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14 The expansion of agricultural production in late Iron Age and Roman Britain

by Marijke van der Veen
and Terry O'Connor

Abstract

The late Iron Age and Roman period saw the creation of settlements not primarily involved in agricultural production, and this development is linked to an expansion of agriculture. We identify several different types of expansion, each leaving a distinct archaeological imprint. Both the process of adoption or rejection of new strategies and the choice of strategy are directly influenced by factors such as availability of land and labour and the social position of the farmer. The growing regionalisation of the country during the period concerned reflects variations in these factors across the country. We suggest that the identification and analysis of this regional diversity should be a key area for research during the next ten years, and that environmental archaeology needs to apply an analytical and explanatory approach to this problem while, at the same time, becoming more embedded within explanatory frameworks for social change.

Late Iron Age and Roman Britain

The time span considered here is the Iron Age and Roman period, approximately 500 BC to AD 400. During this time a number of cultural, sociopolitical, economic, and, perhaps, demographic changes occurred, any one of which may have had an impact on the agricultural systems in operation at that time. During the Iron Age we see a growing regionalisation of the country: regional patterns of settlement, social structure, subsistence strategy, and belief system emerge (Cunliffe 1991). Some regions are characterised by population nucleation and by a marked stratification of society, while others show considerably less change from the preceding period. Variations in population growth and pressure, access to resources, and physical distance from the continent have all been put forward as possible explanations for this development (Cunliffe 1991; Darvill 1987). From the late Iron Age, the growth of long-distance trade and the consequent increase in contact with the Mediterranean world resulted in considerable social and economic changes in the south-eastern part of the country and the growth of major ports and market centres (*oppida*). The Roman period is, of course, primarily characterised by the arrival of an occupying army and by the introduction of a different cultural and socioeconomic system. The latter was a gradual process, in part building on the earlier, indigenous Iron Age changes in social stratification and settlement pattern, while the burden of the occupying army fell largely on societies in the northern part of the country, probably emphasising already existing regional differences (Millett 1990). During this period we see the first appearance of towns and, perhaps, the development of a money-based market economy (Greene 1986).

Thus, during the period under study we see the creation of settlements not primarily involved in agricultural production (hillforts, *oppida*, Roman forts, towns) and the consequent need for surplus production in the rural areas in order to feed the people in the new settlements. There is considerable evidence that the density of settlement and intensity of land use increased around this time (Cunliffe 1991; Haselgrove 1989), and the evidence for agricultural expansion has been discussed in a series of syntheses (Grant 1989; Jones 1981; 1984; 1989; 1996; King 1978; 1984; Maltby 1996). Major regional differences in the degree and rate at which these changes occurred have been identified (Jones 1984; 1989), and it is recognised that both indigenous and external factors played a role in the expansion of agriculture and the adoption of innovations in this period (Jones 1989; Millett 1990). This is not the place to describe these developments in detail or to review the existing evidence; for this the reader is referred to the synthetic articles mentioned above. Here we aim to discuss some of the strategies available to farmers intent on expanding their production, the extent to which we are, at present, able to recognise these in the archaeological record, and the areas in which future research may usefully be focused.

Agricultural expansion, intensification, and extensification

Before discussing the options available to farmers responding to the need for surplus production, it is necessary to define some terms. In the literature we often see the use of the term 'intensification' of agriculture, generally meaning the expansion of agriculture. This term is in some ways unfortunate as, in an agricultural context, the term 'intensification' has a very specific and far more restricted meaning, denoting the opposite of extensification. Intensification, in the strict sense, signifies the increase of output per unit area by increasing the input, whether of labour or of other resources, while extensification signifies the increase of output per capita by increasing the area under cultivation without an associated increase in labour or other input. Both strategies result in a productive increase, but the implications in terms of land use and resource scheduling are quite different, and so, therefore, is their possible archaeological imprint.

Subtle differences in the way these terms are used do, however, exist. Boserup (1965) defined intensification as the change in the 'ratio of the area under crop to the total area under crop *plus* fallow' and saw intensification as the process of reducing the amount of land left fallow. She suggested that an increase in population forces a shift from extensive to intensive forms of agriculture, and that spatial variations in farming practices can, therefore, be explained by differences in population pressure. While this model has been very influential in archaeological discussions of past agriculture, its underlying assumptions make it inappropriate for Iron Age and Roman Britain, if only because societies in Iron Age and Roman Britain were not pure subsistence societies without outside contacts. Boserup saw intensification as a natural progression away from extensive forms of agriculture in response to population pressure, which may be the reason why the term intensification is often seen as synonymous with expansion; but this is not the way we use the term here (see below).

Boserup was, however, correct in identifying a relationship between population density and farming strategies; this relationship is apparent even in the modern, developed world (Grigg 1995, 158). The industrialised countries have seen a decline in the agricultural labour force since the nineteenth century, as a result of higher wages in industry and the mechanisation of farming, while the area under cultivation has remained constant, which has resulted in an increase in the amount of land per worker. But even here we see a link between population density and agricultural strategy (Grigg 1995, 151–8). In densely populated areas land is expensive but labour is abundant and relatively cheap, so the best choice is to maximise the output per unit area, by investing in input that increases yields (fertilizers, pesticides, herbicides) and concentrating on intensive forms of agriculture. In areas of lower population density land is relatively cheap, but labour expensive and here the best choice is to concentrate on maximising output per capita, by spending more on labour-saving machinery and less on inputs that increase yields. An example of the former is the Netherlands with its intensive pig rearing and its horticulture (flowers, bulbs, vegetables), and an example of the latter is Britain with its extensive sheep rearing in the uplands, or America with its extensive cereal growing.

To summarise, we use the following definition of the terms: intensive agricultural systems are those where the input per area and the return per area are high, but the return per capita is low (eg horticulture); extensive agricultural systems have low input per area and low return per area, but the return per capita is high (eg sheep rearing, large-scale cereal growing). Thus, following Grigg (1995), we see intensive and extensive forms of agriculture as different strategies, different responses to local conditions. Intensive and extensive farming systems are options or strategies available to farmers at any one time and place, and local conditions, be they social circumstances, availability of land, labour, or markets, determine which response is the more appropriate at any one time, recognising that farmers may switch from one to the other and back again, or adopt a combination of both for different parts of their production.

A thorough discussion of why changes in agricultural production take place is outside our remit, but we note that studies of modern farming communities show that innovations are not automatically accepted, even when the benefits are easily identifiable (Bayliss-Smith 1982; Grigg 1970; 1995; Spedding 1988), and a recognition of this phenomenon is essential to our understanding of the regional variation we see in Iron Age and Roman Britain. First of all, the specific characteristics of the innovation play a role: simple or gradual innovations are more easily adopted than complex or expensive ones, but there are both economic and social factors to consider too. Economists tend to believe that the adoption of innovations is largely determined by the farmer's economic assessment of the innovation, while sociologists argue, correctly, that the social circumstances and the psychological make-up of the farmer are the main determining factors as they have a major influence on the farmer's perception of the potential benefits of the innovation. Land ownership, personal wealth, size of the farm, and control over the decision-making process all influence farmers' ability to implement changes, while their readiness to adopt change is linked to personal characteristics such as age, education, social standing and integration, and business attitude (Bayliss-Smith 1982; Grigg 1970; 1995, 174; Husain 1979; Spedding 1988).

