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Pollen-analytical perspectives on the end of Roman Britain

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Abstract

Pollen analysis is increasingly being used to investigate the landscape context of the end of Roman Britain, and specifically the extent to which there was continuity or change in land use and farming practices. Approaches vary from the use of single-off site pollen sequences to the assessment of databases of large numbers of sites, but all are faced with the necessity of considering key interpretative issues such as pollen source areas and chronological precision. This paper presents an overview and critique of pollen-based approaches to the question of post-Roman landscape continuity and change, highlighting the need for caution in site selection, inter-site comparison, and in extrapolation to the landscape scale. Consideration is given to what is meant by continuity in palaeoenvironmental terms, based on ecological studies of vegetation responses to grazing exclusion and land abandonment. The implications of these studies for future approaches to detection of post-Roman landscape continuity and change in palaeoenvironmental sequences are discussed.

Key words:

Pollen analysis, post-Roman period, continuity, woodland regeneration

Introduction

The end of the Roman period in Britain was a time of major social and economic change, the character of which is much debated (e.g. Esmonde-Cleary 1989; K. Dark 2000; Gerrard 2013; Haarer 2014). This might be expected to have resulted in changes in land-use regimes, the nature of which can be explored by pollen analysis of contemporary sequences of deposits. Changes in the ratio of arboreal:non-arboreal pollen can indicate variation in the relative proportions of woodland and

open land, while the presence of pollen of crops and weeds may indicate particular types of agricultural activity (Behre 1981). Applications of pollen analysis to this issue range from analysis of single sequences (e.g. Waller 2010; Brown 2010, 2013) to the assessment of multiple sites on a variety of spatial scales (e.g. Turner 1979; 1981; Dark 1996; 2000, 150-154; Dark and Dark 1996; Dumayne-Peaty 1999; Rippon *et al.* 2015; Davies 2019), but all are faced with the necessity of considering key interpretative issues such as the comparability of data between sites, pollen source areas and chronological precision. This paper presents an overview and critique of pollen-based approaches to the question of post-Roman landscape continuity and change, and a consideration of how ecological studies of the effects of grazing exclusion and land abandonment can inform approaches to this issue. While the focus of discussion here is primarily Britain, the issues are of relevance to studies of mid-first millennium environmental change more widely in north-west Europe (e.g. Dreßler *et al.* 2006; Woodbridge *et al.* 2019; Deforce *et al.* 2020), and indeed to the pollen-analytical investigation of vegetation responses to periods of land abandonment at other times (e.g. Dark 2006).

Previous research

Prior to the widespread availability of radiocarbon dating, pollen sequences from Britain south of the Antonine Wall that showed woodland regeneration after major (presumed prehistoric) clearance were often argued to reflect the collapse of Romano-British agricultural systems soon after Roman military control was relinquished in the early fifth century (e.g. Moore 1968). The first application of radiocarbon dating to the issue, in the late 1970s, seemed to suggest a different pattern, however. On the basis of pollen sequences from north-east England, Judith Turner (1979) argued that much of that area was farmed throughout the Roman period until at least the sixth century, with woodland regeneration only after that date. The suggestion of initial post-Roman continuity rested on radiocarbon dates centred on the sixth or seventh centuries argued to be associated with woodland regeneration phases, but at some of her sites, such as Fellend Moss and Steng Moss in Northumberland (Davies and Turner 1979), the tree/shrub pollen curves increase **before** the radiocarbon-dated level, suggesting that regeneration had already begun at an earlier date. Most pollen sequences from this area probably do not, in fact, show a period of initial post-Roman continuity, or have a temporal resolution too coarse to enable any such period to be distinguished (Dark and Dark 1996).

In a later paper, incorporating further radiocarbon-dated pollen sequences – mainly from northern England and Scotland – Turner concluded that 'the majority of pollen diagrams indicate a regenerated forest and a lower proportion of arable and pasture land.... Some show no change and only a very small proportion indicate a higher level of activity than in the Iron Age' (Turner 1981, 71). This evidence was subsequently extrapolated to other areas, resulting in a general perception that abandonment of land and woodland regeneration were widespread after Roman withdrawal from Britain, a view first seriously challenged by Martin Bell (1989).

By the 1990s the number of off-site pollen sequences with radiocarbon dates for the Roman to post-Roman transition period in Britain had increased to the extent that a new overview was possible, although there remained a bias in the distribution of sites to northern and western Britain (Dark 1996; 2000, 134-154). This showed that the fifth-to-eighth centuries were not a period of general agricultural stagnation in Britain – approximately half of the pollen sequences indicated continuity or an expansion in the extent of open land – but there was clear evidence of post-Roman regeneration in most sequences from the area of the Antonine and Hadrianic frontiers which had seen substantial loss of woodland in or before the Roman period (see also Dark and Dark 1996; Dumayne-Peaty 1999).

Subsequently, the 'Fields of Britannia' project (Rippon *et al.* 2015) used pollen data (combined with evidence from field boundaries and on-site assemblages of plant and animal remains) to examine the extent to which the landscape of Roman Britain survived into the medieval period, concluding that there was 'considerable regional variation in the degree to which patterns of land-use changed in the early medieval period' (Rippon *et al.* 2015, 309). A combination of on- and off-site pollen sequences were used to produce average figures for changes in different categories of land use between the Roman and 'early medieval' periods in nine regions south of Hadrian's Wall considered to be geographically and culturally distinct. Unfortunately, however, this averaging of results from relatively few pollen sequences across large swathes of England and Wales obscured potentially interesting patterning in the pollen data, notably the clear evidence for post-Roman woodland regeneration in the northern frontier region, noted above (Dark 1996; 2000, 150-154; Dark and Dark 1996; Dumayne-Peaty 1999; and see Mighall *et al.* 2004). Furthermore, the inclusion of on-site data in the statistical analyses is problematical when the aim is to assess continuity and change on a landscape scale, as on-site pollen sequences often have very local source areas – limited to the confines of the site itself rather than the broader landscape – and so are intrinsically likely to indicate open conditions whatever was happening further afield. On-site

sequences are also far less likely to have accumulated over long periods without disturbance, making them less than ideal as a resource for detecting potential continuity locally, let alone in the broader landscape.

