Seven thousand years of alternative history: the tree-ring story

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Summary

Little dendrochronological information finds its way into forestry literature, despite the interest that it has for foresters. Using radiocarbon dating and correlation analysis a 7272-year oak tree ring chronology has been established for Ireland. Ring patterns of successively older timbers have been overlapped far back in time using the ring patterns of living trees which overlap those of historic timbers, back to archaeological timbers and eventually naturally-preserved, sub-fossil 'bog' timbers. Ring patterns and anomalously wide and narrow individual rings are used to verify and supplement the historic record. The relative abundance of oak timbers at different times provides valuable clues to levels of woodland use, human population patterns and trade. Past climatic environments can also be reconstructed using ring patterns. Dendrochronology provides tantalising evidence for the factual basis of a number of mythological events. Further development of the technique is likely to lead to improved understanding of past environments.

Foreword

People interested in trees tend to be fascinated by the process of tree-ring dating or dendrochronology. Studies involving tree-rings open up a whole new window on the past with the particular benefit of precise dating. It is the ability to date tree-rings precisely which opens up the possibility of adding new independent information to the existing historical record. However, it is ironic that little dendrochronological information finds its way into forestry literature. Most publications on the subject are aimed at archaeological, environmental and dendrochronological audiences. Perhaps this article will go some way to introducing foresters in Ireland to some of the possibilities offered by this quite remarkable method.

Introduction

In the 1960s a set of three circumstances gave rise to a serious study of Irish tree-rings.

1. From a purely scientific standpoint, there was a continuing controversy relating to the issue of radiocarbon calibration. It had been observed during the 1950s and early 1960s that radiocarbon dates on organic samples of known age - archaeological samples from regions with historical chronologies such as Egypt - tended to be too young by as much as several centuries in the period before 1000 BC. As a result Hans Suess in the United States had made a long series of radiocarbon measurements on wood

samples of known age from the American bristlecone pine (*Pinus aristata* and *P. longaeva*) tree-ring chronology as a calibration exercise (Suess, 1970). The bristlecone chronology had been constructed using the ring patterns of many of these extremely long-lived trees. Dendrochronologists were able to supply Suess with small blocks of tree-rings of precisely known age right back to 6000 BC. The problem was that the Suess calibration curve – which related dates in radiocarbon years to real dates in calendar years – contained short-term variations, so-called 'wiggles' which made interpretation of radiocarbon dates difficult. In addition, there were doubts about the validity of a high-altitude American calibration - the bristlecone pines grew at around 3000 m – and whether it could be used to calibrate radiocarbon dates in the Old World.

2. In the mid-1960s the University at Belfast had acquired a radiocarbon capability, and
3. it had been observed that large numbers of sub-fossil 'bog' oaks were being excavated as the result of land drainage and motorway construction in the north of Ireland.

As a result of these various factors, a decision was taken in the Palaeoecology Centre at Queen's University to investigate the possibility of building a 6000-year oak tree-ring chronology in Ireland and re-calibrating the radiocarbon timescale with low-altitude, Old World, tree-ring samples. Once that decision was taken there were only three possible routes forward. Either dendrochronology would be found not to work successfully in Ireland – an option which was all too believable in the late 1960s – or, it would be shown that dendrochronology would work as a method but it would not be possible to find oak timbers of all periods and the chronology building exercise would fall short of it's 6000-year objective, or, just possibly, a long chronology might be constructed. As things turned out, despite a number of difficulties, a 7272-year oak chronology was completed by 1982 (Pilcher *et al.*, 1984) and the Belfast, high-precision, radiocarbon calibration curve was published in 1986 (Pearson *et al.*, 1986). This combined completion of the tree-ring chronology and the radiocarbon calibration marked the fulfilment of the primary scientific objective. That work, of course, left the legacy of the long Irish oak chronology - at the time one of only a handful of such chronologies in the World - and its potential for archaeological dating and palaeo-environmental research.

