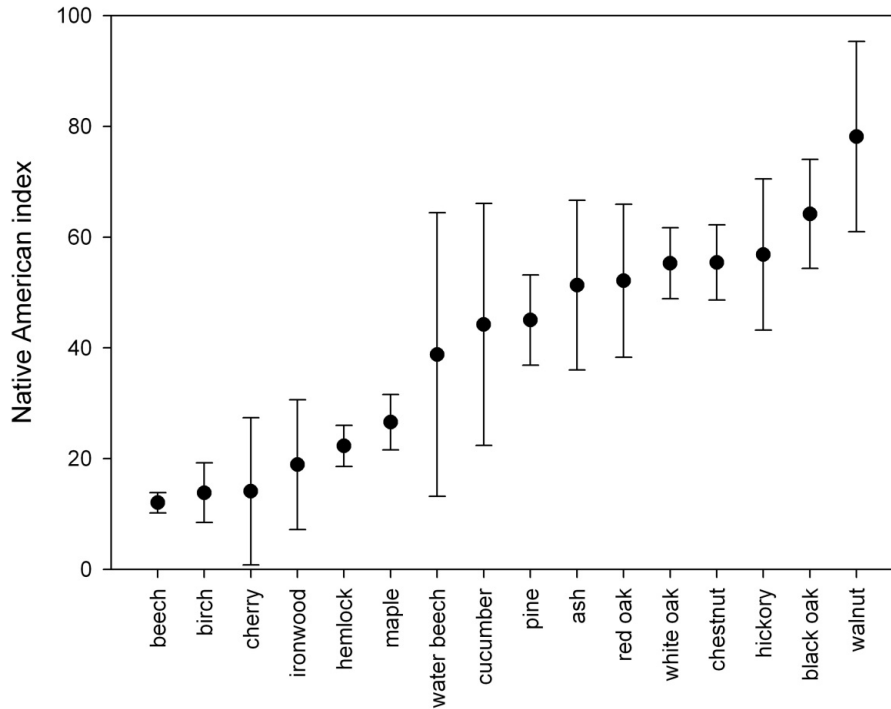


Fig. 4. Mean Native American index values and 95% confidence intervals for species with sample sizes greater than 10, with the exception of walnut, which has a sample size of 8.



opposed to 6 km grid cells caused minimal changes to the outcome of the DCA (data not shown). When the mean values of NAI were compared among species, oak, hickory, and chestnut scored among the highest with walnut, yielding the highest mean value of nearly 80 (Fig. 4). In contrast, beech, birch, hemlock, and maple scored among the lowest, with 95% confidence intervals that fell well outside those species present in the oak–hickory–chestnut forest type (Fig. 4). Variance in NAI value was high for cherry, water beech, cucumber, and red oak, each of which had a sample size of fewer than 15 trees (Fig. 4).

In a comparison between regions of low (<10) and high (>10) Native American activity, beech, hemlock, and maple dominated areas of low Native American activity, while oak, beech, hemlock, chestnut, pine, and maple dominated regions of high Native American activity (Table 2). Combined, oak hickory, and chestnut composed 1.4% of the low Native American activity zone and 34.3% of the high Native American activity zone. An NAI threshold of 10 provided a conservative division between zones of high and low Native American influence and divided the total number of trees into two groups of comparable size (Table 2). Increasing the NAI threshold to 50 yielded similar results with a combined oak, hickory, and chestnut relative density of 38.8% and 8.9% for the high and low regions, respectively.

In a comparison between regions of low (<10) and high (>10) Native American influence, the low-influence region had a higher mean elevation by approximately 50 m (Table 3). Also, average slope and the standard deviation of elevation (an index of topographic roughness) were significantly lower in areas of low influence (Table 3). This suggested that although the region of low influence was higher in elevation, topography was less variable than in areas of high influence. With respect to landform, valleys occurred

with approximately the same frequency in both regions (Table 3). However, plateaus were more abundant in regions of low activity, while sideslopes were less abundant (Table 3). This was consistent with our finding of a steeper average slope and higher standard deviation of elevation in the regions of high Native American influence. Geologically, there were also some dissimilarities between the two regions. The Pottsville group was much more common in the regions of low Native American influence because this group was associated with the eastern portion of the study area (Table 3). Despite some differences between the regions of high and low Native American influence, a logistic regression showed that NAI was the most significant predictor of oak–hickory–chestnut. Landform and geology were also significant, but the Wald χ^2 statistic value for NAI was more than twice that of either of these other two variables (Table 4).

