

A 223 year (AD 1779-2001) modern oak tree ring chronology from Allt Lanlas, Llanerchaeron, Ceredigion

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Abstract

Dendrochronological samples were obtained from living or felled oak (*Quercus petraea*) trees at Allt Lanlas SSSI (N.G.R SN477 604), an 8 ha 'hanging' oak woodland situated within the grounds of the National Trust owned Llanerchaeron estate, Ceredigion, Wales. This research was undertaken to answer a number of predetermined questions concerning the difficulty of estimating the ages of trees within the estate. Furthermore, wider issues exist concerning the application of dendrochronology to the western extremes of Britain, with areas such as West Wales relatively poorly understood in terms of woodland, vernacular architecture and archaeological tree ring data.

Dendrochronological analysis indicates that the oak trees of Allt Lanlas were planted between AD1779-1790, regardless of girth. The ring width patterns display high inter tree correlation with t values of up to 17.87 between trees. A 13 tree master chronology is highly correlated with other British tree ring chronologies. Local historic climate data (mean spring/summer precipitation AD 1858-1987, Rhayader) is compared to residual ring width values and correlation suggests moisture is a significant limiting factor in the incremental growth of these trees.

Introduction

Allt Lanlas is situated in the grounds of the National Trust Llanerchaeron Estate. The woodland commands a south-westerly aspect, on a slope which rises from around 35m at the foot of the Aeron River to around 140m O.D. Mudstones and shales of the Aberystwyth Grit Formation are overlain in the Aeron Valley by brown earths of the Conway Association, indicative of the climate and relief of the area (Rudeforth, 1992). Soil pH ranges from 3.5-4.5, typical of acid sessile oak woodland (Peterken, 1993).

Following the creation of the long European oak chronologies in the 1970s, Baillie (1982) acknowledged that dendrochronological material from the marginal areas of Britain may not fit into a single British 'master' tree ring chronology. The south west of Britain, along with parts of East Anglia has presented problems in terms of chronology building and has been the focus of recent study (Bridge, 2000; Hillam, 1997) with a parallel drawn to Brittany, also relatively isolated and Atlantic exposed with heavily dissected peninsulas (Bridge, 2000). The variety of microclimates that can exist in these marginal areas means that annual tree growth in two adjacent woodlands can vary to such an extent that

crossdating becomes problematic. This is further complicated by the relatively stress free maritime environment of areas such as West Wales. Tree growth is often very similar every year as the tree is rarely short of water and is not responding to environmental stress in the same way as more 'sensitive' trees. These 'complacent' tree ring series, as they are known present a real problem in cross-dating, as the climatic 'signature' necessary for successful cross-dating is not present. In West Wales the problem of complacent trees is further hindered by a long tradition of coppicing (Linnard, 1982), resulting in woodlands comprised of young trees often less than 80 years old. The vernacular architecture of West Wales is also of a tradition that has traditionally utilized scant and expensive timber resources, resulting in houses of clom and stone construction with small 'scarfed' cruck roof timbers, generally unsuitable for tree ring dating (Peate, 2000). Indeed, in 18th and 19th century Ceredigion timber was said to be the most expensive component of a building (Davies, 1976).

Attempts to date building phases in the Llanerchaeron estate had proved inconclusive, aside from the successful dating of 18th century imported German oak floorboards (N. Nayling, pers. comm.).

Attempts to estimate tree age within the estate had likewise proved unsuccessful.

Study area

Poor silvicultural management in Wales during the early post medieval period had led, by the late 18th century to government incentives to plant trees (Davies, 1976; Linnard, 1972). During the 18th century, Ceredigion, in common with much of Wales, was a major exporter of oak bark, a vital component in the tanning industry that depended on short (30yr) planting cycles (Davies, 1976; Linnard, 1982). Mature timber stocks were essential for shipbuilding which was widespread along the Ceredigion coast, particularly at nearby (2.5 miles) Aberaeron, where, during the late 18th century, local timber supplies had been almost exhausted (Jones, 1968). Chiefly as a result of nationalist feeling against the French, the government incentives to plant trees for future naval use reached their zenith in the late 18th/early 19th century (Schama, 1997).

