

Appendix S1: Document-Based Reconstruction of Land Use and Forest Cover at Monticello circa 1826

Jefferson enabled access across Monticello by constructing a series of roundabout roads that were at increasing distances (1st through 4th roundabouts) from the main house at the summit (shown by shaded relief). These roundabout roads were interconnected to allow movement up and down the mountain (Fig 1).

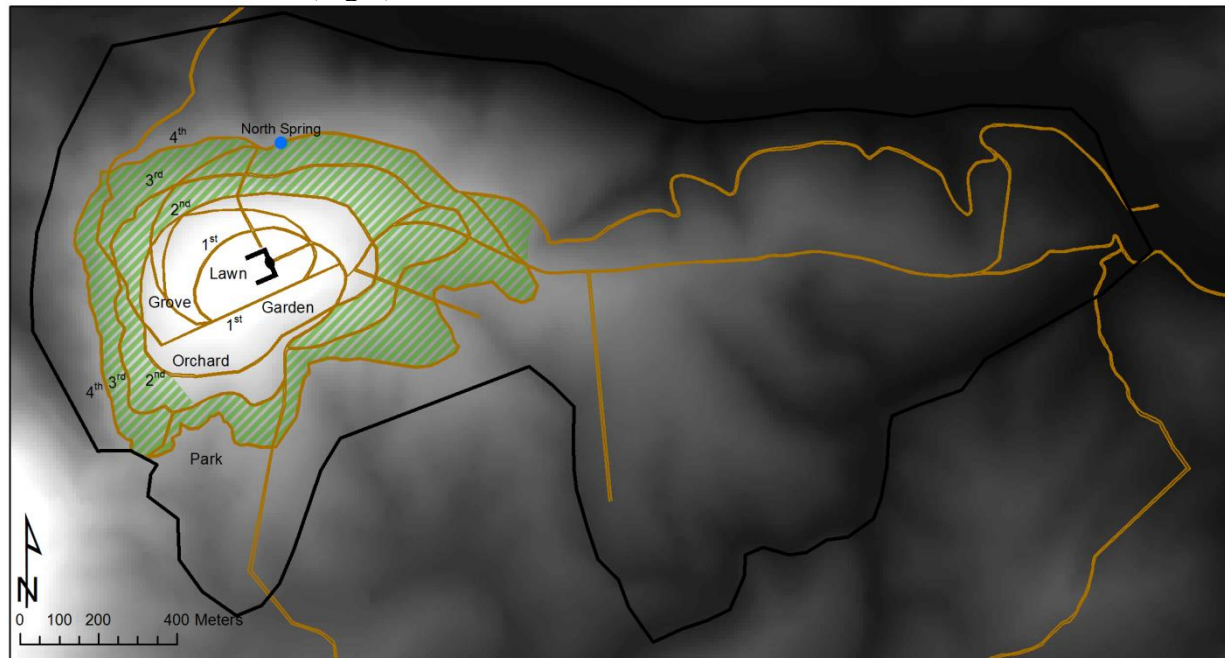


Fig. 1. Ornamental land use showing roundabout roads reconstruction from archaeological surveys and the timber zone (green cross-hatching) as interpreted by Jefferson documents.

Within the second roundabout, Jefferson constructed orchards, gardens, and wide lawn as part of his aesthetic design for Monticello following the conventions of English gardens (Beiswanger 1984). He also clearly noted the location of his Grove and Park, both which remained in forest cover. On the back of a survey, Jefferson alludes to the dimensions of his timber zone; however, interpreting its location has been uncertain prior to this documentary analysis using GIS:

above the Timber zone are 80. acres.

The circuit of the Timber zone at its upper limit is 400.po.

at its lower limit 600.po.

it's breadth must be $31\frac{1}{2}$ po.=173 $\frac{1}{4}$ yds which will to make it's contents 100 acres. but instead of making it of equal breadth lay off its lower edge level from the spring or rather with just so much descent as will carry the water of the spring all around the mountain. the zone at the spring will be but 137 yds wide; but the hill there being excessively steep, it will soon spread out to a much greater breadth so as to make up what it loses in breadth there. (Jefferson 2016)

Assuming that Jefferson was referring to the North Spring, the closest spring to the main house, these calculations suggest that the shape of the timber zone with its inner and outer limits, or boundaries, approximated by the circumference of two circles forming a ring around the summit. A circle with a circumference of 400 poles (2000 m) has an area of 80 acres (30 ha) while a circle with a circumference of 600 poles (3000 m) has an area of 180 acres (70 ha). These calculations suggest that Jefferson was simply roughly estimating, or perhaps idealizing, the areal extent of his timber zone in a manner that could be easily solved using the equation for a circle's area. These upper and lower circuits are approximately congruent with Jefferson's second and forth roundabouts, which have circumferences of 1890 m and 3790 m, respectively, and delineate an area of 100 acres (40 ha) (Fig. 1). Additionally, the distance from the North Spring southward to the second roundabout is approximately 130 m, similar to Jefferson's measurement of 137 yards (125 m) on the north side of the mountain, where the slope is steepest.

