A dendroclimatological analysis of Brown's Lake Bog Preserve, Wayne County, Ohio

Kendra Devereux

July 5th, 2018

Report submitted to Karen Seidel, The Nature Conservancy

Abstract

Tree ring chronologies can be used in dendroclimatology to study past climate, to predict growth during future climate, and to learn about environmental change in the past. In this study, over the past several years, 53 tree cores taken from 26 white oak trees (*Quercus alba*) were sampled from Brown's Lake Bog Preserve in Shreve, Ohio to build a chronology. This chronology was then used to correlate ring widths to climate data. The ring-width chronology was correlated to temperature, precipitation, and drought records using KNMI Climate Explorer to examine the effect of climate on tree ring growth (Trouet and Oldenborgh 2013). Strong negative correlations were noted in temperature for the month of June, strong positive correlations for precipitation for the months of June and July, and strong positive correlations for the Palmer Drought Severity Index for the months of June-August. These results indicate that precipitation has a larger effect on ring width during the hotter months, when the trees are under more stress. A release (increase in ring widths) was present in the chronology starting around 1820, likely a result of the changes brought by settlement. Settlers would have selectively logged trees for building homes, reducing competition for the trees left standing. Other anthropogenic factors are also likely causing ring width to remain larger than pre-settlement rings, such as nitrogen and CO_2 fallout from fossil fuel burning, windblown matter from farms that contain nutrients, and increased precipitation due to climate change.

Introduction

Tree rings are used in climate research to examine past climate and to predict tree growth during future climate trends and events. The chronologies created from studying tree rings can also be used in cross-dating to determine the age of historical buildings. In this study, 53 tree cores from white oak (*Quercus alba*) trees in Brown's Lake Bog Preserve in Shreve, Ohio are used to examine how past climate affected the trees' growth. Using data collected from the OARDC climate station in Wooster, Ohio, it is possible to correlate the growth patterns observed in the tree rings to climate data such as precipitation and temperature. This tree ring study was conducted to provide a climate analysis for The Nature Conservancy and the Friends of Brown's Lake Bog.

Brown's Lake Bog Preserve is located 2 miles west of the town of Shreve in Wayne County, Ohio within the Western Allegheny Plateau Ecoregion. Temperatures typically range from around 20° F (-6° C) in the winter and 80° F (27° C) in the summer and precipitation is highest during the months of May and June (Figure 1). The preserve was purchased by The Nature Conservancy in 1966 and was declared a National Natural Landmark in 1968. It is open to the public and contains short nature trails.

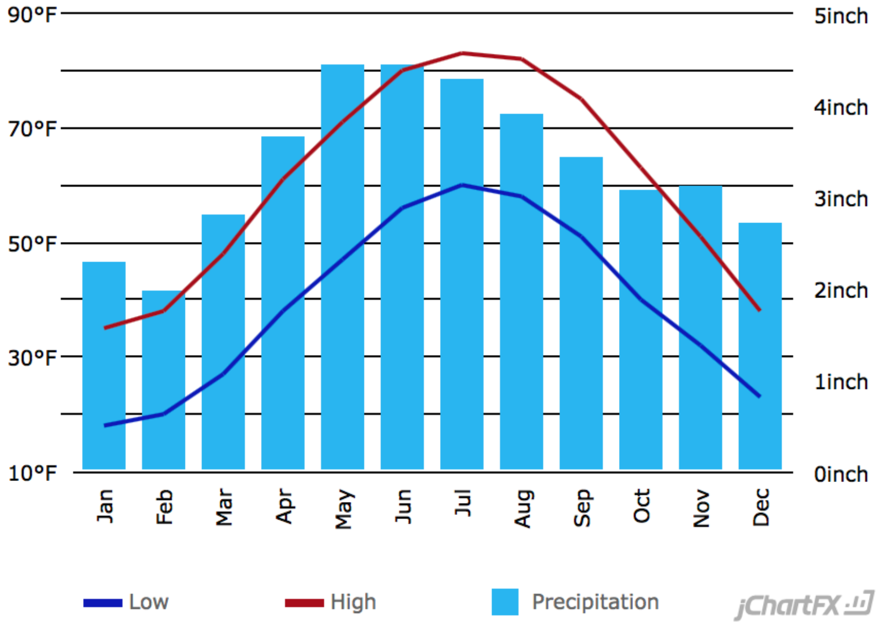

Figure 1. Climograph of Wayne County, Ohio. Figure from U.S. Climate Data.