Lessons learned in the course of building an oak dendrochronology in Ireland

In order to construct a long chronology along classic dendrochronological lines, it is necessary to overlap the ring patterns of samples from successively older timbers far back in time. This process starts with the ring patterns of living trees which overlap those of historic timbers, back to archaeological timbers and eventually naturally-preserved, sub-fossil 'bog' timbers. As modern timbers were acquired to test whether cross-dating was possible between the ring patterns of different trees, almost the first observation made related to the age of oaks. It became apparent that oak trees in Ireland were nothing like as old as people believed. There were widespread notions about oaks being many centuries old; these notions were not borne out by ring counts. Most oaks in Ireland occur on landed estates and were planted in the 18th or 19th centuries. Oaks surviving from the 17th century are notably rare, with only a handful having been observed in thirty years of study. Thus, the longest ring pattern for a living oak in Ireland, sample Q528 from Shanes Castle, Co Antrim, runs back only to AD 1649 (obviously it would be nice to prove this record wrong). An additional fact rapidly became apparent. It was observed that modern oaks (those grown since the early 18th century) on average exhibited rings twice as wide as ancient timbers. Initially it was thought that this might be due to the parkland nature of the modern trees – put narrow-ringed, forest-grown, oaks out in a parkland and they would grow bigger (?). However, it is now apparent that this is not the case and a more likely explanation for the larger size and faster growth of modern oaks is that they are imported stock, brought over from Britain or the continent to enhance the estates in which they were planted (Baillie and Brown, 1995).

However, none of these problems interfered with the issue of cross-dating ring patterns and building a modern oak chronology. A methodology was developed which allowed the dendrochronologists to reliably cross-march ring patterns to their correct relative felling dates using a combination of computer-correlation programs and visual matching. As a result, within a few years of starting, a well-replicated oak master chronology, which linked modern trees to historic building samples of the 17th or 18th centuries, was available back to AD 1380 (Baillie, 1974 & 1982). This chronology can be most easily visualised as a year-by-year record of mean oak growth, for Irish oak, for every year back to AD 1380. Immediately this chronology was completed several types of information could be exploited. First, new samples could be dated by matching their ring patterns against the pattern of the master chronology – a commercial service providing tree-ring dates for archaeologists and building historians became a practicality. Second, the details of the master chronology could be investigated at annual resolution. For example the growth ring for AD 1947 was always notably wide, whereas that for AD 1816 was always notably narrow; both were years of unusual climatic extremes – 1816 was notable for being known as the 'year without a summer' in the North Atlantic region. Clearly there was stored environmental information in the master ring pattern. This is graphically illustrated by going back to the growth rings for AD 1740-42. These show a catastrophic growth reduction which must be related to the anomalously cold year AD 1740 {the coldest year in the whole of Manley's (1974) 350-year Central England Temperature Record} and which coincides with the "last great demographic crisis of the pre-industrial era" (Post, 1985). Furthermore, the act of dating the wide selection of oak timbers which did become available showed some interesting trends in building activity. No buildings containing native oak timber could be found later than AD 1716, most later building in the 18th century used either hedgerow or sub-fossil timbers (low status housing) or imported pine, presumably from Scandinavia or the Americas (high status and industrial building). Of the buildings which did yield native oak timbers, a clear pattern of building dates began to emerge which reflected the social/political history of Ulster in the 17th century. No buildings were dated to the period of the AD 1640s, or to the later 1680s, whereas clusters of dates in the periods after AD 1658 and after AD 1690 coincided with flushes of 'plantation'. It appeared that the act of dating oaks provided facts consistent with the documentary historical framework.

Further back in time

The story of the construction of the Belfast long chronology is well documented elsewhere (Baillie, 1982 & 1995). Suffice to say the chronology building process broke down into the construction of long, robust sections of chronology and the subsequent linking of these robust sections. For example, the chronology for the last 2000 years was principally composed of four sections, namely:

1. a living-tree chronology spanning the present to 1649,
2. a late/post medieval chronology spanning c1350 to 1716,
3. a medieval Dublin chronology spanning 855 to 1306,
4. an Iron Age/Early Christian chronology spanning 13 BC to AD 896.