Discussion

Previous studies have defined catchment zones as circular regions within specific radii (i.e., 5 and 7 km) of village sites (Vita-Finzi and Higgs 1970; Flannery 1976; Ruffner 1999; Black and Abrams 2001). In our revised approach, catchment zones may assume any configuration, providing a more detailed estimate of Native American influence across the landscape. The results of this analysis on the Allegheny Plateau demonstrate a close correspondence between oak–hickory–chestnut forests and sites of prolonged Native American occupation. Indeed, our estimate of Native American occupation appears to be the best predictor of oak, hickory, and chestnut in comparison with a number of topographic and edaphic variables. Yet despite this correspondence, a challenging problem is establishing cause and effect rela-

Table 2. Witness tree species translations to common names, and relative densities of witness tree species in high (>10 Native American index (NAI)) and low (<10 NAI) Native American impact sites.

Common name	Scientific name	Low NAI	High NAI
Ash	<i>Fraxinum americana</i> , <i>Fraxinus pennsylvanica</i>	0.8	0.8
Aspen	<i>Populus grandidentata</i> , <i>Populus tremuloides</i>	0.2	0.0
Basswood	<i>Tilia americana</i>	0.1	1.7
Beech	<i>Fagus grandifolia</i>	49.5	20.1
Birch	<i>Betula alleghaniensis</i> , <i>Betula lenta</i>	7.7	2.9
Black oak	<i>Quercus velutina</i> , <i>Quercus rubra</i>	0.5	4.7
Cherry	<i>Prunus serotina</i>	1.1	0.5
Chestnut	<i>Castanea dentata</i>	1.9	10.2
Chestnut oak	<i>Quercus prinus</i>	0.0	0.7
Cucumber	<i>Magnolia acuminata</i>	0.7	1.2
Dogwood	<i>Cornus florida</i>	0.0	0.3
Elk horn	<i>Acer pennsylvanicum</i>	0.2	0.1
Gum	<i>Nyssa sylvatica</i>	0.0	0.1
Hemlock	<i>Tsuga canadensis</i>	19.6	14.8
Hickory	<i>Carya</i> spp.	0.5	2.7
Ironwood	<i>Ostrya virginiana</i>	1.7	1.2
Laurel	<i>Kalmia latifolia</i>	0.0	0.3
Maple	<i>Acer saccharum</i> , <i>Acer rubrum</i>	8.9	10.7
Pine	<i>Pinus strobus</i>	1.7	7.3
Poplar	<i>Liriodendron tulipifera</i>	0.0	0.4
Red oak	<i>Quercus rubra</i> , <i>Quercus velutina</i>	0.0	1.8
Serviceberry	<i>Amalanchier</i> spp.	0.0	1.0
Spice bush	<i>Lindera benzoin</i>	0.1	0.0
Striped maple	<i>Acer pennsylvanicum</i>	0.4	0.0
Walnut	<i>Juglans nigra</i> , <i>Juglans cinerea</i>	0.0	1.0
Water beech	<i>Carpinus caroliniana</i>	3.0	0.9
White oak	<i>Quercus alba</i>	1.4	14.2
Witch hazel	<i>Hamamelis virginiana</i>	0.1	0.4
Sample size		845	766

tionships. Did Native Americans choose to occupy sites already dominated by oak, hickory, and chestnut or did Native American activities increase oak, hickory, and chestnut and foster a distinct forest community that would not have otherwise existed? Given historical accounts, archaeological evidence, and the physiological attributes of oak, hickory, and chestnut, we believe that Native Americans played at least some role in altering forest composition.