While many of these factors are linked to individual circumstances, some, admittedly broad, generalisations can be made. Boserup (1965) already identified that farmers in subsistence societies have different priorities from those in market economies. Subsistence societies typically show limited goals, an absence of specialisation, a slow rate of change, little response to price mechanisms, and a preference for leisure. The overall aim is to feed the family, and to minimise risk; many achieve this by growing 'a little bit of everything'. In a market economy, on the contrary, we see strong specialisation, an emphasis on cash crops and other commodities, surplus production, a rapid response to price fluctuations, and frequent innovations. Output and profit are maximised, principally through specialisation and innovation.

It is important to remember that these two examples are extremes at opposite ends of a continuum, and that within each society there are individuals who are able to respond to the need to change more rapidly and more readily than others. As well as that, even in market economies, feeding the family remains important. Thus the social and psychological make-up of the farmer and the structure of society in which farming communities find themselves, as well as availability of land and labour, directly influence the ability of farmers to react to new developments and the type of expansion they choose.

If we are to identify in Iron Age and Roman Britain when, where, and, ultimately, why farmers altered their agricultural strategies, we need, among other things, to be able to identify in the archaeological record the various forms that agricultural expansion can take. Here several types of expansion are considered:

- a general expansion of the area under cultivation and/or pasture, largely in response to population growth; this should not be confused with extensification, as it concerns the bringing into cultivation/pasture of new areas by new people and does not, necessarily, involve changes in crop/animal management
- an increase in yield within the existing area through a shift to new crops or animals, which may be higher yielding or offer other advantages; this should not be confused with intensification, as it does not necessarily involve changes in crop/animal management, though we recognise that changes in crops and animals can be the result of a change of management regime (see below)
- an increase in yield through a change in cultivation or management regime – intensive or extensive depending on local availability of land, labour, manure, and traction power; this may include changes in the ratio of animal to crop husbandry
- a change towards more specialised production, ie of cash commodities to sell through a market in order to engage with new exchange mechanisms where these existed
- a shift towards a non-domestic mode of production, ie production of staples primarily to fulfil demand elsewhere, over and above that of the family/village; intentional surplus production, not to be confused with surplus production that is used as risk buffering against bad years (see Bakels 1996)

To conclude, the expansion of agricultural production can take many forms, of which intensification and extensification are but two expedient responses. We would like to stress that the options identified above are neither exhaustive, nor mutually exclusive. Intensive and extensive strategies can take place on the same farm, are often associated with changes in crop or animal species, and can be combined with the introduction of a few cash commodities or a switch to a non-domestic mode of production, as we will see below. As mentioned above, regional and local differences in the availability of land, labour, and social structure will have influenced the degree to which these options were adopted and, therefore, the extent to which farmers and societies actively participated in the new developments and opportunities brought about by the invasion of the Roman army.

If we are to recognise and understand these regional differences, we need first to identify the archaeological imprint of these options and second to ensure that our database consists of a regional coverage of the resolution and quality required to pick up these differences.

Crop and livestock husbandry

This section considers the extent to which the options listed above can be identified in the archaeological record. While the aim is to refer to both plant and animal resources in each sub-section, it will be clear that both the nature of the source materials and the evidence available to date make this difficult and the balance between the botanical and faunal evidence is, consequently, unsatisfactory. Writing this article has highlighted not only the need for more integration of the different lines of evidence, over and above bones and seeds, but also the enormity of this task, especially as the chronological and spatial resolution of our database is still very poor.

The expansion of production

By the Iron Age and Roman period, much of the British countryside can be characterised as open land, and the existing evidence suggests that the amount of land given over to cultivation and grazing had gradually increased (though not at a constant rate) from the Neolithic period onwards, a process almost certainly due primarily to a growth in population. While pollen analysis demonstrates that this opening-up of the landscape was asynchronous across the country, it is possible to say, as a broad generalisation, that large-scale clearances were taking place across the entire country during the Iron Age and Roman period, but occurred earliest in the south and east and progressively later in the north and west (Bell 1996; Turner 1981). Recent palynological evidence from palaeochannels in lowland river valleys suggests that large-scale clearances in the lowlands may have occurred as early as the Late or even Middle

Bronze Age (Brown 1997, 215–18), corroborating existing evidence for marked regional variation and highlighting the value of applying pollen analysis to as wide a range of sediments as possible.

Linking changes in pollen diagrams to specific historical events remains problematic. Dumayne and Barber (1994; 1997), McCarthy (1995), and Tipping (1997), for example, have taken quite different views on the significance of 'clearance events' in pollen diagrams from sites close to Hadrian's Wall. This debate centres on whether ^{14}C dates are sufficiently precise to show whether a given clearance event was synchronous with, or consequent upon, the Roman arrival in the region, or happened a matter of decades earlier. With the availability of AMS dates, there is the need to re-analyse some pollen sequences with more ^{14}C dates of the relevant horizons, and to combine these with refined wiggle-matching and Bayesian calibration methods. It also remains difficult to identify whether the expansion of cleared land was primarily for arable or pastoral purposes. The use of so-called arable and pastoral indicators has become rather discredited (Behre 1986; Groenman-van Waateringe 1988; Maguire 1983), and this is clearly an area that merits further research.

The highly targeted use of pollen and land snail data from small catchments to locate areas being taken into grazing and cultivation and the increased emphasis on recognising the spatial scale of vegetational events through the pollen record (Bradshaw 1991) is to be welcomed, and this now needs to be combined with a clearer definition of the palynological attributes that characterise degrees of grazing pressure. In parallel, further detailed work on 'open country' land snail communities is urgently needed to allow more confident recognition of 'grazed grassland' communities. Recent work in this field has taken research away from naive use of sweeping analogue communities (eg Evans 1991) and focused development of the use that Rouse, Evans, and others (Evans *et al* 1992, Whittle *et al* 1993) have made of correspondence analysis and the more subtle recognition of mollusc taxocoenes offers the possibility of interpreting these 'open country' communities in ways that can contribute directly to the investigation of changing patterns of pastoral land use.

It is also possible that more information resides in 'failed soils', such as colluvial infills in valleys. Research such as that conducted by Allen (1988), Bell (1992), and Tipping and Mercer (1994) has suggested that cultivation of potentially unstable slopes through later prehistory is likely to have been a major trigger for accelerated colluviation, though caution is needed when associating accelerated colluviation with cultivation, and when assuming that permanent pasture is relatively stable. We need research into the small-scale geomorphological consequences of increased grazing pressure; and a better understanding of whether it is cultivation, or the abandonment of cultivation, that triggers the destabilisation of soils and consequent colluviation. How such information might be manifested in colluvial deposits is not clear, though investigation of the magnetic and iron species (ie the forms of iron oxides, sesquioxides, and hydroxides) characteristics of the sediments may offer a way forward, particularly if combined with examination of sediment micromorphology, such as that undertaken by Macphail (1992) at Ashcombe Bottom, Sussex.