This interpretation of the ornamental land use of Jefferson's timber zone is also supported by reading further in his 1806 draft letter to William Hamilton, Jefferson discusses how trees form part of his aesthetic interpretation of English Gardens in Virginia:

Their [England's] sunless climate has permitted them to adopt what is certainly a beauty of the very first order in landscape. Their canvas is of open ground, variegated with clumps of trees distributed with taste. They need no more of wood than will serve to embrace a lawn or glade. But under the beaming, constant and almost vertical sun of Virginia, shade is our Elysium. In the absence of this no beauty of the eye can be enjoyed... The only substitute I have been able to imagine is this. Let your ground be covered with trees of the loftiest stature. Trim up their bodies as high as the constitution & form of the tree will bear, but so as that their tops shall still unite & [yield] dense shade. A wood, so open below, will have nearly the appearance of open grounds. Then, when in the open ground you would plant a clump of trees, place a thicket of shrubs presenting a hemisphere the crown of which shall distinctly show itself under the branches of the trees. (Jefferson et al. 2008).

As early as 1771, Jefferson was already planning his vision for his version of an English landscape at Monticello including a waterfall from a "spring on the North side of the park," a temple and burying place "among antient [ancient] and venerable oaks" with instructions to "thin the trees. cut out stumps and undergrowth. remove old trees and other rubbish, except where they may look well" (Jefferson et al. 2008). Jefferson toured English estates with John Adams in 1786 along with Whately's influential text on English landscape gardens. Whately described contemporary English parks as typically grand, expanses of woods and lawns for walking or riding while gardens as more ornamental areas for pleasure walking (1777). Additionally, trees could be maintained singularly, in clumps, in groves, or as woods within a landscape. Woods maintained both their overstory and understory while groves contained only overstory trees (Whately 1777). Jefferson's modification for the Virginia climate was to maintain his English garden as a grove instead of isolated clumps. The garden grounds were still differentiated from his adjoining park further down the south slope by its greater distance from the house, the presence of deer, and a greater sense of picturesque wilderness within it.

Several of Jefferson's letters also mention an inclosure surrounding the house and grounds at the top of Monticello. This fenced area likely corresponded to the timber zone described on survey N129 in the 1790s (Jefferson 1778). On N211, Jefferson writes that a survey of 174 acres (70 ha)

along the fourth roundabout should be enclosed by fencing for a “pleasure grounds” (Jefferson 1809). Fences during the Colonial period were often constructed to keep livestock out of fields (Silver 2001). At Monticello, Jefferson extolls Capt. Bacon to prevent an “animal of any kind” from entering the fencing and gates surrounding the top of Monticello (Pierson 1862) and depicts portions of this fencing on surveys titled “Monticello: mountaintop (plat), 1809” (Thomas Jefferson. N225; K169 [electronic edition]. Thomas Jefferson Papers: An Electronic Archive. Boston, MA: Massachusetts Historical Society, 2003. www.thomasjeffersonpapers.org) and a “Survey and Plat for Land Purchased from Richard Overton” (The Papers of Thomas Jefferson Digital Edition, ed. James P. McClure and J. Jefferson Looney. Charlottesville: University of Virginia Press, Rotunda, 2008–2017. rotunda.upress.virginia.edu/founders/TSJN-01-38-02-0291).

Capt. Bacon also recalled that a fence enclosed the upper portion of the mountain (approximately 300 acres or 120 ha) within which Jefferson would not allow trees to be cut nor animals to run loose within it (Pierson 1862). Jefferson also advised Capt. Bacon to use fallen wood prior over “cutting down a tree for fire-wood or any other purpose” and to use branches and hollow trees when possible (Jefferson et al. 2008).

While Jefferson’s plans for an English park and gardens at Monticello were among the earliest in North America, it is likely that these plans were not completed (Beiswanger 1984). During her 1809 visit, Margaret Smith was skeptical that Jefferson could finish these plans (Smith 1906). While Jefferson did carry through on design gardens and planting trees immediately around his house at this time (Druckenbrod and Chakowski 2014), four years later he wrote that he had “made no progress in the improvement of my grounds” (Jefferson et al. 2008).