A number of Native American land-use practices could explain a shift from northern hardwood forests to oak-hickory-chestnut forests. First, clearing forests near villages for agricultural fields would have led to increases in early-successional edge species. Oak and hickory are intermediate in shade tolerance and often benefit from canopy openings and old fields (Abrams 1992). Similarly, intense collection of wood for fuel and building supplies would have thinned forests near villages and facilitated oak and hickory establishment. Also, Native populations may have engaged in arboriculture, in which trees competing with desired species were eliminated by girdling. Other eastern cultures are known to have fostered hickory and walnut in this fashion, thereby creating highly productive orchards (Munson 1986). Furthermore, Iroquois prized black walnut to the extent that they likely introduced it near village sites in Upstate New York (Wykoff 1991). The only place black walnut occurs in the present study area is immediately adjacent to village sites and has the highest NAI value, suggesting some type of

cultivation or selection. Perhaps more important than the effects of agriculture and arboriculture, Native American use of fire was likely a widespread mechanism of oak, hickory, and chestnut proliferation. Many early- to mid-successional forest species, including oaks, hickories, and chestnuts, have several key biological adaptations to fire disturbances including thick corky bark, a tenacious ability to resprout following top kill due to a high root/shoot ratio and dormant buds, and resistance to rot or compartmentalization of rot (Lorimer 1985; Abrams 1992; Brose et al. 2001). These species also benefit from postfire site conditions, such as the open understory and reduced number of competitors, and xerification of the site through consumption of duff and exposure of soil (Abrams 1992; Brose and Van Lear 1998).

Historical records cite numerous examples of Native American burning throughout the northeastern United States (Whitney 1994), and early explorers, surveyors, and settlers commonly referenced an open forested landscape along the Allegheny River. George Burges, a surveyor working under Andrew Ellicott for the Holland Land Company, identified open "glades along river" and "burnt hills" near Conoquenessing, an Indian village downriver from the study area (Burges 1965). During the same 1794–1795 surveying expedition, Andrew Ellicott noted that the site of Warren (site of Conewango Village in the present study) was covered with a luxuriant growth of white oaks, black oaks, and red oaks of large size (Schenck 1887). Joshua Sharpless, a minister who

Table 3. A comparison of topographic and edaphic characteristics in regions of high (>10 Native American index (NAI)) and low (<10 NAI) Native American impact.

	Low NAI	High NAI
Elevation (m)		
Mean	537.9	487.1
SD	57.4	64.2
Max.	346.0	319.0
Min.	717.0	655.0
Range	371.0	336.0
Slope (%)		
Mean	7.1	8.8
SD	5.4	6.1
Max.	0.0	0.0
Min.	46.4	52.0
Range	46.4	52.0
Landform		
North sideslope	18.3	23.5
South sideslope	17.8	24.1
Plateau	31.4	19.5
Valley	32.5	32.9
Geological formation		
Allegheny	5.7	0.0
Catskill	2.6	0.5
Chadakoin	1.4	9.7
Corry Sandstone through Riceville	1.7	19.8
Cuyahoga group	0.0	0.1
Pottsville group	57.6	16.2
Shenango	0.0	0.3
Shenango through Cuyahoga	4.3	26.8
Shenango through Oswayo	21.7	4.5
Shenango through Riceville	0.1	3.6
Venango	4.8	18.6

visited the Cornplanter towns on the upper Allegheny River, spoke of the fine grasses along Brokenstraw Creek near Buckaloons (1798). North of the study area in Cattaraugus County, New York, “the first settlers found in the midst of the forest, open glades, which had at some day been made clear by fire...kept clear by annual burnings” (Ellis 1879). Townships along the Genesee River in New York (lands occupied by Seneca Iroquois) were dominated by “Prairies, or unwooded plains” (Parker 1968). While we must read these early accounts with an appreciation of their context and intended audience (cf. Russell 1983; Forman and Russell 1983), they do provide evidence that natives burned certain areas near settlements.