A different choice of crops and animals

In this section the evidence for changes in crops and animals that have been recorded for the period and the implications of these changes in terms of scales of production are discussed. To start with crops, two major changes in the choice of wheat crop have been identified. The switch from emmer wheat to spelt wheat during the Iron Age, and the switch from glume wheats (emmer and spelt) to free-threshing bread wheat during the early post-Roman period, are developments recorded in Britain, as well as other parts of western Europe (Jones 1981; 1984). Bread wheat (*Triticum aestivum*) is the main, if not only, species of wheat grown in Britain and western Europe today. It is likely that farmers who started to grow bread wheat early (ie during the late Iron Age or Roman period) may be correctly recognised as innovators and it is important to identify where in Britain this innovation first took place (Jones 1989).

The advantage of bread wheat over emmer and spelt is thought to be the easy removal of the chaff; this means a reduction in processing time after the harvest and a reduction in volume and weight on long distance transport (Green 1979 as quoted in Jones 1981; emmer and spelt were often transported as spikelets). Bread wheat has been found as early as the Neolithic, but the number of grains is always very low and the occurrences are sporadic; there is no evidence that it represented an important crop at that time. Traces of bread wheat have also been found on several Iron Age sites, but it remains difficult to assess the importance of this crop in this period, as there are problems with the dating evidence of some records and the correctness of the identifications in others. Two late Iron Age sites have been mentioned in the literature as having fairly substantial amounts of bread wheat: Bierton, Buckinghamshire, and Barton Court Farm, Oxfordshire (Jones 1981; 1984; 1986). The dating evidence for Bierton, however, has been questioned: the bread wheat may be of Saxon rather than Roman date (Mark Robinson personal communication), and it is possible that several more Iron Age records of bread wheat represent Saxon material, owing to the difficulty of distinguishing Iron Age and

Saxon pottery in some regions (Mark Robinson personal communication). Grains of bread wheat from two late Iron Age sites in north-east England, when radiocarbon dated, turned out to be medieval and modern in date (van der Veen 1992, 60, 74), although accelerator dates on bread wheat chaff from another Iron Age site in the same region did identify this material as late Iron Age in date (ibid, 61, 74). Furthermore, grains of bread wheat are difficult to distinguish from those of spelt wheat and hard wheat, a problem highlighted in a recent article (Hillman *et al* 1996), and there is some doubt over the correctness of published identifications based on grain rather than chaff (Dominique de Moulins personal communication).

The first time bread wheat is found in large quantities is during the Roman period, but most of these records are from non-agricultural settlements. There are too few archaeobotanical records from Romano-British settlements to be able to assess the case for importation versus local production. Thus, we are at present unable to trace the history of the cultivation of bread wheat in this country with any accuracy. Clearly, a re-evaluation of the existing records of bread wheat from Iron Age and Roman sites, using the latest morphological criteria as well as biomolecular and chemical methods, coupled with an extensive AMS dating programme, is urgently needed.

The existing record for the shift from emmer to spelt wheat is much better, but even here the regional resolution of the database is poor. While there are plenty of Bronze Age records of spelt wheat across the country, it is not until the Iron Age that emmer wheat was replaced by spelt wheat, though this switch was not universal in either space or time (Jones 1981; 1984; van der Veen 1992). The increased preference for spelt has been the subject of much discussion. Jones explained it by the fact that spelt can grow on the heavier clay soils and is hardier than emmer and, therefore, very suited to winter sowing, allowing a general expansion of agriculture through access to previously marginal soils and a new growing season (Jones 1981; 1984; 1996). The evidence from growing experiments at Butser Ancient Farm has always suggested that emmer and spelt had similar yields (Reynolds 1992), so differences in yield never entered these discussions. Recent results from a national wheat growing experiment do, however, provide a slightly different picture. Emmer and spelt were grown on experimental plots across the country for three years (1987–90; van der Veen and Palmer 1997), and the results indicate that spelt is higher yielding than emmer, and that this is statistically significant. This is different from the results at Butser Ancient Farm, where both species were grown in experimental fields for more than 15 years (Reynolds 1992); here there is no statistically significant difference in the yield between the two species.

This difference in results can be explained as follows: in the recent study it was clear that spelt was higher yielding than emmer when the temperatures in January were low, which confirms the hardiness of spelt referred to earlier. In warm winters the difference between the two species was negligible, but in cold winters spelt performed better, and a similar analysis of the Butser yield figures has corroborated this pattern. Thus, spelt outperforms emmer except in warm years and in certain parts of the country (eg at Butser where warm winters occur more frequently, van der Veen and Palmer 1997). The shift towards spelt wheat recorded in the Iron Age can, therefore, be related to one of three closely interrelated factors: its tolerance of heavier soils, its hardiness, and its higher yields, all three, of course, crop characteristics beneficial to farmers intending to expand their production.

The fact that clear regional variations have been identified in the timing of the switch to spelt wheat indicates that the choice of crop was more complex than just choosing a new crop for its yield, soil tolerance, or hardiness, something we already know from studies of modern farming communities (see above). It is important to emphasise here that these regional differences do not conform to the highland/lowland division of the country, as postulated in the past, but that differences in the uptake of spelt wheat have been recorded within these broad zones (eg between the Upper Thames Valley and Wessex; Jones 1984) and also within Cunliffe's regions (eg within the north-eastern zone; van der Veen 1992). This suggests that the need for expansion was not uniform across the country or within the regions as defined by Cunliffe (1991), or that not all farmers chose spelt wheat (ie cereals) as the method through which to expand their production. So far, however, the switch to spelt wheat has been regarded as a straightforward decision to start sowing a different species of crop. There is, however, evidence to suggest that the switch may have come about through a change in cultivation regime (see below).

It is more difficult to predict, and so to test, whether relative changes in the numbers of livestock species reflect particular production strategies. Domestic animals mostly provide more than one resource, and so a diachronic change, say, from cattle to sheep could represent a change in meat production, or could be a consequence of changes in the desirability of producing wool rather than cereals. An increase in the area of land cultivated for cereals would necessitate an increase in the numbers of cattle retained as plough oxen. That said, there are some chronological and regional variations in the relative abundance of different livestock that might be linked to production strategies. King (1978) summarised a large volume of published work up to that date, and set down a number of generalisations which are perhaps due for re-assessment. Roman sites with a military connection typically produce bone assemblages with a very high relative abundance of cattle bones, whereas Iron Age sites and Romano-British sites in less 'Romanised' areas typically show a higher proportion of sheep bones. King also notes that villas and later Roman sites typically produce a higher proportion of pig bones than do earlier Roman and 'native' sites. Although King's survey is 20 years old, subsequent work has tended to confirm these generalised patterns, although the reason for them has not been analysed in any detail.