Unable to meet his expenses with proceeds from agriculture, Jefferson died heavily in debt in 1826. Jefferson’s family sold Monticello in 1831 and, the house and surrounding grounds were eventually bought by a Naval Officer, Uriah Levy, in 1834 (Leepson 2002). Except for a period of contested ownership after Uriah’s death in 1862, during which the grounds and house fell into disrepair, Monticello was maintained as a tribute to Jefferson by Uriah, and then his nephew, Jefferson Levy who eventually assumed ownership in 1879 (Leepson 2002, Urofsky 2001). According to an 1899 magazine article, Jefferson Levy kept “the old house, the green terraces, the wide lawns, and the ancient trees as they were in the hands of the first owner” (Peterson 1899 cited in Urofsky 2001). By 1914, timber on the property was considered valuable in appraising the property (Leepson 2002). The property was then sold by Jefferson Levy to the Thomas Jefferson Foundation in 1923 (Urofsky 2001). In 1908, Jefferson Levy’s niece wrote for her school newspaper about the large size of the trees that grew along the sides of the steep ravine along the west slope of the timber zone (Urofsky 2001).

The earliest aerial photograph of Monticello shows sections of the timber zone remaining on the north and south sides (Fig 2).



Fig. 2. ca. 1927-1928 oblique aerial of Monticello oriented eastward showing early successional evergreen forests recruiting on the upper southeast slope (a) and portions of the timber zone as a partial band around the house (b). [Credit: Thomas Jefferson Foundation, Inc. at Monticello].

Considering Jefferson's writings and those of his contemporaries, it is possible to reconstruct a documentary model of forest cover circa 1826 at Monticello (Fig. 3). Returning to the opening quote in the Introduction from the draft letter to William Hamilton, Jefferson notes that the lower two-thirds of the northern quadrant of his mountain is forested and then the upper third is forested across the entire mountain. The upper third (200 m) occurs at the approximate elevation of the fourth roundabout above the Rivanna River on the north slope. This interpretation suggests that Jefferson was referring to the timber zone spreading around the crown of Monticello. Jefferson also referred to his Grove and Upper Park as forested. In an agreement with the Directors of the Rivanna River Company in 1810, Jefferson allows the harvesting of timber and non-timber quality trees from the lower north slope (Jefferson 1810). Thus, Jefferson's use of this forested area varied from ornamental near the summit to a source of wood resources near the base.

Visitors to Monticello during Jefferson's lifetime and later in the nineteenth century record a similar extent of forest cover. When Lt. Francis Hall visited in 1817, he wrote that the "whole of the sides and base are covered with forest, through which roads have been cut circularly ... the summit is an open lawn" (Jefferson et al. 2008). Other contemporary references between 1815 and 1822 portray a similar appearance with forested slopes . containing "a noble forest of oaks in all stages of growth and of decay, Their trunks straight and tall put forth no branches till they reach a height almost equal to the summits of our loftiest trees in New England (Gray 1824 cited in Rosenberger 1953).