Fire ignitions could have come from any number of Native American activities. Native Americans used fire to clear agricultural land after overstory trees had been girdled and allowed to die. These fires undoubtedly escaped, as would have cooking and camping fires. Also, Native Americans are widely reported to have deliberately set forest fires, recognizing the multiple benefits of fires in upland oak (Maxwell 1910; Day 1953; Mellars 1976). According to Caldwell (1958), natives actively manipulated forest resources, particularly mast species (oak–hickory–chestnut), achieving “primary forest efficiency”, whereby they maintained areas of more abundant food resources that led ultimately to a higher

Table 4. Logistic regression of oak, hickory, and chestnut against several edaphic and topographic variables and the Native American Index (NAI).

Variable	df	Wald χ^2	<i>p</i> value
Aspect	3	4.47	0.2152
Elevation	1	1.36	0.2432
Slope	1	1.34	0.2463
Geology	8	37.18	<0.0001
Landform	3	17.22	0.0006
NAI	1	90.53	<0.0001

Note: Wald statistic values are shown as well as degrees of freedom (df) and significance ($p > \text{Wald } \chi^2$). Oak, hickory, and chestnut were grouped into an “oak” category and all other species were grouped into an “other” category for the regression. See Table 3 for a listing of all topographic and edaphic variables.

degree of residential stability. Directly, human-caused fires (*i*) increased browse quality and quantity for deer, thus increasing net productivity of the deer herd as well as concentrating the herd in managed areas, (*ii*) increased acorn quality and quantity, central to mast collection for winter–spring subsistence, and (*iii*) reduction of forest floor litter, thus easing mobility, mast collection, and reducing energy consumption. Burning large areas probably led to predator satiation by providing more browse and mast than could be exploited by deer and other herbivores. The recent discovery of two acorn caches dating to 200 BC at Buckaloons, an extensive occupation site in northwestern Pennsylvania, provides compelling evidence for the collection and processing of large numbers of nut resources (J.M. Adovasio, unpublished data).

Habitation of the study area was long enough that Native American land uses could have significantly altered forest composition. Archaeological information leads us to believe that Native hunter–gatherers occupied this landscape for nearly 4000 years. In that amount of time, Native burning and clearing activities would have increased the amount of mast species, early-successional forage sites, browse quality and quantity, and concentrated the deer herd in managed areas where hunters could harvest them more efficiently (Day 1953; Mellars 1976). In this positive feedback loop, native management activities would have led to an ever-increasing efficiency in providing food resources for the population while increasing the overall abundance of the species on which their subsistence depended. Effects on forest composition were likely most pronounced during the century before European settlement as Native American populations, and inevitably resource extraction, dramatically increased (McConnell 1992). Large groups of eastern tribes including the Delaware (Lenape) and Shawnee moved into this region as they were displaced from their eastern homelands. The increased population density at these river villages would have increased pressure on forest resources. Such intense activity just prior to settlement could have magnified the effects of Native Americans on the landscape, and somewhat increased the clarity of the results of this study. Yet the majority of forest changes almost certainly occurred over the centuries of occupation prior to this westward migration.

Other data sources also suggest that Native Americans affected forest composition on the Allegheny Plateau. In a wit-

ness tree reconstruction immediately west of our study area, Whitney and DeCant (2003) speculate that Native American activity may be in part responsible for oak and chestnut forests. A dendroecological analysis of a 426-year-old white oak forest located approximately 1 km from the Buckaloons village site indicates that disturbance frequency declined following European settlement (Ruffner and Abrams 2002). During the Late Woodland (1600–1700) period of the white oak chronology, the disturbance-free interval (DFI) lasted 26.2 ± 4.0 years, which decreased during the Historic period (1700–1800) to 11.0 ± 0.7 years and increased again to 28.5 ± 2.8 years following European settlement. The significantly higher frequency of disturbance during the Late Woodland period, and especially the Historic period, implies that Native Americans were an important source of disturbance in this forest (Ruffner and Abrams 2002).