Most recently Rippon and Fyfe (2019) offered an additional perspective on the 'Fields of Britannia' study by exploring the effect of using model-based correction of pollen data (specifically REVEALS) on the vegetation patterns. This was limited, however, by the need for raw pollen counts – available for less than 20% of the sites in the original database – and for aggregation of the data over 500-year time slices (AD 250-750 and 750-1250), designed to reduce uncertainties in inter-site comparison. Obviously, these slices cut across the end of the Roman period, demonstrating the limitations of the method at present to anything other than the most broad-brush approach to long-term landscape continuity and change.

Until recently, Wales had especially few relevant pollen sequences – for the lowlands particularly – but new analyses and synthesis by Tudur Davies (2019) has helped to improve this situation. The results differ from those of Rippon *et al.* (2015), probably due both to the greater availability of lowland sites and differences of approach. Davies used only off-site sequences, avoiding the issue of lack of representativity of the broader landscape in on-site samples, and assessed change on a sequence by sequence basis rather than Rippon *et al.*'s problematical approach of trying to calculate precise pollen percentages without access to original pollen counts, and then averaging them over large areas. Thus, while Rippon *et al.* (2015, 304) concluded that 'overall the pattern of land-use within Upland Wales appears to show a strong degree of continuity', Davies (2019, 182) notes that in the fifth and sixth centuries for Wales overall 'numerous sampling sites exhibit increased heath and woodland pollen, possibly indicative of the abandonment of settlements or reduction in areas managed for farming practices', but with the proviso that a few sites show no change and in north Wales there is some evidence for woodland clearance.

Clearly, differences in approach to the pollen-based assessment of post-Roman continuity and change, both in terms of criteria for selecting sites for database inclusion and in data handling, may radically affect the conclusions of such studies. It is important, therefore, that these criteria are stated clearly – another issue with the Rippon *et al.* (2015) study. The implications of these choices will now be discussed, followed by a consideration of how ecological studies of vegetation change in areas from which grazing has been excluded, and on abandoned agricultural land, can inform our understanding of changes in the pollen record for the end of Roman Britain.

Issues in the use of pollen sequences for assessing post-Roman landscape continuity and change

Selection of pollen sequences to examine this issue would usually begin with decisions on which type of site to include from the range of contexts where pollen may be preserved, and on what is considered an acceptable degree of chronological control. There is then the question of how the relevant information will be extracted from the chosen sequences (e.g. subjective assessment of change or statistical approaches) and interpreted, and the extent to which it is possible to extrapolate from the site to the wider landscape.

Site selection: site type and pollen source area

Pollen sequences from different site types differ fundamentally in the scale of vegetation that they reflect. As a very general rule, for off-site sequences the larger the site of deposition the larger the pollen source area (Jacobson and Bradshaw 1981), but a key consideration also is whether the deposits themselves are vegetated. Thus, lake sediments might contain pollen assemblages that are a fair reflection of the surrounding vegetation on a regional scale (e.g. Fossitt 1994), but in a similarly-sized mire the pollen may be dominated by the growth of on-site vegetation comprising taxa such as grasses (*Poaceae*) and heather (*Calluna vulgaris*) which may be difficult to distinguish from regional vegetation (Dumayne-Peaty and Barber 1998; Bunting 2003). Furthermore, mire plant communities are strongly influenced by local site hydrology and climate – providing a principal source of climatological data for northern and western Britain (e.g. Blackford and Chambers 1991; Charman *et al.* 2006) – factors that may obscure any pollen signal from changes in human activity in the broader catchment.

A key issue in attempting to assess land-use change at the end of the Roman period in Britain is that the main distribution of large peat bogs and natural lakes – traditionally the primary source of Holocene pollen sequences – is biased towards upland areas of the north and west least likely to have been involved in major agricultural production. The search for sites beyond these areas has necessarily focused on smaller sites of organic deposition, of which spring-fed mires and floodplain palaeochannels have proved to be especially useful. Palaeochannels may contain both organic and minerogenic alluvial deposits, as at Lyminge in Kent (Maslin 2018), Dorney in Buckinghamshire (Parker *et al.* 2008) and Yarnton in Oxfordshire (Greig 2004), reflecting the changing hydrological regime over periods of centuries or sometimes millennia. Pollen sources in

alluvium may be complex, however, with a large component of pollen transported from the wider stream/river catchment and reworked from earlier deposits. Pollen preservation in alluvium is often significantly poorer than in floodplain organic deposits, probably due to a combination of oxidation as a result of fluctuating water levels and reworking. This may result in assemblages biased towards relatively resistant pollen types such as Lactuceae (dandelion group), which not only persist in sediments when other taxa have decayed away, but remain identifiable even in an advanced state of deterioration. This probably explains the notable abundance of Lactuceae pollen in part or all of the palaeochannel sequences mentioned above, especially that from Oxey Mead, Yarnton, where Lactuceae (= Cichorioideae) exceeded 50% of the pollen sum in the medieval alluvial deposits (Greig 2004). Palaeochannel sequences must, therefore, be interpreted with due regard to the probability of differential preservation, especially in relation to shifts between deposition of organic sediments and alluvium.

Archaeological contexts such as waterlogged pits and ditches may yield pollen sequences, but these tend to be dominated by on-site depositional processes such as waste disposal. As such, their pollen inputs may tell us little or nothing about the vegetation of the broader landscape, or provide an unrepresentative picture of it. At Barton Court Farm villa, Oxfordshire, for example, pollen samples were obtained from three wells, two dating from the Roman period and one 'Saxon' (Miles 1986). One of the Roman-period wells contained a large quantity of mosses 'from between and behind the stones' lining it, their species composition suggesting that they had originally been collected from an area of woodland (Dickinson 1986 microfiche VIII.6). Unsurprisingly, pollen analysis of the moss indicated a higher tree and shrub content than in a non-moss sample from the same well (Greig 1986 microfiche VIII.7:3). Conversely, cereal pollen was absent from the moss sample but present in the non-moss sample, as well as in the single samples from the two other wells. This cereal pollen was considered likely to represent deposition of plant material brought to the site from elsewhere (termed 'floral pollen', as opposed to 'atmospheric pollen', by Greig (1986 microfiche VIII.7:3)), rather than local cereal cultivation.

A further example is provided by excavations at Silchester Roman town in Hampshire (Fulford and Clarke 2011). Here, samples from a cess-pit estimated to have been filled by c. AD 125 were dominated by pollen of Brassicaceae (cabbage family), Apiaceae (carrot family) and Poaceae, including cereals (Dark 2011). Analysis of macroscopic plant remains from the same deposits (Robinson 2011) demonstrated the presence of a variety of culinary herbs, including coriander

(*Coriandrum sativum*), dill (*Anethum graveolens*) and celery (*Apium graveolens*) (all members of the Apiaceae), and cereals, suggesting that food remains (deposited directly or following ingestion) were the primary source of pollen to the deposits. These foods need not have been grown locally - indeed at least some of the foods used at Silchester were continental imports (Robinson 2011).