The preserve also contains an open kettle-hole lake surrounded by a floating sphagnum moss mat. The floating sphagnum mat is able to insulate the water from rapid temperature changes and is naturally acidic, which maintains the boreal plant community. More than 20 rare plants are found in the preserve, including purple pitcher plants and round-leaved sundew. The surrounding 80 acres of lowland forest support shallow ephemeral pools for most of the year. The bog and lake are glacial relicts and the hills on the property are glacially-formed hills called kames (Ohio Department of Natural Resources, 2018).

Methods

Our data file contains 53 white oak cores taken from 26 trees in Brown's Lake Bog, collected by students from the College of Wooster over the past few years (Table 1). Using 5-millimeter increment hand-borers with a hollow drill bit, each core was extracted and placed into a labeled plastic straw for transport back to the lab.

Tree ID	First Year	Last Year	Tree ID	First Year	Last Year
BLB01	1816	2004	**BLB14**	1665	2005
BLB02	1866	1987	**BLB15**	1758	2003
BLB03	1753	2004	**BLB16**	1880	2004
BLB04	1845	1995	**BLB17**	1766	2005
BLB05	1856	2004	**BLB18**	1838	2003
BLB06	1800	2004	**BLB19**	1723	2003
BLB07	1847	2002	**BLB20**	1861	2004
BLB08	1814	2004	**BLB21**	1818	2004
BLB09	1813	2004	**BLB22**	1862	2004
BLB10	1788	2002	**BLB23**	1839	2004
BLB11	1837	2004	**BLB24**	1930	2016
BLB12	1884	2004	**BLB25**	1947	2015
BLB13	1771	1973	**BLB26**	1836	2017

Table 1. This table shows the first and last years of the 26 trees.

In the lab, each core was removed from the straw and glued into a wooden mount. Once dry, the cores were sanded using two different belt sanders with different grain sizes. The cores were further polished with hand sand-paper until the rings were clearly visible. Using a microscope, the rings of each core were counted and measured to the nearest 0.001 mm using a Velmex measuring table.

The cores were then cross-dated against multiple chronologies from Northeast Ohio with the aid of the computer program COFECHA (Holmes, 1983). The program correlates the series to existing chronologies to ensure that the calendar dates determined by counting the rings were correct. This also allowed for missing rings to be found, since tight growth sometimes makes it difficult to accurately count the rings.

A raw chronology of the ring widths was created (Figure 2). The computer program ARSTAN was then used to create a standardized chronology of the Brown's Lake Bog trees (Figure 3) (Cook, 1985). We standardized the data with a horizonal line through the mean in order to filter out low-frequency variations, such as trends in growth due to age, size and biological persistence (Fritts, 1976). Along with the raw data, the standardized chronology was then correlated with climate data using a website called KNMI Climate Explorer (Trouet and Oldenborgh 2013). Specifically, the ring widths were correlated against temperature, precipitation, and PDSI records of drought from the OARDC climate station in Wooster, Ohio.