These robust sections reflected episodes of timber abundance separated by weak periods or 'gaps' where timbers were scarce to non-existent. Extensive sampling over thirty years has shown that this pattern is itself robust, in that the periods of abundance and weakness have not changed even with many more samples obtained. So, for example, the gap in the 14th century is closely related to the Black Death of 1347-50, with many oaks regenerating from the mid-century onwards. The depletion of Irish timbers across the 9th century was so severe that the link in the chronology actually exploited English ring patterns from sites in Exeter and London. This pattern of depletion/abundance is shown in Figure 1.

Exactly the same approach was used in constructing the prehistoric chronology. In this case the primary material consisted of several thousand naturally preserved oak trunks, mostly from the North of Ireland. Again it was found that long robust site chronologies could be constructed with relative ease. In retrospect it became clear that the bog oaks encountered in drainage were in no way random in occurrence. The oaks were survivals of a regenerating woodland that had colonised the surfaces of peat bogs for many centuries at a time. Thus groups of oaks, apparently sampled at random, would contain timbers whose ring patterns overlapped in time. In addition, the narrow growth rings associated

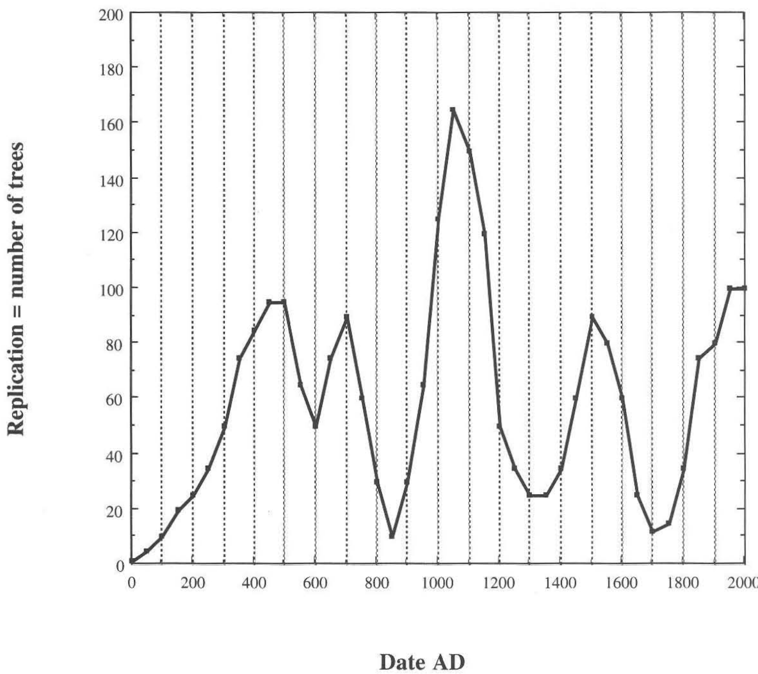

Figure 1: *Depletion/abundance of Irish oak timbers.*

with almost all ancient oak specimens in Ireland {mean ring width 1.0 mm over seven millennia (Baillie and Brown, 1995)} meant that oaks were relatively long lived (average age around 250 years with a small number of specimens up to almost 500 years). These timbers were therefore ideal for chronology building as the long ring patterns of contemporaneous trees could be overlapped with confidence to produce long site chronologies. With long, well-replicated, site chronologies being produced, the difficulty reduced to linking these robust chronological units across the periods of weak replication or gaps. Indeed, most of the overall 7000-year chronology was in existence by around 1977, though it took until 1982 to finally bridge the last gaps in the Irish chronology in the first and tenth centuries BC, again using English ring patterns.

This latter fact in itself indicates that long-distance cross matching was increasingly acceptable to dendrochronologists. When chronology building started in Europe it simply was not known over what geographical distances cross matching would apply. As chronologies were developed it became apparent that high correlations could be obtained between long sections of chronology from Ireland and Scotland, then England, then from England to Germany. Now it is clear that there is common signal in all of the regional chronologies from Ireland to Poland. This does not mean that one can date Polish or German trees using an Irish chronology – obviously Irish timbers should be dated against a local Irish chronology for the same species – but it is possible to isolate a highly stable year-by-year signal representative of European oak growth (a concept which would have been unthinkable before the chronologies were constructed).