Pollen analyses also suggest that Native Americans altered forest composition, consistent with the results of this witness tree study. Throughout the eastern deciduous biome, paleoecological studies have attributed floral and faunal changes from late-successional to early-successional species to anthropogenic disturbance and resource manipulation (Adovasio et al. 1985; Delcourt et al. 1986, 1998; Patterson and Sassaman 1988). In southern Ontario a period of Iroquois occupation and agricultural clearing apparently caused a transition from northern hardwood to white pine – oak forests (Clark and Royall 1995). More locally, a distinct increase in *Quercus* occurred in northwestern Pennsylvania forests approximately 2100–1700 BC, roughly concurrent with the Late Archaic – Woodland cultural expansion around 1500–1000 BC (Walker and Hartman 1960). Also, preliminary comparison of a 6500-year pollen core from Jones Run, a site just east of the high Native American influence area, with that of a much more distant pollen core (8500 years) from the eastern part of the study area indicates differences in disturbance regime (C.M. Ruffner, unpublished data). Both cores show continuous dominance of northern hardwood – hemlock (*Fagus grandifolia*, *Betula* spp., *Pinus strobus*, and *Tsuga canadensis*), but the Jones Run pollen core contains four times as much charcoal. Jones Run is located in a protected mesic cove dominated by mesophytic species such as beech, sugar maple, and hemlock. This position on the landscape would protect species typical of the northern hardwood forest type, explaining its dominance in the pollen core. Yet Jones Run is only 2 km downwind of sites with NAI values >10 and would be positioned to capture high charcoal output from the Allegheny River valley.

In conclusion, catchment analysis demonstrates a strong association between regions of Native American occupation and oak, hickory, and chestnut forest distribution on the Allegheny Plateau of northwest Pennsylvania. Given the wide distribution of witness tree data, future catchment analyses could help clarify the extent and character of Native American influence throughout the eastern and midwestern United States and even allow for comparisons of Native American influence across diverse forest types, physiographic regions, and Native American cultures. Wherever possible, witness tree analysis should be combined with palynology and dendrochronology techniques. The deep time perspectives of palynology and dendrochronology would complement the landscape-level forest snapshots captured by witness tree

analyses and yield the most robust estimates of Native American influences on forest composition.

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References

- Abrams, M.D. 1992. Fire and the development of oak forests. *Bio-science*, **42**: 346–353.
- Adovasio, J.M., Carlisle, R.C., Cushman, K.A., Donahue, J., Guilday, J.E., Johnson, W.C., Lord, K., Parmalee, P.W., Stuckenrath, R., and Wiegman, P.W. 1985. Paleoenvironmental Reconstruction at Meadowcroft Rockshelter, Washington County, PA. *In* Environmental extinctions: man in late glacial North America. *Edited by* J.I. Mead and D.J. Meltzer. Peopling of the Americas Edited Volume Series. Center for the Study of Early Man, Orono, Maine. pp. 73–110.
- Batek, M.J., Rebertus, A.J., Schroeder, W.A., Haithcoat, T.L., Compas, E., and Guyette, R.P. 1999. Reconstruction of early nineteenth-century vegetation and fire regimes in the Missouri Ozarks. *J. Biogeogr.* **26**: 397–412.
- Black, B.A., and Abrams, M.D. 2001. Influences of Native Americans and surveyor biases on metes and bounds witness-tree distribution. *Ecology*, **82**: 2574–2586.
- Bourdo, E.A., Jr. 1956. A review of the General Land Office survey and of its use in quantitative studies of former forests. *Ecology*, **37**(4): 754–768.
- Brose, P.T., and Van Lear, D.H. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. *Can. J. For. Res.* **28**: 331–339.
- Brose, P., Schuler, T., Van Lear, D., and Berst, J. 2001. Bringing fire back: the changing regimes of the Appalachian mixed-oak forests. *J. For.* **99**: 30–35.
- Burges, G. 1965. A journal of a surveying trip into western Pennsylvania under Andrew Ellicott in the year 1795: when the towns of Erie, Warren, Franklin, and Waterford were laid out. J. Cumming Publishers, Mount Pleasant, Mich.
- Caldwell, J.R. 1958. Trend and tradition in the prehistory of the eastern United States. *Am. Anthropol. Assoc. Mem.* **88**.
- Cerutti, J.R. 1985. Soil survey of Warren and Forest Counties, Pennsylvania. USDA Soil Conservation Service, Washington, D.C.
- Chapman, J., Delcourt, P.A., Cridlebaugh, P.A., Shea, A.B., and Delcourt, H.R. 1982. Man–land interaction: 10,000 years of American Indian impact on native ecosystems in the lower Little Tennessee River Valley, eastern Tennessee. *SE Archaeol.* **1**(2): 115–121.
- Ciolkosz, E.J., Waltman, W.J., Simpson, T.W., and Dobos, R.R. 1989. Distribution and genesis of soils of the northeastern United States. *Geomorphology*, **2**: 285–302.
- Clark, J.S., and Royall, P.D. 1995. Transformation of a northern hardwood forest by aboriginal (Iroquois) fire: charcoal evidence from Crawford Lake, Ontario, Canada. *Holocene*, **5**: 1–9.