Thus, on-site pollen sequences are likely to be dominated by site-specific processes, making them a poor indicator of broader landscape change, while use of off-site sequences requires careful evaluation of the potential contribution of *in situ* vegetation to overall pollen deposition. Detailed inter-site comparison would ideally only be made between similar site types such as lakes and mires – and, even then, only when the basin size is similar – but to adopt such an approach for the current question would make the available dataset vanishingly small. The most practical strategy is, therefore, to consider the interpretation of change at each site individually with due regard to its likely pollen source area, potential for differential pollen preservation etc.

Chronological control and temporal resolution

Another fundamental issue in choosing sites suitable to address the question of post-Roman continuity and change is dating. Is the degree of chronological control appropriate? The inherent imprecision of radiocarbon dating makes it impossible to pinpoint exactly the part of an off-site pollen sequence corresponding to the traditional ‘end’ of Roman Britain in the early fifth century or even, in many cases, to the fifth century at all – a problem discussed in the context of the start of the Roman period by Dumayne *et al.* (1995) and more generally by Baillie (1991).

In recent years, radiocarbon laboratories have been able to offer results for samples from the first millennium AD with a standard deviation of around ± 20 -30 years, but this still represents a range of 80-120 years at 2σ , even before calibration. Results from determinations made up to and including the 1990s had greater error terms, often between ± 50 and ± 80 years, but sometimes even more (Table 1). For example, a potentially post-Roman woodland clearance phase in the pollen sequence from Codsand Moors, Exmoor, Somerset, was dated 1660 ± 130 BP (I-16,091) (Francis and Slater 1992), a range of 520 years at 2σ before calibration. Furthermore, radiocarbon dating of most pollen sequences analysed in the 1990s and earlier involved the use of bulk samples. While dating by accelerator mass spectrometry (AMS) can use individual or a small number of identified plant remains, conventional dating often required a substantial slice of peat or sediment – sometimes up to 10 cm thick (Table 1) – which itself may have taken decades (at least) to accumulate, blurring the relationship between the radiocarbon determination and the ‘event’ in

the pollen record that it is designed to date. For example, the 8 cm-thick radiocarbon sample from Codsand Moors, noted above, probably represents a period in excess of 300 years at the estimated accumulation rate of that sequence.

The form of the radiocarbon calibration curve for the middle of the first millennium AD is also important. There is a reversal in the curve which the most recent version (IntCal 20, Reimer *et al.* 2020) places at around cal. AD 270, with the effect that a sample of that date would be effectively indistinguishable in radiocarbon terms from one of the late fourth century, both producing radiocarbon determinations centred on c. 1700 BP. This is illustrated in Figure 1 with the AMS date for a period of significant change in woodland composition (the expansion of beech (*Fagus sylvatica*)) at Epping Forest, Essex (Grant and Dark 2006; Dark 2017, fig. 2.3). Although the date has a relatively small error term of ± 29 , and so a range of 116 years at 2σ before calibration, the 'wiggles' in the calibration curve produce a two-part calibrated range of 255-285 (16.7% probability) and 326-422 (78.8% probability). The change in the woodland, probably reflecting its use for grazing and/or management for timber and underwood, is most likely to have occurred in the late Roman period or very soon after, but could have been in the mid-late third century.

This reversal in the calibration curve is followed by a minor plateau at around 1600 BP, spanning almost 100 calendar years between c. 440 and 530 cal. AD. Samples with true ages between these dates would produce effectively identical radiocarbon determinations centred on 1600 BP. This means that calibration of single radiocarbon dates from around this time may produce particularly large age ranges, as illustrated in Figure 2 by calibration of a date from Talkin Tarn, Cumbria (Langdon *et al.* 2004). Similar radiocarbon reversals and plateaux occur in the eighth and ninth centuries, highlighting the need to avoid the sort of chronological pseudo-precision shown in the 'Fields of Britannia' projects' division of the 'early medieval period' for the purposes of statistical analysis of the pollen data into the periods AD 411-499, 500-849, and 850-1066 (Rippon *et al.* 2015).

It is perhaps worth noting also that before existing pollen sequences are compared it is essential to recalibrate their radiocarbon dates to the latest calibration curve so that they are comparable. The longer ago a radiocarbon date was obtained and calibrated the more likely it is to diverge from the currently accepted calibration. Table 1 compares the original calibrated dates for pollen sequences with deposits dated to approximately the fifth century with the results of recalibration using the most recent IntCal 20 datasets (Reimer *et al.* 2020). It is notable that in

some cases the recalibrated age range may differ by decades from the original one, and that the new range may be wider or narrower than was originally the case (Figure 3).

In fact, there remain rather few pollen sequences where vegetational changes at around the time of the Roman-post-Roman transition have directly associated radiocarbon dates. More commonly the date of any such changes has been estimated by interpolation between adjacent pairs of radiocarbon determinations, requiring careful assessment of the stratification for disturbance such as peat cutting (e.g. Grant *et al.* 2009). Where large numbers of closely spaced dates are available for a sequence it is possible to model the accumulation rate by wiggle matching to the calibration curve (e.g. Yeloff *et al.* 2007), but this approach remains too expensive to have been widely adopted.

Having determined the rate of sediment accumulation, it is necessary to check the temporal resolution of the relevant part of the pollen sequence, which depends on its sampling interval. 'Conventional', as opposed to 'high-resolution', pollen sequences commonly have a resolution of a 1-2 samples/century, but it may be less. Pollen analysts rarely explicitly state the temporal resolution of their data, yet it is a key consideration in determining how that data can be used. There are notable exceptions: for example, Martyn Waller (2010) estimated that for the part of his Ashted Common, Surrey, pollen sequence that accumulated between c. cal. AD 150 to 500 the samples were at intervals of c. 12 years. He also noted that each sample represented c. 4 years of accumulation, highlighting the fact that, as with samples for radiocarbon dating, each pollen sample itself has a time-depth depending on the thickness/stratigraphical depth that it covers (commonly 0.5-1 cm). However, four years is a relatively short time-span for a sample: Grant *et al.* (2009) estimated that their sediments from Barrow Moor in the New Forest, Hampshire, accumulated at a rate of 34.6 years/cm during the second half of the first millennium AD, so that each of their 1 cm-thick pollen samples from this part of the sequence would represent c. 35 years. However well dated a pollen sequence may be, in terms of the accuracy with which the sediment accumulation rate may have been determined, its ability to detect change will depend on the pollen sample thickness and the interval between the samples. Obviously, a sequence where the pollen samples are 200 years or more apart will be useless in attempts to detect vegetation changes lasting a few decades. The implications of the temporal resolution of pollen data are discussed further below in relation to the speed with which vegetation might be expected to have responded to land-use change at the end of the Roman period.