A detailed vegetational history of Ceredigion based on pollen evidence by Moore (1994) indicates a distinctive peak in agriculturally associated pollen during 1793-1815 from lowland and upland sites. Increased arboreal pollen during the 19th and 20th centuries is attributed to tree planting activities on private estates and by the Forestry commission.

Llanerchaeron estate has been described as a rare survival of a small 18th/19th century gentry estate and was bequeathed to the National Trust in 1989. A map of 1760 shows no tree cover at Allt Lanlas with a further map of 1803 showing the surrounding valley sides to be heavily wooded. This supports anecdotal and dendrochronological evidence for mid 18th century clear felling followed by planting in the late 18th century, though no estate record has been found mentioning tree planting at this time at Allt Lanlas. The importance attached to tree planting at this time cannot

be overemphasized. Grants and prizes were awarded and the economic importance attached to forestry in the Aeron valley is demonstrated in the following quote by Walter Davies, government agricultural enquirer for south Wales .

“The valley of Aeron has also its slopes interspersed with woods, chiefly Oak as in most places on the slate tract. In the year 1792 a copse wood tract of 29 acres, on a southern declivity in this valley was bought by a gentleman for £400. The whole was fenced and protected from injury. The weedings in bark and wood for fencing paid periodically the interest of the purchase money or nearly so. In 1792 the saplings, mostly oak with some ash, were from, 1-10 years growth. In 1809 a lot was sold for £750. In 1813 another lot for £375. There still remains what is valued at £500. In all £1625 from a spot of sideland purchased in 1792 for £400. From another property on the slopes of the valley, the rental of which, a few years back, did not exceed £300, timber has been sold in the last few years to the amount of £9000. Such examples shew the propriety and consequent profit of protecting woodlands....There are many other spirited planters in the county and among them W. Lewis of Llanerchaeron; J.N. Williams of Castle Hill, J. Lloyd of Mabus, A.T.J. Gwynne of Tyglyn and L. Parry of Gernos who have recently planted from forty to sixty and hundred thousand each, beside a great number who have planted twenty to fifty thousand each. The smaller yeomanry also follow in the rear; even tenants aspire to the premiums of the society, for planting on landlords property.”

Walter Davies (1814):44-45.

Methods

Previous studies of the trees within the Llanerchaeron estate provided the rationale for dendrochronological investigation.

“The only way of adding definition to the ages of the trees would be to carry out a systematic tree ring dating programme to construct an absolute chronology on which to hang the relative one gained in this survey. Tree ring dating can, and will give an added level of fact to the theorizing which can, and will occur using the data as it exists.”

Laidlaw & Palmer (1999): 54.

“Interpretation of the trees at Llanerchaeron is highly dependent on judgements regarding age, planting and species. Observation of fallen trees at Llanerchaeron reveals large differences in growth

increment rates due to weather, crowding, shading and selective felling”

Ede and Mayes (1993): 29.

Following discussion with National Trust and CCW staff it was decided to undertake a program of dendrochronological sampling within the estate. The oaks on the southwestern slope of Allt Lanlas seemed ideal for dendroclimatological testing, with evenly sized single stemmed trees, with ring width variations reflecting the stress caused by steep slopes, thin soils and shallow rock substrata (Fritts, 1976). Trees in the eastern area of the woodland demonstrated more complacent ring widths probably due to closer water table proximity and gentler relief. In addition to constructing an absolute, well replicated 223 year chronology it has also been possible to establish a precipitation/tree growth relationship. To calibrate a chronology for climate testing a simple solution is to use:

“...least squares techniques in a multivariate regression that statistically estimates the chronology value from a number of predictor climatic variables such as precipitation and temperature.”

