e-ISSN 2785-2709

Lagoonscapes
Vol. 5 – Num. 2 – December 2025

Tree-Rings as Text: Reading the Climatic and Life History of an Irish Oak

Francis Ludlow
Trinity College, Ireland

Eva Jobbová
Trinity College, Ireland

David M. Brown
Queen's University Belfast, UK

Christopher Morris
Trinity College, Ireland

Abstract Parallels readings of natural and human archives offer many advantages in environmental history. Such literacy is best fostered at the undergraduate level onward. We thus offer a teachable case study that focuses on how an oak sample prepared for dendrochronological analysis at Queen's University Belfast can be 'read' and placed in dialogue with the Irish Drought Impact Database. This demonstrates the value of the oak record but also the need for its critical interpretation. It opens questions about how human management shaped its environment whilst growing in the Botanic Gardens Park, Belfast.

Keywords Climate history. Dendrochronology. Drought. Natural and human archives. Newspapers.

Edizioni Ca'Foscari

Check for updates

Peer review

Submitted 2025-10-26
Accepted 2025-11-19
Published 2025-12-18

Open access

Citation Ludlow, F.; Jobbová, E.; Brown, D.M.; Morris, C. (2025). "Tree-Rings as Text: Reading the Climatic and Life History of an Irish Oak". *Lagoonscapes*, 5(2), 445-470.

DOI 10.30687/LGSP/2785-2709/2025/02/009

1 Introduction

Across the environmental humanities (EH) and wider interdisciplinary teaching, a scarcity of worked case studies, syllabi and curricula exists. In EH, O'Gorman et al. (2019) argue that programme growth has outpaced pedagogical development, with insufficient discussion of classroom practice, despite efforts such as Garrard's (2012) *Teaching Ecocriticism and Green Cultural Studies*. For interdisciplinary teaching broadly, teachers at all levels can lack appropriate models, making implementation difficult (Nagle 2013), a situation with precedent in earlier integrative efforts (Davison, Miller, Metheny 1995). In ecology, a deficit of published teaching case studies is noted (Smith, Paradise 2022), and studies of schools and undergraduate settings describe limited guidance for cross-disciplinary teaching (Sisti 2021; Lim 2025). In this context, efforts such as the *Environmental Humanities Syllabus Project*, which curates syllabi and assignments, are of great value.[1]

In the space available, we focus upon environmental history as an important field within broader EH studies. As J.R. McNeill (2010, 348) states, environmental history is "more than most varieties of history [...] an interdisciplinary project", drawing not only on "published and archival texts" but also on natural (biological and physical) archives, such as sediment cores that can reveal past vegetation and land use. Its "essential purpose", Donald Worster (1996, 5) argues, is to (re)open a "doorway" between the humanities and the environmental sciences, to trace how the biophysical world has influenced human affairs and how people have understood and themselves shaped nature. The practical hurdles of working across archaeology, ecology, botany, and climatology are very real, but combining their data and perspectives "will help push along the frontiers of knowledge" (McNeill 2010, 365). More recently, the concept of consilience, coined by Whewell (1840) and popularised by Wilson (1998), has been revived to frame efforts at unifying knowledge from across the humanities and natural sciences. This is not to be achieved by erasing disciplinary differences, but by treating our sources and methods as complementary (e.g., linking tree rings with texts). In pursuing this, Izdebski et al. (2016, 9) argue that disciplines mainly differ in "methods, habits, and cultural traditions", not in the essence of their work, and hence "consilience is already there". The task is now to realize it in a practical sense via improved communication, shared research questions, transparent data/uncertainty handling, and genuinely collaborative study designs

1 Based at the Environmental Humanities Research Center, University of California, Irvine. See `https://www.humanities.uci.edu/environmentalhumanitiesresearch/syllabus-project`.

(Izdebski et al. 2016), whilst McCormick (2011) emphasizes the need to train historians to work across methods and sources, including at an undergraduate level.

There are two main challenges. First are epistemic and methodological gaps: natural and human archives offer evidence on different scales, seasons, and have distinct uncertainties. Aligning them demands careful cross-dating, calibration, and transparent source criticism, without privileging one archive over another. Overviews explicitly flag these issues (e.g., Ludlow, Travis 2019; Nash et al. 2021; Izdebski et al. 2022), as well as warning against climate determinism, urging researchers to articulate mechanisms while acknowledging limitations. Second are collaboration and training hurdles: historians and scientists use different vocabularies, metrics, and standards of proof; effective consilience requires shared frameworks, versioned and open data, and reproducible methods, ideally taught from undergraduate levels onward and embedded in joint projects (McCormick 2011; 2019).

2 Reading Irish Dendrochronological Records

From the late 1960s, dendrochronologists (Michael Baillie, David Brown, Jonathan Pilcher and colleagues) at Queen's University Belfast began assembling tree-ring growth width measurements from the island's two native oak species (Sessile and Pedunculate), both being suited to chronology development given their longevity, clear annual rings, and a relative (though not total) absence of missing, partial, or false rings. By overlapping ring-widths from living oaks with ring-widths from historic structural timbers (e.g., from church roofs or archaeological sites like medieval mills), and again with ring-widths from even older 'subfossil' oaks preserved in the anaerobic conditions of peat bogs and lake margins, they built long annual-resolution chronologies that anchored contemporary tree-rings to those of deep time. One milestone was a 7,272-year Western European oak chronology integrating material from the north of Ireland, Britain, and Germany (Pilcher et al. 1984). Student-friendly summaries of this endeavour are given by Baillie (1982; 1995), Pilcher and Brown (2014) and Plunkett et al. (2024).

Scholars have long recognised that the annual growth rate of trees varies under the influence of weather, offering a means to 'reconstruct' past climatic conditions before the era of instrumental weather recording (Douglass 1919). A landmark of this dendroclimatological approach is the 1,100-year reconstruction from high-elevation Bristlecone Pines in California's White Mountains (La Marche 1974). In Ireland, while early oak chronology building was undertaken to refine the radiocarbon calibration curve and deliver precise dates for archaeological contexts from which oak samples could be obtained (Baillie 1982; 1995), early studies did compare modern oak chronologies with nearby meteorological station data to ascertain whether a clear enough climate signal existed for climatic reconstruction (Hughes et al. 1978; Briffa et al. 1983). However, Ireland's mild maritime climate complicated these efforts. Unlike Bristlecones growing in harsh 'temperature-limited' sites at high elevations, Irish oaks do not usually inhabit a climatically 'marginal' growth environment, so their ring widths integrate multiple meteorological influences in a manner that can be difficult to untangle.[2] These can even include non-growing-season conditions. For example, Irish oaks tend to grow more poorly after mild winters. A possible explanation is that such winters, not uncommon in Ireland, sustain metabolic activity during an intended period of dormancy, consuming carbohydrates ideally reserved for the following year's growth (Pilcher, Gray 1982). Given these issues, García-Suárez, Butler and Baillie (2009) noted that dendroclimatic reconstructions using Irish oaks had for several decades been largely set aside.

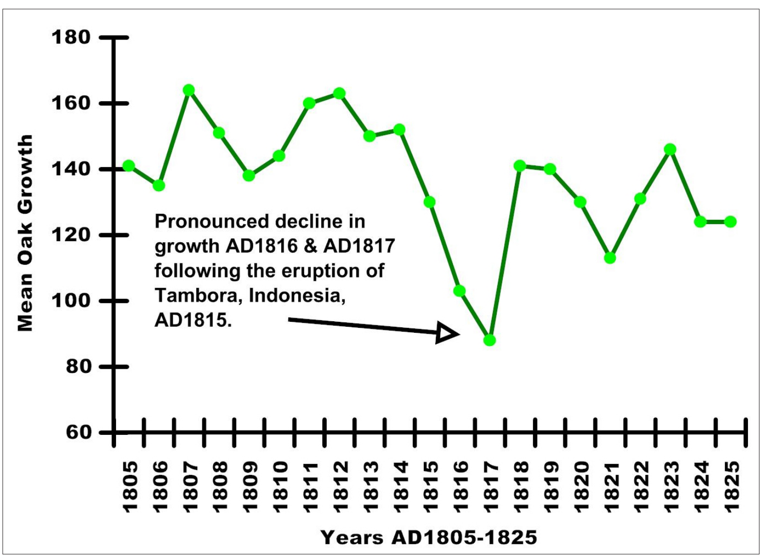


Figure 1 Annual mean ring width index of Irish oak growth, AD1805-1825. Data: Michael Baillie and David Brown. Figure after Ludlow 2011

2 In reality, all trees do this, but dendroclimatology is more straightforward for 'marginal' locations (e.g., high altitude, high latitude, arid) where growth is mainly controlled (directly or indirectly) by one dominant climatic variable (e.g., temperature, precipitation).