Other applications

Once chronologies are available and dates are being produced with confidence (using replication as the ultimate check on the dating procedure), it becomes possible to accumulate information to develop broader pictures. Indeed, this was hinted at above when it was pointed out that the tree-ring dates for 17th century buildings in Ulster reflect the history of the period. As the chronologies were pushed further back in time problems were experienced in bridging the 14th century AD. It became apparent that what was being seen was a 'depletion/regeneration' phase, associated with the Black Death of 1347-50. Old trees were being cut down up to the mid 14th century; from the mid-century onwards oaks were regenerating. Thus the longest-lived oaks sampled from 16th and 17th century buildings in Eastern Ireland had all started growing just after 1350. This hiatus, which implies that either coppiced or marginal land went back to forest, possibly due to the lack of people to tend the woodland, was only bridged with timbers from the west of Ulster, where presumably the effects of the Black Death were different - but perhaps pressure on woodland in western areas was always less than in the east.

The interesting point about this observation of a depletion regeneration phase in the mid 14th century is that it can be paralleled with a building hiatus in Germany lasting from 1348 to around 1440. Something similar is seen in Greece. It is possible to suggest that dendrochronology alone would have raised the suggestion of a Europe-wide population decline in the mid 14th century even if history had not recorded the event (Baillie, 1995). This comment is made because, as we go further back in time, the historical record inevitably starts to thin. The hope must be that dendrochronology can either indicate some earlier events which history has failed to record or elaborate the record for other periods which are poorly recorded. An example of the latter relates to the accumulating picture of happenings around AD 800 where German dendrochronologists found difficulty in bridging one of their gaps. Now a gap can be due to numerous causes, but dendro dates can themselves provide clues. Just around 800 we find the greatest number of horizontal watermills being constructed in Ireland. As mills imply cereals, and lack of timbers implies human pressure, it is possible to suggest that this was a period on expanding human population. As oaks start to regenerate a century later the implication is that the human pressure has reduced - there may have been less humans. It is hints such as these which the dendrochronologists can supply to historian colleagues.

Trade

While most of the timbers recovered from buildings and archaeological sites are local in character, it is inevitable that some timbers will have moved as part of trade. In Britain it is now apparent that many Medieval oaks did not grow in these islands but were imported from the Baltic as part of Hansa trade with England and Flanders. One important example of the movement of timbers in the opposite direction is the finding by Neils Bonde (1998) from the Museum in Copenhagen that one of the famous Roskilde blockships, named Skuldelev 2, was actually of Irish origin. Indeed, so similar were the ring patterns from the boat to the master chronology constructed for the Dublin excavations that it is virtually certain that Skuldelev 2 was a Dublin boat. Thus, not only can dendrochronologists date oak timbers, they can is some instances locate their original area of growth. As more and more regional chronologies come on line examples such as this should multiply. One outstanding anomaly, which may have a trade explanation, relates to oaks from Hillsborough Courthouse, Co Down. The courthouse is late 18th century and originally had panelled oak pews. Several of the panels were sampled for analysis and it was clear that the trees were very straight grained and regularly grown. The panels provided a replicated ring pattern of some 300 years. However, extensive comparisons with available chronologies from all over northern Europe have singularly failed to produce significant correlations – the Hillsborough timbers don't match anything in Europe. Logic suggests that they may well be from eastern America. However, there are as yet no available oak chronologies from the eastern United States with which to compare the ring patterns.

Given this last example, it is worth stressing that the Hillsborough timbers are exceptional. Irish oak timbers have a very high success rate when it comes to dating. Structures have been dated from throughout Ireland, for example, horizontal watermills have been dated from north Antrim to west Cork.