Results

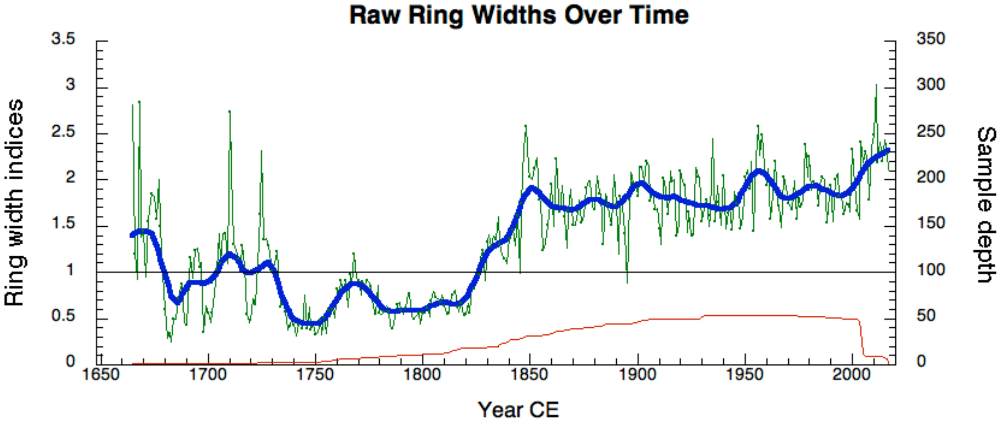

Figure 2. The raw chronology displays ring widths before standardization and the number of samples over the time span 1665-2017. The number of cores (sample depth) is indicated with the red line along the bottom of the graph.

The raw data was compiled into a chronology (Figure 2). Note that there is a release beginning around 1820 and that ring widths double by 1850. Ring widths continue to rise slowly through today, but this trend is not present in the standardized chronology (Figure 3). Few samples dated earlier than 1740, causing a higher variability in the ring width data until around the 1740s (Figure 2). With more replication in more recent years, there is less variability.

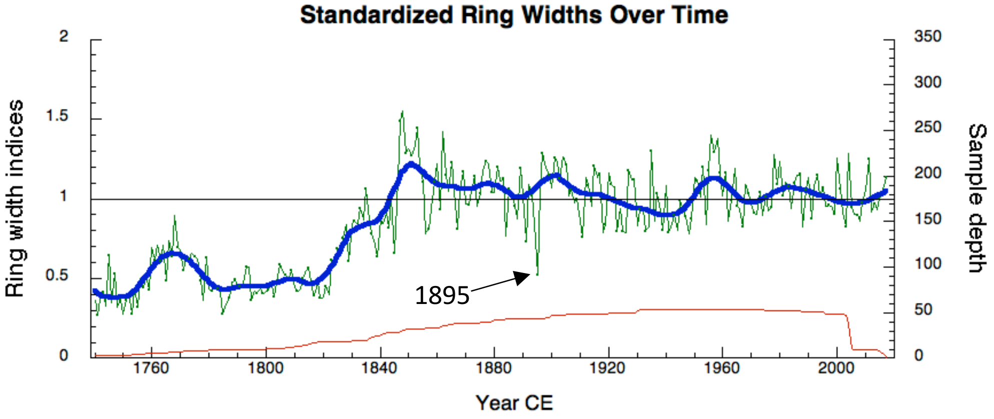

Figure 3. This standardized chronology displays ring widths and the number of samples over the time span 1740-2017. The drought year of 1895 is indicated by the black arrow. The number of cores (sample depth) is indicated with the red line along the bottom of the graph.

The data was then standardized with a horizontal line through the arithmetic mean (Figure 3). The graph was truncated at 1740 because there was little replication in the data before 1740, causing high variability that does not have much significance. Note that there is a rapid increase in ring width between 1820-50, with a doubling in size by the 1850s. Ring width does not continue to rise after this spike as it does in the raw chronology (Figure 2).

We then used this standardized data to compare ring width to both monthly temperature (Figure 4) and precipitation (Figure 5) records. We used the OARDC climate station located in Wooster, Ohio (which contains over 100 years of climate data) for all correlations since Brown's Lake Bog is also located in Wayne County. The histograms below show which months have the strongest correlations for mean temperature and precipitation. For temperature, there is a strong negative correlation for the month of June. For precipitation, there is a moderate positive correlation for May and strong positive correlations for June and July.