Even so, long Irish oak chronologies reveal years of markedly reduced growth (Baillie, Munro 1988; Baillie 1995). When these 'poor-growth' years occur across widely separated sites in and beyond Ireland, a climatic cause is likely, with few other mechanisms able to impose such broad coherence on growth (Kelly et al. 1989). After the April 1815 Tambora eruption, which depressed European temperatures and produced the 1816 'year without a summer', Irish oak growth contracted sharply in 1816 and in 1817 exhibited a deep growth minimum **[fig. 1]**. Moreover, with improved statistical approaches, dendroclimatologists have successfully incorporated Irish oaks in the landmark Old World Drought Atlas (Cook et al. 2015). This finds sufficiently consistent sensitivity in the oaks to reconstruct Irish (and European) soil moisture for the Common Era using a grid of 5,414 0.5-degree cells (~50 km each, depending on latitude). Combining multiple species (oak, Scots pine, beech, ash, etc.), each with different climate sensitivities, offers further insights into climate history before instrumental weather records become more consistent in Ireland in the late eighteenth century (notably at Armagh Observatory; Butler et al. (2005)), although non-oak chronologies are not yet especially long (García-Suárez, Butler, Baillie 2009).

Beyond contributing to Irish climate history and historical dating, the oaks have also contributed to the history of Irish architecture, demography, settlement and landscape management (e.g., Baillie 1994; 2006; Brown, Baillie 2012; Adelman, Ludlow 2014; Ludlow, Crampsie 2018; Campbell, Ludlow 2020). Thus, we emphasize their importance as an archive for environmental historians and offer a reflective 'reading' of one notable oak sample, drawing from our own undergraduate and postgraduate teaching. This provides a model for others to adapt, including by using tree-ring chronologies more relevant to their own regions.[3] Several thousand chronologies are accessible from the International Tree-Ring Data Bank (ITRDB) globally,[4] although their distribution favours temperate, boreal (or high elevation) zones where pronounced seasonal cycles promote distinct growing season ring formation.[5]

3 Rubino and Baas (2019) provide a well-illustrated introduction to dendrochronology, focusing on the dating of North American buildings and cultural landscapes, ideal for teaching.

4 https://www.ncei.noaa.gov/products/paleoclimatology/tree-ring.

5 Scarcity of chronologies from tropical and sub-tropical regions reflects a lack of clear seasonal cycles that promote clear annual ring formation, but also reflect past funding biases, though availability is increasing (Groenendijk et al. 2025). Anchukaitis (2017) provides a map of ITRDB chronologies.

3 Testimony of Sample Q11445

Figure 2 shows a sample taken from a mature oak that had grown on the Great Lawn of the Botanic Gardens Park, Belfast, but was felled in January 2012, on which occasion Jonathan Pilcher and David Brown, dendrochronologist at the Dendrochronology Lab, Queen's University Belfast, procured a sample. Because the tree was deliberately felled, having been assessed as unstable, there was no need to use a non-destructive tree-ring borer to extract a straw-width sample for ring-width measurement. Instead, a chainsaw was used to take a larger sample running 55.3cm from bark to core (including first ring and pith), giving a more intuitive picture of the tree's response to its growing conditions through time. The sample was assigned a Q code (Q11445), a number that implies the many thousands of samples processed up to 2011.[6] Preparation for ring measurement involved polishing the sample and the application of chalk powder which, when brushed across the sample, reveals the larger 'early growth vessels' that transport nutrients vertically through the growing ring. These are visible as lines of white dots that reveal each year's annual growth onset in spring (around April).

Figure 2 Full image of oak sample Q11445 from the Botanic Gardens Park, Belfast, comprising 180 annual rings, 1832 to 2011, inclusive. Photograph by the Authors

Ring counting returned an age of 180 for this oak, which had its first ring in 1832. With a known felling date of 2011, the years across which its growth spanned did not require identification by the cross-dating required for timbers from historical, archaeological or natural contexts for which rings can be counted and measured but are of initially unknown date.[7] Q11555 can be used as a witness

6 Ring width measurements for each sample counted at Belfast and listed by Q code can be found at `https://chrono.qub.ac.uk/bennett/dendro_data/dendro.html`.

7 Rubino and Baas (2019) describe the cross-dating procedure in which patterns in the width of tree-rings from a sample of unknown age are matched against patterns in a sample for which the date of each ring is known. If a match is found, ages can be transferred from the rings of the already dated sample. Baillie (1982; 1995) discusses this for Ireland.

statement for the oak's local environment, one of special interest to the history of botany in Ireland (for which see Synnott 1997), presumably being planted shortly after the opening of the Botanic Gardens Park, Belfast, in 1828. While the tree avoided the adverse climate following Tambora's eruption in 1815, the evidence of its rings shows that it still experienced variable fortunes with prolonged periods of greater and lesser growth, punctuated by specific years of anomalously poor growth.

In some years, the tree suffered alongside the humans under whose management it grew, as when droughts impacted its growth. In other cases of human suffering, as during the Great Irish Famine of 1845-52, it appears indifferent, perhaps even benefitting from the above-average precipitation of these years (Murphy et al. 2017), when it exhibits some of the widest rings in its 180 years. Much of the large size of these rings should, however, be attributed to the 'early growth trend' (or juvenile growth) that is well-known to tree-ring specialists. This is a distinctive feature that many students will remark upon when studying an image of Q11445 and is clearly visible in ring-width measurements **[fig. 3]**. The early growth trend is driven by physiology and geometry (not weather, which albeit still influences year to year variation),[8] in which younger trees grow larger rings (on average) for the first few decades of their life, but decreasingly so, as each year's growth must spread around a larger circumference.

This offers a good starting point for students to discuss the challenges of tree-rings as sources of climate information. Dendroclimatologists address this issue in various ways. This includes the selection of samples from mature trees with many rings so that those affected by the early growth trend may be discarded or 'averaged out' (ultimately both approaches involve ensuring that climate inferences are not based upon a single witness, which is a sentiment that history students should appreciate).[9] It is also possible to address the early growth trend by fitting a line to the ring-width data that models (tracks) the average long-term trend. This can then be subtracted (or otherwise removed) from the data, in a 'detrending' process that leaves only year-to-year or decade-to-decade variation that more specifically reflects climate.

8 As in, shorter term growth variability induced by weather is superimposed upon the early growth trend.

9 Important when the pith or first growth ring of a tree is not identifiable and hence the juvenile growth years cannot be as readily identified.

e-ISSN 2785-2709

Figure 3 Tree-ring-width measurements for Q11445. Years are on the horizontal axes and standardised (relative) ring width measurements are on the vertical axes. Figure courtesy of David Brown

This discussion highlights the issue of growth variation on different time-scales: longer-term (low-frequency) trends that evolve across several decades, superimposed on which is shorter-term (high-frequency) variability occurring year to year or decade to decade. Climate itself varies on these frequencies and dendroclimatologists seek to capture as much of this as possible from their trees, but must reckon with non-climatic influences on growth. While individual oaks respond similarly to large-scale regional influences such as common growing season weather, they are complex biological organisms and will express common influences in somewhat different ways. This partly arises from the mediating influence of local or site-specific environmental contexts, including human activity. For a dendroclimatologist, these influences are studied so that their effects can be removed (as with early growth trends), but for environmental historians (also landscape historians, historical ecologists, historical geographers and others) their main interest in tree-rings may indeed lie in what their variations reveal of human agency. In the context of the managed park in which our oak tree grew, sudden and persistent changes in average growth visible in figure 3 thus have additional potential significance.