At Thorpe Thewles, Rackham (1985; 1987) draws attention to a relative increase in sheep bones in the last Iron Age phase, and even suggests that taphonomic attrition may have depressed the amplitude of the increase. A smaller increase in sheep is also noted by Grant *et al* (1991) at Danebury, where the relative increase is largely at the expense of pigs, and comes, again, in the very last Iron Age phase. This is clearly not the beginnings of a move towards what was to become the 'typical' Roman pattern of exploitation, as most Roman assemblages from Britain are predominantly of cattle bones. A shift towards sheep would be consistent with an expansion into areas not suitable for cereal agriculture, or with an increased emphasis on the production of wool.

The predominance of cattle in Roman assemblages, however, might be more consistent with an increase in the production of cereals, with adult cattle becoming available as a source of meat largely as a side-product of cereal agriculture. If the shift to cattle was primarily for meat, then one might expect the cattle to be relatively young at death, which is not the case, and we might also expect pig bones to be relatively abundant. Pigs, after all, are the most efficient of the three common domesticates in terms of rapid meat production. However, pig bones tend to be relatively scarce on later Iron Age and early Roman sites.

At a fairly coarse level of analysis, then, the animal bone evidence is consistent with the evidence from plant macrofossils in indicating an increased emphasis on cereal production in the Roman period. Grant (1989) has argued this case, but suggests that the trend began in the Iron Age. This is difficult to confirm or refute on the available data, although the data from Thorpe Thewles and Danebury certainly suggest otherwise. A few sites have yielded well sealed bone assemblages from the very earliest stages of Roman occupation, but these are often very small. Thus the earliest assemblages from Segontium (Noddle 1993) and Silchester (Maltby 1984) show much the same predominance of cattle as the later phases at both sites. One fears that we have a problem of comparability between, for example, hillforts, undefended Iron Age sites, Roman military sites, *coloniae*, villas, and so on. There may be some evidence that the apparent increase in cereal production is matched by an increase in the keeping of cattle, but we need well stratified data from individual sites that extend from the Iron Age into the Roman period in order to get around this problem of comparability.

Intensive and extensive production regimes

By the middle of the first millennium BC the expansion of agriculture no longer consisted primarily of the growing population taking new areas into cultivation, ie the type of expansion identified above. Apart from the fact that, by this time, the expansion of production was affected by the lack of suitable new land, which resulted in the need to take into cultivation land that was previously regarded as marginal or unsuitable (Jones 1981), the expansion was now also no longer primarily a result of population growth, but included a response to social stratification and the development of non-agricultural sections of the population, and thus the need for surplus production, over and above that produced to buffer bad years. This required a new type of expansion, one that increased the amount of food available, and this could be done either within the existing area by increasing productivity (intensification), or by extending the area under cultivation without expanding the existing labour force or other input (extensification). This section tries to identify what archaeological traces these different strategies leave behind.

One way we can identify management regimes of crops is through analysing the arable weed assemblages associated with them (Behre and Jacomet 1991; Hillman 1991; G Jones 1992; M Jones 1988; Küster 1991). An example of a case study in which different management regimes were identified is that of six late Iron Age sites in north-east England (van der Veen 1992; 1995). The statistical analysis of the charred seed assemblages identified two groups of sites, which differed from one another in both the types of cereals cultivated and the weed flora associated with these crops. Group A sites are characterised by the presence of emmer wheat, some spelt wheat, barley, and arable weed species indicative of intensive soil working (digging or ploughing), weeding and manuring, and, consequently, fertile soil conditions, ie an intensive cultivation regime. Group B sites are characterised by spelt wheat, barley, and arable weed species indicative of limited soil working and manuring and, consequently, less fertile soil conditions, ie a more extensive cultivation regime (van der Veen 1992). Moreover, the differences between the two groups of sites were not limited to crops and weed species. The sites were located in different parts of the region, they were characterised by different types of settlement (defended/non-defended), social structure of society (different degrees of centralisation), and tribal affinity (Votadini/Brigantes; ibid). Thus, not only does this case study demonstrate that different cultivation strategies can be identified in the archaeobotanical record, but it also demonstrates that these differences can be related to archaeologically identifiable differences between the two societies. The latter aspect has been explored in more detail by Ferrell (1995; 1997), who identified differences in the spatial organisation of these societies (isolated versus integrated), which could be linked to the observed differences in modes of production.

It is interesting to note here that at both groups of sites barley was treated differently from wheat. In both cases it was associated with the poorest soil indicators, suggesting that the barley crop was grown under more extensive conditions than the wheat crop, highlighting differences in the relative status of these crops, and the fact that both cultivation regimes can be in operation on the same farm.

Another issue raised by the results of the case study is that of the choice of crop. We have so far assumed that farmers wanting to expand moved to growing spelt wheat, rather than emmer, but the evidence also allows a different hypothesis. At the Group A sites both wheat species, emmer and spelt, were associated with one another, suggesting that they were either grown as a mixture (maslin) or as separate crops receiving the same treatment. The evidence suggests that under an intensive cultivation regime (Group A) emmer is the dominant crop, while under a more extensive form of cultivation (Group B) spelt wheat is dominant. This could mean that emmer flourishes under an intensive system and that spelt competes better under a less intensive system, probably because of its tolerance for more marginal soils and its hardiness. If a farmer decided to expand by increasing the area under cultivation without an associated increase in available traction, manure or labour, then a gradual deterioration of the soil conditions in the fields would result. Thus, if a mixture of emmer and spelt was sown (and the archaeobotanical evidence suggests that this is likely) then, over the years, there would be a marked increase in the proportion of spelt within the fields at the expense of emmer, and emmer would ultimately disappear. The results from this case study suggest the hypothesis that a change in cultivation regime could bring about a change in the dominant wheat crop in the fields. If this is what happened, then the change-over from emmer to spelt wheat need not have been a conscious decision to change crops, but may have been the result of a change in cultivation regime (van der Veen 1995; van der Veen and Palmer 1997). Either way, the switch to spelt can be used as a marker to identify an expansion of agricultural production.

There is some evidence from Germany that corroborates the pattern identified here. Knörzer (1964; 1984) noted in the lower Rhineland not only a switch from emmer to spelt in the Iron Age and Roman period, but also an association of spelt wheat with arable weed species indicative of poor soil conditions, which he related to an increase in the scale of production and a consequent degradation in the soil conditions. There is, clearly, an urgent need for more detailed statistical analyses of other, comparable, data sets to test whether similar patterns can be identified elsewhere.

Differences between these management regimes relate to the amount of soil working and manuring in each and, therefore, to the degree to which animals are integrated within the productive system. Small-scale, intensive agriculture may need no more than a few cattle to cover the requirement for manure and traction, but may be combined with extensive hill-farming of sheep, while large-scale cereal production requires large numbers of cattle, especially when harvesting and when preparing soil for the following crop. It may not be a coincidence that the evidence for poor soil conditions found associated with the evidence for spelt and agricultural expansion in the later Iron Age co-occurs with evidence for an emphasis on sheep, eg Danebury and Thorpe Thewles. While these sheep offer wool and the utilization of agriculturally unproductive lands, they cannot help with the working of the fields or the ploughing-in of manure, and they appear in these two cases not to have provided enough manure themselves to maintain soil fertility. There are, however, at present too few sites where both the seed and bone assemblages are of sufficient quality to test this hypothesis in detail, and this is clearly a priority for the future.