Fritts & Swetnam (1996): 136-137.

This was carried out using simple least squares regression residual values on Microsoft Excel, with instructions downloaded from: www.plantbio.ohiou.edu/epb/instruct/ecology

Due to limited climate data availability only precipitation data was compared to the residual ring width values. The nearest precipitation data (Rhayader – Tynant 1858-1987) was obtained from the Global Historic Climate Network (GHCN2).

Cross dating tree ring width sequences is the key to successful dating (Baillie, 1995: 249). To create a site master curve there must be a high degree of correlation in the growth patterns between the individual trees. A ‘site

master’ curve may well iron out background noise associated with individual samples and enhance the signal of the main factor influencing tree growth, that is either climatic or environmental factors (Baillie, 1995). A site master of 13 individual trees mean ring width sequences was created and compared to other British and European tree ring chronologies.

The results of the dendrochronological study of Allt Lanlas show that all the trees are contemporary with each other, with most trees appearing to have been planted between AD 1779-1790. In addition to providing much needed tree ring data for west Wales the results provide important information regarding the economic and landscape history of the estate.

Located as they are on a steep rocky slope with dense undergrowth, tree location was marked using a Garmin Etrex Summit GPS. Due to the difficult working conditions it was decided to sample trees in a roughly north-south transect up the slope. In addition, several trees were sampled in the flatter eastern area of the woodland.

Samples were obtained using a 50cm Haglof increment corer. Trees were girthed at breast height as is the standard for tree measurement (Jones, 1959). Trees from the steep slope were cored from the east and west sides due to the compression associated with the upslope side of the tree. Two cores were obtained from each tree in order to avoid crossdating errors.

Four soil samples were also obtained from within the woodland and characterized using Munsell Soil Colour Charts and pH values. This was considered important as trees growing on similar soil types may show closer correlation than trees in the same region (Bridge, 2000).

Following air drying samples were mounted end-grain upwards on wooden boards. These were then machine sanded with

progressively finer sandpaper from 120 to 400 grit.

Ring widths were measured to 0.01mm on a travelling stage attached to a computer running a program designed by Tyers, (2000). Ring widths are measured from the beginning of each yearly increment of early growth cells to the start of next years earlywood vessels.

Cross dating was achieved using Cros 73 computer program. This program calculates a statistical t value for correlation at every point of overlap between two data sets. Cros 73 is designed to calculate the product moment correlation coefficient r at each position of overlap, so the value of students t is calculated from r to give a significance value for the length of overlap. A full description of this methodology is provided by Baillie and Pilcher (1973).

As Baillie (1995) suggests, the correlation value (t) acts a guide to the dendrochronologist. The individual tree ring sequences plotted as semi logarithmic graphs should match visually and there should be a lengthy overlap. In the case of

living trees, any added or missing rings should be quickly identified. To ensure that the ring sequence of a tree is correctly measured it should be compared to all other trees from the series to ensure correct measurement.

Results

Table 1 shows the number of trees (2 cores per tree) comprising the Lanlas master ring width chronology at each 10 year segment. This ranges from 1 to 13 trees. Figure 1 shows the span in years of each tree used for the compilation of the 13 timber mean. Trees 26, 18, 19 and 16 were used despite the most recent parts of these trees being too narrow for ring width measurement. Table 2 shows t values between each of the individual tree cores used in the master chronology. Table 3 shows the t values between each of the trees (2 cores per tree) used in the master chronology. Table 4 shows the strongest correlations ($t > 5$) between the Lanlas chronology and other British/European tree ring chronologies. Figures 2 and 3 demonstrate an attempt to ascertain the influence of precipitation and temperature on annual growth of the Lanlas trees.