On-site contexts may offer the potential for more tightly constrained chronologies than off-site contexts such as mires and lakes due to the presence of well-dated artefacts, especially coins, typologically-dated pottery (e.g. Manning *et al.* 1997), and potentially wood datable by dendrochronology, but they rarely offer long sequences of continuous deposition due to processes such as refuse dumping and ditch clearing. Furthermore, pollen analysis from such contexts has often involved just a few spot samples, so that the preferred option of assessing continuity/change from a single continuous sequence is impossible.

Pollen sums and inter-site comparability

Fundamental to studies making statistical comparisons between multiple pollen sequences is the need to ensure comparability of data between sites. Percentage data presented in pollen diagrams may have been calculated using a variety of pollen sums: a sum based on the total pollen and fern spores (excluding obligate aquatics) is often used, especially for pollen sequences from lakes such as Crose Mere, Shropshire (Beales 1980), and Hockham Mere, Norfolk (Bennett 1983), but by no means universal. For mires, where local vegetation may contribute much of the pollen to the assemblages, taxa considered likely to have been growing *in situ* – such as ferns (Pteropsida), alder (*Alnus*), heathers (Ericaceae) and sedges (Cyperaceae) – are often excluded from the main sum. For example, the pollen sequence from the blanket mire at Codsand Moors (Francis and Slater 1992) was based on a sum of total land pollen excluding fern spores, while that from the raised mire near Tregaron (Cors Caron), Ceredigion, used ‘% non-mire pollen excluding *Calluna*, Cyperaceae, *Alnus* and aquatics’ (Hughes *et al.* 2001).

These different sums make comparison between sites problematical and recalculation of the data to a common sum essential for detailed numerical comparison between sequences. This can be difficult to achieve using printed pollen diagrams – which remain the main source of data at present – as the figures must be read from the diagrams and then recalculated to the new sum. For example, my database and analysis of pollen sequences for the first millennium AD (Dark 2000) used the common sum of % total pollen and fern spores excluding obligate aquatics, recalculating the data where necessary, to produce average pollen percentages for arboreal pollen for the part of each sequence estimated to have accumulated in successive periods from the late Iron Age to the Viking Age. In recognition of the inherent imprecision of this approach – both in terms of percentage calculation and identification of the correct part of each sequence using radiocarbon dates – the data were mapped by site in broad % ranges. The subsequent analysis by Rippon *et al.*

(2015) does not mention this issue of variable pollen sums, or indicate how the pollen percentage calculations – the vast majority of which must have been derived from printed pollen diagrams rather than raw data – were made. It is, therefore, unclear how, or even if, inter-site differences in pollen sums were allowed for. This highlights the importance of clear information on data handling when comparing multiple pollen sequences, as without it there is no way to assess the validity of the results.

Scales of analysis

As discussed above, pollen sequences from different types and sizes of depositional context may have very different source areas, making extrapolation to the broader landscape inappropriate in many cases. Rippon *et al.* (2015) employed their mixture of on- and off-site sequences to map averaged pollen percentage data over nine substantial regions, creating a false impression of homogeneity, despite the fact that some of their regions had very few sites indeed: in Wales, for example, no data at all were available for the island of Anglesey, and only a single site (Borth Bog/Cors Fochno) for the ‘Coastal Lowlands of Cardigan Bay’, yet these sub-regions (*pays*) were indicated as sharing a common pattern of post-Roman vegetational change with ‘Upland Wales’, including the mountains of Snowdonia!

Very few parts of Britain have sufficient pollen sequences to allow identification of patterns of land-use change at the Roman/post-Roman transition on the sub-regional or regional scale, rather than events within the primary pollen catchments of individual sites. The Hadrian’s Wall area currently has the greatest number of sequences for this period, most of which display woodland regeneration (Dark 1996; Dark and Dark 1996; Dumayne-Peaty 1998; Dark 2000). Elsewhere, many more sequences are needed, ideally with overlapping pollen source areas, to allow inter-site comparisons to be made so that the relative significance of site-specific and broader landscape-scale changes can be assessed.

Defining and identifying continuity and change in ecological terms

The issues discussed above highlight a number of problems with much of the pollen data currently available for assessing possible changes in vegetation and land use at the end of the Roman period in Britain. In attempting to address these issues it is important to be clear about what we might expect to see in the pollen record arising from different land-use scenarios. Continuity is generally considered to be indicated by a lack of significant change in the pollen record, but relatively short-

term changes would be missed in pollen sequences with low temporal resolution. Discontinuity is usually inferred from an increase of arboreal pollen, taken to indicate colonisation of abandoned agricultural land by shrubs then trees, but is there adequate temporal resolution of the pollen sequence, combined with sufficiently precise dating control, to identify when regeneration began – and so to be able to construct hypotheses about what might have triggered it? Most currently available pollen sequences for the first millennium AD have a sampling interval equivalent to decades or centuries, so the question arises, how long would we expect it to take for abandoned land to revert to woodland? This is best approached using ecological studies of vegetation recolonisation of former agricultural land.

Ecological studies of land abandonment

Research on the fate of abandoned farmland has been especially prominent in North America (e.g. Myster 1993), but there are some studies from temperate parts of Britain and Europe which are more directly relevant here. A particularly long-term perspective comes from Rothamsted Experimental Station, Hertfordshire, where two arable fields (Broadbalk and Geescroft Wildernesses) were abandoned in the 1880s and their vegetation then recorded for over a century (Harmer *et al.* 2001). Woody species – hazel (*Corylus avellana*), hawthorn (*Crataegus monogyna*), ash (*Fraxinus excelsior*), pedunculate oak (*Quercus robur*) and wild rose (*Rosa* sp.) – colonised Broadbalk after about a decade, and after 30 years had created a dense thicket of trees and shrubs, with abundant brambles (*Rubus fruticosus* agg.) and ivy (*Hedera helix*). Colonisation was slower at Geescroft: it was almost 30 years before trees and shrubs were first recorded. Broadbalk was closer to an existing area of woodland, and therefore a major potential seed source, than Geescroft, but both were adjacent to hedges containing mature trees, and Harmer *et al.* (2001) attributed the difference in recolonization rates to differences in soil and precursor vegetation rather than seed availability.