These changes are evident in a visually intuitive manner in high-resolution images **[fig. 4]**. Focusing on the years 1832 to 1920, the early growth trend of large rings is readily apparent, including a transitional phase toward maturity from the late 1850s to around 1880, when rings remain generally large, but decreasingly so. The picture then becomes complicated. In the early 1880s, growth briefly plateaus, perhaps marking the onset of its more mature growth phase, but soon exhibits erratic behaviour with a notable short-lived peak in 1890 followed by a deep minimum in 1894 and 1895 (see change of overlay from orange to cyan in figure 4). This episode marks a 'step change' into what (certainly from 1900 onward) can be deemed the tree's mature phase.[10] This exhibits a lower but largely consistent longer-term growth rate, around which annual values oscillate, punctuated by some particularly low values, to which we will return. Students may speculate upon the difficulties of placing a definite end date on the early growth trend, as well as other visible anatomical features, such as the relatively smaller values during the first decade of growth **[fig. 4]**, or the several decades of lighter-coloured rings toward the end of the tree's life **[fig. 1]**.[11]

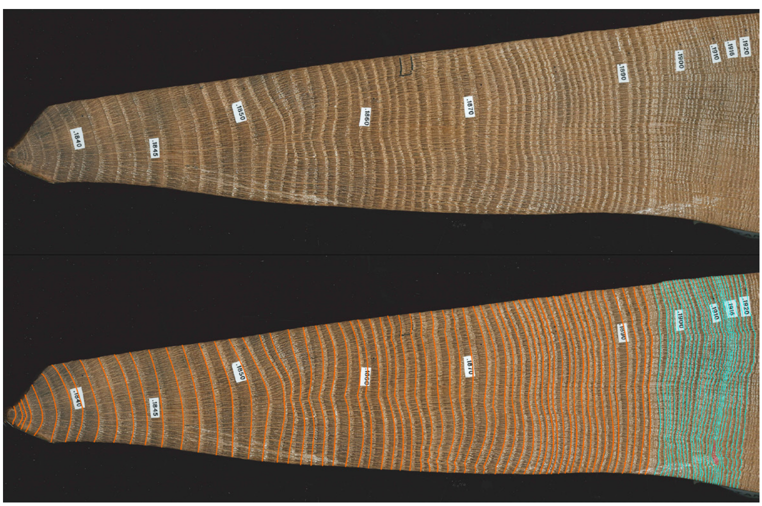


Figure 4 Closer view of first 'half' of Q11445, with coloured overlay on bottom marking the onset of each year's early growth (spring vessels). Photograph by the Authors

10 The transition time from juvenile growth varies between species, and even within species, influenced by local contexts (often lasting longer in open versus enclosed competitive (e.g., woodland) environments), but up to 60 years would not be unusual for oak (Haneca 2005).

11 Students may gain insight by researching early 'disturbance events' and sapwood (Baillie 1982; 1995; Rubino, Baas 2019).

Students can be prepared by select readings that suggest the types of human intervention that can drive large jumps in tree growth (as seen between 1880 and 1900, or post-1970 **[fig. 3]**). Deliberate interventions such as coppicing, pollarding or other pruning,[12] plus accidental damage, can suppress growth for multiple years (Bridge et al. 1986; Gilman 2015; Muigg et al. 2020; Sanmiguel-Vallelado et al. 2024), as can soil compaction (Day, Bassuk 1994). Thinning of stands can benefit the remaining trees with less competition for light, water and nutrients (Attocchi 2015). In contrast, changes to local hydrology caused by extraction (e.g., wells), paving, drainage or other construction may alter groundwater access to the temporary or longer-term benefit or detriment of growth (e.g., Netsvetov et al. 2019).[13] These concerns naturally invite students to consider the history of the Botanic Gardens Park and the wider cultural and scientific context of the period. For this, they can find a starting place in the major dates of the Park's history supplied by the Friends of the Botanic Gardens Park, Belfast.[14] Dates of potential relevance include new feature and exhibit construction, changes to the Park's ownership (and, relatedly, visitor numbers) and uses. All can be explored as potential influences on the Park's local environment and management regime, and compared to patterns seen in figures 3 and 4.

McCracken (1971) and Scott (2000) provide more depth for lesson plans but, in brief, the Park started as a private venture of the Belfast Botanic and Horticultural Society (established 1827) and opened on a 14-acre site in 1828. The opening and subsequent efforts in planting diverse flora and constructing exhibits occurred in the context of the transition into the Victorian Era (1837-1901) boom for naturalist and scientific societies. National bodies such as the Royal Geographical Society (1830) and the Royal Microscopical Society (1839) facilitated provincial field clubs that arranged lectures, trips and specimen exchanges. Railways and cheap print accelerated these networks. The royal garden at Kew (England) was given over as a public botanic garden in 1840 and other municipal botanic gardens flourished. These provided collections and venues for public science that increasingly involved the middle classes,

12 Coppicing occurs low to the ground, with regrowth producing multiple small shoots for fuel, charcoal, fencing, etc.. Pollarding occurs higher up and (beyond any intended uses for the resulting regrowth) may include removal of branches for safety or aesthetic purposes, especially in garden settings. Students visiting the Park can be tasked with inspecting for evidence of either practice.

13 When benefitting a tree, these factors may trigger a rapid impulse in growth (a 'growth release').

14 https://fobbg.co.uk/welcome/belfast-botanic-gardens/botanic-gardens-history/.

including in Belfast (Johnson 2025), which boasted societies such as the Belfast Natural History and Philosophical Society (1821) (Synnott 1997; Finnegan 2025). Science continued to professionalize with laboratories, standard terminologies, journals and university posts, though amateur naturalists remained important.[15] Colonial and other networks of correspondence, collecting and exchange tied this together,[16] progressing natural history from an elite pastime into a mass civic but also increasingly professional endeavor.

In the Park, our oak grew near the southernmost corner of the Great Lawn, next to a busy pathway and near to major developments **[fig. 5]**.[17] In its early life it 'witnessed' (on 22 June 1839) the laying of the foundation stone of the famous Palm House (lying roughly 120m north-northwest) with its two wings finished in 1840 and a central dome added in 1852. Closer, and 68m slightly uphill west-northwest, was the 33.5m-long enclosed and heated Tropical Ravine house. This was under construction from the mid-1880s and opened in 1889 under head gardener Charles McKimm, with some 5,000 paying visitors in 1890 (McCracken 1971).[18] Our oak also experienced events with major attendance, not least the roughly 300,000 at the Unionist Convention in 1892.[19] In 1893, Belfast Corporation bought the Park and on January 1st 1895 opened it free to the public, investing in further works, including the extension of the Tropical Ravine between 1900 and 1902 (now 56m long).[20] Students may usefully discuss these developments as plausible causes of environmental disturbance (contributing to the growth trends and notable variability discussed earlier) by soil turnover, compaction, root disturbance or drainage changes, with the conversion to a public park also potentially

15 The Park's entanglements in these processes can be glimpsed in the botanical observations of Thompson (1847) and the remarks of Dickie (1864; preface).

16 The Park featured in the *International Exchange List of the Smithsonian Institution* of 1897, p. 247.

17 The map in figure 5 was accessed via the Department for Communities' HERoNI Map Viewer: `https://experience.arcgis.com/experience/8bb16b64f0994385a5c141027ae9d33e/`. The landscape of the Park can be traced through time in several other historical maps here.

18 See `https://www.belfastcity.gov.uk/Things-to-Do/Tropical-Ravine/History-of-the-Tropical-Ravine`.

19 Students can profitably search the digital collections of National Museums NI for historical images of the Park, including major events such as the 1892 convention. See, e.g., images from the Welch collection via `https://collections.nationalmuseumsni.org/home`.

20 A warmer "stove" section was added in 1900, with a further 1902 extension for a heated pond for the giant Victoria waterlily (McCracken 1971).

e-ISSN 2785-2709

bringing new maintenance routines.[21] Later, the Park accumulated more features and uses, including playing fields (1930), a rose garden (1932) and wartime allotments (1940s) (McCracken 1971). Further refurbishments occurred in 1983 (Palm House and Ravine) and from 2013 to 2018, when the Tropical Ravine was restored (Scott 2000; Patman, Armstrong 2020).

Figure 5 Left: Approximate former location of Q11445 oak tree (333701, 372418 TM65 Irish National Grid, north is up), looking southeast toward the corner of the Great Lawn from the vicinity of the Tropical Ravine house. Right: Annotated six-inch County Series map (3rd edition, 1900-32) centred on the Botanic Garden Park, Belfast. 1. General location of Q11445, at which there are deciduous trees persistently (if probably diagrammatically) noted on historical maps. 2. Tropical Ravine House. 3. Palm House. Photograph by the Authors, taken on 12 September 2019

4 Comparing Witnesses: Reading Q11445 and the IDID

Even absent the microscope used when formally measuring ring widths, native oaks in Ireland characteristically produce rings wide enough to see unaided, making any scanner with moderate resolution a useful tool in capturing growth variation for students to study. At moderate zoom, figure 6 reveals several aspects of the tree-ring counting and measurement process at Belfast. These are akin to manuscript notations (glosses) with which history students will be familiar, the interpretation of which makes for useful discussion. Sample Q11445 has also had special glossing, with labels added to identify (usually) every tenth year as an interpretative guide.

21 Charles McKimm, the force behind late-Victorian improvements, was made General Superintendent of Parks for Belfast in 1903, promoting a citywide approach to park management.