AD 1779										146	214									1	1
-	185	254	282	274	115	231	291	268	355	264	1	1	2	3	4	4	4	4	4	4	4
-	222	218	171	162	297	166	240	144	238	155	4	5	6	6	6	7	7	7	7	7	8
AD 1801	181	244	154	148	226	145	177	203	156	170	8	8	8	8	9	9	10	10	10	10	11
-	228	220	174	158	153	166	110	119	210	118	11	11	11	11	11	11	11	11	11	11	11
-	124	112	159	92	109	94	120	155	185	151	11	11	11	11	12	12	12	12	12	12	12
-	97	142	118	118	133	120	155	134	101	92	12	12	12	12	12	12	12	12	12	12	12
-	109	87	87	51	106	81	119	140	99	90	12	12	12	12	12	12	12	12	12	12	12
AD 1851	89	76	93	105	94	75	110	111	109	144	12	12	12	12	12	12	12	12	12	12	12
-	123	153	110	122	147	121	192	134	154	140	12	13	13	13	13	13	13	13	13	13	13
-	200	158	138	101	227	139	138	184	188	166	13	13	13	13	13	13	13	13	13	13	13
-	135	194	198	180	185	187	158	240	154	201	13	13	13	13	13	13	13	13	13	13	13
-	222	222	126	188	199	130	169	178	167	187	13	13	13	13	13	13	13	13	13	13	13
AD 1901	155	149	200	160	149	157	177	176	200	188	13	13	13	13	13	13	13	13	13	13	13
-	150	171	186	153	118	122	195	164	167	150	13	13	13	13	13	13	13	13	13	13	13
-	120	142	102	165	158	147	147	161	156	137	13	13	13	13	13	13	13	13	12	12	12
-	163	170	106	99	141	197	125	125	201	133	12	12	12	12	12	12	12	12	12	12	12
-	131	138	102	100	175	147	149	142	103	119	12	12	12	12	12	12	12	12	12	12	12
AD 1951	146	148	118	147	138	131	107	127	101	135	11	11	11	11	11	11	11	11	11	11	11
-	138	182	172	134	137	133	128	103	111	85	11	11	11	11	11	11	11	11	11	11	11
-	117	110	123	108	90	102	133	159	121	105	11	11	11	10	10	10	10	10	10	10	10
-	106	199	154	108	197	119	153	140	131	120	10	10	10	10	10	10	10	10	10	10	10
-	142	144	110	105	83	112	112	100	118	120	10	10	10	10	10	10	10	10	10	10	10
AD 2001	123										10										

Table 1: LANLAS 13 timber mean.

Ring width values (0.01mm) are shown on the left. The number of trees comprising each mean ring width value is on the right. Dated AD 1779 to AD 2001. Average ring width 150.08, Sensitivity 0.21.