Environmental reconstruction

It was always obvious that if dendrochronology worked as a dating method, and that oaks in Ireland were developing recognisably similar patterns of wide and narrow rings, then the tree-ring patterns must contain at least a partial record of the past environment. As indicated in the introduction, oaks do seem to respond negatively to cold conditions, as seen in 1816 and the early 1740s. A speculative extension of this line of thinking led to the discovery of what can be called 'narrowest ring events' in the Irish bog oak chronology. These are points in time when a significant proportion of bog oaks exhibit their narrowest rings. Since oaks are relatively long-lived, and as many factors could cause a narrowest ring, the occurrence of clusters of narrowest rings, in different trees, on different bogs, should indicate some notable environmental effects. The initial result of discovering a series of narrowest-ring dates was the apparent identification of significant volcanic dust-veil events at, for example, 2345 BC, 1628 BC, 1159 BC, 207 BC and AD 540. The dates are supplied by the tree-ring records. The link to volcanoes comes from dated layers of sulphuric acid found in the ice cores from Greenland (Baillie and Munro, 1988). This story was brought about because of the occurrence of other strands of evidence for notable volcanic activity at around these dates. Originally, an American dendrochronologist, Val LaMarche had indicated a frost ring related to volcanic activity at 1627 BC in his bristlecone pine record (LaMarche and Hirschboeck, 1984). Then Danish workers had indicated the presence of volcanic acid in ice-cores (Table 1) dated to AD 540±10, 210±10 BC, 1120±50 BC and 1644±20 BC (Hammer *et al.*, 1980; 1987).

Table 1: *Volcanic acid layer dates from Hammer et al. (1980 & 1987) and the original list of narrowest ring events in the Irish oak record (Baillie and Munro, 1988)*

Volcanic acid dates	Narrowest ring dates
540 ±10 AD	540 AD
50 ±10 BC	
210 ±30 BC	207 BC
260 ±30 BC	
1120 ±50 BC	1159 BC
1390 ±50 BC	
1644 ±20 BC	1628 BC
	2345 BC
2690 ±80 BC	
3150 ±90 BC	3195 BC
4400 ±100 BC	4370 BC

These observations suggested that the narrowest tree rings were related to volcanic events. This impression was added to when workers in Belfast dated the Icelandic eruption Hekla 4 to 2310±20 CalBC[1]. What was particularly interesting about these particular dates was their proximity to episodes of civilisation collapse/culture change/Dark Ages. For example, the Greek Dark Ages traditionally begin in the 12th century BC while it is possible to find authors who would suggest that the Dark Ages start in the early 6th century AD. Moreover, it is interesting that the conventional chronology in China suggests dynastic change at 1617 BC and 1122 BC, not far from the Irish narrowest ring dates (Baillie, 1995).

However, it is fair to say that there was always tension in the volcano story simply because most volcanologists do not believe that volcanic eruptions can collapse civilisations. Normally, in recent times at least, the effects of even quite large volcanic eruptions have been limited to two or three years. This tension was compounded as it became clear that the event at AD 540 was really quite exceptional in terms of the last two millennia. It's exceptional nature is best seen by the clarity with which it shows up in a wide grid of tree-ring chronologies from the north of Russia through Europe to North and South America. As exceptional events should have exceptional causes, and as the actual evidence for a major volcanic eruption at AD 540 was less than definitive, this raised the question whether the environmental downturn might have been caused by something other than a

[1] CalBC indicates calibrated radiocarbon dates compatible with historical dates.

volcano[1]. When to this query was added the observation of 'stones falling from the sky' in and around 207 BC (Forsyth, 1990), and references to comets at the start and end of the Shang dynasty (Sagan and Druyan, 1985), a rather more sinister scenario began to emerge for consideration (Baillie, 1999). Might the dust veils at the dates listed above actually have been due to Earth's interaction with cometary debris? This question, it turned out, had already been posed by several cometary astrophysicists, most notably Bailey, Clube and Napier (Bailey *et al.*, 1990; Clube and Napier, 1990). It cannot be without interest that Isaac Newton himself believed that the biblical Flood had been caused by a comet in 2349 BC, using Ussher's dating (Schechner Genuth, 1997). This latter section would be laughable were it not for the fact that Old Testament history, ancient Chinese history and much mythology all supports the bombardment from space scenario. For local interest, Arthur, who traditionally dies close to AD 540, is derived from Celtic mythology and is equated to CuChulinn. CuChulinn is a re-birth of the god Lugh whose attributes make him almost a direct description of a close comet. In brief, Lugh is described as coming up in the west, being as bright as the Sun and having a long arm and a fiery spear with which he delivers terrible blows. In the Arthur-related Grail legend, it is the blow by Lugh's spear which caused the 'Wasteland'. This use of mythology would also be laughable were it not for the recent finding by Courty (1998) of a soil layer in Syria, which contains a range of glassy balls and glazed over shards of archaeological debris which she dates to around 2350 BC {see also Peiser (1998) for evidence of a global disaster around 4000 years ago}.