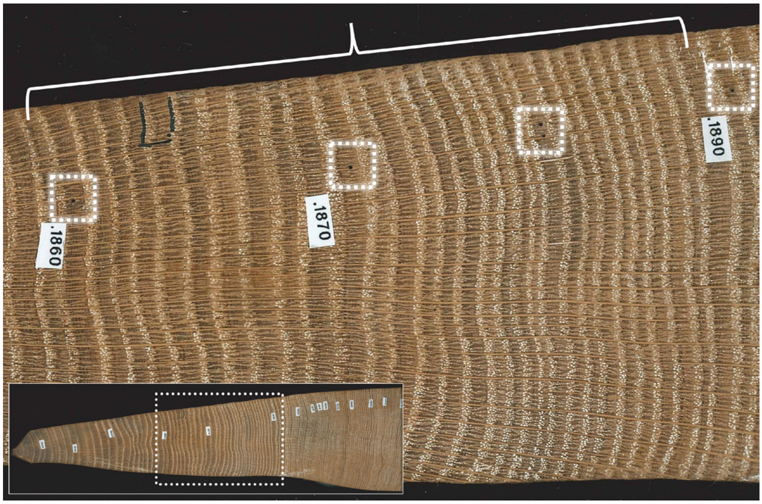


Figure 6 Section of Q11445 covering 1859 to 1891, with annotations by David Brown as guide in the counting process (small pin holes highlighted in white squares that mark the first year of each decade), plus labels showing the final year in each decade. Students may note that pin holes periodically change to doubles and triples, denoting 50 and 100 years counted, respectively. The upper white bracket demarcates 31 years from 1860 to 1890, inclusive, and students can be asked to see if their own count totals 31. Counting can also be attempted on later portions when the rings are smaller and more irregular. Photographs by the Authors

An advantage in the study of Irish environmental history is the island's rich written record, including some of the longest running newspapers globally, spanning from 1733 to present. Over 100 different newspapers (more than six million pages of content) are available through the Irish Newspaper Archives (INA), a searchable online database containing the largest digital archive of historic Irish newspapers.[22] Although the INA does not contain all Irish newspapers, it offers a representative sample of Irish local and national titles that sees ongoing expansion. The INA has already been used in climate research, such as the study of 19th and 20th century droughts and their socio-economic impacts (Noone et al. 2016; Murphy et al. 2017). It has also been exploited to systematically identify and categorise drought impacts between 1733 and 2019 within the Irish Drought Impacts Database (IDID) (Jobbová et al. 2024).

The IDID comprises 11,000 individual impact records drawn from 6,000 newspaper articles and is freely accessible online (Jobbová et al. 2022),[23] detailing the spatiotemporal extent of droughts, their socio-economic and political contexts, reported consequences and

22 `https://www.irishnewsarchive.com`.

23 `https://zenodo.org/records/7216126`.

any mitigation strategies adopted. As a teaching resource, it can be paired with other archives to demonstrate the value of employing multiple lines of evidence. When newspaper accounts are compared with instrumental weather data, for example, there is a broad but imperfect agreement. Some years that exhibit relatively low precipitation levels can have unexpectedly few newspaper reports of drought, whereas some relatively wetter years contain numerous reports of drought and its consequences **[fig. 7]**. The disparity between instrumental meteorological records and newspaper drought reporting implies that socioeconomic (e.g., agricultural) vulnerabilities that evolve through time and space control what weather conditions are deemed important, making humans sometimes indifferent witnesses to environmental variability. Having students further explore this disparity using sources such as the INA, IDID and instrumental weather data has great potential for self-directed learning, but is beyond our core focus here.

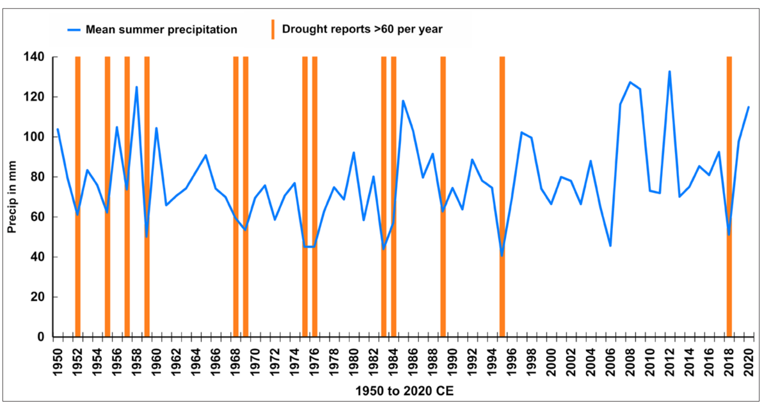
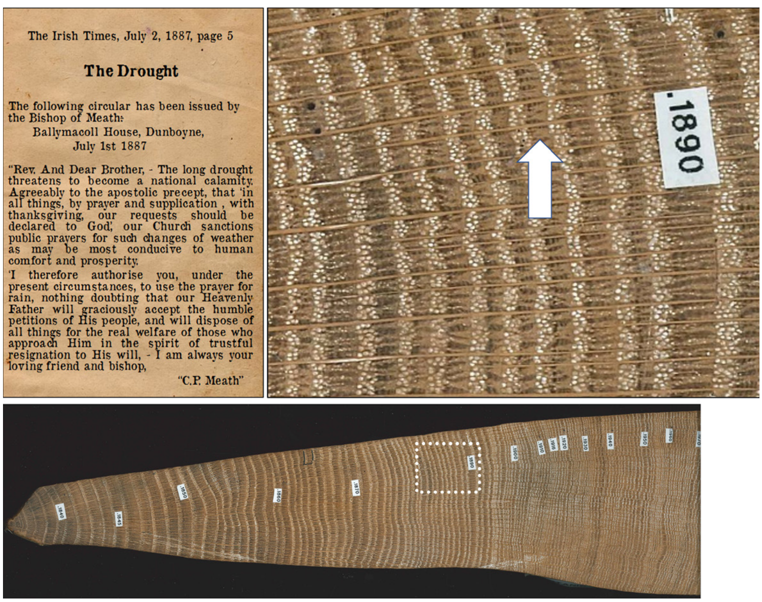


Figure 7 Precipitation and drought reporting, 1950-2020 (after Jobbová et al. 2023). Blue line shows mean Irish June-August rainfall from the Island of Ireland Precipitation Network (Noone et al. 2016; Murphy et al. 2018). Orange bars show years with >60 newspaper reports about drought (60 corresponds with a natural break in the distributions of report frequencies, identifying droughts deemed severe by the print media). The figure illustrates agreements and disparities between more objective meteorological data and droughts considered worthy of news reporting (e.g., year 2006)

Comparing testimonies from the IDID to our oak shows that these trees, like humans, are also complex and sometimes indifferent witnesses. Students can be pointed to the case of the drought in 1887, for which the IDID furnishes abundant evidence. This is identified as one of the most severe droughts for the past 150 years in Ireland (Noone et al. 2017), resulting in widespread crop failure (Barrington 1888). This motivated attempts at mitigation that were dependent upon the prevailing cultural (here Christian religious) context, with *The Irish Times* of 2nd July 1887 issuing a circular from the Bishop of Meath approving prayers against the drought **[fig. 8]**. With the drought commencing in spring and reaching its pinnacle in summer 1887 (essentially the full growing season for oaks), it is reasonable to expect that the growth of our oak would have been curtailed. Yet, as figures 3 and 8 show, the tree grew well this year. This realization usually provokes discussion. Informed by their readings, students may for example consider whether the tree should be considered "complacent" (Fritts 1976; Speer 2010). In complacent trees, their local site is such that there is a relatively accessible water supply even during dry periods (being close to the water table or supplied by human intervention, perhaps more credible in the context of a managed park bordered to the east by the River Lagan).[24]



The Irish Times, July 2, 1887, page 5

The Drought

The following circular has been issued by the Bishop of Meath:
Ballymacoll House, Dunboyne,
July 1st 1887

"Rev. And Dear Brother, - The long drought threatens to become a national calamity. Agreeably to the apostolic precept, that 'in all things, by prayer and supplication , with thanksgiving, our requests should be declared to God,' our Church sanctions public prayers for such changes of weather as may be most conducive to human comfort and prosperity.

'I therefore authorise you, under the present circumstances, to use the prayer for rain, nothing doubting that our Heavenly Father will graciously accept the humble petitions of His people, and will dispose of all things for the real welfare of those who approach Him in the spirit of trustful resignation to His will, - I am always your loving friend and bishop,

"C.P. Meath"

Figure 8 Top left: Extract from *The Irish Times* of 2 July 1887 (after Murphy et al. 2017). Top right: a zoom in to Q11445, with the ring for 1887 indicated with a white arrow. Bottom: general position of the zoom in on the larger sample. Oak sample photographs by the Authors

24 Students may note growth maxima from 1890 to 1892 **[figs 3, 9]**, high relative to the preceding decade. Precipitation levels in these years are not far from the average (Murphy et al. 2018), and do not clearly explain such high growth. Students might thus like to consider a growth release as an explanation.