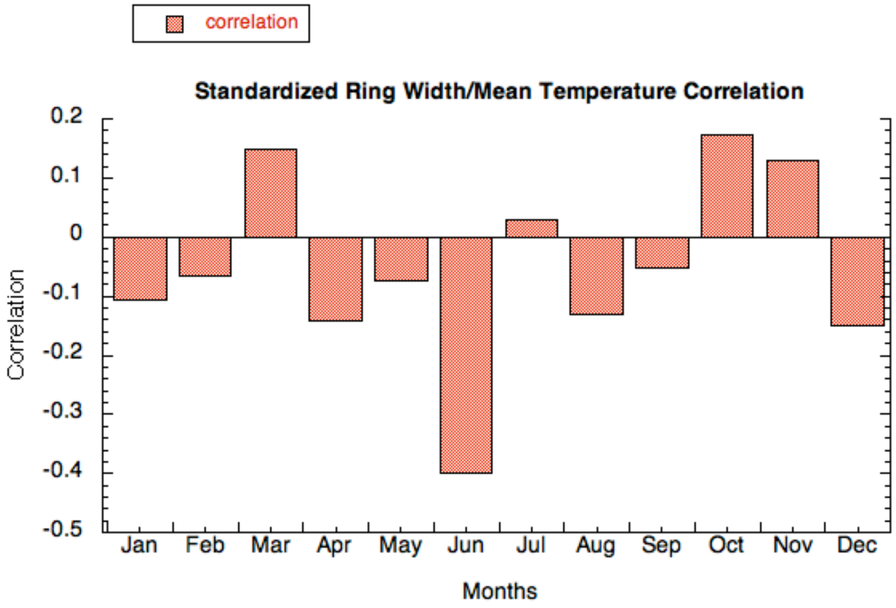

Figure 4. Histogram showing ring width correlation with mean monthly temperature. The month of June has the strongest correlation of nearly -0.40. Mean monthly temperature data is from the OARDC climate station.

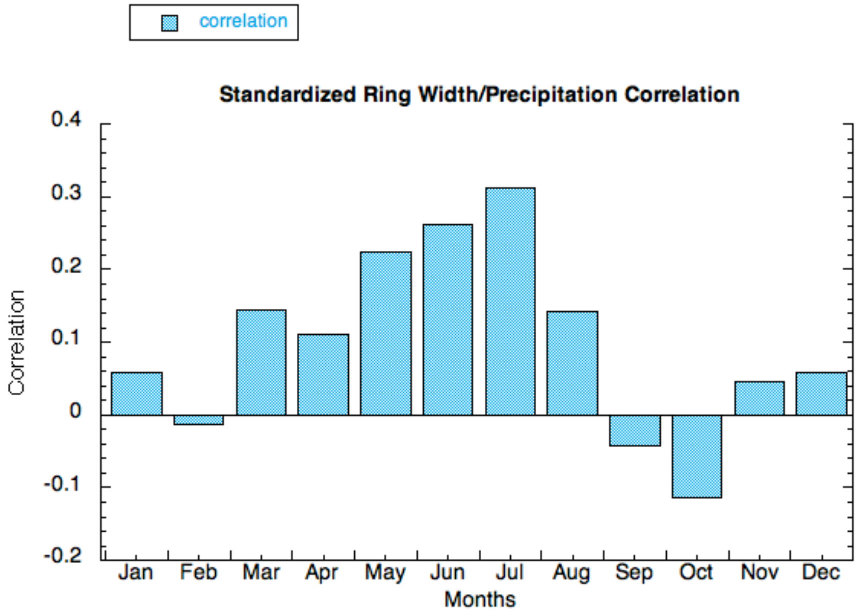

Figure 5. Histogram showing ring width correlation with precipitation. The positive correlations for the months of May-June were all significant and July had the strongest correlation of 0.31. Monthly precipitation data is from the OARDC climate station.

Tree ring widths can also be compared to drought records using the Palmer Drought Severity Index (PDSI) (Cook and Krusic, 2004). The PDSI measures dryness based on both precipitation and temperature in which positive values indicate wetter conditions while negative values indicate drier, drought-like conditions. We correlated our tree ring width measurements to these drought records and found the highest correlations to be among the months June-August (Figure 6). High correlations are indicative of smaller ring width values for years in which the summer months were drier and more drought-like. We can see evidence in this by picking a year that has a relatively small ring width, such as 1895 (Figure 3), and seeing that the PDSI data for that year shows drier conditions across Ohio (Figure 7).