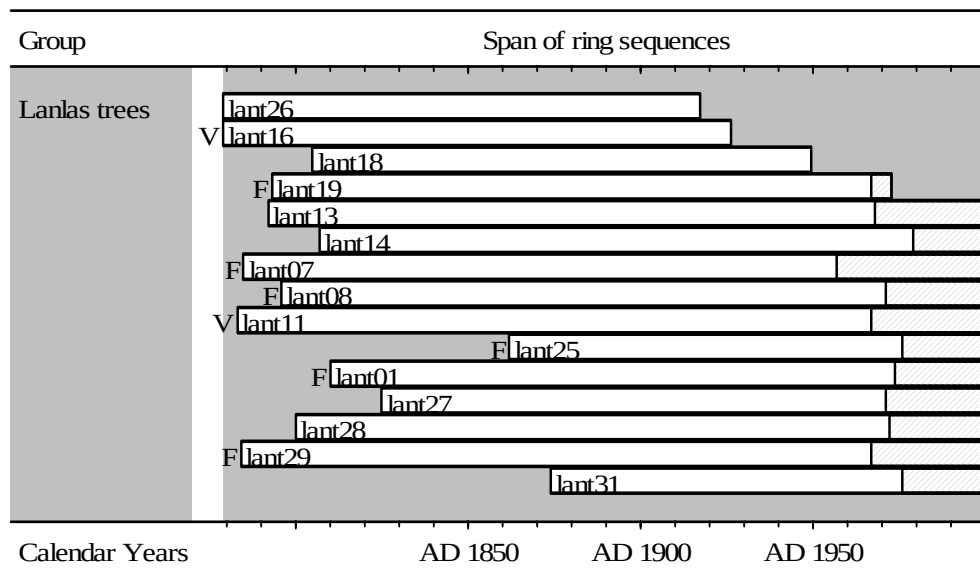


Figure 1. Components of Master Sequence.

Tree ring sequences as bars. Shaded areas represent sapwood.

Table 2. Correlation (t) values between dated cores.

- = t-values less than 3.00

Filenames	-	-	lant07	lant08	lant11	lant13	lant14	lant16	lant18	lant19	lant25	lant26	lant27	lant28	lant29	oak2
-	Start	dates	AD 1785	AD 1796	AD 1783	AD 1792	AD 1807	AD 1779	AD 1805	AD 1793	AD 1862	AD 1779	AD 1825	AD 1800	AD 1784	AD 1874
-	Dates	end	AD 2001	AD 2001	AD 2001	AD 2001	AD 2001	AD 1927	AD 1950	AD 1973	AD 2001	AD 1918	AD 2001	AD 2001	AD 2001	AD 2001
lant01	AD 1810	AD 2001	7.49	10.92	9.74	10.57	11.00	6.66	6.84	6.75	5.92	5.36	9.85	9.95	8.69	4.28
lant07	AD 1785	AD 2001	*	10.59	11.46	12.39	9.71	9.58	7.04	8.90	6.86	6.16	8.27	10.30	8.36	3.89
lant08	AD 1796	AD 2001	*	*	13.47	15.87	15.24	11.93	9.44	11.03	7.35	8.47	10.11	11.52	9.49	5.06
lant11	AD 1783	AD 2001	*	*	*	15.86	16.47	10.99	9.41	9.58	7.93	8.89	12.02	14.20	8.93	6.11
lant13	AD 1792	AD 2001	*	*	*	*	17.48	13.59	10.74	10.73	7.93	9.06	11.64	12.96	13.01	6.26
lant14	AD 1807	AD 2001	*	*	*	*	*	10.30	12.04	9.52	7.76	7.09	11.53	11.48	10.35	5.64
lant16	AD 1779	AD 1927	*	*	*	*	*	*	8.16	12.34	6.08	9.75	6.64	8.86	7.96	3.15
lant18	AD 1805	AD 1950	*	*	*	*	*	*	*	5.72	7.54	5.84	8.25	7.52	6.62	5.14
lant19	AD 1793	AD 1973	*	*	*	*	*	*	*	*	5.54	7.85	7.69	9.64	9.28	3.97
lant25	AD 1862	AD 2001	*	*	*	*	*	*	*	*	*	-	5.14	8.24	5.73	4.77
lant26	AD 1779	AD 1918	*	*	*	*	*	*	*	*	*	*	8.90	4.24	9.51	-
lant27	AD 1825	AD 2001	*	*	*	*	*	*	*	*	*	*	*	8.64	9.63	4.82
lant28	AD 1800	AD 2001	*	*	*	*	*	*	*	*	*	*	*	*	8.24	4.46
lant29	AD 1784	AD 2001	*	*	*	*	*	*	*	*	*	*	*	*	*	6.30

Table 3. Correlation (*t*) values between dated trees.