The IDID again proves useful in testing this interpretation, with a further notable drought just six years later in 1893, and to which Q11445's potential complacency should presumably still apply. Students will find that this was one of the most impactful droughts in nineteenth century Ireland, with 176 records in the IDID (Jobbová et al. 2024). Such was its severity that a rain-making scheme involving the detonation of balloon-lofted dynamite was somewhat wryly proposed **[fig. 9]**. Inspecting the rings for 1893 again implies a tree apparently indifferent to these conditions, but the rings for 1894 and 1895 are different. Figure 9 reveals these as much smaller, and irregular in shape, with little of the 'late wood' that forms after the initial spring growth with its large early vessels. If again primed by their readings of tree-ring literature, students may suggest that this reflects the tendency for oaks (and other species) to exhibit not only multi-year responses to climatic and other shocks, but also a lagged expression.[25] Here, oaks may show minimal impact during a drought year, being sustained by carbohydrate reserves and/or groundwater reserves, but only to postpone the expression of that impact.[26]

Recognizing the potential for such mismatches in timing is critical when using tree-rings to identify climatically stressful years in regions or periods for which human documentation of climate is not abundant.[27] A related nuance is seasonality. Oaks are less sensitive to non-growing season weather,[28] but a lagged or multi-year expression may be more likely if drought occurred in (or continued into) autumn and winter (Babst et al. 2012), perhaps reducing groundwater recharge for the next growing season. One advantage of comparing the Irish oaks and newspapers is that the latter often provide this crucial context and in some cases offer precise drought start/end dates, if still informed by shifting human priorities (Jobbová et al. 2024). Thus, the IDID shows that impacts of the 1893 drought were

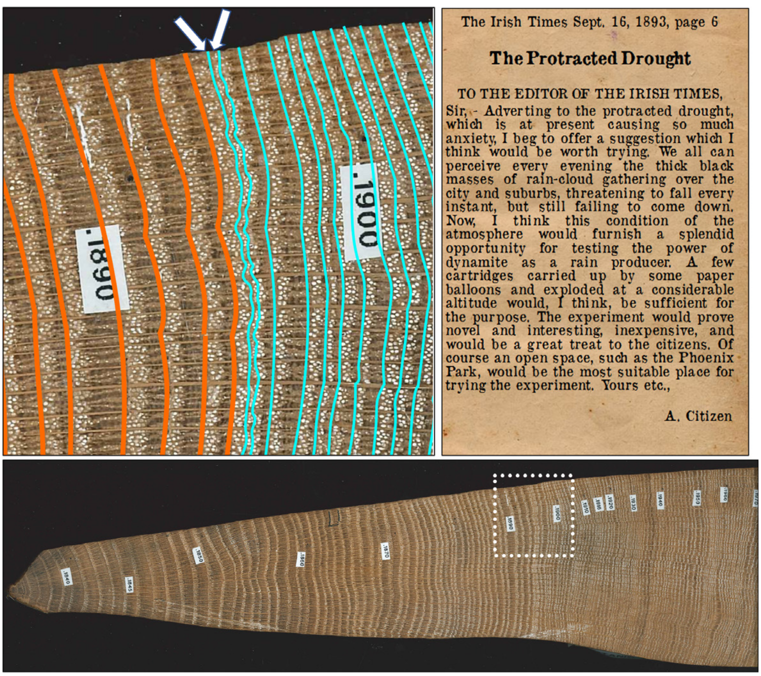
25 One teachable example (simplified here) concerns summer 1540 in Central Europe. Over 300 written reports suggest extreme heat and an 11-month 'mega-drought' (Wetter et al. 2014). This was queried by Büntgen et al. (2015) using tree-ring evidence, which did not support such conditions in 1540. Pfister et al. (2015) then pointed to a possibly lagged tree-ring response with a notable minimum evident in 1541.

26 The 1893 drought and its potentially lagged expression can introduce students to 'autocorrelation' in tree-ring series, in which the width in any given year can be positively correlated with the widths of the preceding few years. Put differently, the width of a ring will be affected not only by the weather or other transient influences in the current year, but also weather and other transient influences in those years immediately preceding.

27 E.g., Ludlow and Kostick (2026) use continental European oak growth minima as independent evidence of drought in explaining famines reported in written sources, 750-1000.

28 Dormancy and associated 'frost hardening' protect oaks from all but the coldest winters, though (conversely), recall the tendency to poor growth following mild Irish winters (main text).

still being reported in June 1894, and newspapers again reported long drought in May and June of 1895, if not as stressful (to humans) as the 1893 drought in terms of impact reports. Nonetheless, our oak grew even more poorly in 1895, with the third narrowest ring in its 180 years **[fig. 3]**, suggesting that the narrow rings of 1894 and 1895 are a compound and partly lagged expression of extended drought conditions across these years. As if further complexity was needed, students may recall that the Park came into new ownership (and potentially new tree and ground management practices) in 1893, being opened free to the public on January 1st, 1895, also potentially impactful in terms of visitor numbers and behaviours.[29]



The Irish Times Sept. 16, 1893, page 6

The Protracted Drought

TO THE EDITOR OF THE IRISH TIMES,

Sir, - Adverting to the protracted drought, which is at present causing so much anxiety, I beg to offer a suggestion which I think would be worth trying. We all can perceive every evening the thick black masses of rain-cloud gathering over the city and suburbs, threatening to fall every instant, but still failing to come down. Now, I think this condition of the atmosphere would furnish a splendid opportunity for testing the power of dynamite as a rain producer. A few cartridges carried up by some paper balloons and exploded at a considerable altitude would, I think, be sufficient for the purpose. The experiment would prove novel and interesting, inexpensive, and would be a great treat to the citizens. Of course an open space, such as the Phoenix Park, would be the most suitable place for trying the experiment. Yours etc.,

A. Citizen

Figure 9 Top left: Zoom in to rings immediately before and after the 1893 drought. Each year's start is outlined just before the onset of early growth (usually April onward) featuring clearly visible large spring vessels (white dots) and the darker (summer) late wood. The switch to cyan lines denotes the start of a step-change to persistently reduced growth from 1894 onward. Arrows denote the anomalously poor growth of 1894 and 1895. Bottom: Location of the zoomed-in section. Top right: *The Irish Times* letter of 16 September 1893, proposing a weather modification scheme (after Murphy et al. 2017). Oak sample photographs by the Authors

29 The great scale of the Unionist Convention in 1892 also makes it a plausible disturbance event, but if it had a significant impact on our oak, it might have been expected to more credibly first register in 1893 rather than in 1894.

e-ISSN 2785-2709

The IDID identifies other droughts which, when compared to the Q11445, offer further lessons. Students can be pointed to evidence of drought in 1938 (114 reports compared to just 7 for 1937), for which the *Irish Press* (21st April) reports that "Large numbers of sheep and lambs are dying from drought on the Glencolumkille, Co. Donegal Mountains [Ulster] [...] Streams have dried up completely". Later, the *Anglo Celt* (23rd April) tells us:

> Never within memory was water so scarce on highland farms in Ballybay neighbourhood [Co. Monaghan, Ulster] at Easter. Farmers have to convey supplies to stock from the lakes. The prolonged drought is retarding the crops and rain is anxiously awaited. The local mills too are experiencing the want of water in the race.

Students may then be tasked with identifying the same year in Q11445 **[fig. 10]**, using their growing understanding of tree-ring counting, aided by the labels already attached to the sample. Here they can identify a narrow ring in 1938 without any apparent multi-year or lagged impact. They may note that newspapers identify the drought mainly at the start of the spring growing season and into early summer (especially April to May), with apparent recovery later.[30] These circumstances may have credibly confined the tree-ring expression of drought to 1938.

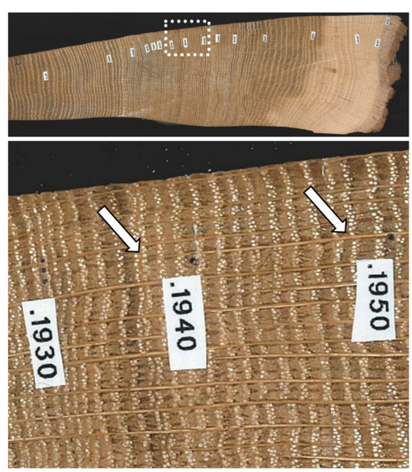


Figure 10
Bottom: Zoom in to rings for the 1930s and 1940s, with drought years (1938 and 1949) indicated by arrows. Top: General location of these decades in Q11445.
Photographs by the Authors

30 E.g., the *Evening Echo* (27th July 1938), states: "Meadowing, though in some cases short because of earlier drought of April and May, promises on the whole a fairly good return, with most of it saved in good condition. [...] In some places mangolds and turnips were disappointing but have shown improvement with the better turn of the weather".