The importance of dung in systems where crop yields need to be maximised would seem obvious enough, yet the subject has received scant attention in the context of British prehistory. Bakels (1997) has reviewed the evidence from continental Europe, and concludes that manuring has been practised from the Late Neolithic onwards. One of the more effective means of maximising crop yields while making maximum use of crop by-products as animal feed is to allow livestock (usually sheep, because of their ability to graze even very short plant growth) to graze the crop aftermath. The remaining stubble and weeds are of little use to humans, being expensive to collect, difficult to store, and of negligible food value to an omnivorous primate. Stubble and weeds, however, can be readily collected and stored in the form of livestock, and may then be utilised by people as meat or secondary products. In addition, the urine and dung of the livestock replace soil nutrients, especially nitrogen, removed with the crop. If livestock are spatially restrained (folded), the manuring can be highly concentrated, giving maximum benefit to the following year's crop. This procedure, commonly termed 'direct manuring', requires relatively small fields with well-defined boundaries, or the use of mobile boundaries analogous to modern wire or hurdle fences.

The so-called Celtic field systems often associated with later Iron Age and Romano-British settlement would seem to have been well suited to direct manuring. To test this, soil analyses within such systems should seek to detect high levels of total phosphorus, probably with moderate enhancement of magnetic susceptibility, but with the absence of dense finds of abraded pottery or other domestic debris. If manuring is largely indirect, through the application of household waste, then in a period such as the later Iron Age and Romano-British period, substantial amounts of pottery ought to have found their way onto field surfaces. If manuring was largely direct, straight from the sheep, then the amounts of pottery on field surfaces should have been much less. A third procedure, in which animals are stalled and soiled bedding is utilised as manure, would be more difficult to detect, unless through the identification in ancient anthrosols of plants or materials inconsistent with the location. The use of a low-utility plant such as heather (*Calluna vulgaris*) as animal bedding, for example, could result in macrofossils or pollen of that species being recovered from what would otherwise appear to be a cultivated field. What is required here is not so much new techniques as focused, problem-oriented application of existing techniques. To go one step further, the existence of intensive cereal production might also be confirmed by finding a correlation between sites with emmer and small fields with evidence for manuring.

While it may be difficult to identify intensive and extensive management systems from animal bone assemblages, integration of bone data with the evidence from plant remains offers a way forward, and other lines of evidence may be successfully used. Increasing the numbers of livestock grazing on a given area of land (intensification) is likely to require closer management and control of that land. Hay production is one example, and this is first attested in the Roman period (Greig 1984; Jones 1989; Lambrick and Robinson 1979); another is the construction of boundaries, exclosures, droveways, and the like, such as those structures which Pryor (1996) has recently reinterpreted in terms of Bronze Age stock management in the Fenland. Site and monument surveys of these often large-scale landscape features can be used to locate possible grazing areas, followed by extensive soil analyses of attributes such as total soil phosphorus and magnetic susceptibility. This approach has been applied to an upland study area near Malham, North Yorkshire, enabling areas of managed grazing and exclosures in which crops may have been grown in a late prehistoric landscape to be recognised (McIlwaine and O'Connor forthcoming). The few settlement sites in the area typically yield a mixture of 'native' and Roman pottery, perhaps indicating that the intensified management of this particular area of upland was a phenomenon of the Iron Age–Roman transition.

One such site excavated in 1997 appears to lie at the core of a 'managed landscape', and yielded mostly Roman pottery, including some *terra sigillata*, from what is otherwise a typical cluster of 'prehistoric' roundhouses. Midden material from the structure has produced a bone assemblage, not yet fully analysed, in which sheep predominate. Perhaps this site is another example of the emphasis on sheep noted in the late Iron Age phases at Thorpe Thewles and Danebury, but here in a Roman chronological context, and associated with a surrounding landscape laid out apparently to facilitate the management of livestock. We thus have to examine the animal bone evidence in two ways, as evidence for the integration of livestock with crop production, and as evidence for livestock production *per se*. While the available data may lack the desired quality and quantity, there is clearly ample scope for modelling different production strategies and their archaeological outcomes, and then using that essentially speculative exercise to inform the research designs of subsequent field research.

The creation of products for a market

It is very difficult not only to identify commodities produced for exchange, but also to separate these from surplus production as part of a non-domestic mode of production; the difference is one of scale. As a broad generalisation we can identify a first stage, where farmers produce staples on a subsistence level, but introduce the production of a few commodities in order to engage with new exchange mechanisms and acquire new goods, while the last stage represents the present day situation where the entire agricultural production of a farm is geared towards the demand of the market, rather than the needs of the family or community.

The first, admittedly tentative, evidence for the production of agricultural cash commodities dates to the Roman period; the apparently large-scale production of beer is a good example. Evidence for the production of malt comes from the so-called corn driers. They are first identified in the first century AD, but mostly date to the third and fourth centuries. They are now thought to have been multifunctional structures associated with both the production of malt and with the preparation of grain for large-scale storage and transport (Reynolds 1981; Reynolds and Langley 1979; van der Veen 1989; see also below). Charred grain assemblages from five corn driers (Bancroft villa, Buckinghamshire, Catsgore, Somerset, Hibaldstow, Lincolnshire, Mucking, Essex, and Tiddington, Warwickshire) provided conclusive evidence that these structures were used to roast germinated grain for the production of malt, the main raw material in the manufacture of beer (van der Veen 1989). While beer must have been produced throughout prehistory, this is the first evidence that the production was organised on a scale that suggests something beyond domestic consumption. Martin Jones (1981) has suggested that the production of beer may be interpreted as a response of British farmers to seasonal problems of cash flow. By holding back part of the cereal harvest, beer could be brewed and sold all year round, at a higher price than the grain would have fetched at harvest time.

Other potential cash crops are vegetables, herbs and fruit. In the Roman period we find, for the first time, clear evidence for the cultivation of garden and orchard plants: dill, celery, asparagus, beet, cabbage, carrot, apple, medlar, cherry, plum, etc (Dickson 1994; Greig 1991; Murphy and Scaife 1991; Robinson 1981; 1992). This is not to say that none of these food plants were cultivated in the preceding periods (though the rarity of waterlogged assemblages from Iron Age and earlier contexts does pose problems here), but again there is a difference of scale. The abundance and frequency of these finds, often from military and urban sites, is suggestive of market gardening, and thus the development of an intensive form of production developed in response to the demand from the new, non-agricultural settlements. Evidence for a possible suburban market garden has been recovered at Balkerne Lane, Colchester (Crummy 1984, 138–41; Murphy and Scaife 1991), and evidence for Roman period vineyards at North Thoresby, Lincolnshire (Webster and Petch 1967) and Wollaston, Northamptonshire (Meadows 1996) has been recorded. The evidence for an increase in garden and orchard crops is not unique to Britain, but has been recorded in many other parts of the Roman empire (Kreuz 1995; Pals 1997; van Zeist 1991). A comprehensive review of all the new records of these species and the nature of the sites on which they are found, is desirable.