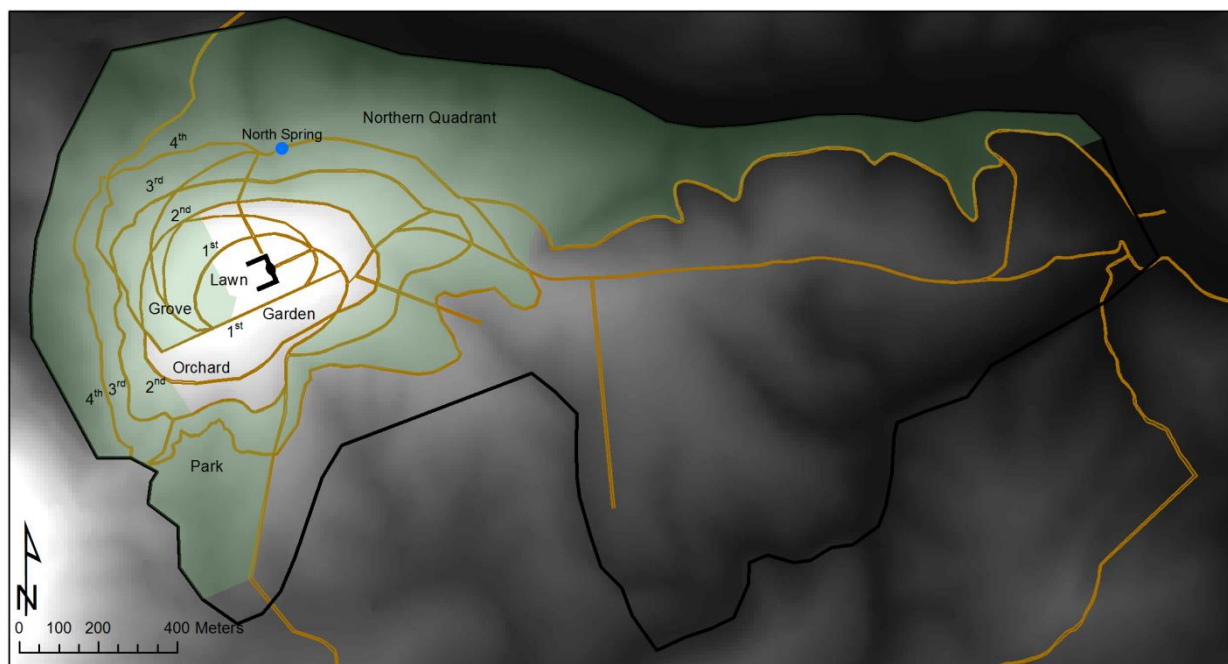


Fig. 3. Document-Based Reconstruction of Forest Cover at Monticello circa 1826

While Jefferson doesn't write directly of the composition of his forests, he occasionally referred to trees by location and species in surveys, deeds, and writings of Monticello. The trees within or bordering forest cover during Jefferson's lifetime are generally more characteristic of later successional forests than those in agricultural cover (Table 1).

Table 1: Trees listed in surveys, deeds, and also instructions to an overseer (dated December 8, 1806) at Monticello by Jefferson and grouped by whether the document refers to trees within forest or agricultural land use as reconstructed in Appendix S3. Common names of trees are those used by Jefferson.

Common name	Scientific name	Agriculture	Forest
Apple	<i>Malus pumila</i>	X	
Ash	<i>Fraxinus americana</i> or <i>pennsylvanica</i>		X
Cherry	<i>Prunus</i> spp.	X	
Chestnut	<i>Castanea dentata</i>		X
Blackgum	<i>Nyssa sylvatica</i>		X
Locust	<i>Robinia pseudoacacia</i>	X	
Maple	<i>Acer</i> spp.		X
Oak	<i>Quercus</i> spp.	X	X
Oak, White	<i>Quercus alba</i>		X
Pawpaw	<i>Asimina triloba</i>		X
Peach	<i>Prunus persica</i>	X	
Persimmon	<i>Diospyros virginiana</i>	X	
Pine	<i>Pinus</i> spp.	X	X
Poplar	<i>Liriodendron tulipifera</i> or <i>Populus</i> spp.	X	
Walnut	<i>Juglans nigra</i>	X	

Literature Cited

- Beiswanger, W. 1984. Temple in the garden: Thomas Jefferson's vision of the Monticello landscape. In: Maccubbin, R.P, Martin, P., & Colonial Williamsburg Foundation (eds.) *British and American gardens in the eighteenth century: eighteen illustrated essays on garden history*, pp. 170-199. Colonial Williamsburg Foundation, Williamsburg, VA, US.
- Druckenbrod, D.L. & Chakowski, N. 2014. Dendrochronological Dating of Two Tulip Poplars on the West Lawn of Monticello. *Tree-Ring Research* 70:41-48.
- Gray, F.C. 1824. Thomas Jefferson in 1814: Being an account of a visit to Monticello, Virginia, Club of Odd Volumes, Boston, MA, US.
- Jefferson, T., E. M. Betts, and P. J. Hatch. 2008. *Thomas Jefferson's garden book, 1766-1824: with relevant extracts from his other writings*. Thomas Jefferson Foundation, Charlottesville, Virginia, USA.
- Jefferson, T. 1778. Monticello: timber zone (plat), verso, [1778], by Thomas Jefferson. N129; K94d [electronic edition]. Thomas Jefferson Papers: An Electronic Archive. Boston, Mass. Massachusetts Historical Society, 2003. <http://www.thomasjeffersonpapers.org/>
- Jefferson, T. 1809. N211. Monticello. "A survey of the 4th Roundabout passing by the Thoroughfare & spring." Ink. Scale: 40 poles = 1". Paper CC (Laid paper. Watermark: H & P). 8 1/8 x 10 1/8 in. About 1809. CSmH9401. Huntington Library, San Marino, CA.
- Jefferson, T. 2016. Papers of Thomas Jefferson Digital Edition. In: Oberg, B.B., & Looney, J.J. (eds.) *American Founding Era Collection*. University of Virginia Press, Rotunda, Charlottesville, VA, US.
- Leepson, M. 2002. *Saving Monticello: The Levy family's epic quest to rescue the house that Jefferson built*. Simon and Schuster, New York, NY, US.
- Peterson, M.H. 1899. The home of Jeffeson. *Munsey's Magazine* 20:618.
- Pierson, H.W. 1862. Jefferson at Monticello: The private life of Thomas Jefferson. Scribner, NY, US.
- Rosenberger, F. C. (ed.). 1953. *Jefferson Reader: A Treasury of Writings about Thomas Jefferson*. E.P. Dutton & Company, New York.
- Silver, T. 2001. A Useful Arcadia: European Colonists as Biotic Factors in Chesapeake Forests. In: Curtin, P.D., Brush, G.S., & Fisher, G.W. (eds.) *Discovering the Chesapeake: The history of an ecosystem*, pp. 149-168. Johns Hopkins University Press, Baltimore, MD, US.
- Urofsky, M.I. 2001. *The Levy family and Monticello, 1834-1923: Saving Thomas Jefferson's house*. Thomas Jefferson Foundation, Charlottesville, VA, US.
- Whately, T. 1777. Observations on Modern Gardening. T. Payne and Son. London. Accessed from <https://archive.org/details/observationsonmo00what>.