SEQUENCE NAME	START DATE	END DATE	T VALUE	REFERENCE CHRONOLOGY
giertz2	AD 1729	AD 1969	9.45	Hereford and Cumberland Siebenlist-Kerner 1978
chk	AD 1883	AD 1980	5.02	Chalkney wood Essex CHK made CMG 2/9/92 11 timber mean
sotterly	AD 1586	AD 1981	6.11	Sotterley Park Briffa et al 1986 CEC10 div10
levenspk	AD 1717	AD 1993	7.37	Levens Park Cumbria Tony Carter Nov1994
charlbry	AD 1828	AD 1979	5.36	Charlbury Oxfordshire Briffa? via DMB 09/1998
hampmod	AD 1635	AD 1972	7.37	Hampshire/Winchester modern Barefoot 1975
oxford	AD 1781	AD 1978	7.02	Oxford Pilcher & Baillie 1980 TRB40 45-58
radley	AD 1812	AD 1979	8.24	Radley Wood Oxfordshire Briffa via DMB 09/1998 51.8N 1.5W indexmaster
westdean	AD 1867	AD 1968	7.21	West Dean woods [Singleton] made IGT
winchstr	AD 1635	AD 1972	7.65	Winchester Barefoot 1975 remake IGT
abbeyfrd	AD 1845	AD 1985	7.55	Abbeyford Wood Devon ABBEYFRD made CMG 22/7/93 9 tree mean
bath	AD 1754	AD 1979	6.41	Bath Pilcher & Baillie 1980 TRB40 45-58
boconnoc	AD 1712	AD 1981	5.44	Boconnoc Briffa et al 1986 CEC08 div10
clovelly	AD 1750	AD 1981	10.5	Clovelly North Devon KM/T15 made CMG 3/8/93
savenake	AD 1651	AD 1982	5.58	Savenake Forest Briffa et al 1986 CEC06 div10
broc_oak	AD 1844	AD 1984	5.48	Brockadale W Yorks - 9 timber mean made JH 28/9/94
ireland_enis	AD 1811	AD 1978	9.87	Eniscorthy Pilcher & Baillie 1980 TRB 40 23-34
ireland_kill	AD 1809	AD 1978	5.63	Killarney Pilcher & Baillie 1980 TRB 40 23-34
ireland_rost	AD 1750	AD 1975	5.6	Rostrevor Pilcher 1976 TRB 36 21-27
ireland_sain	AD 1776	AD 1990	6.57	Saintfield house - ring width N.Ireland Oak - J. Pilcher
ireland_shan	AD 1649	AD 1983	5.8	Shanes Castle Briffa et al 1986 CEC03 div10
towy	AD 1816	AD 1976	6.82	Towy Valley Wales RAM
fr_paris	AD 1618	AD 1984	5.91	Paris Basin version 4 - part E Lambert; Lavier & Bernard 1994

Table 4. Lanlas 13 timber mean *t* values against modern oak ring width sequences from Britain, Ireland and Europe. *t* values over 5 shown.