The analogous cash crops from animals may simply have been meat, or dairy produce such as cheese, which is far more difficult to track in the archaeological record. Again, the difference between subsistence and market production is essentially one of scale, although production of a surplus may lead to a more evident focus on one particular productive strategy, rather than a diversified 'risk management' strategy. For example, it could be argued that the practice of slaughtering animals while still young, as seen at some Roman sites (eg O'Connor 1988, 87–8) is a form of cash-cropping. The difficulty with recognising this strategy lies in the disentangling of, for example, young lambs that represent 'surplus males' culled out of a dairy flock, from young lambs that have been raised and slaughtered as the intended 'crop'. None the less, the presence of young lambs in refuse in a town implies that they have been moved from the place of production, and that in turn implies some form of marketing or redistribution of the resource. The production of surplus meat for sale clearly implies the movement of livestock about the landscape, largely, though not necessarily exclusively, between country and town. The archaeological investigation of such movement brings us back to extensive landscape surveys, and the recognition of structures associated with droving, or with the holding of large numbers of stock. Possible means of recognising different regional populations of animals are discussed below.

We cannot currently recognise from the bones of a cow whether she was regularly milked or not. Clearly a cow or ewe that is allowed to breed regularly will pass through regular phases of lactation, and may differ only a little in this respect from one that has been routinely milked for human consumption. What we are looking for, in effect, is a means of recognising prolonged and intense lactation such as might be interpreted as milking by humans rather than suckling by offspring alone. The conventional use of age-at-death data may enable the recognition of samples drawn from populations with a demography apparently optimal for milk production, but that is only an indirect means of recognising the organised production of dairy produce that might have been encouraged by the development of markets.

Towards a non-domestic scale of production

The first indicators of surplus grain production identifiable in the archaeological record are probably the large subterranean storage pits and above-ground, four-poster granaries of the Iron Age hillforts, although these may partly represent evidence for risk-buffering rather than true surplus-production. By the Roman period, however, we find large granaries associated with all military establishments, an indication that surplus production has occurred elsewhere (Bakels 1996). While it remains a subject of much discussion and speculation whether the grain required to feed the Roman army came from within Britain or from abroad, we know that long-distance grain transport took place. The presence of foreign crops and/or weeds has demonstrated the import of grain in a number of instances. There are examples from London (Straker 1984), Caerleon (Helbaek 1964), and York (Williams 1979), and others from beyond Britain (eg Kuijper and Turner 1992; Pals and Hakbijl 1992; Pals *et al* 1989).

What is clear is that during the Roman period the transport and storage of grain took place on a scale altogether different from that of any previous period, and this is corroborated by the fact that the first evidence for serious damage of grain caused by grain weevils and beetles dates to this period (Buckland 1978; Kenward 1979). The reason that insect infestation was not a problem during the Iron Age or earlier can be explained by proposing that until the Roman period grain was stored in much smaller units, usually for domestic use only, and little bulk transport took place. In the few places where bulk storage was practised, eg at the hillforts, the grain (or at least some of it) was stored in sealed, underground pits, where the rapid accumulation of carbon dioxide proved lethal to the insects, thus inhibiting insect infestation (Buckland 1978).

Other evidence for large-scale cereal production can be found in the occurrence of corn-driers and large watermills (Spain 1984; van der Veen 1989). The appearance of so-called corn-driers has already been mentioned. Apart from their role in the production of malt, they are also associated with evidence for the preparation of grain for large-scale storage and transport (ie parching and drying; van der Veen 1989). Watermills have been identified at three sites along Hadrian's Wall – Chesters, Haltwistle, and Willowford (Spain 1984) – and there are, in some cases admittedly tentative, associations between corn-driers and watermills or large millstones at the Roman villa at Chew Park, Somerset (Rahtz and Greenfield 1977), Heronbridge, Cheshire, Littlecote Park villa at Ramsbury, Wiltshire, and Barton Court Farm Abingdon, Oxfordshire (Spain 1984). Both the drying and/or parching of grain prior to storage or transport and the milling of grain into flour have been carried out throughout prehistory, but on a domestic scale, without the need for specialised structures or using anything other than hand-operated querns. In the Roman period this changed, and the appearance of corn-driers and large mills heralds the first step in the direction of a non-domestic scale of production. What is needed is a systematic compilation of all this evidence, so that a detailed map can be constructed registering when and where these changes occurred and what regional variations can be identified.

If we are to recognise the keeping of increased numbers of livestock, two particular requirements may be proposed. The first is to be able to quantify, if only crudely, the amounts of bone in circulation at different sites or in different phases of a site. One of the biggest weaknesses of archaeological animal bone studies is our apparent inability to relate changes in the relative abundance of taxa to changes in the absolute abundance of one or more taxa (Grayson 1984; Ringrose 1993). Nonetheless, loci at which increased numbers of livestock have been slaughtered and butchered, though not necessarily those at which the livestock were raised, will presumably have generated increased quantities of bone debris. The huge quantities of bone debris recovered from some Roman sites hint at large-scale production and movement of livestock. Piercebridge, for example, is estimated to have yielded at least 250,000 bones (Rackham and Gidney 1984). Although the factors of deposition and diagenesis, let alone excavation policy, will be major determinants of the size of recovered bone assemblages, the sheer quantities of bones at sites such as Piercebridge, Binchester, and Vindolanda do suggest the increased mobilisation of livestock in the Roman period.

Quantifying this increase is obviously problematic, but a way forward might be for further research into bone taphonomy to develop models of bone deposition and incorporation which treat bone fragments as large sediment clasts, irrespective of Linnaean taxonomy. A few researchers, notably Bob Wilson (1996), have made some progress in this direction, and have also shown how difficult a line of investigation it is. If more bone debris is generated by human activity at a particular location, then more of this category of clast is contributed to the depositional processes going on around the site. There are obviously many stages between the recovered assemblage and the number and density of the population from which it is derived; but surely some information about the latter must reside in the former? Despite the exigencies of disposal, redeposition, diagenesis and recovery, even to be able to make generalised, ordinal, statements such as that 'much more bone, and probably more livestock, was in circulation at this site in the later Iron Age phases than in the early phase' would be a step forward.

One further line of enquiry is to examine the utilisation of animal carcasses. It may not always be correct to interpret a change in the utilisation of animal carcasses solely in functional terms. Differences in tradition, and the enhancement of those traditions when different peoples come into contact, will produce patterning within the animal bone record which could on its own be mistaken for changes in butchery practice in response to a need to intensify utilisation, perhaps to generate a commodity for trade. Given that proviso, however, several Romano-British sites in this country and on the near Continent have given evidence of cattle carcasses being butchered to a pattern, with specific joints being processed *en masse*, and sometimes with large quantities of heavily-butchered bone suggesting a coordinated effort to retrieve every possible product from the butchered carcass (van Mensch 1974; van Mensch and Ijzereef 1977; O'Connor 1988). Detailed examination of bone assemblages of good stratigraphic and dating integrity, where recovery was well controlled, should be undertaken in order to determine whether such bone deposits are just a characteristic of Romano-British sites, and then mainly of military sites, or whether similar deposits can be recognised in Iron Age material as well. Careful attention will have to be paid to the burial context, and the possibility of non-functional behaviour constantly borne in mind.