A shorter-term, but still important, study has also been undertaken on abandoned fields adjacent to woodland at Monks Wood, Cambridgeshire. Here both arable (the Old Wilderness, abandoned 1961) and grassland areas (the New Wilderness, abandoned 1996) were monitored via field survey and remote sensing (lidar and photogrammetry) (Walker *et al.* 2000; Sparks and Löbel 2007; Broughton *et al.* 2021). In the New Wilderness the cover of woody (shrub) vegetation (0.5 m or taller) ‘increased rapidly from negligible cover four years after abandonment, to 85-86% after 18-23 years’ (Broughton *et al.* 2021). After 23 years the vegetation averaged almost 3 m in height, but

with a very uneven canopy. In the Old Wilderness woody vegetation had covered the entire area after 53 years. 57% of this vegetation was 8 m or taller by 39 years post-abandonment, increasing to 91% after 53 years, by which time its structure resembled the neighbouring areas of woodland. The species composition of the regenerated woodland differed from that of the 'ancient' woodland, however, being dominated by pedunculate oak and shrubs, including blackthorn (*Prunus spinosa*) and brambles.

These studies indicate the speed (on an archaeological timescale at least) with which woodland may return after agricultural land is abandoned, beginning after about a decade and proceeding to complete woodland cover within approximately fifty years. Similar results have come from the study of abandoned agricultural land at the edge of Białowieża Forest in Poland (Bobic *et al.* 2011) and in the mixed landscape of forest and farmland of central Latvia (Ruskule 2012). The proximity of woodland and hedges undoubtedly accelerates the process of regeneration compared to what might be expected in more open areas, as experiments involving exclusion of livestock from upland grassland/moorland areas with few or no trees demonstrate (e.g. Rawes 1981; Hill *et al.* 1992). While most of the landscape of lowland Britain in the Roman period contained at least some woodland, along with hedges and individual trees, to provide seed sources, some originally wooded upland areas may already have been largely treeless by the end of the Roman period as a result of grazing (Dark 2000, fig. 4.6), and may not, therefore, have seen a return to woodland even if grazing intensity declined.

Increases in arboreal pollen in pollen sequences need not necessarily reflect woodland regeneration at all, however. A similar effect might result from the cessation of coppicing or hedgerow management, allowing flowering of trees and shrubs previously prevented from doing so due to the relatively short interval between cuts. A study of the effects of coppicing on pollen production of some common woodland species found that lime (*Tilia*) became 'palynologically silent' even in long-rotation (20+ years) coppice, but that hazel was able to flower in the shortest likely rotation, even seeming to show enhanced pollen production in the early stages of regrowth (Waller *et al.* 2012). Thus, a post-Roman increase of hazel is more likely to reflect woodland regeneration than cessation of management.

A combination of pollen studies and ecological monitoring indicate that secondary woodland is commonly dominated by oak and hazel, accompanied in the early stages of regeneration by shrubs such as brambles and hawthorn, although these Rosaceous taxa are

strongly under-represented in the pollen record (Dark 2021). By contrast, lime, which was the dominant tree across much of lowland England prior to widespread human activity, seems largely unable to form secondary woodland. Thus, an increase of lime pollen is much more likely to reflect changing woodland management regimes than regeneration.

The fact that abandoned farmland can revert to woodland in a matter of decades means that in most conventional pollen diagrams the process of regeneration will not be detectable, just its end point. Furthermore, if land was abandoned for just a few years, or even decades, but then reclaimed for agricultural purposes, many conventional pollen sequences would fail to detect the regeneration completely and give a false impression of continuity.

Palynological detection potential for different land-use change scenarios

To illustrate how significant the temporal resolution of pollen data is for detection of episodes of woodland regeneration, Figures 4 and 5 present some hypothetical scenarios for an area of lowland farmland abandoned c. AD 400 and how these might appear in pollen diagrams with different levels of temporal resolution. On the basis of the ecological studies discussed above, trees and shrubs would be expected to colonise within between one and a few decades, probably resulting in complete woodland cover by around AD 450 (Figure 4), depending on the availability of local seed sources, intensity of grazing by wild herbivores such as deer and possibly feral cattle, sheep and goats, etc. Trees and shrubs vary in the time it takes for them to mature sufficiently to flower and so produce pollen, but an estimated average of ten years is used. The return of woodland should be detectable in conventional pollen data even with quite coarse temporal resolution, so long as the woodland was not subsequently cleared, but the lower the resolution the more difficult it becomes to accurately pinpoint the part of the sequence at which the change was initiated. This is quite separate from the intrinsic problems of using radiocarbon dating to assign an absolute date to the event.

However, if the abandoned land was brought back into cultivation, or subject to renewed intensive grazing, after a few years or even a couple of decades, this would not be detectable in conventional, or even high-resolution, pollen sequences because trees and shrubs would not have had time to colonise and to flower. Together these stages would be expected to take at least twenty years, so only abandonment for at least this period would register in a pollen sequence. The earlier stages of vegetation succession, which usually involve herbaceous vegetation, are largely undetectable in the pollen record because most of the species involved do not produce

taxonomically distinct pollen. A false impression of continuity would be created. For longer periods of abandonment, the potential for detection depends on the relative lengths of the abandonment and the pollen sampling interval (Figure 5). Decadal sampling would probably detect the return of woodland to land abandoned for 30 years or more, but with lower resolution sampling only longer periods of abandonment would be detected. A 200-year sampling interval, which is not unusual in pollen sequences for the first millennium (e.g. Knowsley Park Moss (Cowell and Innes 1994) and Cefn Ffordd (Chambers 1982)), would probably only detect land abandoned for a century or more, and even this would depend on the precise relationship between the resulting peak of arboreal pollen and the pollen samples.

The intrinsic time-depth of the pollen samples themselves is also significant. In Figures 4 and 5 it is assumed, for the sake of simplicity, that the pollen samples have negligible time depth but, in reality, pollen samples may represent periods of years to decades, as discussed above, with the potential to 'smear' the signal from a relatively short-term vegetation change in the pollen sequence.