- Cuff, D.J., Young, W.J., Muller, E.K., Zelinsky, W., and Abler, R.F. 1989. *The Atlas of Pennsylvania*. Temple University Press, Philadelphia.
- Day, G.M. 1953. The Indian as an ecological factor. *Ecology*, **34**: 329–346.
- Delcourt, H.R. 1987. The impact of prehistoric agriculture and land occupation on natural vegetation. *Trends Ecol. Evol.* **2**(2): 39–44.
- Delcourt, P.A., Delcourt, H.R., Cridlebaugh, P.A., and Chapman J. 1986. Holocene ethnobotanical and paleoecological record of human impact on vegetation in the Little Tennessee River Valley. *Quat. Res.* **2**: 330–349.
- Delcourt, P.A., Delcourt, H.R., Ison, C.R., Sharp, W.E., and Gremillion, K.J. 1998. Prehistoric human use of fire, the eastern agricultural complex, and Appalachian oak–chestnut forests: Paleocology of Cliff Palace Pond, Kentucky. *Am. Antiq.* **63**: 263–278.
- Donehoo, G.P. 1928. *A history of the Indian villages and place names in Pennsylvania*. The Telegraph Press, Harrisburg, Penn.
- Ellis, F. 1879. *A history of Cattaraugus County, NY*. L.H. Everts Publishing, Philadelphia.
- Fenneman, N.M. 1938. *Physiography of the Eastern United States*. McGraw-Hill, New York.
- Flannery, K.V. 1976. The village and its catchment area. *In The Early Mesoamerican village*. Edited by K.V. Flannery. Academic Press, New York. pp. 91–128.
- Forman, R.T.T., and Russell, E.W.B. 1983. Evaluation of historical data in ecology. *Bull. Ecol. Soc. Am.* **64**: 5–7.
- Gordon, R.B. 1940. The primeval forest types of southwestern New York. *N.Y. State Mus. Bull.* **321**: 3–102.
- Hammett, J.E. 1992. The shapes of adaptation: historical ecology of anthropogenic landscapes in the southeastern United States. *Landsc. Ecol.* **7**(2): 121–135.
- Kent, B.C., Rice, J., and Ota, K. 1981. A map of 18th century Indian towns in Pennsylvania. *Pa. Archaeol.* **51**(4): 1–18.
- Krech, S., III. 1999. *The ecological Indian: myth and history*. W.W. Norton & Co., New York.
- Lorimer, C.G. 1985. The role of fire in the perpetuation of oak forests. *In Challenges in oak management and utilization*. Edited by J.E. Johnson. Cooperative Extension Service, University of Wisconsin-Madison, Madison, Wis. pp. 8–25.
- Lutz, H.J. 1930. Original forest composition in north-western Pennsylvania as indicated by early land survey notes. *J. For.* **28**: 1098–1103.
- Marks, P.L., and Gardescu, S. 1992. Vegetation of the central Finger Lakes region of New York in the 1790s. *In Late eighteenth century vegetation of central and western New York State on the basis of original land survey records*. Edited by P.L. Marks, S. Gardescu, and F.K. Seischab. *N.Y. State Mus. Bull.* **484**.
- Maxwell, H. 1910. The use and abuse of forests by Virginia Indians. *William and Mary Quarterly*, **19**: 73–103.
- McConnell, M.N. 1992. *A country between: the Upper Ohio Valley and its peoples, 1724–1774*. University of Nebraska Press, Lincoln, Nebr.
- Mellars, P. 1976. Fire ecology, animal populations and man: a study of some ecological relationships in prehistory. *Proc. Prehist. Soc.* **42**: 15–45.
- Munger, D.B. 1991. *Pennsylvania land records: A history and guide for research*. Scholarly Resources, Wilmington, Del.