Access to imported luxuries and other symbols of wealth

Another well recorded phenomenon in the Roman period is the presence of 'exotic' food items, which, though not representing local expansion of production, do identify long-distance trading contacts and demonstrate wealth. The seeds of grapes, figs, olives, dates, lentils, pine-nuts, cucumber, and coriander have been found in many urban excavations, as well as at Roman forts, and some of these have also turned up at Romano-British settlements (Dickson 1994; Greig 1991; Hall and Kenward 1990; Murphy 1997; Murphy and Scaife 1991; Willcox 1977). To these we can add, of course, the import of wine, olive oil, and fish sauce, as demonstrated by the amphorae found on many sites (eg Sealey and Tyers 1989). As with the garden and orchard crops, it is difficult to monitor the access to these luxury items owing to the rarity of suitable preservation conditions at sites of the preceding period. Some of the crops initially imported were subsequently cultivated within Britain itself, and like the garden and orchard plants their occurrence needs to be plotted in detail against type of site and date, in order to identify patterns of access to wealth and changes through time. While most of these imports concern plant foods, one rather charming rodent represents the animal world: the garden dormouse (*Eliomys quercinus*) has been found in Roman deposits in York and South Shields, though whether this creature was imported deliberately or accidentally remains problematic (O'Connor 1988, 105–10; Younger 1994). Ornamental gardens are also first recorded in the Roman period (Dickson 1994; Murphy and Scaife 1991; Pals 1997). As symbols of wealth they deserve mention here, but they are otherwise outside the scope of this article.

New approaches

Many of the archaeological questions discussed here require a more focused application of existing techniques, but some will benefit from new approaches. Here we briefly mention a few new developments that will play an significant role in the coming years.

The most important recent development is the rise of biomolecular archaeology, in particular the isolation and characterisation of ancient DNA and the use of chemical analyses such as gas chromatography and mass spectrometry (Brown *et al* 1993; Eglinton 1996; Evershed 1993; Evershed *et al* 1992; Hillman *et al* 1993). These techniques could make a significant contribution to the identification of problematic archaeological remains, such as grains of bread wheat. Grains of free-threshing wheat found in Roman granaries cannot be identified to species (hexaploid or tetraploid) without associated chaff but, as bread wheat is the only free-threshing wheat cultivated in north-west Europe at the time, records have, in the past, sometimes been identified as belonging to bread wheat for that reason (eg van der Veen 1994). The grains could, of course, belong to durum wheat, a species more commonly grown in the Mediterranean, which raises the important issue of whether the grain for the Roman army in Britain came from within or outside the country. Interestingly, the preliminary analysis of some charred pottery residues from Roman Bearsden, Scotland, using infrared spectrometry, does point to the possible presence of durum wheat (Camilla Dickson and Frances McLaren personal communication), although the accuracy of this technique in identifying taxonomic and genetic differences still needs further, critical consideration.

With animals there are important questions of recognising regional populations, so as to be able to track past large-scale movements of livestock. One of the great weaknesses of archaeological bone studies is our apparent inability to 'provenance' livestock. We can propose a place of origin for a Northumbrian sceatta, or for a Neolithic polished stone axe, but seemingly not for a cow, which may have been moved hundreds of kilometres during its life as an item of trade and exchange. One means of investigating increased movement and trade of livestock during the later Iron Age and Romano-British periods may be through recognition of large-scale landscape features associated with droving, which returns us to the need for truly extensive sites and monuments mapping. Another approach may be through investigating the genotypes of livestock, principally by way of their phenotypic characters.

At the dawn of reliable agricultural history (about AD 1750), cattle and sheep formed local populations with distinctive characteristics, which presumably resulted from founder effect and a degree of genetic drift abetted by human selection of breeding animals. It is a reasonable presumption that similar regionally delimited populations existed in prehistory. In bringing about greater mixing of such populations, increased trade and exchange of livestock may have modified both the incidence and the local prevalence of particular genetically controlled traits. Research into local genotypes offers a means of investigating the existence and degree of endogamy of local populations, and of recognising the greater mixing of local populations that has been postulated. Genotype can be investigated directly by means of DNA analysis, though any such research needs to be very precisely targeted, and there is a clear need for greater realism in ancient DNA studies. Indirect investigation of genotype may be accomplished through markers such as discontinuous skeletal traits, a field of investigation that merits a far more thorough investigation than it has received to date. Some studies have shown quite distinct site-to-site variation in the prevalence of particular characteristics (Bond and O'Connor forthcoming; Noddle 1978), and the main thing that holds back further research in this area is the relative paucity of research on the prevalence and significance of discontinuous skeletal traits in modern populations. It is ironic, but by no means unusual, to have to say that a lack of appropriate research into modern skeletons is holding back research into ancient bones.

Recognising the uses to which livestock were put is a fruitful area for investigation. We have discussed above the difficulties inherent in recognising dairying. A conventional means of recognising the use of cattle and sheep for dairying has been through the analysis of age at death data, though the interpretations that result are often uncertain and ambiguous. The kill-off models that are conventionally applied to archaeological assemblages tend to be 'steady-state' models, in which herd or flock size is conserved rather than rapidly increased. We need new models, which are appropriate to a period of expansion and intensification, in which there may have been pressure to generate additional livestock for expansion and exchange (and as a buffer against military appropriation) as well as obtaining the range of primary and secondary products. These models need to be heuristic devices that allow the testing of values for different parameters, and, unlike Cribb's 'Flocks' model (Cribb 1984), to reflect the pressures of a fully-integrated agrarian system, not an explicitly pastoral system.

The mathematics of linear programming may be an appropriate foundation for such a model. A complicating factor is that differences in the intensity of management of different herds or flocks may have resulted in differences in the rate of attrition of the teeth, thus making age attribution more difficult. If sheep are grazed at high densities, the sward may be grazed down so far that significant quantities of soil are ingested. If the soil mineral material is particularly siliceous, this can appreciably accelerate the rate of attrition of the teeth, making a sheep appear to be 'older' on dental grounds than its actual age (Healy and Ludwig 1965; Healy *et al* 1967). Detecting inter-sample differences in attrition rate is not simple, but Bond and O'Connor (forthcoming) report a possible instance in medieval material from York.