Of course, many land-use scenarios other than those illustrated here are possible. The key point here is that the ability of pollen analysis to detect continuity is critically dependent on the sampling resolution, and that the lower the resolution the greater the risk that short-medium term periods of land-use change will go undetected, with attendant implications for interpretation of changes in agriculture and economy at the end of the Roman period in Britain.

Discussion and conclusions

At present, consideration of any potential land-use changes associated with the withdrawal of Roman political and military control from Britain must be based on evaluation of a disparate body of pollen data, most of which was originally collected for other purposes. Evaluation of the issues of chronological control, pollen source area and comparability between sequences where different pollen sums have been employed are critical to its appropriate use. Most pollen sequences covering the first millennium AD offer at best multi-decadal resolution for a period when the form of the radiocarbon calibration curve means that there are several protracted (on the scale of a human lifetime) periods which are, in radiocarbon terms, effectively indistinguishable. Greater chronological precision may be achieved if sufficient radiocarbon determinations are available to allow wiggle-matching to the calibration curve, as demonstrated by Yeloff *et al.* (2007) for a pollen sequence from Butterburn Flow, north of Hadrian's Wall. There, a series of 42 AMS dates was

obtained from the 4 m-long sequence, achieving decadal chronological resolution over the last c. 5000 years with respect to modelling of the sediment accumulation rate, but resolution of the pollen data was lower than this: each pollen sample spanned 1.1 cm of deposit, representing between c. 12 and 22 years, while the spacing between the pollen samples was estimated to represent periods of between 14 and 112 years. The ecological experiments discussed above indicate that the pollen data themselves must have at least decadal resolution for it to be possible to pinpoint any specific trigger to woodland regeneration.

High-resolution pollen sampling has most often been applied to issues of prehistoric human-environment relations, such as the impact of later Mesolithic hunter-gatherers on their environment (e.g. Simmons and Innes 1996) or vegetation changes at the time of the Neolithic elm decline (e.g. Peglar 1993), on the grounds that these were short-term events – lasting only a few years – affecting the extent and character of tree cover in a predominantly wooded landscape. Such an approach would be no less valuable for understanding landscape change at the end of the Roman period, where it is often more a case of seeking changes in the extent of tree cover in a predominantly open landscape. As discussed above, the lag between land abandonment and the return of palynologically-detectable amounts of woodland means that even the highest-resolution (potentially annually resolved in the case of laminated lake sediments) pollen data could not identify land abandonment lasting only a few years. Where longer periods of abandonment did lead to detectable levels of woodland regeneration, however, the timing and duration of that regeneration could provide valuable insights into the changing socio-economic situation, but at present the chronological limitations of almost all of the available pollen data allow only the most broad-brush approach to this question.

Vegetation changes apparent in pollen sequences dated to the middle of the first millennium AD need not necessarily be directly related to human activity at all. There is good evidence from multiple proxies for climatic deterioration across north-west Europe, and indeed much of the Northern Hemisphere, at this time (summarised in Dark 2000, 19-28; McCormick *et al.* 2012; Helama *et al.* 2017), including in response to major volcanic eruptions in AD 535/536 and 539/540 (Sigl *et al.* 2015). These climate events have been suggested to have triggered crop failure, plague and potentially some of the major socio-political changes of the mid first millennium (Büntgen *et al.* 2016). There is currently a lack of sufficiently precisely dated and highly resolved pollen data to disentangle the different possible causes of vegetation change in the middle of the first millennium, although use of multiple palaeoenvironmental proxies can assist. For example,

combining analysis of macroscopic plant remains with pollen can help to distinguish vegetation growing locally from that in the wider catchment (e.g. Dark 2022), as well as indicating the effects on *in situ* vegetation of local hydrological change, which may in turn reflect broader patterns of climate change (e.g. Barber and Charman 2003). Analysis of charcoal particles on pollen slides may play an important role in establishing an anthropogenic origin for certain changes (e.g. Mighall and Chambers 1995, 1997; Caseldine *et al.* 2012; Dark 2005, 2019) yet, surprisingly, has still not become routine in analysis first-millennium deposits.

In seeking to generate new palaeoenvironmental data relating to the end of Roman Britain it is important to ensure that the approach is appropriate to the spatial and temporal scale of the anticipated changes. More sequences are needed from sites where the pollen data can be directly linked with archaeologically-attested Roman/post Roman-period activity but in a context where the deposits are unlikely to have been compromised by those activities. This approach has been used to explore the fate of the area around Hadrian's Wall at the end of the Roman period, by analysing 'off-site' sequences (in this case, lake-edge sediments) immediately adjacent to the wall and adjacent Roman road (the Stanegate) and seeking 'markers' for activities associated with their construction and use in the deposits (Dark 2005, 2019). This approach based on what might be termed 'near-site' sequences combines the certainty of a human presence at the appropriate time within the pollen catchment of the site with a reduced risk that related activities disturbed or truncated the deposits. In this case, the 'markers' employed to complement the pollen record were micro-charcoal particles (some of which retained sufficient anatomical detail to provide clues to the type of vegetation being burned) and layers of mineral inwash, detected by magnetic susceptibility, x-ray and loss-on-ignition analysis. Many other possible markers exist, depending on the types of activity likely to have been involved at the site in question, including human intestinal parasites, fungal spores and geochemical signatures of activities such as mining and metalworking (e.g. Mighall *et al.* 2002, Caseldine *et al.* 2012).

Multi-proxy analyses of 'near-site' sequences thus offer enhanced potential both to distinguish between natural and anthropogenic sources of change and to assess whether these changes might be linked to variations in the scale and character of archaeologically-attested activity within the pollen catchment of the site. Currently, it is clear that some woodland regeneration occurred in some parts of Britain in the middle of the first millennium, but it is difficult to disentangle the varied potential triggers and assess the broader significance, if any, of this regeneration. While we might seek to ascribe it to loss of the Roman military market and

consequent abandonment of arable land in the fifth century, climatic deterioration in the fifth/sixth century, or even, given the chronological uncertainties caused by the form of the calibration curve, the economic crisis of the third century (Auer and Hinker 2021), at every site there will have been local factors driving at least some of the changes in the pollen record. For example, increases of willow (*Salix*) and/or alder (*Alnus*) pollen might reflect reduced grazing on local flood-prone pasture, but they could alternatively result from local hydrological changes which might, in turn, be due to shifting climate or human activities such as drainage or re-routing of water courses, or even a rise of water table caused by woodland clearance in the wider catchment. In attempting to generate a 'big picture' it is important not to forget the interpretative nuances involved at the level of the individual site.