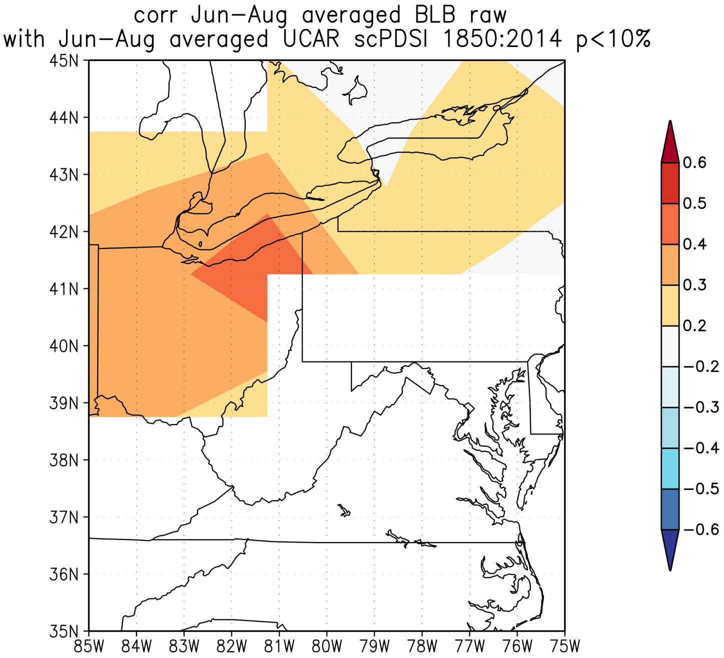

Figure 6. This map shows drought over Ohio and correlates PDSI to the ring width data from Brown's Lake Bog. The darker the color, the higher the correlation is. In Northeast Ohio, where the bog is located, the correlation is high at about 0.4.

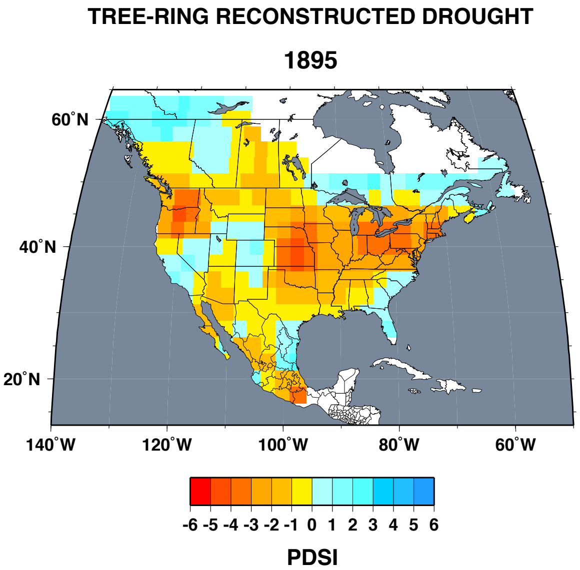

Figure 7. This PDSI map displays the PDSI measurements of drought for the year 1895. Warm colors indicate drier conditions. In Ohio, drought was severe for this year with a PDSI value of -4.

Discussion

As seen in our chronology (Figure 3), ring width increases over time. This is in conflict to the typical growing pattern of trees which produce thinner rings as trees get older and the tree's circumference gets larger. Trees put on the same amount of wood each year, yet as their diameter grows, the wood needs to be spread over a larger area, causing the rings to decrease in width (Cook, 1987). Most likely, our chronology displays an atypical growth pattern due to the changes brought by settlers, which led to reduced competition for the trees at Brown's Lake Bog.

In addition to the gradual increase in ring width, there is a spike in ring width (a release) that begins around 1820 (Figure 2, 3), which is also likely a result of the changes brought by settlement. Although people began to settle in the Ohio area during the 1700s, the majority of people arrived during the early to mid 1800s, after Ohio was given statehood in 1803 (Galbreath, 1925). Wayne County was established in 1796 and had a population of 3,206 by 1800. The population rose rapidly and by 1820, it was at 11,933. By 1850, when ring width stopped increasing, population was at 32,981. Population stopped increasing so rapidly and instead remained relatively constant for longer periods of time (Galbreath 1925). During this time, roads were built, and people would have begun clearing land for farms and homes at a much higher rate than before.