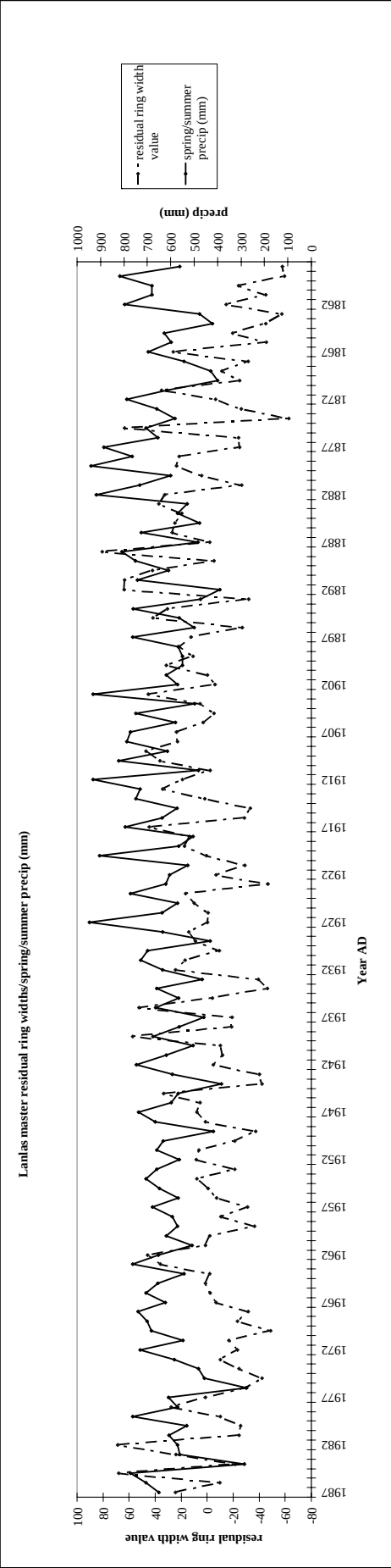


Figure 2.

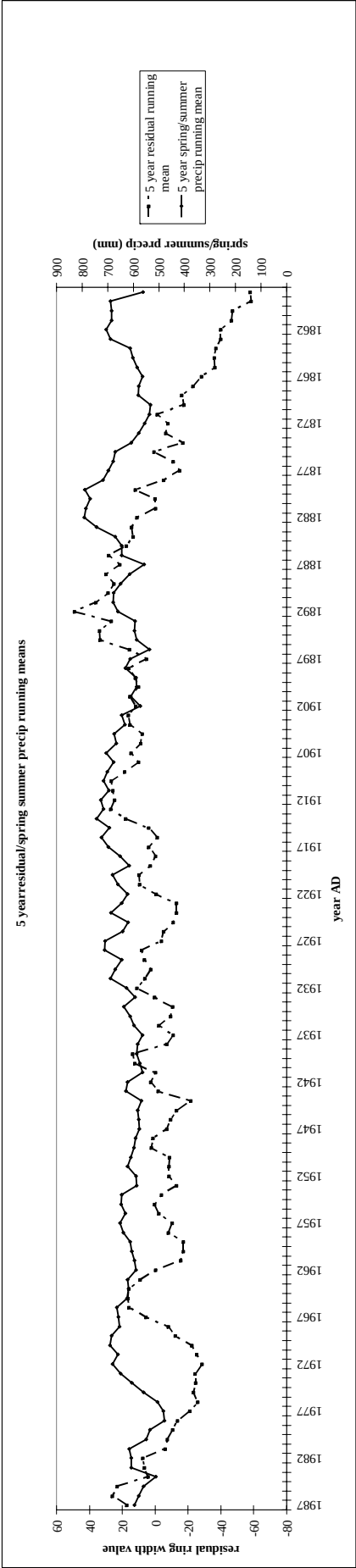


Figure 3.

		VAR00001	VAR00002
VAR00001	Pearson	1	.324
	Correlation		
	Sig. (2-tailed)		.000
	N	130	130
VAR00002	Pearson	.324	1
	Correlation		
	Sig. (2-tailed)	.000	
	N	130	130

** Correlation is significant at the 0.01 level (2-tailed).

Table 5. Correlation between spring/summer precipitation and raw ring width (0.01 mm) data (1858-1987)

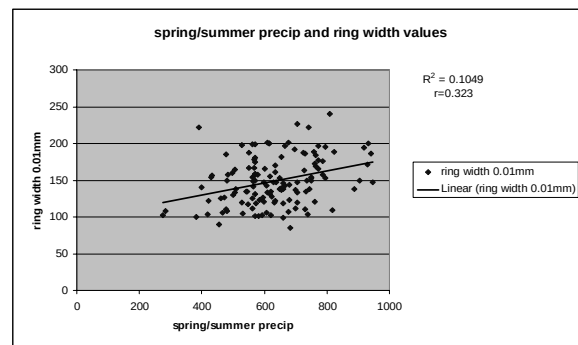


Figure 3. Scatter plot of spring/summer growth and raw master ring width values.