A further consideration is that Ulster, the province in which our oak grew, was clearly affected in 1938. Although Ireland is small, and droughts or frosts associated with large-scale anti-cyclonic conditions are usually felt widely, there can be meaningful geographical variation in their severity. Even beyond local site factors like soil, slope, aspect and elevation, tree-rings from different regions will display some difference in patterns that increases (generally) with distance. Indeed, an instructive early episode in Irish dendrochronology was a dispute over whether there was such significant variation in British Isles climate on small scales (including microclimates) that dendrochronology would not work to build larger regional chronologies because there would be insufficient commonality in growth patterns to enable cross dating (Fletcher 1980; 1986). This was incorrect (Baillie 1980; 1983; 1984; Baillie et al. 1985).[31] Nonetheless, understanding the geographical extent of droughts is a key piece of the puzzle in reading tree-rings. Conversely, spatial variations in tree growth can allow us to reconstruct the spatial character of droughts and pluvials across Europe into the past when written records are scarce (e.g., Cook et al. 2015).

Irish newspapers often report the area most affected by droughts and, as noted, the IDID attempts to capture their geographical (and temporal) dimensions.[32] For example, drought in 1949 is identified as one of the three most impactful droughts in the entire record (179 reports), yet Q11445 does not register any growth minimum in that year or immediately after **[fig. 10]**.[33] Mapping entries in the IDID indicates that agriculture and livestock impacts were greatest in the east and southeast and, while public water supply impacts were widely reported, the north of the island (including Belfast) appears

31 Baillie (1995,16) notes: “studies of oak growth have shown that there is a strong common element to the patterns over surprisingly large geographical areas”. Common weather variation across a region (i.e., climate) is the only factor that can explain this. Part of J.M. Fletcher’s skepticism about whether dendrochronology would ‘work’ across the British Isles was the provenance of the tree-rings he counted. These came from art-historical panels from paintings and the rings from these samples showed little common variation with British oaks. However, these panels were made from imported Baltic oaks that naturally experienced little weather in common with oaks from the British Isles. This discovery has had many applications: by finding which regional chronologies a given oak sample best matches, it can reveal patterns of historical trade in timber or timber products (e.g., Daly, Tyers 2022; Seim et al. 2024).

32 When using the IDID, it should be noted that even if the database entry indicates that the specific drought has occurred at a given place and time, that does not mean that it *only* occurred there and then.

33 Note, 1949 does not clearly appear among the most extreme drought events in instrumental meteorological records.

e-ISSN 2785-2709

less affected **[fig. 11]**.[34] It must, however, be kept in mind that fewer newspapers from the six counties of Northern Ireland are included in the INA, which may exaggerate the apparent lack of severity here.

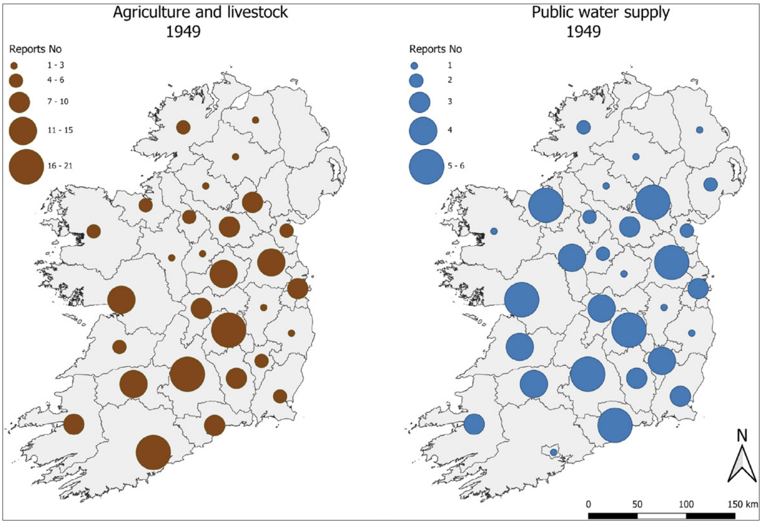


Figure 11 Most frequent impact categories for the 1949 drought, with size of the circle indicating number of reports of impacts (IDID) per county (after Jobbová et al. 2024)

5 Conclusion

Sweeney (1997, 255) describes Ireland as "a meteorological sentry post for much of northwestern Europe" and notes that:

> It is in its vicinity that the skirmishes between air masses which determine the climatic fingerprints of much of the continent are often first observed, and their sting removed. It is here that the harbingers of weather for areas further east may be first assessed and the knowledge used to provide early warning of imminent weather events […] and it is in the vicinity of Ireland that any significant changes in oceanic circulation associated with global warming in Europe will be first detected.

34 Reports indicate dry conditions already in April 1949 and by the end of June many counties especially in the south-east reported serious water shortages, with water rationing. Rain was only reported in July.

Reading the Irish oak tree-ring record alongside that of the Irish newspapers, making use of the full span of reliable historical recording from the early 1700s to the present, and earlier making use of sources such as Irish medieval annals that also document extreme weather for many centuries,[35] can tell us much about the biases and priorities of both species as witnesses to Irish climate history and how both interacted through time. Similar readings can be undertaken in the many regions for which tree-ring chronologies are available. Even if restricted to Ireland, a systematic use of the Irish oaks is a task that can occupy many students and scholars interested in the multiple centuries of Irish history for which these trees have acted as witnesses.[36] In writing this paper, we have endeavored to highlight (including in our footnotes) potential classroom discussion points, exercises and online resources, including the tree-ring data itself, alongside complementary archives. It is hoped that this brief paper will serve as a useful and transferable model to help promote training in the cross-disciplinarity and diversification of sources that is the hallmark of excellent research in the environmental humanities (e.g., Campbell 2016; Grillo 2022; Arnoux 2023).

Acknowledgements

The authors thank Rory Connolly and two anonymous reviewers for valuable feedback on earlier versions of this text. We thank Jonanthan Pilcher for information on the Botanic Gardens Park, Belfast. This paper builds upon work undertaken as part of the Irish Drought Memories project, funded by an Irish Research Council grant (COALESCE/2019/43), and represents a contribution to the European Research Council (ERC) Synergy 4-OCEANS project (grant agreement no. 951649) under the European Union's Horizon 2020 research and innovation programme.

35 Available in translation at the Corpus of Electronic Texts (CELT): `https://celt.ucc.ie`. See Ludlow; Travis 2019 and Campbell; Ludlow 2021 for such a usage.

36 Students may consider many other events in reading Q11445 or other oaks. These include 'mast years' with superabundant acorn production that potentially drain a tree's reserves, major windstorms that might suppress oak growth if branches are lost (or might facilitate growth if a tree's competitors were felled), or outbreaks of various fungal, insect, bacterial or viral pathogens that can impact growth.

Bibliography

Adelman, J.; Ludlow, F. (2014). "The Past, Present and Future of Environmental History in Ireland". *Proceedings of the Royal Irish Academy*, 114C(7), 359-91, https://doi.org/10.3318/priac.2014.114.07.

Anchukaitis, K. (2017). "Tree Rings Reveal Climate Change Past, Present, and Future". *Proceedings of the American Philosophical Society*, 161(3), 244-63. https://api.semanticscholar.org/CorpusID:146475538.

Arnoux, M. (2023). *Un monde sans ressources: Besoin et société en Europe (XIe–XIVe siècles)*. Paris: Éditions Albin Michel.

Attocchi, G. (2015). *Silviculture of Oak for High-Quality Wood Production* [PhD Dissertation]. Uppsala: Swedish University of Agricultural Sciences. https://pub.epsilon.slu.se/12078/1/attocchi_g_150402.pdf.

Babst, F.; Carrer, M.; Poulter, B.; Urbinati, C.; Neuwirth, B.; Frank, D. (2012). "500 Years of Regional Forest Growth Variability and Links to Climatic Extreme Events in Europe". *Environmental Research Letters*, 7, 045705. https://doi.org/10.1088/1748-9326/7/4/045705.

Baillie, M.; Hillam, J.; Briffa, K.; Brown, D.M. (1985). "Re-Dating the English Art-Historical Tree-Ring Chronologies". *Nature*, 315, 317-19. https://doi.org/10.1038/315317a0.

Baillie, M.G.L. (1980). "Dendrochronology – the Irish View". *Current Archaeology*, 73, 61-3.

Baillie, M.G.L. (1982). *Tree-Ring Dating and Archaeology*. London: The University of Chicago Press.

Baillie, M.G.L. (1983). "Is There a Single British Isles Oak Tree-Ring Signal?". Aspinall, A.; Warren, S.E. (eds), *Proceedings of the 22nd Symposium on Archaeometry* (University of Bradford, Bradford, U.K., 30 March-3 April 1982). Bradford: School of Physics & Archaeological Sciences, University of Bradford, 73-82.