Clearing land of trees would have reduced competition for light, resources, and space for the trees left standing. White oaks are able to regenerate quickly in gaps but are poor competitors under closed canopies (Abrams, 2003). Cutting down trees would clear canopy space, which would have allowed the white oak trees to begin growing larger rings, as seen in the chronology (Cook, 1987). Ring width does not go back down after this spike but remains constant through today. The leveling-off of ring width coincides with the leveling-off of population size. Several factors could be causing the ring width to remain constant through today, including a low-frequency rise in precipitation due to climate change, increased CO_2 and nitrogen from fossil fuel burning, or windblown sediment matter from farms that could contain phosphorus or nitrogen (Figure 8). Although, atmospheric CO_2 is increasing as a result of anthropogenic activities, it most likely does not have a significant effect on the doubling of tree ring width (Jacoby and D'Arrigo, 1997).

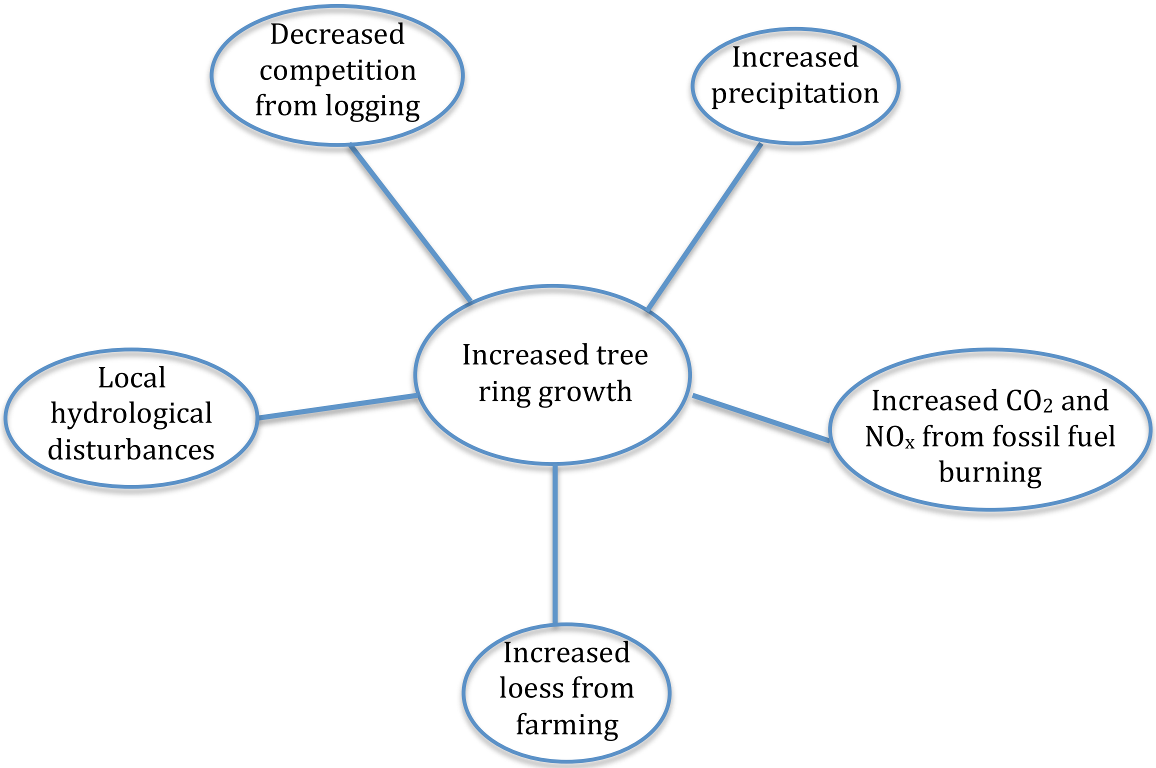

Figure 8. Diagram showing a number of factors that may have an effect on the increase in ring size.

Not surprisingly, ring width has a positive correlation with precipitation and a negative correlation with temperature. The positive correlation with precipitation is highest during the summer months because these are the hottest months of the year (Figure 4). During the hotter months when the trees are under more stress, tree growth is more sensitive to moisture. White oak trees are especially sensitive to water balance in the early growing season, which can be observed in the ring widths and in the strong correlations during May-June (Tardif et al., 2006). The stress that trees are under during the hotter months also explains the strong negative correlation with temperature seen in Figure 3 and the strong correlations with PDSI in Figure 5.