Appendix S2: Example Time Series Analyses of Tree-Ring Series

Iterative growth-curve detrending using a negative exponential growth curve was used to reconstruct canopy conditions at recruitment. Removing growth curves within tree-ring series in closed canopy forests typically proceeds by fitting a negative exponential curve to the entire series; if that fails, then a linear regression. Trees that began growing in a canopy gap, but were unable to reach the canopy prior to lateral gap closure record an initial negative exponential growth decline, requiring a subsequent release event to attain canopy status. That release event causes poor fit with a monotonic, negative exponential curve or linear regression.

Additionally, intervention detection using a Hugershoff curve was used to reconstruct disturbance growth indices. Figures 1-3 show an example of this method applied to a yellow poplar tree on the north slope, where much of the 1967 logging occurred. The initial negative exponential fit of this series up to the logging year (indicated with red triangle at lowest value of error term variance) indicates that it recruited under open canopy conditions with a greater initial growth rate.

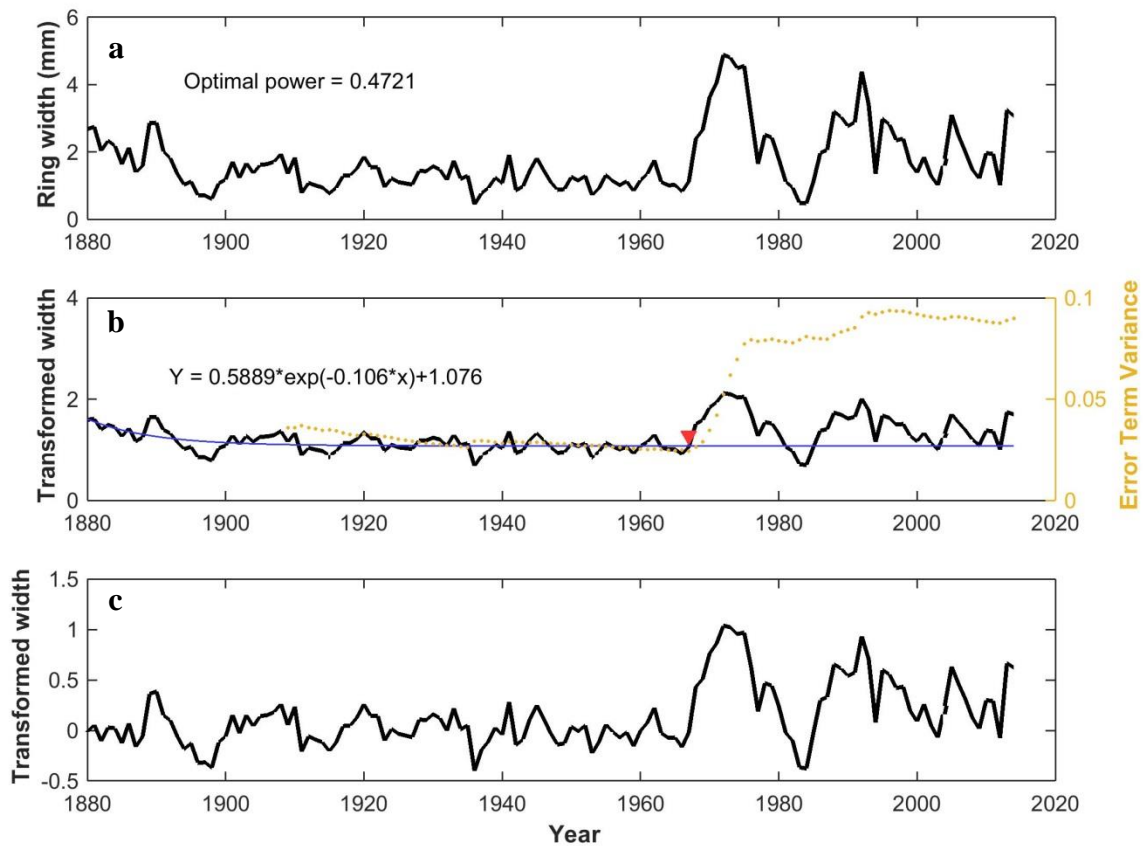


Fig. 1: Iterative growth-curve detrending of a yellow poplar on Monticello's north slope. Ring width measurements (a). Power transformed ring widths that are best fit to a negative exponential curve extending to 1967 (blue line), when the logging occurred (b). Growth-curve detrended ring-width series showing greater stationarity for autoregressive analysis (c).

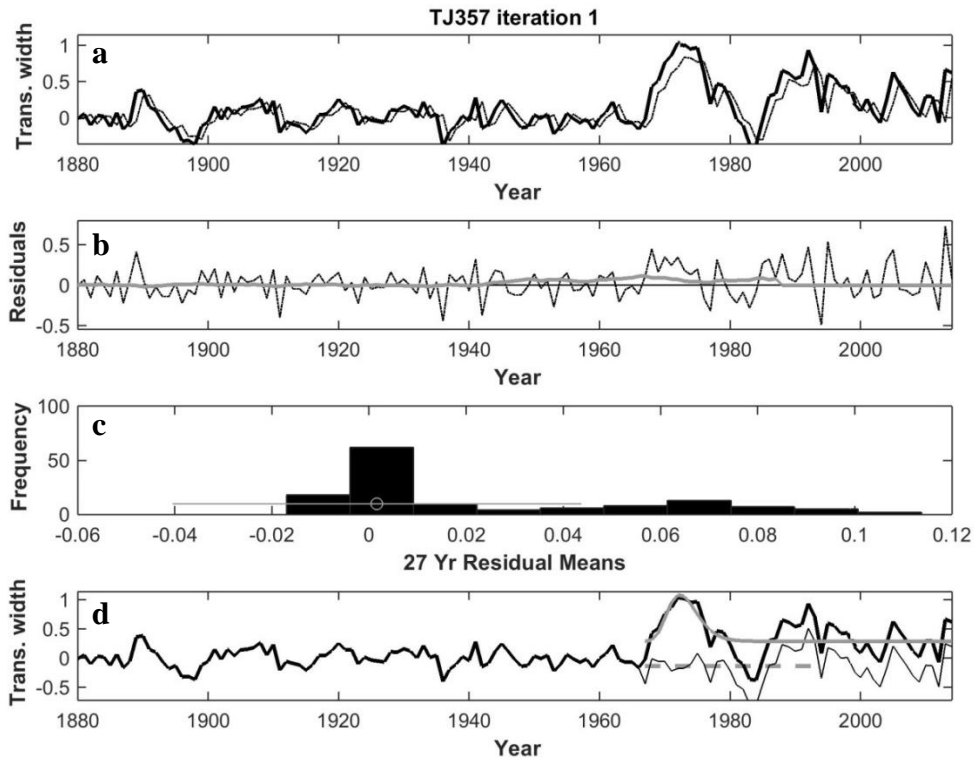


Fig. 2: Curve intervention detection of a yellow poplar on Monticello's north slope. Detrended series (bold line) best fit by a first order autoregressive model with a 0.81 coefficient (thin line) (a). Residuals from AR1 model fit show a period of poor fit beginning in 1967 and extending for 27 years as shown by the increase in the 27-year running mean (gray line) (b). The 27-year mean at 1967 is greater than 99.95% of 27-year residual means across this series, identifying it as an outlier (c). Hagershoff curve fit to series (bold line) beginning in 1967 (gray line). Subtracting the Hagershoff curve fit disturbance detrends this series in transformed units (d).