Baillie, M.G.L. (1984). "Some Thoughts on Art-Historical Dendrochronology". *Journal of Archaeological Science*, 11(5), 371-93. https://doi.org/10.1016/0305-4403(84)90019-0.

Baillie, M.G.L. (1994). "Dendrochronology Raises Questions About the Nature of the AD 536 Dust-Veil Event". *The Holocene*, 4, 212-17. https://doi.org/10.1177/095968369400400211.

Baillie, M.G.L. (1995). *A Slice Through Time: Dendrochronology and Precision Dating*. London: B.T. Batsford.

Baillie, M.G.L. (2006). *New Light on the Black Death*. Stroud: Tempus.

Baillie, M.G.L.; Munro, M.A.R. (1988). "Irish Tree Rings, Santorini and Volcanic Dust Veils". *Nature*, 332, 344-6. https://doi.org/10.1038/332344a0.

Barrington, R.M. (1888). "The Drought of 1887, and Some of its Effects on Irish Agriculture". *Journal of The Statistical and Social Inquiry Society of Ireland*, 9, 223-47. http://hdl.handle.net/2262/6122.

Bridge, M.C.; Hibbert, F.A.; Rackham, O. (1986). "Effects of Coppicing on the Growth of Oak Timber Trees in the Bradfield Woods, Suffolk". *The Journal of Ecology*, 74(4), 1095-102. https://doi.org/10.2307/2260236.

Briffa, K.R.; Jones, P.D.; Wigley, T.M.L.; Pilcher, J.R.; Baillie, M.G.L. (1983). "Climate Reconstruction from Tree Rings: Part 1, Basic Methodology and Preliminary Results for England". *Journal of Climatology*, 3, 233-42. https://doi.org/10.1002/joc.3370030303.

Brown, D.; Baillie, M. (2012). “Confirming the Existence of Gaps and Depletions in the Irish Oak Tree-Ring Record”. *Dendrochronologia*, (30), 85-91. `https://doi.org/10.1016/j.dendro.2010.09.003`.

Büntgen, U. et al. (2015). “Commentary to Wetter et al. (2014): Limited Tree-Ring Evidence for a 1540 European ‘Megadrought’”. *Climatic Change*, 131, 183-90. `https://doi.org/10.1007/s10584-015-1423-1`.

Butler, C.J.; García-Suárez, A.M.; Coughlin, A.D.S.; Morrell, C. (2005). “Air Temperatures at Armagh Observatory, Northern Ireland”. *International Journal of Climatology*, 25, 1055-79. `https://doi.org/10.1002/joc.1148`.

Campbell, B.M.S. (2016). *The Great Transition: Climate, Disease and Society in the Late-Medieval World*. Cambridge: Cambridge University Press.

Campbell, B.M.S.; Ludlow, F. (2020). “Climate, Disease and Society in Late-Medieval Ireland”. *Proceedings of the Royal Irish Academy*, 120C, 159-252. `https://doi.org/10.3318/priac.2020.120.13`.

Cook, E.R. et al. (2015). “Old World Megadroughts and Pluvials During the Common Era”. *Science Advances*, e1500561. `https://doi.org/10.1126/sciadv.1500561`.

Daly, A.; Tyers, I. (2022). “The Sources of Baltic Oak”. *Journal of Archaeological Science*, 139, 105550. `https://doi.org/10.1016/j.jas.2022.105550`.

Day, S.D.; Bassuk, N.L. (1994). “A Review of the Effects of Soil Compaction and Amelioration Treatments on Landscape Trees”. *Arboriculture & Urban Forestry*, 20(1), 9-17. `https://doi.org/10.48044/jauf.1994.003`.

Davison, D.M.; Miller, K.W.; Metheny, D.L. (1995). “What Does Integration of Science and Mathematics Really Mean?” *School Science and Mathematics*, 95(5), 226-30. `https://doi.org/10.1111/j.1949-8594.1995.tb15771.x`.

Dickie, G. (1864). *A Flora of Ulster, and Botanist’s Guide to the North of Ireland*. Belfast: C. Aitchison.

Douglass, A.E. (1919). *Climate Cycles and Tree Growth: A Study of the Annual Rings of Trees in Relation to Climate and Solar Activity*, vol. 1. Washington: Carnegie Institution of Washington.

Finnegan, D.A. (2025). “Science in 19th-Century Belfast”. Murphy, E.; Donnelly, C. (eds), *Antrim History and Society: Interdisciplinary Essays on the History of an Irish County*. Dublin: Geography Publications, 549-72.

Fletcher, J. (1980). “Does Dendrochronology Work?” *Current Archaeology*, 71, 374-5.

Fletcher, J. (1986). “Dating of Art-Historical Artefacts”. *Nature*, 320, 466. `https://doi.org/10.1038/320466a0`.

Fritts, H.C. (1976). *Tree Rings and Climate*. London, New York, San Francisco: Academic Press.

García-Suárez, A.M.; Butler, C.J.; Baillie, M.G.L. (2009). “Climate Signal in Tree-Ring Chronologies in a Temperate Climate: A Multi-Species Approach”. *Dendrochronologia*, 27, 183-98. `https://doi.org/10.1016/j.dendro.2009.05.003`.

Garrard, G. (ed.) (2012). *Teaching Ecocriticism and Green Cultural Studies*. London: Palgrave Macmillan.

Gilman, E.F. (2015). “Pruning Severity and Crown Position Influence Aspect Ratio Change”. *Arboriculture & Urban Forestry*, 41(2), 69-74. `https://doi.org/10.48044/jauf.2015.008`.

Grillo, P. (2022). “Introduzione: fra storia umana e storia della natura”. Albini, G.; Grillo, P.; Raviola, B.A. (a cura di), *Il fuoco e l’acqua: Prevenzione e gestione dei disastri ambientali fra Medioevo e Età Moderna*. Milano: Pearson Education Resources Italia; Università degli Studi di Milano, 3-15.

Groenendijk, P. et al. (2025). “The Importance of Tropical Tree-Ring Chronologies for Global Change Research”. *Quaternary Science Reviews*, 355, 109233. https://doi.org/10.1016/j.quascirev.2025.109233.
Haneca, K. (2005). *Tree-Ring Analyses of European Oak: Implementation and Relevance in (Pre-)Historical Research in Flanders* [PhD Dissertation]. Ghent: Ghent University.
Hughes, M.K.; Gray, B.; Pilcher, J.; Baillie, M.G.L.; Leggett, P. (1978). “Climatic Signals in British Isles Tree-Ring Chronologies”. *Nature*, 272, 605-6. https://doi.org/10.1038/272605a0.
Izdebski, A. et al. (2016). “Realising Consilience: How Better Communication Between Archaeologists, Historians and Natural Scientists can Transform the Study of Past Climate Change in the Mediterranean”. *Quaternary Science Reviews*, 136, 5-22. https://doi.org/10.1016/j.quascirev.2015.10.038.
Izdebski, A. et al. (2022). “L’émergence d’une Histoire Environnementale Interdisciplinaire: Une Approche Conjointe de l’Holocène Tardif”. Traduit par A. Heudre. *Annales Histoire, Sciences Sociales*, 77(1), 11-58. https://doi.org/10.1017/ahss.2022.114.
Jobbová, E. et al. (2022). “Irish Drought Impacts Database v.1.0 (IDID) (v.1.0.) [Data set]”. *Zenodo*. https://doi.org/10.5281/zenodo.7216126.
Jobbová, E. et al. (2023). “Institutional Management and Planning for Droughts: a Comparison of Ireland and Ontario, Canada”. *Biology and Environment, Proceedings of the Royal Irish Academy*, 123, 1-24. https://doi.org/10.1353/bae.2023.a905271.
Jobbová, E. et al. (2024). “The Irish Drought Impacts Database (IDID): A 287-Year Database of Drought Impacts Derived from Newspaper Archives”. *Geoscience Data Journal*, 11(4), 1007-23. https://doi.org/10.1002/gdj3.272.
Johnson, A. (2025). “The Middle Class of Victorian Belfast”. Murphy, E.; Donnelly, C. (eds), *Antrim History and Society: Interdisciplinary Essays on the History of an Irish County*. Dublin: Geography Publications, 525-48..
Kelly, P.M.; Munro, M.A.R.; Hughes, M.K.; Goodess, C.M. (1989). “Climate and Signature Years in West European Oaks”. *Nature*, 340, 57-60. https://doi.org/10.1038/340057a0.
La Marche, V.C. (1974). “Palaeoclimatic Inferences from Long Tree-Ring Records”, *Science*, 183, 1043-8. https://www.science.org/doi/10.1126/science.183.4129.1043.
Lim, R.B.T.; Tan, C.G.L.; Voo, K.; Lee, Y.L.; Teng, C.W.C. (2025). “Reflective Perspectives on Interdisciplinary Teaching in Public Health Education: Insights from a Mixed-Methods Approach”. *International Journal for the Scholarship of Teaching and Learning*, 19(1), Article 9. https://doi.org/10.20429/ijsotl.2025.190109.
Ludlow, F. (2011). “Tree Ring Chronology of Meteorological Extremes for Ireland, AD425-1650”. *Irish Meteorological Society Newsletter*, 5, 54-9.
Ludlow, F.; Travis, C. (2019). “STEAM Approaches to Climate Change, Extreme Weather and Social-Political Conflict”. de la Garza, A.; Travis, C. (eds), *The STEAM Revolution: Transdisciplinary Approaches to Science, Technology, Engineering, Arts, Humanities and Mathematics*. New York: Springer, 33-65. https://doi.org/10.1007/978–3–319–89818–6_3.
Ludlow, F.; Crampsie, A. (2018). “Environmental History of Ireland, 1550-1730”. Ohlmeyer, J. (ed.), *Cambridge History of Ireland*. Vol. 2, *Early Modern Ireland, 1550-1730*. Cambridge: Cambridge University Press, 608-37. https://doi.org/10.1017/9781316338773.027.
Mallory, J.P.; Baillie, M.G.L. (1988). “*Tech ndaruch:* The Fall of the House of Oak”. *Emania: Bulletin of the Navan Research Group*, 5, 27-33.