The Palmer Drought Severity Index measures relative dryness based on available temperature and precipitation data. Negative numbers signify drier conditions while positive numbers signify wetter conditions. Tree rings will be thinner during drier conditions. For example, 1895 was a very dry year (Figure 7) and the ring width for 1895 is smaller than the rings around it from wetter years (Figure 3). Thinner rings are present at most years where the PDSI values are further into the negatives. Wider rings are present at years where the PDSI values are further into the positives (which indicates wetter conditions that year).

Uses for Tree Ring Chronologies

Tree rings record climate data in the way that their rings grow. Thus, the chronologies produced can be used to study past climate. In addition to learning more about the past, we can also use the ring data correlated with existing climate data to help us predict how tree growth will look in the future as climate continues to change. For example, with climate change, parts of the world (including Ohio) are getting wetter (Trenberth, 2011). By looking at how trees grew during increased precipitation in the past, we can better predict what may change as the trees experience more precipitation in the future.

Chronologies such as the one created here for Browns Lake Bog can also be used to date historical structures. They are commonly used in archaeology to date houses, barns, and cabins.

Recently, a sunken ship recovered from the Boston harbor was dated using data from our lab (Creasman, et al., 2015). Dates of construction can be obtained by cross-dating samples from historical structures to existing chronologies. Tree ring data is one of the most accurate ways to date structures since it can date a structure to a season of a year based on how complete the outer ring is.

Acknowledgements

Special thanks to the Sherman-Fairchild foundation and the Applied Methods and Research Experience (AMRE) program at the College of Wooster for this opportunity. Also, thanks the College of Wooster Department of Earth Sciences and Dr. Greg Wiles, our project advisor, for making this possible and collecting the samples over the past several years. Thanks to The Nature Conservancy for letting us obtain core samples and to the Friends of Brown’s Lake Bog.

References

Abrams, M. D., 2003, Where has all the white oak gone?: BioScience, v. 53, p. 927-939.

Cook, E. R., 1985, A time series analysis approach to tree-ring standardization [PhD Thesis]: Tuscon, University of Arizona, 183 p.

Cook, E. R., 1987, The decomposition of tree-ring series for environmental studies: Tree Ring Bulletin, v. 47, p. 37-59.

Cook, E. R., and Krusic, P. J., 2004, The North American Drought Atlas: Lamont-Doherty Earth Observatory and the National Science Foundation (available at https://iridl.ldeo.columbia.edu/SOURCES/LDEO/.TRL/.NADA2004/.pdsi-atlas.html).

Creasman, P. P., Baisan, C., and Guiterman, C., 2015, Dendrochronological evaluation of ship timber from Charlestown Navy Yard (Boston, MA): Dendrochronologia, v. 33, p. 8-15.

Fritts, H.C., 1976, Tree rings and climate: New York, Academic Press.

Galbreath, C. B., 2011, History of Ohio, Volume 1: Chicago and New York, The American Historical Society, 710 p.

Holmes, R. L., 1983, Computer-assisted quality control in tree-ring dating and measurement: Tree Ring Bulletin, v. 43, p. 68-78.

Jacoby, G. C and D'Arrigo, R. D., 1997, Tree rings, carbon dioxide, and climate change: Proc. Natl. Acad. Sci. USA, v. 94, p. 8350-8353.

Ohio Department of Natural Resources, 2018, Brown's Lake Bog State Nature Preserve: http://naturepreserves.ohiodnr.gov/brownslakebog (accessed June 2018).

Tardif, J. C., Conciatori, F., Nantel, P., and Gagnon, D., 2006, Radial growth and climate responses of white oak (*Quercus alba*) and northern red oak (*Quercus rubra*) at the northern distributing limit of white oak in Quebec, Canada: Journal of Biogeography, v. 33, p. 1657-1669.

Trenberth, K. E., 2011, Changes in precipitation with climate change: Climate Research, v. 47, p. 123-138.

Trouet, V. and Oldenborgh, G. J., 2013, KNMI Climate Explorer: a web-based research tool for high-resolution paleoclimatology: Tree-Ring Research, v. 69, p. 3-13.

U.S. Climate Data, 2018, Wooster Climate graph: https://www.usclimatedata.com/climate/wooster/ohio/united-states/usoh1069 (accessed June 2018).