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Declaration of interest statement

The author reports that there are no competing interests to declare.

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Figure captions

Figure 1: The radiocarbon calibration curve for the late Roman and early post-Roman periods with the calibration for an AMS date from Lodge Road Bog B, Epping Forest (Grant and Dark; Dark 2017) using OxCal v4.4.4 (Bronk Ramsey 2009) with the IntCal 20 datasets (Reimer *et al.* 2020). Note that the reversal in the curve at cal. AD 270 produces a two-part calibrated range.

Figure 2: The radiocarbon calibration curve for the late Roman and early post-Roman periods with the calibration for an AMS date from Talkin Tarn, Cumbria (Langdon *et al.* 2004) using OxCal v4.4.4 (Bronk Ramsey 2009) with the IntCal 20 datasets (Reimer *et al.* 2020). Note the spreading of the calibrated range resulting from the minor plateau in the curve between c. cal. AD 440 and 530.

Figure 3: Original (thin lines) and new (thick lines) IntCal 20 radiocarbon calibrations for sites from Table 1 where the recalibrated range differs by more than 20 years from the original result, arranged in order of the date when the determination was made (most recent at the top).

Figure 4: A possible scenario for woodland regeneration following abandonment of an area of agricultural land c. AD 400 (arrow), and how it might be registered in pollen sequences of differing temporal resolution (samples at intervals of 10-200 years) if it then remained abandoned for at least 200 years. For the purposes of illustration, it is assumed that the pollen samples themselves have negligible time-depth. AP = arboreal pollen.

Figure 5: Possible scenarios for an area of agricultural land abandoned c. AD 400 (arrow) for 30, 50 or 100 years and then reclaimed, and how they might be registered in pollen sequences of differing temporal resolution (samples at intervals of 10-200 years). Periods of abandonment of 20 years or less would not register even in sequences with decadal or better resolution due to the lag in tree/shrub colonisation and flowering, while the registration of longer periods depends on the

pollen sampling interval. For the purposes of illustration, it is assumed that the pollen samples themselves have negligible time-depth. AP = arboreal pollen.

Table 1: Pollen sequences south of the Antonine Wall with a radiocarbon date centred on the fifth century AD = c. 1600-1700 BP, arranged in order of first publication date. For C14 sample depth, ‘?’ indicates sample depths read from the pollen diagrams where not specified in the original publication. The radiocarbon dates have been recalibrated using OxCal v.4.4.4 (Bronk Ramsey 2009) with the latest IntCal 20 datasets (Reimer *et al.* 2020). The original published calibrations are provided for comparison.

	Region	Site type	C14 sample depth (cm)	Date (BP)	Lab code	Original calibration (AD) if any (2σ)	New calibration, OxCal with IntCal 20, 95.4% prob (AD)	Original publication
Dun Law 3	S Scotland	Mire	62-63	1650 \pm 35	SUERC-24029	262-538	262-276 (4.1%) 345-483 (72.7%) 490-538 (18.7%)	McCulloch <i>et al.</i> 2021
Lyminge	SE England	Palaeochannel	147-152	1628 \pm 30	OxA-33563	349-536	383-542	Maslin 2018
Erglodd/Cors Fochno (Borth Bog) (Trench 6)	W Wales	Raised bog	46-46.5	1620 \pm 40	Beta-235895	340-540	365-553	Caseldine <i>et al.</i> 2012
Cas Troggy, Wentwood	SE Wales	Spring-fed mire	60-61	1680 \pm 40	Beta-238646	250-430	250-295 (16.0%) 311-439 (72.8%) 461-478 (2.1%) 497-534 (4.6%)	Brown 2010, 2013
Ashtead Common	SE England	Former clay pit	139	1700 \pm 40	Beta-259675	250-420	247-425	Waller 2010
Barrow Moor, New Forest	S England	Valley mire	82	1688 \pm 25	SUERC-4708	260-420	258-280 (14.0%) 333-419 (81.5%)	Grant <i>et al.</i> 2009
Dorney	Central S England	Palaeochannel	60-63	1670 \pm 40	CAMS-54444	250-440	255-286 (11.9%) 325-441 (70.4%) 450-479 (5.0%) 495-535 (8.1%)	Parker <i>et al.</i> 2008
Epping Forest	SE England	Valley mire	118-119	1691 \pm 29	OxA-15768	250-420	255-285 (16.7%) 326-422 (78.8%)	Grant & Dark 2006; Dark 2017
Yarnton floodplain (section B)	Central S England	Palaeochannel	65-75	1640 \pm 50	OxA-7361	250-550	258-281 (4.8%) 332-550 (90.7%)	Greig 2004
Yarnton Oxe Mead (section 3)	Central S England	Palaeochannel	85-95	1675 \pm 55	OxA-7360	230-530	249-296 (15.4%) 309-484 (69.2%) 489-538 (10.9%)	Greig 2004
Talkin Tarn	N England	Lake	58 74	1600 \pm 50 1670 \pm 40	CAMS-70066 CAMS-68463	340-600 260-530	365-582 255-286 (11.9%) 325-441 (70.4%)	Langdon <i>et al.</i> 2004