McCormick, M. (2011). "History's Changing Climate: Climate Science, Genomics and the Emerging Consilient Approach to Interdisciplinary History". *Journal of Interdisciplinary History*, 42, 252-73. https://doi.org/10.1162/JINH_a_00214.

McCormick, M. (2019). "Climates of History, Histories of Climate: From History to Archaeoscience". *Journal of Interdisciplinary History* 50, 3-30. https://doi.org/10.1162/jinh_a_01374.

McCracken, E. (1971). *The Palm House and Botanic Garden, Belfast*. Belfast: Ulster Architectural Heritage Society.

Muigg, B. et al. (2020). "Tree Rings Reveal Signs of Europe's Sustainable Forest Management Long Before the First Historical Evidence". *Scientific Reports*, 10, 21832. https://doi.org/10.1038/s41598-020-78933-8.

Murphy, C.; Noone, S.; Duffy, C.; Broderick, C.; Matthews, T.; Wilby, R.L. (2017). "Irish Droughts in Newspaper Archives: Rediscovering Forgotten Hazards?". *Weather*, 72, 151-5. https://doi.org/10.1002/wea.2904.

Murphy, C. et al. (2018). "A 305-Year Continuous Monthly Rainfall Series for the Island of Ireland (1711-2016)". *Climate of the Past*, 14, 413-40. https://doi.org/10.5194/cp-14-413-2018.

Nagle, B. (2013). "Preparing High School Students for the Interdisciplinary Nature of Modern Biology". *CBE – Life Sciences Education*, 12(2), 144-7. https://doi.org/10.1187/cbe.13-03-0047.

Nash, D.J. et al. (2021). "Climate Indices in Historical Climate Reconstructions: a Global State of the Art". *Climate of the Past*, 17, 1273-314. https://doi.org/10.5194/cp-17-1273-2021.

Netsvetov, M.; Prokopuk, Y.; Puchałka, R.; Koprowski, M.; Klisz, M.; Romenskyy, M. (2019). "River Regulation Causes Rapid Changes in Relationships Between Floodplain Oak Growth and Environmental Variables". *Frontiers in Plant Science*, 10, Article 96. Thttps://doi.org/10.3389/fpls.2019.00096.

Noone, S. et al. (2016). "Homogenization and Analysis of an Expanded Long-Term Monthly Rainfall Network for the Island of Ireland (1850-2010)". *International Journal of Climatology*, 36, 2837-53. https://doi.org/10.1002/joc.4522.

Noone, S.; Broderick, C.; Duffy, C.; Matthews, T.; Wilby, R.L.; Murphy, C. (2017). "A 250-Year Drought Catalogue for the Island of Ireland (1765-2015)". *International Journal of Climatology*, 37, 239-54. https://doi.org/10.1002/joc.4999.

O'Gorman, E. et al. (2019). "Teaching the Environmental Humanities". *Environmental Humanities*, 11(2), 427-60. https://doi.org/10.1215/22011919-7754545.

Patman, S.; Armstrong, A. (2020). "Restoration of the Tropical Ravine House, Belfast Botanic Gardens". *Garden History*, 48(1), 97-106. https://www.jstor.org/stable/27136941.

Pfister, C. et al. (2015). "Tree-Rings and People – Different Views on the 1540 Megadrought. Reply to Büntgen et al. 2015". *Climatic Change*, 131, 191-8. https://doi.org/10.1007/s10584-015-1429-8.

Pilcher, J.R.; Gray, B. (1982). "The Relationships Between Oak Tree Growth and Climate in Britain". *Journal of Ecology*, 70, 279-304. https://doi.org/10.2307/2259880.

Pilcher, J.R.; Baillie, M.G.L.; Schmidt, B.; Becker, B. (1984). "A 7,272-Year Tree-Ring Chronology for Western Europe". *Nature*, 312, 150-2. https://doi.org/10.1038/312150a0.

Pilcher, J.; Brown, D. (2024). "In Memoriam: Michael Lockhart Baillie 1944-2023". *Tree-Ring Research*, 80, 52-4. https://doi.org/10.3959/TRR2024-5.

Plunkett, G.; Reimer, P.J.; Blaauw, M.; Brown, D.M.; Palmer, J.; Pilcher, J. (2024). "Mike Baillie – Slices of Time". *Radiocarbon*, 66(4), 605-9. https://doi.org/10.1017/RDC.2024.101.

Rubino, D.L.; Baas, C. (2019). *Dating Buildings and Landscapes with Tree-Ring Analysis: An Introduction with Case Studies*. Abingdon: Routledge.

Sanmiguel-Vallelado, A.; Sangüesa-Barreda, G.; García-Hidalgo, M.; Coca, M.E.; Olano, J.M. (2024). "Reconstructing 450 Years of Pollarding Events in Spanish Deciduous Oak Woodlands Using Machine Learning". *Forests*, 15(12), 2090. https://doi.org/10.3390/f15122090.

Scott, R. (2000). *A Breath of Fresh Air: The Story of Belfast's Parks*. Belfast: Blackstaff Press.

Seim, A. et al. (2024). "Timber Trade in 17th-Century Europe: Different Wood Sources for Artworks of Flemish Painters". *Scientific Reports*, 14, 18216. https://doi.org/10.1038/s41598-024-68641-y.

Sisti, M.K.; Robledo, J.A. (2021). "Interdisciplinary Collaboration Practices Between Education Specialists and Related Service Providers". *The Journal of Special Education Apprenticeship*, 10(1), 1-19. https://doi.org/10.58729/2167-3454.1123.

Smith, K.G.; Paradise, C.J. (2022). "Teaching the Process of Science with Primary Literature: Using the CREATE Pedagogy in Ecological Courses". *Ecology and Evolution*, 12(12), e9644. https://doi.org/10.1002/ece3.9644.

Smithsonian Institution (1897). *International Exchange List of the Smithsonian Institution: Corrected to July, 1897*. Washington D.C.: Smithsonian Institution.

Speer, J.H. (2010). *Fundamentals of Tree-Ring Research*. Tucson: University of Arizona Press.

Sweeney, J. (1997). "Ireland". Mayes, J.; Wheeler, D. (eds), *Regional Climates of the British Isles*. London and New York: Routledge, 254-75.

Synnott, D. (1997). "Botany in Ireland". Foster, J.W. (ed.), *Nature in Ireland: A Scientific and Cultural History*. Dublin: The Lilliput Press, 157-83.

Thompson, W. (1847). "Comparison of the Periods of Flowering of Certain Plants in the Early Spring of 1846, in the Botanic Garden of Belfast and the Jardin des Plantes at Paris". *Annals and Magazine of Natural History*, 19, 223-6.

Wetter, O. et al. (2014). "The Year-Long Unprecedented European Heat and Drought of 1540 – A Worst Case". *Climatic Change*, 125, 349-63. https://doi.org/10.1007/s10584-014-1184-2.

Whewell, W. (1840). *The Philosophy of the Inductive Sciences, Founded Upon their History*. 2 vols. London: J.W. Parker.

Wilson, E.O. (1998). *Consilience: The Unity of Knowledge*. New York: Alfred A. Knopf.