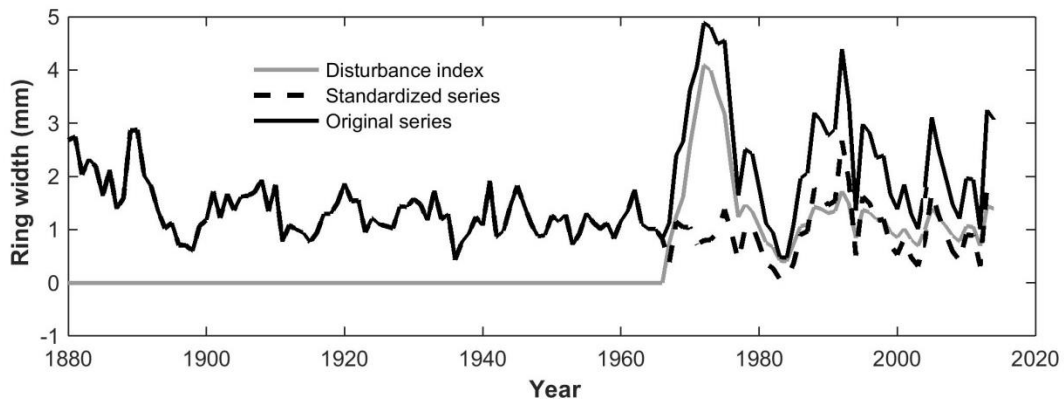


Fig. 3: Re-expressing intervention detection to original units of ring widths (with growth-curve trend included). The difference between the original series and the disturbance-standardized series enables a reconstruction of a disturbance growth index (gray line) quantifying the timing, duration, and magnitude of the 1967 logging event on this tree.

Appendix S3: Historical Land Use and Estimates of Forest Cover at Monticello through Time