- Munson, P.J. 1986. Hickory silviculture: a subsistence revolution in the prehistory of eastern North America. *In Emergent horticultural economies of eastern woodlands*. Edited by W.F. Keenan. Southern Illinois University, Carbondale, Ill. pp. 1–20.
- Parker, A.C. 1968. *Parker on the Iroquois*. Edited by W.N. Fenton. Syracuse University Press Syracuse, N.Y.
- Patterson, W.A., III, and Sassaman, K.E. 1988. Indian fires in the prehistory of New England. *In Holocene human ecology n northeastern North America*. Edited by G.P. Nicholas. Plenum Publishing, New York. pp. 107–135.
- Pyne, S.J. 1983. Indian fires. *Nat. Hist.* **2**: 6–11.
- Quinn, A.G., and Adovasio, J.M. 1996. Test excavations at 36WA132, Allegheny National Forest. Mercyhurst Archaeological Institute, Erie, Penn.
- Roper, D.C. 1979. The method and theory of site catchment analysis: a review. *In Advances in archaeological method and theory 2*. Edited by M.B. Schiffer. Academic Press, Tucson, Ariz. pp. 119–140.
- Ruffner, C.M. 1999. *A regional and catchment analysis of Native American influences on pre-European settlement forests of the Allegheny Plateau*. Ph.D. dissertation, The Pennsylvania State University, University Park, Penn.
- Ruffner, C.M., and Abrams, M.D. 2002. Dendrochronological investigation of disturbance history for a Native American site in northwestern Pennsylvania. *J. Torrey Bot. Soc.* **129**: 251–260.
- Russell, E.W.B. 1983. Indian-set fires in the forests of the north-eastern United States. *Ecology*, **64**: 78–88.
- Schenck, J.S. 1887. *History of Warren County, Pennsylvania*. D. Mason & Co., Syracuse, N.Y.
- Seischab, F.K. 1990. Presettlement forests of the Phelps and Gorham Purchase in western New York. *Bull. Torrey Bot. Club* **117**: 27–38.
- Snow, D.R. 1994. *The Iroquois*. Blackwell Publishing, Cambridge, Mass.
- Spurr, S.H. 1951. George Washington, surveyor and ecological observer. *Ecology*, **32**: 544–549.
- Sykes, C.M. 1980. Swidden horticulture and Iroquoian settlement. *Archaeol. East. N. Am.* **8**: 45–52.
- Vita-Finzi, C., and Higgs, E.S. 1970. Prehistoric economy of the Mount Carmel area of Palestine: Site catchment analysis. *Proc. Prehist. Soc.* **36**: 1–37.
- Walker, P.C., and Hartman, R.T. 1960. The forest sequence of the Hartstown Bog area in western Pennsylvania. *Ecology*, **41**: 461–474.
- Wallace, P.A.W. 1965. *Indian Paths of Pennsylvania*. Pennsylvania Historical and Museum Commission, Harrisburg, Penn.
- Whitney, G.G. 1990. The history and status of the hemlock-hardwood forests of the Allegheny Plateau. *J. Ecol.* **78**: 443–458.
- Whitney, G.G. 1994. *From coastal wilderness to fruited plain*. Cambridge University Press, Cambridge, UK.
- Whitney, G.G., and DeCant, J.P. 2003. Physical and historical determinants of the pre- and post-settlement forests of northwestern Pennsylvania. *Can. J. For. Res.* **33**: 1683–1697.
- Williams, M. 1989. *Americans and their forests: a historical geography*. Cambridge University Press, Cambridge, Mass.
- Wykoff, M.W. 1991. Black walnut on Iroquoian landscapes. *North-east. Indian Q.* **4**: 4–17.