An alternative approach is to examine the chemistry and histology of the bones themselves. First, Ca/Sr ratios in bone mineral are responsive to bone mineral turnover in lactating females. Some work has been undertaken to investigate the use of Ca/Sr ratios in cattle bones as a means of recognising possible dairy cows in archaeological assemblages (Mulville 1994). The results are inconclusive but not necessarily discouraging, and there is clearly potential for more work in this area. Second, lactating females mobilise and redeposit large amounts of bone tissue, and this process can leave distinctive histological traces in the skeleton. The detail depends on the season in which the animal is slaughtered, and thus at what point the cycle of bone demineralisation and remineralisation is interrupted. A radiographic approach has been proposed and tested, based on the thinning of cortical bone observed in some lactating female ungulates (Horwitz and Smith 1991). Though non-destructive, this approach has several fundamental weaknesses, which could be overcome to some extent through a more direct procedure based on thin-section examination. Radiographic examination may allow thinning of cortical bone to be recognised, but would not allow the discrimination of cortical bone loss through lactation from that resulting from general inanition or other, pathological, conditions. The examination of undecalcified bone thin-sections is an under-used procedure, and further research in this area is strongly encouraged.

The use of cattle as traction animals has been discussed, and is at the heart of the integration of livestock with cereal production. We might speculate that pressures towards increased crop production would lead to at least some cattle being used largely as draught animals, with a concomitant impact on their skeletons. Animal bone palaeopathology is a seriously under-developed subject; the presence of a particular hip arthropathy in cattle from a Neolithic site has been used as evidence that cattle were used for traction (Armour-Chelu and Clutton-Brock 1988), and others have drawn attention to a possible link between lower-limb pathology and traction (Bartosiewicz *et al* 1993; Higham *et al* 1981). The weakness with this research to date has been our poor characterisation and classification of arthropathies in non-human material, and our lack of data pertaining to prevalence in past populations. If we are to recognise increased use of cattle for traction through an increased prevalence of strain-related arthropathies, then we need to know exactly what the characteristic arthropathies are, and we need much better data on background prevalence of these conditions. A complicating factor is the possibility that some forms of arthropathy may be correlates of skeletal senescence, thus necessitating modern data on the relationship between the prevalence of different forms of arthropathy and the age structure of the population, and greater attention to the age structure of archaeological populations within which the prevalence of arthropathies is being investigated.

Fundamental to our recognition of ancient crop management regimes is a detailed knowledge of the behaviour of arable weeds in different 'man'-made environments. So far, research has concentrated on both autecological and phytosociological approaches, as well as on pattern recognition within archaeobotanical assemblages. Important new research has been initiated by Glynis Jones and colleagues (Charles *et al* forthcoming) measuring functional attributes of arable weeds and using these as indicators of the potential of species to cope within a particular (man-made) environment. This approach is completely new; it moves away from formal analogies, and as such avoids the problems associated with some of the previous methods. This new approach is highly original and extremely timely, as it forms a logical and essential progression of the research carried out so far and will provide a much-needed tool for the interpretation of archaeological evidence. By identifying the biological reason for particular weed associations one can start to reconstruct, using archaeobotanical evidence, cultivation regimes not available today, and thereby circumvent problems inherent in previous approaches. The results of this research project will, therefore, be of very considerable importance to our understanding of the choices made by farmers in Iron Age and Roman Britain.

Conclusions

In this paper we have tried to identify the types of strategies available to farmers intent on expanding their production and we have suggested that most of these can be identified in the archaeological record by using existing technologies, though we have also pointed to areas where new technologies could bring significant new contributions. What is needed most of all is a more focused, problem-orientated approach and a better integration between the various sources of data. This should, where possible, involve quantitative analyses of associations and relationships between the various 'markers' of agricultural expansion and wealth generation. For example, is there a correlation between spelt and cattle; between specialised slaughtering and non-agricultural settlements; between exotic foods and other wealth and Romanisation indicators; or between emmer wheat, small fields and manuring? Identifying patterning in space and time will allow us to start identifying areas (and individual sites) where innovations were implemented early, and areas where innovations were either implemented late or not at all. To a certain extent this information is already available; for example, we know that spelt wheat first became dominant in parts of the south and east of the country, and here we also find the earliest development of *oppida*, villas, towns, corn driers etc, all markers of an expansion of agriculture, an increase in the scale of production, and the development of non-agricultural sections of the population. The southern and eastern parts of the country have, however, too often been treated as a uniform entity, even though we know this to be incorrect. Furthermore, we still know very little about the other parts of the country and what choices were made there.

Cunliffe (1991) identified five different regions within Iron Age Britain, using archaeological evidence. In the next ten years research needs to focus on the extent to which different agricultural practices coincide with these, whether any regional variation in the Iron Age continues into the Roman period, or whether the magnitude of the Roman occupation imposed its own divisions. As we have mentioned above, our database does not, at present, have a regional coverage of the resolution and quality required to address these issues. To remedy this we need archaeological fieldwork to be channelled towards regional projects outside the south and east of England, and funds to be directed towards a small number of large-scale research projects that aim to integrate the various lines of evidence we have discussed.

This integration of the different sources of data may be facilitated by using the concept of energy capture and flow. We have stressed the role of soil working and manuring in the different crop management regimes, and manuring can usefully be seen as a way of maximising the utility of grazing livestock, and of utilising otherwise unavailable energy sources (hill grazing and scrub) (Thomas 1983; 1989). The archaeological study of manuring has of necessity to bring together the study of the main source of manure (animals), the medium to which it is applied (soil), and the organisms that directly (plants) and indirectly (humans and soil biota) benefit from it. An energy flow paradigm must also consider fodder, a topic that has not received sufficient focus in the context of Roman and earlier Britain. The production of fodder crops, whether grazed directly or cut and stored, offers a means of managing the energy available through the year, both by maximising availability at certain times and by storing food to mitigate seasonal shortages.

We have repeatedly mentioned quantitative developments, whether as a prerequisite to detailed analyses of weed and crop associations, or to allow new models to be developed of energy flows and outputs in postulated agrarian systems. This is more than just the use of larger and better-quality datasets. We need a greater willingness to put guesstimated numbers into our models, in order to see if they work at all, or to test the susceptibility of a system to fluctuations in, for example, grain yield or cattle birth rate. We have argued that the expansion of production is a key question for the later Iron Age and Romano-British period. Expansion is a matter of quantities, so it follows that our attempt to model and understand that process has to be quantified as well. Not least, we may be able to identify which variables are the critical ones, where minor fluctuations produce major consequences, and so to redirect our questioning of the archaeological data.

In conclusion, we have highlighted the fact that there are many types of agricultural expansion, each of which leaves a different archaeological imprint. We have also emphasised the role of factors such as availability of land and labour, as well as the social position of the farmer in the process of adoption or rejection of new strategies and the choice of strategy. Variations in these factors across the country are likely to be responsible for the growing regionalisation that has been recorded during the period, the extent to which agricultural expansion took place, and the form it took. Research in the next ten years needs to identify and analyse this regional diversity in more detail as this process is crucial to our understanding of the long-term development of agriculture in the various regions of Britain. We suggest that such research is most likely to succeed if environmental archaeology moves from descriptive and comparative applications to more analytical and explanatory approaches while, at the same time, becoming more embedded within the explanatory frameworks for social change.

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