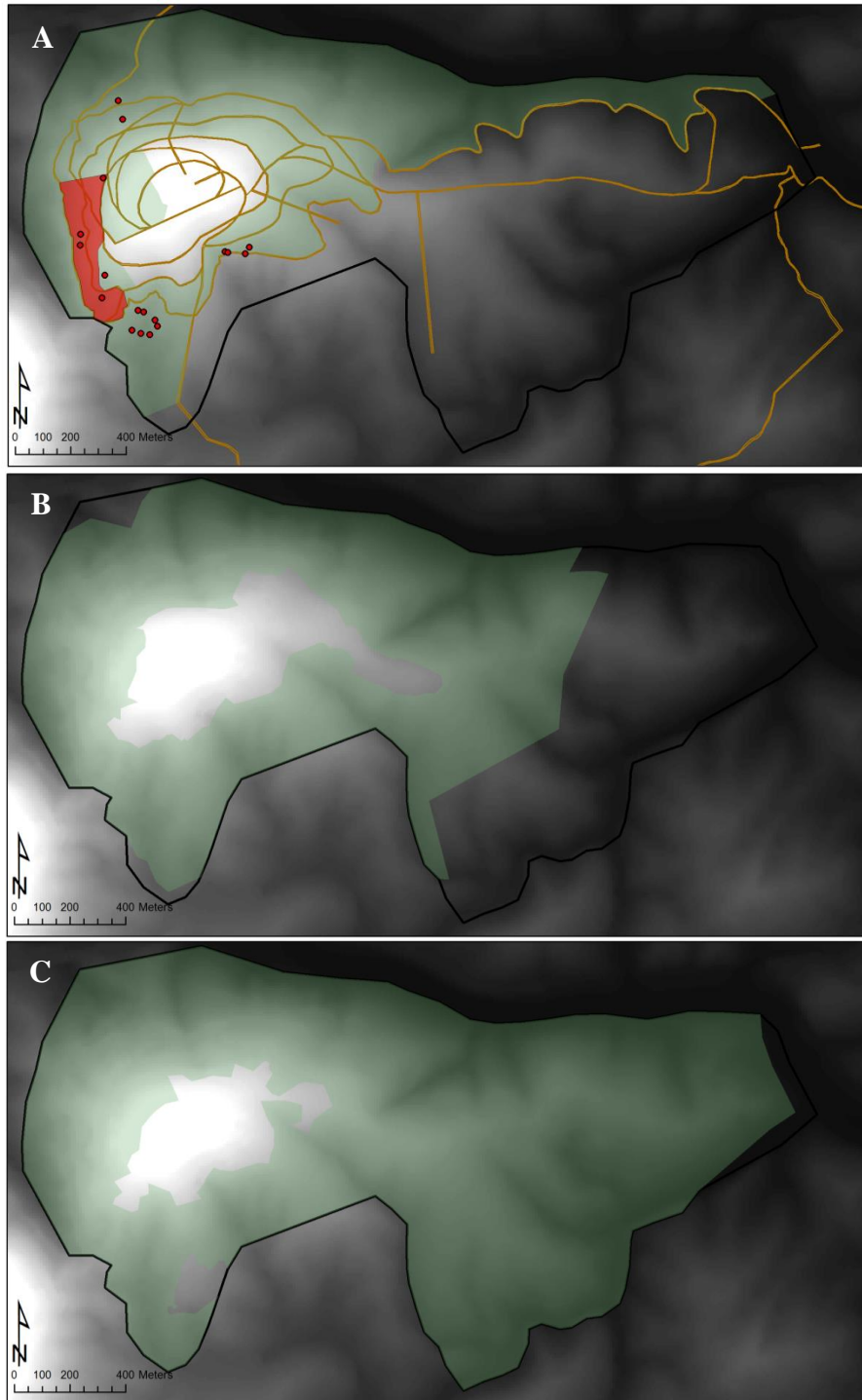


Fig. 1: Reconstructed forest cover (in light green) at Monticello circa 1826 from documentary evidence along with roads and trees dating to Jefferson's lifetime (a). Red dots indicate location of individual trees while red polygon encompasses an additional 17 trees found in an initial sampling without marking individual locations. Estimated forest cover in 1937 (b) and 1994 (c) from aerial photographs. Forest cover is overlain on a 30m DEM.

Appendix S4: Species Names in NMDS Ordination.

<i>Abbrev.</i>	<i>Genus</i>	<i>Species</i>
ACNE	<i>Acer</i>	<i>negundo</i>
ACRU	<i>Acer</i>	<i>rubrum</i>
AIAL	<i>Ailanthus</i>	<i>altissima</i>
ALIN	<i>Alnus</i>	<i>incana</i>
ASTR	<i>Asimina</i>	<i>triloba</i>
CACA	<i>Carpinus</i>	<i>caroliniana</i>
CAAL	<i>Carya</i>	<i>alba</i>
CACO	<i>Carya</i>	<i>cordiformis</i>
CAGL	<i>Carya</i>	<i>glabra</i>
CAOV3	<i>Carya</i>	<i>ovalis</i>
CAOV2	<i>Carya</i>	<i>ovata</i>
COOC	<i>Celtis</i>	<i>occidentalis</i>
CECA	<i>Cercis</i>	<i>canadensis</i>
CHVI	<i>Chionanthus</i>	<i>virginicus</i>
COFL	<i>Cornus</i>	<i>florida</i>
CR	<i>Crataegus</i>	<i>spp</i>
DIVI	<i>Diospyros</i>	<i>virginiana</i>
FAGR	<i>Fagus</i>	<i>grandifolia</i>