Discussion

The results of the individual core *t* values (Table 2) clearly demonstrate that the highest correlations are between two cores from the same tree. Trees 13, 14 and 16 demonstrate very high *t* values between 12.15 and 14.75. If these samples were of unknown provenance (i.e. archaeological material) it would be assumed that they have come from the same tree.

The correlation value between trees in the western area of Lanlas is stronger than between these trees and those in the eastern area of the wood. The composition and relief of this area is different. There are fewer oak trees and more regenerative beech and ash. It is likely that this area was harvested during the nineteenth century and that the remaining oak trees are probably remnants

from this felling. At the beginning of the ring sequences of these trees the rings are narrow. After 40-50 years growth the ring widths increase noticeably, possibly as a result of decreased competition. The trees themselves are bigger in girth than many of the oaks in the western area, indicating more favorable, open growing conditions. Decreases in ring width toward the present day may be attributable to the beech trees. Beech is known to be a serious competitor with oak for dominance, being more responsive to soil nutrient concentrations. On low nutrient soils oak is likely to have the advantage, and on high nutrient soils beech is likely to be favored (Jones, 1959). The eastern area of Lanlas appears to be more favourable to tree growth, with gentler relief, less acid soil and closer to the water table.

This study demonstrates the danger of attempting to age trees through girth size. Tree 26, for example, only had a 94cm girth. Despite its small size it contained a ring sequence dating back to 1779. As with some of the other trees shown in Figure 1, Tree 26 was not measurable in the latter part of the sequence. Rings from the latter part of Trees 26, 16, 18 and 19 were too narrow to measure and were therefore not included.

There can be a clear definition of geographical ranges with regard to matching ring sequences from living trees (Bridge, 2000). The preference of *Quercus petraea* for western Britain and the eastern and western extremes of Ireland (Jones, 1959) is reflected in the high correlation between the Lanlas master sequence and trees from geographically similar areas. Clovelly (*t* = 10.50) demonstrates the highest match with the Lanlas trees and shares a similar steep coastal location, exposed to the same climatic influence. Enniscorthy (*t* = 9.87) on the east coast of Ireland is geographically close to Allt Lanlas and shares similar Atlantic influence. High *t* values are also evident for Oxfordshire chronologies. This may indicate climatic influence along a

similar line of latitude. In essence the high correlation between the Lanlas master and a wide variety of other European chronologies demonstrates similar Atlantic influence on tree growth. Although ring width variation in European oaks is assumed to be of climatic origin (Bridge et al, 1986), the role of insect defoliation in determining incremental growth should also be considered (Fritts and Swetnam, 1989; Gradwell, 1975; Jones, 1959). In Ireland, narrow rings in the 1840s are thought to be attributable to heavy insect defoliation (Baillie, pers. comm., 2001). This phenomenon is reflected in the Lanlas ring widths, with 1844 being the narrowest mean ring width (Table 1). Bad harvests are documented for 1845 in Ceredigion (Lewis, 1990). However, it is likely that insect defoliation is a product of climatic variability with a single causal factor for ring width variation difficult to determine.

Conclusions

By comparing residual ring width values against historic climate data (precipitation – Rhyader-Tynant) it is evident that for the last 130 years at least, Lanlas tree growth is influenced by spring/summer precipitation. High raw ring widths and residual values are linked to high precipitation years. In years of markedly low spring/summer precipitation there is a marked decrease in ring width, with, as expected markedly dry years affecting the next few years growth increments (e.g 1893, 1944 and 1976). The *r* value between raw ring width and precipitation (see Table 5) though not huge, and only explaining around 20% of the variance, is significant at the 0.01 level. A way of increasing the correlation value would be to test individual monthly precipitation data against ring width values, rather than mean spring/summer data. This would identify the period of greatest growth and would further understanding of climate/tree growth relationship in West Wales. The application of other techniques (e.g isotopic analysis and densitometry) to these samples, in conjunction with higher

resolution climate data, would likewise further understanding of the environmental influences on these trees.

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