The incredible thing about this story is that it has it's origins in some very narrow growth rings in oaks which grew rooted on the peat of Irish bogs. Suffice to say that if one turns to an article published by Britton in 1937 which includes some early decanting of information from the Irish annals, he notes that 'lakes overflowed' in Ireland in 2341 'BC' and 1629 'BC'. Trees suffer, lakes break out - how might the annalists have got it so right? In fact, if one wants to play games, and one goes back to the Annals of the Four Masters, produced by Michael O'Clery and his learned colleagues in the early 17th century, and annotated by O'Donovan (1848), one finds that in 'The Age of the World, 4020' i.e. in 1180 'BC' one Sirna acquires sovereignty of Ireland. Now Sirna is credited with reigning for either 150 years (Four Masters) or 20 years (O'Donovan, *op. cit.*) so that one could interpret this to mean that he either died "with a countless number of the men of Ireland" in 1030 'BC' or 1160 'BC'. As one of the other narrowest ring events spans 1159-1141 BC in the Irish tree-rings, obviously O'Donovan's interpretation would make for a more interesting story (it is important to stress that R.B. Warner would not allow this interpretation). If O'Donovan were correct then it would also be intriguing that, yet again, five rivers erupted in Sirna's reign. If lakes and rivers consistently break out around the time of the narrowest ring events, that hints at a consistent tectonic cause - or maybe it just got a lot wetter? The independent evidence provided by an unfinished dug-out boat, made from oak and found out in Lough Neagh, dating to AD 524±18 has already been connected with a rise of the level of the lough at that time (Baillie, 1995), a time close enough to AD 540 to hint at a similar cause to the earlier events.

[1] For the purposes of this article it is probably sensible to ignore super-eruptions. This class of volcano, exemplified by the eruption of Toba, Sumatra, some 74,000 years ago, could collapse civilisation. However, none have been observed during the Holocene (the last 10,000 years). The recent suggestion of a super-volcano in February AD 535 (Keys, 1999) is not supported by geological evidence. Had such an eruption occurred its effects would undoubtedly be seen globally in the tree-ring for AD 535 as the effects would have been immediate, global and devastating.

Conclusion

The successful construction of a seven millennia long Irish oak chronology means that there is now an absolute timescale against which historians, archaeologists and environmentalists can place their deductions. This year-by-year record can be interrogated in a number of different ways and the narrowest-ring work discussed above demonstrates the potential. Since all the rings in a dated specimen can be assigned to their calendar year of growth, dendrochronologists can study factors such as growth initiation phases (by dating the innermost rings of the trees). Episodes of widespread regeneration can become visible and results can be compared with those from other countries. At a local level, the fact that most bog oaks blew over (and were preserved by being buried in peat) means that attempts can be made to reconstruct episodes of increased storminess in the distant past. Similarly the occurrence of reaction wood (where a tree has been pushed over and attempts to right itself) or growth anomalies such as frost damage, or included sapwood, can allow the occurrence of severe environmental conditions to be reconstructed.

Overall, there is no restriction on the types of analyses. For example, the wood cellulose which grew in any year in the last seven millennia can be isolated for chemical or isotopic study. No-one knows what stories might emerge as such analyses proceed. Moreover, the absolute nature of dendrochronology means that information from any year in Irish oaks can be compared with deductions for that same year from trees from elsewhere around the globe. Finally, as I have pointed out elsewhere, oak trees seem to have been granted the gift of immortality - they can tell us their exact years of growth long after they are dead - and more importantly, they never lie - the stories they provide are independent of human history and much less biased. However, one other message seems clear from the work outlined above; when oak trees suffer humans also seem to suffer. It might serve us well to look after our Irish oaks.

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