FRAM	<i>Fraxinus</i>	<i>americana</i>
FRPE	<i>Fraxinus</i>	<i>pennsylvanica</i>
GLTR	<i>Gleditsia</i>	<i>triacanthos</i>
HAVI	<i>Hamamelis</i>	<i>virginiana</i>
ILOP	<i>Ilex</i>	<i>opaca</i>
JUNI	<i>Juglans</i>	<i>nigra</i>
JUVI	<i>Juniperus</i>	<i>virginiana</i>
LISI	<i>Ligustrum</i>	<i>sinense</i>
LIBE	<i>Lindera</i>	<i>benzoin</i> var. <i>benzoin</i>
LITU	<i>Liriodendron</i>	<i>tulipifera</i>
MORU	<i>Morus</i>	<i>rubra</i>
NYSY	<i>Nyssa</i>	<i>sylvatica</i>
OSVI	<i>Ostrya</i>	<i>virginiana</i>
PATO	<i>Paulownia</i>	<i>tomentosa</i>
PIEC	<i>Pinus</i>	<i>echinata</i>
PIVI	<i>Pinus</i>	<i>virginiana</i>
PRAV	<i>Prunus</i>	<i>avium</i>
PRSE	<i>Prunus</i>	<i>serotina</i>
QU	<i>Quercus</i>	<i>spp</i>
QUAL	<i>Quercus</i>	<i>alba</i>
QUCO	<i>Quercus</i>	<i>coccinea</i>
QUPR	<i>Quercus</i>	<i>prinus</i>
QURU	<i>Quercus</i>	<i>rubra</i>
QUVE	<i>Quercus</i>	<i>velutina</i>
RHPE	<i>Rhododendron</i>	<i>periclymenoides</i>
ROPS	<i>Robinia</i>	<i>pseudoacacia</i>
SAAL	<i>Sassafras</i>	<i>albidum</i>
TIAM	<i>Tilia</i>	<i>americana</i>
TSCA	<i>Tsuga</i>	<i>canadensis</i>
ULRU	<i>Ulmus</i>	<i>rubra</i>
VIAC	<i>Viburnum</i>	<i>acerifolium</i>
VIPR	<i>Viburnum</i>	<i>prunifolium</i>