							450-479 (5.0%) 495-535 (8.1%)	
Rookhope (RH2)	N England	Blanket mire	44-46	1655±50	SRR-6472	257-536	255-286 (8.4%) 325-545 (87.1%)	Mighall <i>et al.</i> 2004
Valley Bog, Moorhouse National Nature Reserve	N England	Blanket mire	151-153	1675±50	SRR-6464	243-530	250-295 (15.0%) 311-482 (70.9%) 491-537 (9.5%)	Mighall <i>et al.</i> 2004
Cors Caron (Tregaron Bog) (Southeast Bog, TRE98)	W Wales	Raised mire	37	1610±40	CAMS-60857	347-544	384-562	Hughes <i>et al.</i> 2001
Foulshaw Moss (FM1A)	NW England	Raised mire	23-24 29-30	1675±60 1685±65	CAR-546 CAR-547	241-539 184-539	247-539 241-539	Wimble <i>et al.</i> 2000
White Moss (WMN2)	NW England	Raised mire	36-38	1630±60	CAR-703	260-597	256-284 (4.9%) 327-571 (90.6%)	Wimble <i>et al.</i> 2000
Rough Tor South, Bodmin Moor	SW England	Raised mire	115	1675±45	OxA-6007	240-440 (1996)/ 250-460 and 480-530 (2000)	251-294 (14.6%) 314-480 (72.7%) 492-537 (8.1%)	Gearey & Charman 1996; Gearey <i>et al.</i> 2000
Cefn Glas (A)	S Wales	Valley mire	76-77	1700±70	CAR-415		224-540	Smith & Green 1995
Winmarleigh Moss	NW England	Raised mire	40-45	1680±80	GU-5022		222-561	Middleton <i>et al.</i> 1995
Knowsley Park Moss	NW England	Mire	42-48	1680±50	Birm-1177	240-440	248-299 (17.2%) 306-442 (65.7%) 449-480 (4.9%) 494-536 (7.7%)	Cowell & Innes 1994
Codsend Moors, Exmoor	SW England	Blanket mire	55-63	1660±130	I-16,091		124-644	Francis & Slater 1992
Bryn y Castell (BYC)	N Wales	Valley mire	68-70	1610±70	HAR-6106	320-600 (1997)	257-282 (3.6%) 329-599 (91.9%)	Mighall & Chambers 1995, 1997
Bryn y Castell (BYC2)	N Wales	Valley mire	260-262	1655±50	GrN-17582	250-540 (1997)	255-286 (8.4%) 325-545 (87.1%)	Mighall & Chambers 1995, 1997
Moel y Gerddi	N Wales	Valley mire	17-19	1655±60	CAR-660		250-295 (10.5%) 311-550 (84.9%)	Chambers & Price 1988
Waun-Fignen- Felen (E188S)	S Wales	Blanket mire	2?	1630±65	CAR-439		254-287 (5.8%) 324-575 (89.7%)	Smith & Cloutman 1988
Hockham Mere	E Eng	Lake	129.5- 134.5	1625±45	Q-2225		265-273 (1.2%) 350-552 (94.2%)	Bennett 1983
Cefn Ffordd	S Wales	Blanket mire	c.16-18?	1655±55	CAR-107		252-290 (9.5%)	Chambers 1982

							320-548 (86.0%)	
Croze Mere	W Midlands	Lake	110-119	1610±75	Q-1231		255-286 (4.5%) 325-602 (90.9%)	Beales 1980

Figure 1

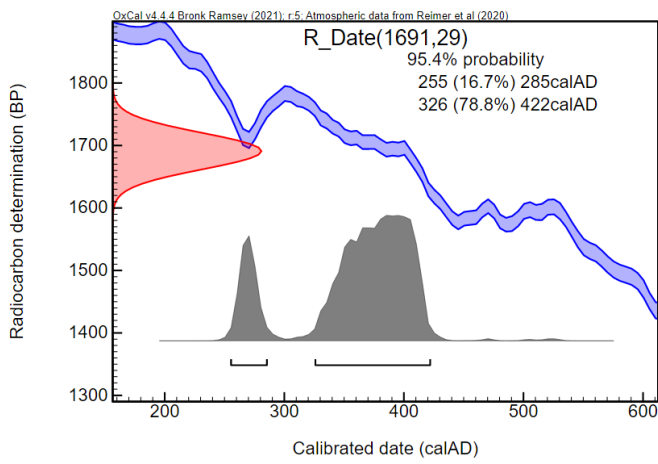


Figure 2

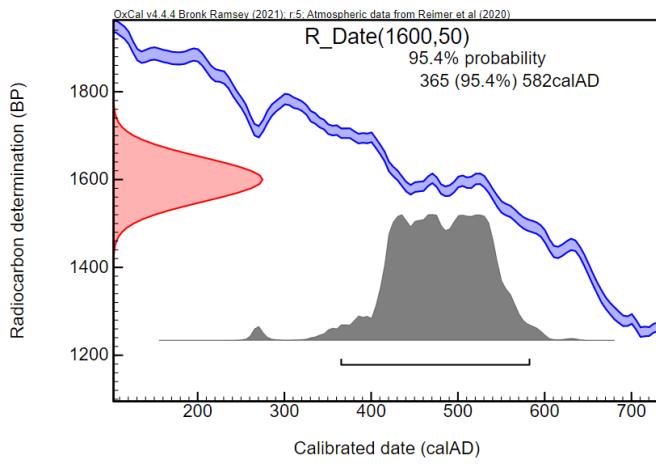


Figure 3

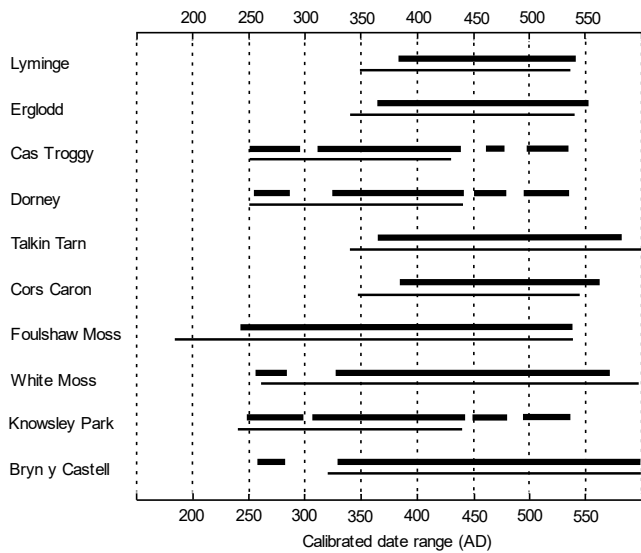


Figure 4

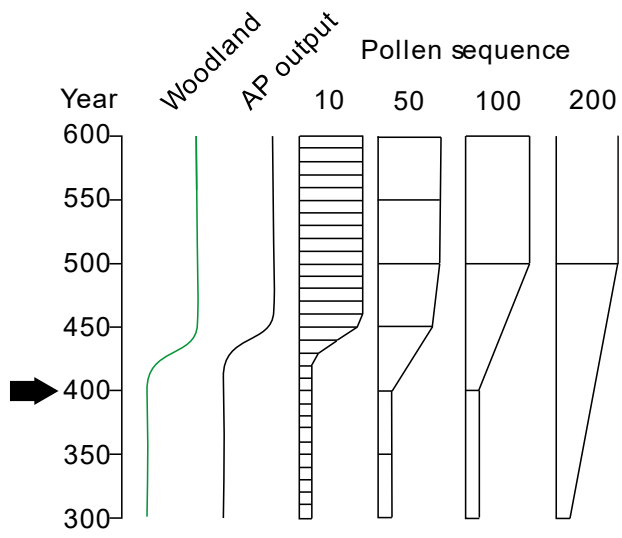


Figure 5

